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# Lean six sigma and sustainability in management research: a scoping review of conceptual and methodological approaches

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## Abstract

**Purpose** – This paper aims to examine how sustainability is integrated into Lean Six Sigma (LSS) within the existing academic literature. While LSS is widely established as a process-oriented management system for performance and quality improvement, it remains unclear how sustainability is embedded in LSS frameworks, tools and governance structures. The study aims to structure this fragmented research field and to identify dominant integration logics and research gaps.

**Design/methodology/approach** – A scoping review identified 68 peer-reviewed studies (2015–2025) across major academic databases. The studies were analysed using an abductive coding approach focusing on organisational levels of integration, sustainability dimensions and integration logics.

**Findings** – The findings reveal a conceptually diverse but weakly consolidated research field. Sustainability is predominantly integrated into LSS at the strategic level, while integration into frameworks and tools remains limited. Most studies focus on ecological and economic sustainability, whereas social dimensions are addressed only marginally. Empirical research is concentrated in manufacturing contexts. The analysis shows a dominance of transversal and hybrid integration logics, indicating that sustainability often functions as an overarching steering logic rather than being systematically embedded in LSS methodologies.

**Practical implications** – Organisations should move beyond treating sustainability as a strategic framing and embed it more systematically into LSS frameworks, tools and project structures, by strengthening the operationalisation of social sustainability.

**Originality/value** – The paper contributes to LSS research by developing a typology of sustainability integration logics and by systematically analysing how sustainability is embedded across LSS frameworks, tools and governance structures.

**Keywords** Lean six sigma, Sustainable development, Scoping review

**Paper type** Literature review

## 1. Introduction

The increasing importance of sustainable development confronts organisations with the challenge of systematically reconciling economic performance with environmental and social requirements. Sustainability is no longer understood solely as a normative guiding principle, but increasingly as a strategic management task embedded in organisational structures, processes and decision-making logics (Asif *et al.*, 2011; Lozano, 2015; Hengst *et al.*, 2020;



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Hermundsdottir and Aspelund, 2021; Bari *et al.*, 2022). Against this background, management approaches combining efficiency improvements with long-term value creation are gaining relevance (Hermundsdottir and Aspelund, 2021; Lima and Jucá, 2024).

LSS represents such a process-oriented management approach, combining lean principles aimed at waste reduction with statistically grounded Six Sigma methods for quality and performance improvement (Antony *et al.*, 2015; Gaikwad and Sunnapwar, 2019; George, 2002; Yadav *et al.*, 2023). Originally rooted in industrial production, LSS is increasingly applied in service sectors, healthcare and knowledge-intensive organisations (Antony *et al.*, 2017; Ghasemibojd *et al.*, 2025; Rana and Jani, 2026).

In parallel, a growing number of scholarly contributions have emerged that examine the potential of Lean, Six Sigma and integrated LSS approaches in the context of sustainable development (Cherrafi *et al.*, 2017; Garza-Reyes, 2015). Several recent literature reviews have examined the relationship between LSS and sustainability from different perspectives. For instance, Chugani *et al.* (2017) analyse the environmental impact of Lean, Six Sigma and LSS approaches, showing that while these methods offer potential for resource efficiency, further empirical validation is needed. Other reviews focus on the integration of Lean, Green and Six Sigma through conceptual frameworks, as well as drivers, barriers and implementation aspects (Gaikwad and Sunnapwar, 2019; Yadav *et al.*, 2023). More recent studies provide broader overviews of methodological developments, application domains and sectoral patterns of sustainability-oriented LSS approaches (Ghasemibojd *et al.*, 2025; Rana and Jani, 2026). At the same time, the literature highlights a fragmented research field characterised by limited methodological integration and a lack of systematic understanding of how sustainability is embedded within LSS methodologies (Chugani *et al.*, 2017; Parmar and Desai, 2019; Ghasemibojd *et al.*, 2025; Rana and Jani, 2026). Against this background, existing research predominantly focuses on effects, implementation aspects and application domains. However, a systematic analysis of how sustainability is conceptually and methodologically embedded within LSS as a management system is still lacking. In particular, it remains unclear which sustainability dimensions are addressed and how they are combined, at which levels (e.g. governance, methods, tools) sustainability is integrated, and which integration logics and steering directions (e.g. strategic vs operational; top-down vs bottom-up) shape this relationship. This gap forms the starting point of the present study.

Given these considerations, a scoping review represents an appropriate methodological approach for structuring a heterogeneous and interdisciplinary research field. Scoping reviews aim to identify the scope and thematic emphases of existing research without evaluating study quality or causal relationships (Arksey and O'Malley, 2005; Peters *et al.*, 2021). This enables the identification of dominant patterns and underexplored areas. The objective of this study is to provide a structured mapping of the existing body of research on the linkage between LSS and sustainability. The analysis covers key dimensions, including study contexts, methodological designs, LSS frameworks and tools, sustainability dimensions and integration logics.

Building on this foundation, the present study makes three central contributions. Firstly, it provides a theory-informed overview of how sustainability is conceptualised within LSS research across different analytical dimensions. Secondly, it develops an empirically grounded typology of integration logics between LSS and sustainable development. Thirdly, it analyses how sustainability is embedded within LSS frameworks, tools and governance structures.

The remainder of this paper is structured as follows. Section 2 outlines the theoretical foundations and analytical framework, Section 3 describes the methodology, Section 4

presents the results, and Section 5 discusses the findings. Sections 6–9 present the implications, limitations, future research directions and conclusion.

## 2. Theoretical foundations and analytical frameworks

### *2.1 Sustainable development as a multidimensional steering concept*

Sustainable development is understood as a development principle that aims to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987). It refers to the systematic consideration of ecological, economic and social requirements along value creation processes and within management practices (Azimi and Saleh, 2025; Batista *et al.*, 2018). Sustainability is increasingly conceptualised as a strategic management task that is embedded in organisational structures, processes and steering mechanisms (Asif *et al.*, 2011; Bari *et al.*, 2022; Hengst *et al.*, 2020). The Triple Bottom Line continues to be widely used in the literature and represents a central analytical framework for structuring sustainability dimensions (Batista *et al.*, 2018; Lăzăroiu *et al.*, 2020; Nica *et al.*, 2025; Nogueira *et al.*, 2023), distinguishing between ecological, economic and social dimensions (Elkington and Rowlands, 1999). Recent sustainability discourses have also introduced expanded frameworks such as ESG and circular economy concepts. However, for the purposes of the present review, the Triple Bottom Line provides the more suitable analytical framework, as it offers a clear and widely established distinction between ecological, economic and social dimensions and thus allows a structured coding of the reviewed studies.

For analytical clarity, the present study distinguishes between economic performance outcomes, ecological impacts of organisational activities and social aspects related to work, organisation and employee involvement. This differentiation follows prior literature conceptualising sustainability along these three interrelated dimensions (Batista *et al.*, 2018; Lăzăroiu *et al.*, 2020) and serves solely as an analytical coding framework without implying normative weighting. Sustainability is further conceptualised as an organisational implementation and steering perspective of sustainable development, reflected in strategic objectives, operational measures and decision-making logics (Hengst *et al.*, 2020; Lăzăroiu *et al.*, 2020; Lozano, 2015). The literature simultaneously highlights tensions between the long-term normative orientation of sustainable development and the predominantly efficiency- and performance-oriented logics of established management approaches (Asif *et al.*, 2011; Hengst *et al.*, 2020; Hermundsdottir and Aspelund, 2021; Lozano, 2015). This ambiguity forms a central starting point for analysing how sustainability is embedded in management systems such as LSS.

### *2.2 Lean six sigma as a socio-technical management system*

LSS is an integrated management approach that combines Lean Management and Six Sigma as two improvement philosophies that originally developed independently (Pepper and Spedding, 2010; Tian, 2024). Lean Management primarily aims at the elimination of non-value-adding activities and the efficient design of value creation processes (Womack *et al.*, 1990). Six Sigma focuses on the reduction of process variation and defects through data-driven problem-solving methods (Schroeder *et al.*, 2008; Tennant, 2001). Within LSS, these complementary objectives are integrated into a unified improvement approach (Pepper and Spedding, 2010; Tian, 2024).

In the literature, LSS is commonly understood as a holistic management system that extends beyond a mere collection of methods and tools (Albliwi *et al.*, 2015; Antony *et al.*, 2017; Ghasemibojd *et al.*, 2025) and can be conceptually related to socio-technical system perspectives, as Lean itself has been theorised as a system comprising interacting social and

technical subsystems (Gamage *et al.*, 2025), suggesting that LSS similarly integrates technical and organisational dimensions. A central element is a structured improvement methodology, typically the DMAIC cycle (Define–Measure–Analyze–Improve–Control) or, in the case of new developments, the DMADV cycle (Define–Measure–Analyze–Design–Verify), which guide the systematic implementation of improvement projects (Antony *et al.*, 2017; George, 2002). This methodology is complemented by a broad toolset and organisational elements such as project selection mechanisms and governance structures as well as leadership and role systems (Antony *et al.*, 2017). LSS thus encompasses elements of strategic orientation and organisational steering.

The benefits of LSS reported in the literature include improvements in efficiency and productivity, cost reductions, quality enhancements, as well as increased transparency and standardisation of processes (Albliwi *et al.*, 2015; Sakib *et al.*, 2025; Salah *et al.*, 2010). These characteristics make LSS suitable for addressing complex organisational goal systems, including sustainability-related objectives (Chugani *et al.*, 2017; Parmar and Desai, 2019). Accordingly, LSS is conceptualised in this study as a multi-level management system, distinguishing between the framework level (e.g. DMAIC, DMADV), the tool level (specific methods and instruments) and governance and steering elements. However, existing studies do not consistently differentiate at which of these levels sustainability aspects are integrated.

### *2.3 Integration logics of sustainable development and lean six sigma*

The integration of sustainable development into existing management systems is discussed in the organisational and management literature as a distinct theoretical and practical challenge (Asif *et al.*, 2011; Bari *et al.*, 2022; Lozano, 2015). Sustainability is frequently positioned at the strategic level and associated with long-term objectives, normative orientations and overarching steering ambitions, whereas established management approaches such as LSS are primarily oriented towards operational processes, efficiency improvements and continuous improvement (Albliwi *et al.*, 2015; Antony *et al.*, 2017; Hengst *et al.*, 2020; Hermundsdottir and Aspelund, 2021). Linking these perspectives therefore requires the alignment of different goal systems, time horizons and steering logics (Asif *et al.*, 2011; Bari *et al.*, 2022; Lozano, 2015).

Within the literature on integrated management systems, conceptual approaches range from additive and partial forms of integration to fully integrated systems characterised by shared objectives, processes and structures (Jørgensen *et al.*, 2006). Maturity and stage models further conceptualise integration as a gradual process in which sustainability is progressively embedded into existing management systems (Baumgartner and Ebner, 2010; Nguyen and Kanbach, 2024). The existing literature on sustainability integration primarily differentiates between levels (Kiesnere and Baumgartner, 2019) and stages of integration (Sanchez-Planelles *et al.*, 2022) and focuses on aspects such as strategic embedding, process integration and organisational implementation (Jacobsen *et al.*, 2020). While these approaches provide important insights into the depth and development of integration, they offer only limited conceptual differentiation regarding the specific linkage logic through which sustainability and management approaches are connected in practice. Accordingly, this section focuses on the conceptual logic through which sustainability and management approaches are linked. In contrast, the following section shifts the focus to the organisational levels and steering directions at which these linkages are realised.

### *2.4 Organisational levels and steering directions*

Organisational change and management approaches can be located at different levels and along distinct steering logics. In management and organisation theory, a common distinction

is made between strategic and operational levels, which differ with regard to their time horizon, decision-making scope and function within the organisation (Hengst *et al.*, 2020; Hermundsdottir and Aspelund, 2021; Hrebiniak and Joyce, 1985; Mintzberg, 1978). Strategic levels address long-term objectives, fundamental orientations and governance structures, whereas operational levels focus on concrete implementation within processes, projects and day-to-day work practices (Bari *et al.*, 2022; Hengst *et al.*, 2020).

In addition to this level-based perspective, the literature distinguishes between different steering directions. Top-down-oriented steering logics originate at the managerial level and are disseminated hierarchically throughout the organisation via strategies, goal systems or formalised programmes (Kiesnere and Baumgartner, 2019). Bottom-up-oriented approaches, by contrast, emerge from operational units, projects or employee initiatives and may foster incremental change as well as organisational learning (Birkinshaw *et al.*, 2008; Nonaka, 1994). In practice, organisational change processes often involve a combination of both steering directions, either explicitly or implicitly, with their interplay significantly shaping the design and dynamics of implementation processes.

In the context of LSS and sustainable development, this distinction is particularly relevant. LSS is described both as an operational process improvement instrument and as a strategic management approach governed through goal setting, project selection and governance structures (Antony *et al.*, 2017; Sakib *et al.*, 2025). Sustainable development, by contrast, is primarily positioned at the strategic level, for example through guiding principles, goal systems or management commitment. Existing literature conceptualises the linkage between both approaches across organisational levels and steering directions in diverse ways (Asif *et al.*, 2011; Baumgartner and Ebner, 2010).

### *2.5 Synthesis of the analytical frameworks and derivation of research gaps*

Overall, the preceding sections highlight that while both concepts are well established individually, their integration remains conceptually fragmented and insufficiently systematised. From this synthesis, four central research gaps can be identified:

(1) sustainability dimensions addressed in the context of LSS and their combinations;

(2) analytical and methodological levels at which sustainability aspects are embedded in LSS;

(3) integration logics through which sustainable development and LSS are linked; and

(4) organisational levels and steering directions of sustainability-related LSS approaches.

Together, these perspectives constitute the conceptual framework of the present study and provide the basis for a structured multidimensional analysis of the research field.

## 3. Method

The present scoping review follows the established methodological framework proposed by Arksey and O'Malley (2005), extended by the refinements suggested by Levac *et al.* (2010) and the recommendations for conducting and reporting scoping reviews provided by Peters *et al.* (2021) (see Table 1).

In the *first step*, the research question was identified, thereby defining the overall objective of the study. The intention of the present work is to systematically map and structurally classify the existing body of research on the linkage between LSS and sustainable development to make central patterns, thematic emphases and research gaps

**Table 1.** Authors' synthesis of the procedural steps of the present scoping review based on Arksey and O'Malley (2005) and Peters *et al.* (2021)

| Step | Description |
|---|---|
| 1 | Identification and definition of the research question |
| 2 | Development and refinement of inclusion criteria |
| 3 | Data search |
| 4 | Study selection |
| 5 | Data extraction |
| 6 | Synthesis and mapping of the results |

**Source(s):** Author's own work

within the current discourse visible. Accordingly, the central research question is formulated as follows:

*Q1*. How is sustainable development conceptually and methodologically positioned in the existing academic literature in the context of LSS?

To address this overarching research question, the following sub-research questions were examined (see Section 2):

*RQ1*. Which dimensions of sustainable development are addressed in the context of LSS in the literature, and in which combinations do they occur?

*RQ2*. At which levels of LSS (frameworks, tools, governance) is sustainable development integrated?

*RQ3*. Which integration logics between LSS and sustainable development can be identified in the reviewed studies?

*RQ4*. At which organisational levels and along which steering directions (strategic vs. operational; top-down vs bottom-up) are sustainability-related LSS approaches positioned in the literature?

To address this research question, a set of inclusion criteria was defined i*n Step 2*. These included the temporal scope of the publications, which was restricted to the period between 2015 and 2025. This time frame was selected as both the integrated understanding of LSS and the strategic relevance of sustainable development have significantly increased since the mid-2010s, particularly in the context of global initiatives such as the Sustainable Development Goals (United Nations, 2015). The selected period thus captures the convergence of these developments. Furthermore, peer-reviewed journal articles and conference papers published in English or German and available as full texts were included to ensure a comprehensive and reliable analysis. English was selected as the dominant language of international research; German-language publications were additionally considered to capture potential regional contributions from the German-speaking research context, where LSS and sustainability-related approaches are also well established. Literature reviews were excluded during the search process as the aim of the study is to analyse original conceptual and empirical contributions. Conference papers were included to capture emerging discussions in a developing research field. From a substantive perspective, publications without a direct reference to LSS (e.g. studies focusing exclusively on Lean or Six Sigma) or using a divergent use of the sustainability concept (e.g. "long-term" in the

sense of enduring effects) were excluded. This restriction was applied to ensure conceptual comparability across the analysed studies and to maintain a clear focus on the integrated consideration of LSS in the context of sustainable development. In addition, studies lacking a sustainability focus or using the abbreviation "LSS" with a different semantic meaning than "Lean Six Sigma" were also excluded.

The literature search i*n Step 3* was conducted in two phases. In line with the iterative and reflexive approach characteristic of scoping reviews, the search process was carried out in two consecutive search phases (Arksey and O'Malley, 2005; Levac *et al.*, 2010; Peters *et al.*, 2021). In the first search phase (February 2025), the literature search was performed in the databases Scopus, Web of Science and ScienceDirect. These databases were selected due to their broad coverage of high-quality, peer-reviewed publications in the fields of operations management, quality management and sustainability research, thereby enabling a comprehensive and systematic identification of relevant studies. The search was based on an initial search string that combined terms related to LSS with various ecological and economic sustainability aspects and linked them using Boolean operators:

(1) ("Lean Six Sigma" OR LSS OR "Lean & Six Sigma") AND

(2) (sustainab* OR "Sustainable Development" OR "Green Lean" OR "Eco-efficiency" OR environmental OR "Triple Bottom Line" OR "Green Manufacturing" OR "Sustainable Manufacturing" OR "Eco-friendly Production" OR "Circular Economy" OR "Zero Waste" OR "Resource Efficiency").

The analysis revealed that the initial search string insufficiently captured the social dimension of sustainability and was thematically strongly focused on ecological and economic aspects. In addition, ScienceDirect proved to be a primarily full-text-based platform that is less suitable for the systematic identification of indexed contributions in the social and management sciences. Against this background, and to capture newly published articles as well, a second search phase was conducted on 20 November 2025 using a refined search string and an expanded database selection, thereby repeating *Steps 3 and 4*. The updated search used the databases Scopus, Web of Science and EBSCOhost. The revised search string, which now followed a three-part structure, was as follows:

(1) ("Lean Six Sigma" OR "Lean and Six Sigma" OR "Green Lean Six Sigma") AND

(2) Sustainab* AND

(3) (environmental OR "Green Manufacturing" OR "waste elimination" OR ("Life Cycle" OR "life-cycle") OR ecolog* OR "Carbon footprint" OR "green production" OR economic* OR "operational performance" OR "cost reduction" OR "efficiency" OR Social OR "organizational performance" OR ESG OR "continuous improvement" OR "business excellence" OR "process improvement")

To broaden the coverage of the social dimension of sustainability, additional social sustainability–related terms (e.g. CSR, employee training, health and safety) were provisionally integrated into the search string. Test searches in the selected databases, however, did not yield further relevant results, indicating that social aspects in LSS-related sustainability studies are either already captured through the term sustainab* or remain largely unaddressed. Accordingly, these terms were not retained in the final search strategy. The results of both search phases were subsequently consolidated and subjected to a uniform screening process. The final sample thus reflects the combined evaluation of both search rounds, resulting in 68 full-text studies included in the analysis. The study selection process is documented using a PRISMA-based flow diagram (see Figure 1), enhancing transparency

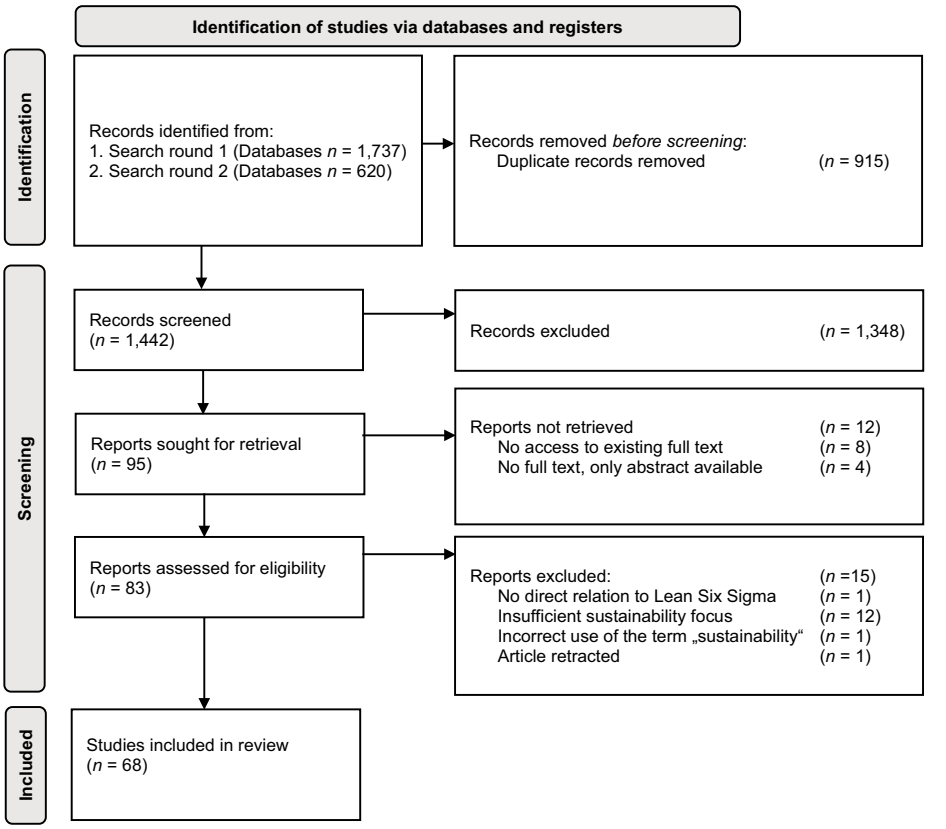


**Figure 1.** PRISMA-ScR flow diagram of the identification, screening and inclusion of studies
**Source:** Author's own work

and methodological rigour. A full list of the reviewed studies is provided in the Supplementary Material.

Data extraction in Step 5 was conducted using MAXQDA software and followed an abductive coding scheme derived from the research questions, combining deductive and inductive elements and allowing for the flexible extension of categories during analysis (Reichertz, 2013; Tavory and Timmermans, 2014). The coding framework covered sustainability dimensions, organisational levels of integration, integration logics and steering directions, while remaining open to emergent thematic patterns identified during analysis. To enhance analytical consistency, categories and coding decisions were repeatedly revisited and iteratively refined throughout the analysis process and critically reflected within ongoing academic exchange and supervisory discussions.

In *Step 6*, the results were summarised, synthesised and mapped. The coding framework combined descriptive mapping (e.g. research types, application contexts, geographical distribution) and methodological mapping (e.g. LSS methods and sustainability-related instruments). For thematic condensation, the approach proposed by Thomas and Harden (2008) was applied to identify central themes and cross-cutting relationships. Generative

artificial intelligence was used exclusively for translation-related editing; no AI tools were used for conceptual development, data analysis or interpretation. A full list of the reviewed studies is provided in Supplementary File 1.

## 4. Results

### *4.1 Descriptive mapping*

This section summarises the temporal, geographical and methodological characteristics of the reviewed studies.

The distribution of publications per year shows a continuous increase in sustainability-related LSS research between 2015 and 2025. Growth becomes particularly visible from 2020 onwards, with publication activity peaking in 2023. For 2025, six publications had been identified as of 20 November (see Figure 2).

The geographical origin of the analysed authors was captured based on their institutional affiliations (see Figure S1 in the Supplementary Material). In total, 224 authors from 30 countries were identified. Authorship is strongly concentrated in Asia, particularly India (79 authors), followed by the UK (22) and the USA (12), whereas contributions from Africa, South America and Oceania remain comparatively limited.

Figure 3 shows the geographical distribution of empirical study countries. Empirical research is similarly concentrated in a small number of countries, with India clearly

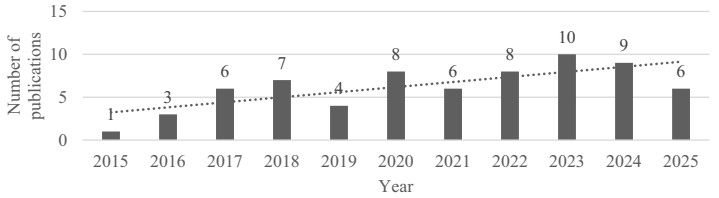


**Figure 2.** Analysis of the number of publications per year between 2015 and 2025 ($n = 68$)
**Source:** Author's own work

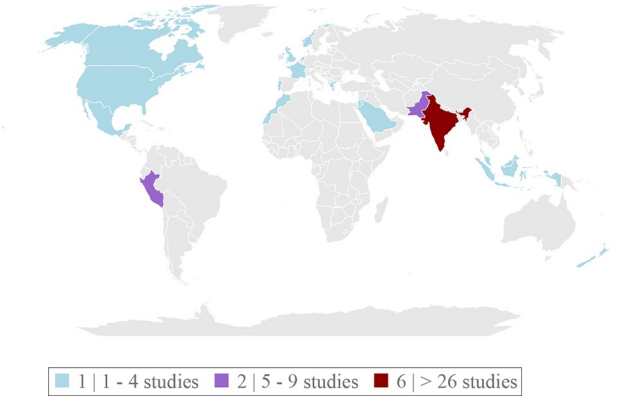


**Figure 3.** Geographical distribution of empirical study countries ($n = 58$)
**Source:** Author's own work

dominating the field (27 studies), followed by Pakistan and Peru (5–9 studies each). Most other countries are represented only marginally. In addition, 13 studies could not be assigned to a specific country, including conceptual papers and studies referring to broader regions.

The comparison between authors' institutional affiliations and empirical study countries reveals a differentiated spatial distribution between research origin and empirical application contexts. While some countries appear both as authors' affiliations and study contexts (e.g. India), others occur only as research origins or empirical settings.

The analysed contributions are distributed across 36 academic journals. The International Journal of Lean Six Sigma (IJLSS) is the dominant outlet ($n = 12$), followed by the Journal of Cleaner Production ($n = 6$) and The Total Quality Management Journal ($n = 4$). Overall, the distribution reflects the interdisciplinary positioning of the topic across quality management, sustainability and engineering-oriented journals.

The methodological mapping of the included studies reveals three main research types: conceptual, empirical and combined conceptual–empirical studies, with empirical studies forming the largest group. Qualitative and mixed-methods designs dominate, while purely quantitative approaches are less frequent. Nine studies could not be clearly assigned to a specific methodological category due to limited methodological specification or the absence of independent data collection; detailed classifications are provided in Tables S I and S II in the Supplementary Material.

To refine the methodological perspective, the analysis additionally examined the overarching study designs of the included studies (see Figure S2 in the Supplementary Material). The studies were classified into case studies, multiple-case studies, cross-sectional studies, expert studies, modelling studies and conceptual studies based on their dominant research logic (Bryman, 2022). The results show a strong emphasis on empirical, practice- and expert-oriented research forms. Case studies constitute the largest group, followed by expert studies and cross-sectional survey designs. Overall, the field remains methodologically heterogeneous, with a clear predominance of single-case and expert-based approaches.

The distribution of industries represented by the analysed actors was classified using the International Standard Industrial Classification of All Economic Activities (ISIC) (United Nations, 2008), allowing a comparable cross-sectoral and subsector-specific analysis. Figure 4 shows both the overall sector distribution and the internal structure of the manufacturing sector (ISIC Section C), which clearly dominates the sample. Overall, the findings indicate a strongly industrial and manufacturing-oriented focus of the empirical research. Within the manufacturing sector, a heterogeneous structure becomes apparent. The relatively high share of "Manufacturing, not specified" points to a limited degree of sector-specific differentiation in a subset of the studies. At the same time, the pronounced shares of the automotive industry (Division 29), as well as – albeit to a lesser extent – the food, electronics and pharmaceutical industries, indicate clearly identifiable industrial focal areas. Overall, the analysis confirms the manufacturing sector as the central field of application, while simultaneously highlighting potential for a more fine-grained, industry-specific differentiation in future research.

### *4.2 Content-related mapping*

The analysis of the strategic approaches reveals a clear dominance of the DMAIC cycle as the central methodological backbone of the reviewed studies (e.g. Alazmi *et al.*, 2025; Aldairi *et al.*, 2017; Kaswan and Rathi, 2019), either in its classical form or in adapted variants incorporating sustainability aspects. Alternative frameworks, such as DMADV or specific Green Lean or Green LSS approaches, occur considerably less frequently and are

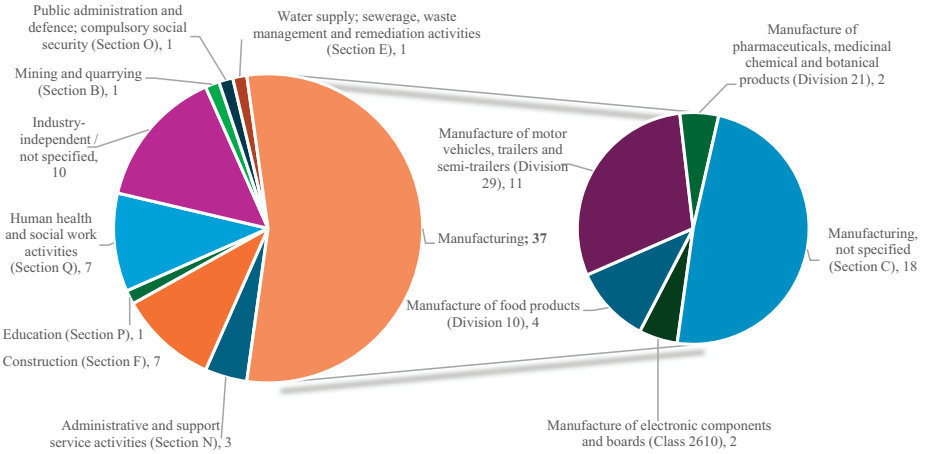


**Figure 4.** Industry distribution of the identified studies based on the ISIC classification

**Source:** Author's own work

mainly applied in conceptual or context-specific studies (e.g. McGlinchey *et al.*, 2025). At the operational level, the analysis shows a strong reliance on established Lean and Six Sigma tools, most prominently Value Stream Mapping (including environmental variants), SIPOC, 5S/6S/7S, Kaizen, FMEA and root-cause analysis techniques, alongside statistical methods such as Pareto analysis, Design of Experiments and control charts (e.g. Ben Ruben *et al.*, 2017; Powell *et al.*, 2017; Swarnakar *et al.*, 2025).

Overall, this distribution suggests that sustainability aspects in most studies build on an established and largely standardised LSS toolset. However, the analysis of the level of integration indicates that these elements are only rarely embedded at the level of LSS frameworks themselves. Only two of the 68 analysed studies integrate sustainability explicitly at both the framework and tool level. Instead, sustainability is predominantly integrated either at the governance level (48 studies) – for example as a strategic objective, enabling factor or steering logic (e.g. Marques *et al.*, 2025; Vasileiou *et al.*, 2024; Zhu *et al.*, 2018) – or at the tool level (18 studies), for instance through environmental assessment instruments applied within otherwise unchanged LSS procedures (e.g. Farrukh *et al.*, 2022; Gholami *et al.*, 2021; Sreedharan *et al.*, 2018). Comprehensive structural integration into LSS procedural frameworks therefore remains the exception (see Table S III in the Supplementary Material).

The analysis of the sustainability focus shows that more than half of the reviewed studies (37 of 68; approximately 54%) address all three sustainability dimensions in line with the Triple Bottom Line (see Table 2). In addition to ecological and economic aspects, these studies also include social dimensions such as employee involvement, qualification, occupational safety or organisational culture. However, the social dimension is often addressed in a functional manner, primarily supporting ecological efficiency or economic performance objectives rather than being treated as an equally weighted sustainability dimension (e.g. Kowang *et al.*, 2016; Motiani and Kulkarni, 2019; Pandey *et al.*, 2018). A further 29 studies (approximately 43%) focus predominantly on ecological and economic sustainability, for example through resource efficiency, emission reduction and cost reduction, while social aspects are only marginally or implicitly considered (e.g. Mkhaimer *et al.*, 2017; Powell *et al.*, 2017; Shokri and Li, 2020).

**Table 2.** Distribution of studies by addressed sustainability dimensions (triple bottom line)

| Sustainability dimensions | Absolute no. | Relative share (%) |
|---|---|---|
| Social-ecological-economic | 37 | 54.4 |
| Ecological-economic | 29 | 42.7 |
| Social-economic | 2 | 2.9 |
| Social-ecological | 0 | 0.0 |
| Ecological only | 0 | 0.0 |
| Economic only | 0 | 0.0 |
| Social only | 0 | 0.0 |
| Total | *68* | *100.0* |

**Source(s):** Author's own work

Studies explicitly combining social and economic sustainability are rare ($n = 2$; approximately 3%). Overall, ecological aspects dominate across the literature, whereas social dimensions are mostly addressed in combination with ecological objectives and only rarely as a primary focus (see Table 2).

Building on existing work on the integration of sustainability into management systems (Asif *et al.*, 2011; Baumgartner and Ebner, 2010; Lozano, 2015), the analysis develops an independent analytical typology that systematises the different linkage logics between LSS and sustainability identified in the reviewed studies. The typology emerged abductively from a comparative analysis of recurring patterns and was not derived *a priori* from the literature. It serves as a structuring device for classifying forms of integration and does not claim theoretical completeness or normative validity.

The six identified combination types – additive, complementary, iterative, integrative, hybrid and transversal – differ primarily with regard to the degree of methodological integration, the temporal logic of application and the functional role of sustainability within

**Table 3.** Typology of linkage logics between LSS and sustainability

| Combination type | Mode of integration | Characteristic features |
|---|---|---|
| Additive | No integration | Sustainability is not integrated into LSS frameworks or tools; both approaches are applied independently |
| Hybrid | Partial methodological integration | Sustainability is integrated into selected phases or tools of LSS, but not across the entire cycle |
| Integrative | Comprehensive methodological integration | Sustainability is systematically integrated into LSS frameworks, phases and tools |
| Iterative | Sequential logic | Sustainability is addressed sequentially after the application of LSS, without structural or methodological integration |
| Complementary | Parallel coordination | LSS and sustainability pursue similar objectives but do not use shared methods, tools or performance indicators |
| Transversal | Overarching steering and evaluation logic | Sustainability functions as an overarching evaluation or steering logic without operational integration into LSS tools |

**Source(s):** Author's own work

LSS applications. Additive and complementary approaches involve absent or parallel application without methodological overlap, whereas hybrid and integrative approaches entail partial or comprehensive integration of sustainability aspects into LSS frameworks or tools. Transversal approaches conceptualise sustainability as an overarching goal- and evaluation-oriented logic operating across LSS processes, while iterative approaches are characterised by a sequential application of LSS and sustainability assessment.

The assignment of studies to the respective combination types was based on an inductively developed coding scheme that captures different forms of methodological linkage between LSS and sustainability (see Table 3).

The typology presented in Table 3 forms the basis for the empirical distribution of integration logics reported in Table 4. Transversal approaches clearly dominate (35 studies) (e.g. Ben Ruben *et al.*, 2020; Mishra, 2022; Rathi *et al.*, 2023), conceptualising sustainability primarily as an overarching goal- or evaluation-oriented logic without operational integration into LSS methods.

Hybrid approaches constitute the second-largest group (22 studies) and involve partial methodological integration, such as sustainability-related performance indicators within DMAIC or environmental and sustainable value stream mapping (e.g. Kaswan and Rathi, 2019; Ortiz-Porras *et al.*, 2023; Sreedharan *et al.*, 2018). Complementary approaches account for 10 studies, applying LSS and sustainability instruments in parallel (e.g. Alazmi *et al.*, 2025; Aldairi *et al.*, 2017; Fargani *et al.*, 2017), while additive approaches are marginal ($n = 1$) (Ali *et al.*, 2020).

Although the typology distinguishes six analytical integration logics, only four are empirically observed; iterative and integrative approaches do not occur in the analysed literature (see Table 4).

In addition, the analysis examined the organisational level at which the integration of LSS and sustainability is positioned. Most studies address both strategic and operational levels, combining overarching objectives, governance aspects and enabling factors with concrete LSS tools and project-based applications. A smaller number of contributions focus exclusively on strategic aspects, such as readiness models, success factors or barrier analyses, without specifying operational instruments, while purely operational applications occur less frequently.

With regard to steering logic, the integration of LSS and sustainability is predominantly described as top-down, often linked to management commitment, strategic goal setting or project selection. Bottom-up approaches are rarely addressed explicitly, and many studies do not clearly specify the direction of steering.

**Table 4.** Absolute and relative frequencies of combination types of LSS and sustainability

| Combination type | Absolute no. | Relative share (%) |
|---|---|---|
| Additive | 1 | 1.5 |
| Hybrid | 22 | 32.4 |
| Integrative | 0 | 0.0 |
| Iterative | 0 | 0.0 |
| Complementary | 10 | 14.7 |
| Transversal | 35 | 51.5 |
| Total | *68* | *100.0* |

**Source(s):** Author's own work

Table 5 synthesises the central findings across the identified analytical dimensions and summarises their broader interpretative implications for the current state of research on LSS and sustainable development.

## 5. Discussion

### *5.1 Structure and maturity of the research field*

The findings of the scoping review allow for a synthesising assessment of the research field on the integration of LSS and sustainable development across several analytical perspectives. In line with the contributions outlined in the introduction, the results show that the field remains weakly structured and only limitedly consolidated. Sustainability is predominantly integrated into LSS in a selective and asymmetric manner, while the distinction between integration logics and levels of integration reveals that sustainable development is frequently addressed at a strategic or conceptual level rather than being deeply embedded into LSS frameworks or tools. Sustainability therefore often remains an additional steering and evaluation logic rather than a structural component of the methodological core logic of LSS.

Overall, the research field remains relatively young, heterogeneous and strongly context-dependent. Although the number of relevant studies has increased markedly in recent years, thematic and methodological fragmentation persists. Particularly striking is the pronounced regional concentration of research in the Indian subcontinent and selected Asian countries. This suggests that, in the sustainability context, LSS is primarily applied as a pragmatic approach to addressing economic and ecological challenges in regions where efficiency improvements and resource savings are of high practical relevance. The underrepresentation of Western industrialised countries points to an uneven regional development of the field and indicates that institutional frameworks and economic priorities substantially shape existing research.

Methodologically, the field is predominantly exploratory in nature. The dominance of qualitative and mixed-methods designs, together with the high proportion of case-based and expert studies, suggests that current research primarily focuses on conceptual structuring and exploratory understanding. In contrast, quantitative, multiple-case and longitudinal studies remain rare, limiting robust conclusions regarding the effectiveness and transferability of sustainable LSS approaches. At the same time, the limited number of empirically validated integration approaches suggests that sustainability-related LSS concepts frequently remain at a strategic and conceptual level. Taken together, this pattern points to a research field in which conceptual breadth is not yet sufficiently supported by methodological depth.

These findings are broadly consistent with previous reviews, which likewise characterise the research field as fragmented, methodologically heterogeneous and insufficiently consolidated (Chugani *et al.*, 2017; Gaikwad and Sunnapwar, 2019; Ghasemibojd *et al.*, 2025; Rana and Jani, 2026). However, while these reviews primarily examine sustainability outcomes, application domains, implementation factors or methodological developments, the present study extends the existing literature by systematically analysing how sustainability is integrated into LSS across different integration logics and organisational levels. In particular, the distinction between integration logics and organisational levels provides a more differentiated explanation of why sustainability frequently remains a strategic or evaluative framing rather than becoming a structural component of LSS frameworks and tools.

From a substantive perspective, a clear sectoral focus on manufacturing can be identified. While this dominance reflects the historical roots of LSS, it simultaneously constrains the generalisability of existing insights. Service sectors, the public sector and knowledge-intensive

**Table 5.** Synthesis of key findings and interpretative implications

| Analytical dimension | Key finding | Interpretative implication |
|---|---|---|
| Sustainability dimensions | • Dominance of ecological and economic dimensions<br>• Social sustainability weakly operationalised<br>• Social aspects mainly treated as supporting factors | • Sustainability primarily linked to efficiency-oriented improvement logics<br>• Social sustainability rarely embedded as an operational objective |
| Levels of integration | • Sustainability mainly integrated at governance and strategic levels<br>• Limited integration into LSS frameworks and tools | • Sustainability functions primarily as an external steering and evaluation logic<br>• Structural embedding into LSS core methodologies remains limited |
| Integration logics | • Dominance of transversal and hybrid approaches<br>• Absence of integrative and iterative approaches | • Predominance of loosely coupled integration forms<br>• Low degree of methodological integration maturity |
| Organisational levels and steering directions | • Strong strategic orientation<br>• Predominantly top-down steering logics | • Sustainable LSS mainly conceptualised as management-driven change<br>• Participatory and learning-oriented dynamics remain underdeveloped |
| Methodological orientation | • Dominance of qualitative, mixed-methods, and case-based studies<br>• Strong reliance on expert-oriented approaches | • Field remains largely exploratory<br>• Limited empirical validation and transferability |
| Sectoral and regional focus | • Strong concentration in manufacturing contexts<br>• High regional focus on asian countries, especially India | • Existing knowledge shaped by context-specific industrial and institutional conditions<br>• Limited broader generalisability across sectors and regions |

**Source(s):** Author's own work

organisations remain clearly underrepresented despite their significant sustainability impacts. Overall, the field has expanded considerably in recent years but remains characterised by contextual dependence, exploratory methodologies and limited theoretical consolidation. This suggests that sustainable development in the context of LSS is still predominantly addressed as an extension of existing efficiency and improvement logics rather than as an independently operationalised organisational transformation perspective. These characteristics inform the following conceptual discussion.

### *5.2 Conceptual positioning of integration approaches*

The content-related analysis of the reviewed studies shows that sustainable development is predominantly addressed selectively in the context of LSS and only rarely operationalised in a comprehensively integrated manner. Although many contributions explicitly refer to all three dimensions of sustainable development in line with the Triple Bottom Line, this reference often remains at an aggregated or conceptual level. In practical terms, ecological and economic objectives dominate, while social aspects – such as employee involvement, qualification or organisational learning processes – are usually considered only marginally or implicitly. Sustainability therefore appears in the existing literature primarily as an extension of established efficiency- and environment-oriented logics rather than as an equally balanced and integrated goal system.

This pattern is clearly reflected in the identified integration logics between LSS and sustainable development. The dominance of transversal approaches indicates that sustainability in many studies mainly functions as an overarching evaluation or framing logic, for example in the form of strategic visions, enabling factors or barrier models. However, a systematic translation of these objectives into operational LSS frameworks or methods occurs only rarely. The developed typology thus reveals that the limited integration of sustainable development is less attributable to a lack of goal orientation than to deficits in methodological translation and operationalisation.

Hybrid integration approaches, by contrast, exhibit a higher degree of methodological interlinkage, as individual sustainability aspects are explicitly embedded into LSS frameworks or tools. Notably, however, this integration is almost exclusively concentrated on ecological dimensions, for instance through extensions of value stream mapping or the incorporation of environmental performance indicators into DMAIC cycles. Social sustainability remains largely underdeveloped even in these studies and is only rarely operationalised in a systematic manner. This points to an asymmetric integration logic in which sustainability aspects gain traction primarily where they align with established efficiency-oriented improvement logics. The absence of integrative and iterative approaches is particularly noteworthy, as it suggests that sustainability is rarely conceptualised as an inherent component of LSS methodologies themselves. Instead, sustainability is mostly positioned as an external evaluative or strategic layer, indicating a comparatively low level of integration maturity.

In addition, the integration approaches are predominantly positioned at a strategic and conceptual level. Many studies emphasise management commitment, governance structures or organisation-wide success factors without consistently linking these elements to concrete operational applications. Accordingly, a top-down-oriented perspective prevails, in which sustainable LSS initiatives are primarily initiated and steered by management. Bottom-up-oriented or participatory implementation logics, by contrast, remain largely neglected. This constellation points to a persistent gap between strategic ambition and operational implementation, which has so far been explicitly addressed and methodologically tackled in only a small number of studies.

Overall, the findings indicate that while the research field exhibits considerable conceptual diversity, this diversity has so far been translated only to a limited extent into coherent and methodologically mature integration approaches. In the context of LSS, sustainable development is predominantly understood as a strategic reference framework or an additional perspective, whereas deeply operationalised forms of integration remain empirically documented exceptions. From a theoretical perspective, the findings demonstrate that different forms of sustainability integration within Lean Six Sigma can be distinguished systematically. The proposed differentiation of integration logics and organisational levels provides a conceptual lens for analysing how sustainability is positioned, translated and operationalised within continuous improvement systems, extending the discussion beyond the assessment of individual success factors or sustainability outcomes. These findings form the basis for the implications for future research derived in the following chapter.

## 6. Implications

### *6.1 Theoretical implications*

The findings of this study highlight a substantial need for further conceptual and theoretical development in research on LSS and sustainable development.

Firstly, the study shows that the integration of sustainability into LSS remains unevenly distributed across regions, sectors and organisational contexts. As a result, the existing research field appears to be shaped more strongly by specific industrial and institutional contexts than by a consolidated understanding of sustainable LSS integration.

Secondly, the findings indicate that sustainability-oriented LSS research still contributes only limitedly to an integrated understanding of sustainability and operational process improvement. Sustainability frequently functions as an additional steering logic, while its structural embedding into the methodological core logic of LSS remains underdeveloped.

Thirdly, the limited operationalisation of social sustainability points to a reduced understanding of sustainability within the existing LSS literature. Social dimensions largely appear as supporting factors for ecological or economic objectives rather than as independent sustainability goals.

### *6.2 Managerial implications*

From a practical perspective, the findings indicate that sustainability in LSS is often addressed at a strategic level without being consistently embedded into operational improvement processes. Organisations should therefore anchor sustainability objectives more firmly within LSS frameworks, project structures and decision-making logics.

While ecological sustainability is comparatively easy to integrate into operational improvement processes, social aspects such as employee involvement, qualification and organisational learning require more systematic consideration. Moreover, the predominantly top-down-oriented configuration of the identified approaches points to strongly management-driven LSS initiatives. Combining strategic direction with participatory and bottom-up-oriented elements may therefore enhance long-term effectiveness.

Finally, the limited empirical validation of many proposed models and frameworks complicates their direct practical application. Organisations should therefore critically reflect on existing approaches, adapt them to specific organisational contexts and systematically evaluate their effects.

## 7. Limitations

This study is subject to several limitations that should be considered when interpreting the findings. Firstly, the analysis is restricted to the studies included in the scoping review.

Despite a systematic search strategy, relevant contributions outside the selected databases, search terms or publication formats may not have been captured, particularly grey literature and non-English publications.

Secondly, the study follows the logic of a scoping review, which focuses on mapping and structuring the research field rather than evaluating methodological quality or empirical robustness. Accordingly, no conclusions can be drawn regarding the effectiveness or superiority of specific approaches.

Thirdly, the content-related analysis relies on a purpose-developed coding framework, which enables systematic comparison but inevitably involves interpretative decisions. Despite transparent procedures, a certain degree of subjectivity in classifying complex and ambiguous studies cannot be fully avoided.

Finally, the findings represent a snapshot of a dynamic and evolving research field and may therefore be complemented or revised by future research.

## 8. Future research directions

Building on the findings of this review, several avenues for future research can be identified. Future research should particularly strengthen the operational integration of sustainability within LSS, especially regarding social sustainability and the structural embedding of sustainability into LSS frameworks and methodologies. In addition, the predominantly exploratory orientation of the field highlights the need for more quantitative, comparative and longitudinal research designs to validate existing approaches and improve their transferability.

The findings further suggest that organisational levels and steering logics require greater attention, particularly regarding participatory and bottom-up-oriented implementation approaches. Moreover, the strong concentration of existing studies in manufacturing and selected regional contexts indicates the need for broader sectoral and geographical perspectives.

Building on the findings and their discussion, Table 6 synthesises the central research gaps and future research directions across the identified analytical dimensions.

## 9. Conclusion

The aim of this study was to systematically capture and structure research on the integration of LSS and sustainable development. Using a scoping review, the study identified dominant patterns, thematic focal points and gaps in a heterogeneous research field.

The findings show that LSS is increasingly discussed internationally in the context of sustainable development; however, the research field remains weakly consolidated. The literature exhibits a strong regional and sectoral concentration, particularly on industrial production contexts and selected Asian countries, while service sectors, the public sector and Western industrialised countries remain empirically underrepresented. These asymmetries limit the transferability of existing insights and underscore the fragmented state of current research.

From a methodological perspective, the field is predominantly exploratory, with a strong reliance on qualitative, mixed-methods and case-based designs. Quantitative, comparative and longitudinal studies remain scarce, resulting in limited empirical evidence on the effectiveness and robustness of sustainable LSS approaches.

Substantively, sustainable development is often addressed selectively within LSS. Ecological and economic dimensions dominate, while social sustainability is rarely integrated in an equally weighted and operationalised manner. Moreover, the linkage

**Table 6.** Future research directions

| Analytical dimension | Identified gap | Future research direction |
|---|---|---|
| Sustainability dimensions | • Weak operationalisation of social sustainability within LSS | • Translation of social objectives into process-level LSS practices<br>• Integration into performance and improvement systems |
| Levels of integration | • Limited embedding of sustainability into LSS frameworks and tools | • Structural integration into DMAIC, DMADV and related methodologies<br>• Empirical validation of integrated approaches |
| Integration logics | • Absence of integrative and iterative approaches | • Investigation of deeply integrated sustainability–LSS linkages<br>• Assessment of implementation effects and dynamics |
| Organisational levels and steering directions | • Predominance of top-down-oriented approaches | • Comparative analysis of participatory and bottom-up approaches<br>• Examination of organisational learning and implementation effectiveness |
| Methodological orientation | • Predominantly exploratory methodological orientation | • Quantitative, comparative and longitudinal research designs<br>• Validation and transferability assessment of existing frameworks |
| Sectoral and regional focus | • Strong concentration on manufacturing and selected regions | • Inclusion of service sectors and public organisations<br>• Expansion across diverse geographical and institutional contexts |

**Source(s):** Author's own work

between LSS and sustainability largely remains at a strategic or conceptual level, with deep methodological integration into LSS frameworks and tools being the exception.

By developing a typology of integration logics, this study makes an independent contribution to structuring the research field. The typology highlights the dominance of transversal and hybrid approaches, while integrative and iterative forms of linkage remain empirically underdeveloped, thereby providing an analytical foundation for future systematic and cumulative research.

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**Supplementary material**

The supplementary material for this article can be found online.

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