



ADVANCED INTERNATIONAL JOURNAL
OF BUSINESS, ENTREPRENEURSHIP
AND SMES
(AIJBES)

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LEAN DIGITAL ECONOMY AND GREEN DEVELOPMENT: A NARRATIVE REVIEW OF SYNERGIES, TRADE-OFFS, AND FUTURE RESEARCH AGENDAS

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Article Info:

Article history:

Received date: 03.08.2026

Revised date: 24.08.2026

Accepted date: 07.09.2026

Published date: 17.09.2026

To cite this document:

Ismail, N. F., Chua, C. R., & Samsi, S. M. (2026). Lean Digital Economy and Green Development: A Narrative Review of Synergies, Trade-Offs, And Future Research Agendas. *Advanced International Journal of Business Entrepreneurship and SMEs*, 8 (29), 1403-1424.

Abstract:

A quick emergence of the synergy between lean management, digital transformation, and sustainable development has changed the modern approaches to gaining efficiency, innovating technically, and being environmentally responsible. Even though the above-mentioned areas have been researched extensively separately before, the importance of exploring the synergy between them and their role in forming the modern lean digital economy and green development has not been emphasized. The purpose of this narrative literature review is to summarize and critically analyse the literature published from 1990 to 2026 regarding the theoretical background, emerging trends, and applications of combining lean and digital ideas and sustainability goals. The review will examine the existing literature in three interrelated thematic categories: the role of digital technologies in innovating and changing the organization; the compatibility of the capabilities in question with the goals of green development; and the role of lean techniques in improving productivity and value creation. It turns out that the combination of lean and digital has significant potential for resource efficiency, organizational resilience, and sustainable economic growth. Nevertheless, the literature raises the issues of technology-induced inefficiency, unevenness of digital readiness, and a lack of empirical evidence about the impact of such combinations on sustainability. In terms of theory, the paper helps to

form an approach which treats digital transformation, green development, and lean techniques as complementary abilities rather than separate notions. Practically, the research provides guidance for scientists, managers, and policymakers who want to formulate strategies that would help to maintain productivity, innovation, and sustainability at a decent level.

DOI: 10.35631/AJBES.829080 **Keyword:**

Lean Digital Economy, Green Development, Digital Transformation, Lean Management, Sustainable Innovation, Industry 4.0, Narrative Review



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Introduction

Globally, governments, corporations, and organisations have made it a major priority to combine the digital economy with green growth. They aspire to build an economy while addressing climate change, resource scarcity, and environmental damage. The rapid development of technologies like artificial intelligence, big data, cloud computing, blockchain, the Internet of Things, and Industry 4.0 has altered how businesses and governments operate. Lean techniques have gained popularity recently due to their ability to reduce waste, improve productivity, and produce more value with less. When these concepts are applied in conjunction with plans, they present significant opportunities to improve the environment, accelerate innovative ideas, make better use of resources, contribute to the achievement of global UN goals, and lower emissions. Further research demonstrates that adopting more environmentally friendly practices can help create cleaner products, better manage energy, and enhance how manufacturing, farming, and service jobs treat the environment.

It is nevertheless challenging to link the lean digital economy with green growth despite these prospects. Digital technologies can boost productivity and lower pollution. They might also raise data center emissions, generate more electronic waste, need more specialised materials, and use more electricity. This could counteract the results if done improperly. Additionally, lean programs that focus on improving things might not always be environmentally beneficial unless they are structured to coincide with green aims. Achieving success requires clear strategies, sensible legislation, the right knowledge, and prudent investments that support digital and environmental change. As countries develop their green ambitions, it is critical for research and policy to comprehend how these goals interact and clash.

Research on this topic is still lacking, despite the fact that more people are studying it. Initial study often focuses on the economy, lean methods, green ideas, or sustainability. They don't use connections to illustrate how they interact with each other. Second, the research varies. China's factories are very productive. Resources are scarce for small enterprises, governments, service providers, and developing countries. Third, various words are used in different contexts. Words like "digital economy," "green digital economy," "digital green change," "Lean 4.0 Green Lean Six Sigma," and "lean-green-digital combination" are used without explanation. Finally, these ideas can be applied in a variety of ways, which makes it difficult to compare the results and use them in different situations.

These problems highlight the necessity of a concept-unifying review. This kind of analysis may gather all the data, pinpoint points of agreement and dispute, and illustrate how lean digital economy plans fit with green goals. Unlike studies that concentrate on a specific site or area, a review can integrate several types of information to present new ideas about sustainability, digital transformation, and improving things as well as to clarify concepts. It can also find areas that need more research, unsolved rule issues, and challenges with concept implementation. For people who plan, run firms, and carry out research to identify practical methods to boost the economy through lean and digital innovations, taking pictures is essential.

So, the goal of this paper is to look at the research on the lean digital economy and green development. It will look at the parts the problems and what needs to be studied next. It will find the missing ideas what rules should do and where to go next. The rest of this paper is organized like this. The next part explains how the review was done to find and put together the research. Then it looks at what the lean digital economy and green developmentary. The next parts talk about the parts of using digital tools, lean ways and being green. They look at the problems. What makes it hard to use these ideas. They also find what should be studied next. The paper ends with what this review adds to ideas what it means for life what rules should do what is not good, about the study and what to look at next.

Review Approach

The study makes use of a narrative review method to summarize and give a critical interpretation to the existing literature concerning the relationship between the lean digital economy and green development. Different from systematic reviews, which mainly involve the synthesis of extensive evidence according to established protocols, narrative reviews offer more flexibility in bringing together conceptual, theoretical, and empirical evidence from a number of different disciplines in order to achieve a thorough understanding and to spot new research directions (Baumeister & Leary, 1997; Ferrari, 2015). Since the concepts of lean management, the digital economy and green development have all developed within a variety of disciplines such as operations management, sustainability, economics, innovation studies and public policy a narrative review is seen as suitable for examining the conceptual relationships, for identifying areas of convergence and divergence, and for suggesting future research programmes.

The search for the relevant literature was carried out only with the use of the Scopus database since it provides extensive coverage of peer-reviewed international journals and is generally regarded as one of the most reliable multidisciplinary indexing databases for research in the fields of management, sustainability, engineering, and the social sciences (Elsevier, 2024). In addition to improving the review's consistency, transparency, and reproducibility,

concentrating the search on a single, high-quality database ensured that the chosen literature met accepted academic quality standards.

Only English-language peer-reviewed journal articles, book chapters, conference papers, and review papers published between 2010 and 2026 were included in the search. This period was chosen because the concept of the digital economy has significantly expanded over the last 10 years due to the quick developments in Industry 4.0, digital transformation, sustainability transitions, and green innovation. After the first search, duplicate records were removed, and the titles, abstracts, and keywords were assessed for their relevance to the review's objectives. Only studies that directly addressed at least two of the review's main themes—lean practices, the digital economy, and green development—or investigated how these themes interacted through technological innovation, sustainability strategies, governance, policy, or organisational transformation were accepted. Publications that solely addressed irrelevant technical concerns, were not written in English, had not received peer review, or were not sufficiently relevant to the objectives of the review were excluded.

The selected studies were analysed using a method that included repeated readings, comparisons, and the creation of thematic syntheses in compliance with established techniques for narrative reviews, rather than statistical meta-analysis or a quantitative evaluation of the quality (Ferrari, 2015; Green et al., 2006).

Themes related to the conceptual foundations, the synergies between green development and the lean digital economy, the implementation trade-offs, policy and governance challenges, technical innovation, and future research avenues were used to classify the evidence. This interpretive synthesis allowed for the identification of recurring patterns, contradictions, theoretical gaps, and future research goals from a variety of academic viewpoints while preserving methodological openness.

As indicated in Table 1, the search technique included a combination of Boolean operators and particular keyword clusters to find literature that addressed synergies, trade-offs, and future research priorities.

Table 1: Summary of Search Strategy and Selection Parameters

Component	Description
Search String	("lean" OR "efficient") AND ("digital economy" OR digitalization) AND ("green development" OR sustainable) AND (innovation OR technology) AND (policy OR framework)
Publication Timeframe	2010–2026
Inclusion Criteria	English-language publications; peer-reviewed journal articles, review papers, conference papers, and book chapters; studies addressing lean management, digital economy, green development, sustainability, innovation, technology, governance, or policy relevant to the review objectives.
Exclusion Criteria	Non-English publications; duplicate records; editorials, notes, dissertations, magazines, and non-peer-reviewed sources; studies unrelated to the interaction between lean, digital economy, and green development.

Selection Approach	Title, abstract, and keyword screening followed by full-text assessment and thematic synthesis based on relevance to the objectives of the narrative review.
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Conceptual Background

To achieve operational excellence, the creation of economic value, and sustainable development, the concept of a lean digital economy combines the ideas of lean management with digital technologies. The Toyota Production System gave rise to lean management, which emphasises resource efficiency, customer value creation, continuous improvement (kaizen), and the methodical removal of waste (muda) (Womack & Jones, 1996). As Industry 4.0 and digital transformation have developed, lean principles have become more and more combined with technologies including artificial intelligence (AI), the Internet of Things (IoT), cloud computing, big data analytics, blockchain, and cyber-physical systems in order to boost productivity, organizational agility, and decision-making (Ciliberto et al., 2024; Eriksson et al., 2023). As a result, the lean digital economy goes beyond simply improving efficiency by using digital capabilities to optimize processes, reduce operational waste, and generate sustainable economic value via data-driven innovation.

The term 'digital economy' generally describes economic activities made possible by digital technologies, digital infrastructure, and data-driven business models which alter the ways in which production, consumption, governance and service delivery take place (Ciocoiu, 2011). Digitalization has now become a key factor in boosting productivity through promoting innovation, enhancing the transparency of information, increasing operational efficiency and allowing for intelligent management of resources in various industries (Chen et al., 2024; Zheng et al., 2023). In the area of sustainability, digital technologies allow for the real-time monitoring of environmental performance, enable intelligent manufacturing, improve visibility within the supply chain, and help to implement policies on the basis of evidence, thus contributing to green transformation and to sustainable economic development (Eshbayev et al., 2024; Pop et al., 2023).

Green development is generally regarded as a method of achieving economic growth which at the same time advances environmental protection, improves the efficient use of resources, promotes social well-being, and ensures long-term sustainability. Unlike traditional growth models that prioritise economic expansion, green development emphasises a balance between economic prosperity and ecological conservation through cleaner production, circular resource use, low-carbon technologies, and sustainable innovation (Qi & You, 2024; Zheng et al., 2023). More academics contend that rather than being only an environmental objective, green development should be seen as a complex transition combining technical innovation, institutional support, organisational capabilities, and policy coordination (Voronkova et al., 2024). Thus, by promoting technological innovation, operational effectiveness, and environmental sustainability, lean management, digital transformation, and green development combine to form a complementary framework that promotes sustainable competitiveness (Vilaça et al., 2026; Yadav et al., 2023).

Key Theories or Frameworks

A range of theoretical methods offer the conceptual basis for understanding the relationship between green development and the lean digital economy. One of the most important of these

is the Resource-Based View (RBV), which holds that businesses may get a sustained competitive advantage through resources and skills that are valued, uncommon, distinctive, and non-replaceable (Barney, 1991). In the framework of the lean digital economy, digital capabilities, organisational learning, lean practices, and green innovation are seen as strategic resources that help companies increase their operational efficiency and environmental performance. The company becomes more robust and contributes to the creation of long-term sustainable value when these complimentary abilities are blended.

The Dynamic Capabilities Theory builds on the RBV by emphasising the importance of an organization's capacity to identify opportunities, take advantage of new technologies, and continuously reconfigure both its internal and external resources in response to changing environments (Teece, Pisano, & Shuen, 1997). Because digital technologies are developing at a quick pace and environmental rules are becoming more stringent, businesses must continually adapt their technology capabilities, operational procedures, and sustainability initiatives. Because of this, dynamic capabilities demonstrate how businesses can integrate digital transformation, lean management, and green innovation to accomplish continuous improvement and maintain their competitive edge in the face of environmental and technological unpredictability.

From an operational point of view, the Lean–Green–Digital integration framework, which is commonly known as Lean 4.0 or Lean–Green–Sustainability 4.0, has become an important conceptual model for explaining how digital technologies reinforce both the implementation of lean principles and environmental sustainability (Ciliberto et al., 2024; Vilaça et al., 2026). The framework states that Industry 4.0 technologies improve traditional lean tools by allowing real-time monitoring, predictive analytics, intelligent automation, and data-driven decision-making, while at the same time increasing resource efficiency, reducing waste, lowering emissions, and aiding the development of circular production systems. Instead of viewing lean, digitalization, and sustainability as separate activities, the framework stresses the complementary and mutually reinforcing nature of these three areas in achieving sustainable operational excellence (Yadav et al., 2023).

In this review, the general idea of sustainable development offers the main policy and social framework. The United Nations Sustainable Development Goals (SDGs) promote the incorporation of economic development, environmental protection, and social inclusion by means of innovation, responsible production, climate action, and effective institutions (United Nations, 2015). Modern studies tend to see the digital economy as a key factor in achieving green development since it enhances resource productivity, aids environmental governance, and helps to achieve low-carbon transitions (Chen et al., 2024; Zheng et al., 2023). Digital transformation does, however, also bring about trade-offs with regard to energy consumption, electronic waste, cybersecurity, and uneven access to technology, underscoring the need to find a balance between the benefits of efficiency and social and environmental sustainability. Together, these theoretical stances offer a comprehensive conceptual framework for analysing the trade-offs, potential avenues for future study, and connections between green development and the lean digital economy.

Thematic Review of Literature

Operations management, digital transformation, sustainability, technical innovation, and environmental governance are all covered in the literature on the connection between the lean

digital economy and green development. However, because lean management, digital capabilities, and green development are often considered as distinct or just partially related areas, the research is still fragmented. Therefore, a thematic synthesis is required to elucidate the contributions of each stream of literature as well as the ways in which the three aspects interact to influence the outcomes of the contemporary lean digital economy. This evaluation views green development, digital capabilities, and lean management as complimentary rather than separate elements. Green development sets the environmental and sustainability goals that these improvements should be evaluated against; digital capabilities offer the visibility, connectivity, analytical intelligence, and scalability needed to optimise processes; and lean management offers the operational discipline needed to find and eliminate waste.

Four interconnected factors make the combination of these three dimensions important. By ensuring that ineffective or non-value-adding operations are handled using lean principles either before or in conjunction with digital automation, it first prevents digitalised waste. Instead of eliminating waste, digitising an inefficient operation could just speed it up. Second, integration aids in resolving the environmental conundrum of digitalisation, whereby technologies that increase operational efficiency may concurrently create environmental challenges due to hardware manufacture, energy usage, data processing needs, and electronic waste.

Therefore, green development offers the sustainability standards required to guarantee that digital expansion does not simply shift environmental costs to other parts of the system. Third, data-driven ecological accuracy is made possible by integration. Real-time data on operational and resource flows is produced by digital technologies like IoT, AI, big data analytics, and advanced automation. Lean management offers the discipline of continuous improvement required to turn this data into action, and green development offers the environmental goals that are used to assess improvements. Fourth, by shifting the lean digital economy away from a limited focus on productivity and cost reduction and toward a balance between economic competitiveness, technical agility, operational efficiency, and environmental responsibility, the integration generates wider sustainable value.

According to this integrated viewpoint, the three dimensions play distinct but complementary functions. Lean management without digital capabilities may be limited by limited visibility and analytical capacity; lean and digital improvements without green development may achieve operational efficiency while ignoring environmental consequences; and digital capabilities without lean principles may automate inefficient processes. As a result, their integration turns discrete efficiency improvements into more systemic ways to create value. This integrative interpretation is supported by the growing literature on Lean 4.0 and Lean–Green–Sustainability 4.0, which presents digital technologies as tools for enhancing lean practices while also advancing sustainability goals (Ciliberto et al., 2024; Vilaça et al., 2026). Digitalisation can support green total factor productivity, eco-innovation, and resource optimisation, according to data from the literature on the digital economy and green development (Chen et al., 2024; Zheng et al., 2023). However, these benefits are still contingent upon organisational and institutional circumstances.

As a result, lean management, digitisation, and green development are not treated as three concurrent research streams in the theme review. Rather, it looks at the ways in which they interact, the circumstances in which their integration yields favourable results, potential trade-offs, and the gaps that stand in the way of a thorough comprehension of the lean digital

economy. The literature is organised around four interconnected themes: (1) the lean digital economy as a catalyst for green growth; (2) synergies between lean, digitalisation, and sustainability; (3) trade-offs and implementation issues; and (4) future research goals and new approaches.

LEAN DIGITAL ECONOMY AND GREEN DEVELOPMENT: A NARRATIVE REVIEW OF SYNERGIES, TRADE-OFFS, AND FUTURE RESEARCH AGENDAS

ACADEMIC METHODOLOGICAL NOTE: The Narrative Synthesis Approach - High-quality narrative reviews organize and synthesize literature by key themes and conceptual lines rather than summarizing individual studies sequentially.

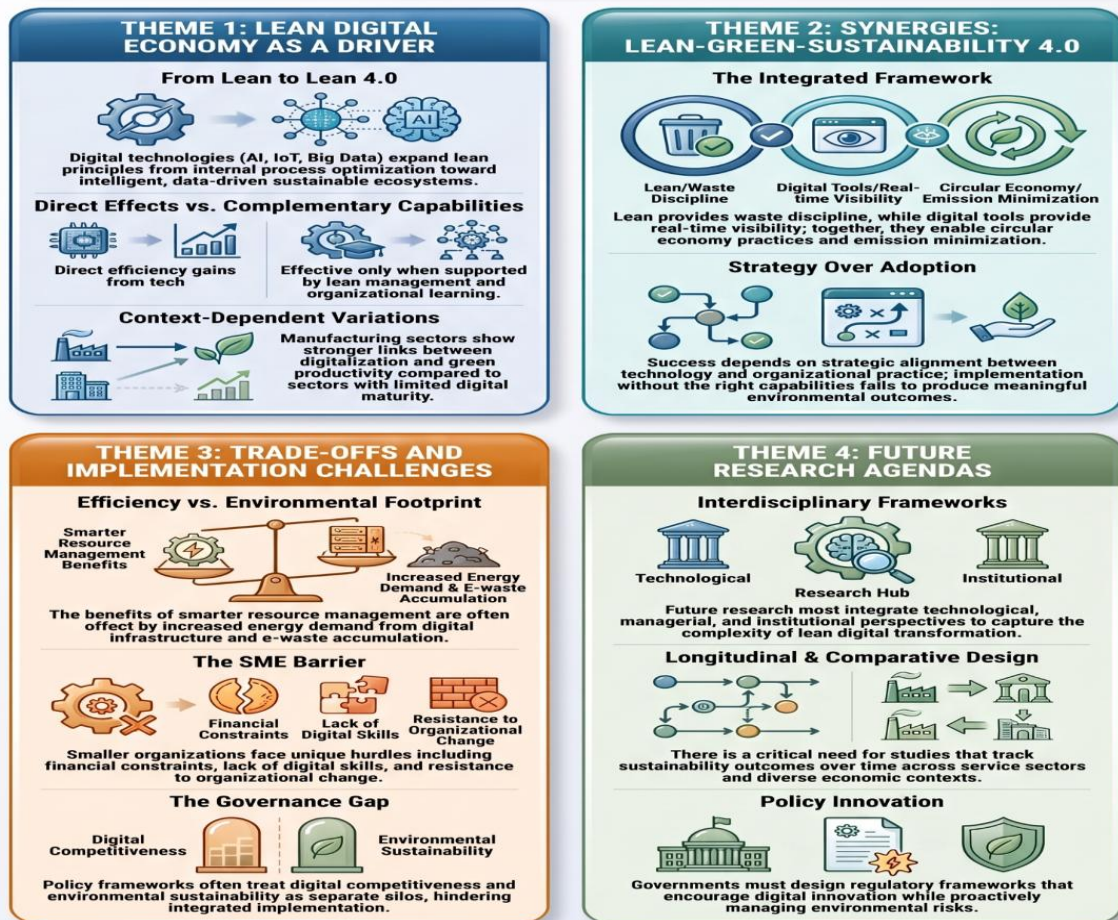


Figure 1: Thematic Review of Literature

Theme 1: Lean Digital Economy as a Driver of Green Development

Organisations' approaches to operational effectiveness, innovation, and environmental performance have fundamentally changed as a result of the rise of the lean digital economy. Lean management has historically concentrated on process optimisation, value generation, ongoing improvement, and the removal of non-value-adding tasks. These concepts now encompass intelligent, linked, data-driven, and more sustainable corporate ecosystems rather than just isolated processes due to the extensive use of digital technology. Organisations can monitor resource flows, detect process abnormalities, optimise production cycles, and react to operational situations in real time thanks to technologies like artificial intelligence (AI), the Internet of Things (IoT), big data analytics, cloud computing, and sophisticated automation.

This convergence is reflected in Lean 4.0, which uses digital capabilities to support more general sustainability goals while reinforcing well-established lean concepts (Ciliberto et al., 2024; Vilaça et al., 2026).

The potential of digital tools to translate lean concepts into more quantifiable, adaptable, and scalable improvement processes is what makes this integration crucial. Material losses, energy usage, process unpredictability, equipment inefficiencies, and other waste causes that would be challenging to identify using traditional methods can all be revealed by real-time data. Automation may increase process uniformity and cut down on wasteful resource consumption, while predictive analytics can help preventative intervention. These technologies do not, however, establish if an activity adds value on its own. Because it offers the ideas for separating value from waste and integrating continuous improvement into organisational procedures, lean management continues to be significant. This reasoning is further extended by green development, which mandates that businesses take environmental results into account in addition to operational performance.

Empirical research shows that digitalisation may support green development at the larger economic level by enhancing resource allocation, eco-innovation, and green total factor productivity (Chen et al., 2024; Zheng et al., 2023). These results imply that digital capabilities can play a significant role in facilitating environmental improvement. However, there is disagreement in the research on the processes behind these effects. One viewpoint highlights the direct benefits of technology, contending that increased information openness, data-driven decision-making, and technological innovation might lessen resource intensity and environmental pressures (Eshbayev et al., 2024; Voronkova et al., 2024). A different viewpoint contends that in order to achieve significant sustainability results, digital tools need complementary organisational capabilities, institutional learning, adaptive management, and supportive governance arrangements (Eriksson et al., 2023; Yadav et al., 2023).

This debate is especially pertinent to the current review's integration argument. Lean management and green development would have less of an impact if digital technologies were intrinsically sustainable. Nonetheless, research indicates that technology skills need to be integrated into suitable organisational procedures and sustainability goals. Green development offers the environmental standards for determining if the ensuing changes produce a net sustainability advantage, while lean management may offer the process discipline required to guarantee that digital expenditures target actual causes of operational waste.

Significant sectoral and geographical variability is also evident in the data. While service-oriented industries and digitally emerging settings continue to be relatively understudied, manufacturing and industrial sectors often offer greater evidence about the relationship between digitalisation, productivity, and green performance (Qi & You, 2024; Zheng et al., 2023). The degree to which digital transformation helps to green development may consequently vary depending on factors such as worker skills, institutional quality, organisational capacities, digital infrastructure, and technical preparedness. As a result, the lean digital economy's contribution should be viewed as context-dependent rather than technologically deterministic.

Even while its strategic significance is becoming more widely acknowledged, there is still much to learn about how digital capabilities, lean methodologies, and green goals work together to provide environmental results. The majority of the literature now in publication

looks at green development and digital transformation as separate study streams, paying very little attention to the mediating and enabling function of lean management. Therefore, the lean digital economy should be conceptualised in future research as an integrated system where environmental stewardship, digital intelligence, and operational discipline all work together to define green development.

Theme 2: Synergies Between Lean, Digitalisation, and Sustainability

The literature identifies substantial synergies among lean management, digitalisation, and sustainability because each dimension addresses a complementary requirement of sustainable transformation. Lean management establishes the principles of waste elimination, value creation, flow, and continuous improvement. Digital capabilities provide real-time visibility, connectivity, analytical intelligence, predictive capability, and automation. Green development establishes objectives relating to resource efficiency, emissions reduction, circularity, and long-term environmental sustainability. The integration of these dimensions therefore enables organisations to move beyond isolated productivity improvements towards coordinated sustainability outcomes.

Digital capabilities are particularly important because they extend lean principles across organisational and supply-chain boundaries. IoT-enabled systems can provide continuous information regarding material and energy consumption, while predictive analytics can identify potential failures and resource inefficiencies before they become significant. Digital platforms can also improve coordination among suppliers, manufacturers, distributors, and other stakeholders. However, the availability of information does not automatically create improvement. While green objectives decide whether such changes contribute to environmental sustainability, lean principles offer the operational processes that transform knowledge into waste reduction and continual improvement. An essential conceptual basis for Lean-Green-Sustainability 4.0 is provided by this interplay (Vilaça et al., 2026).

Resource optimization, waste minimization, technological innovation, environmental monitoring, increased productivity, and better sustainability performance represent the major synergies identified in the literature. Nevertheless, it remains unclear under what conditions these benefits are realized. Based on some research, digital technologies are advantageous in terms of resource optimization, environmental reporting, and monitoring (Chen et al., 2024; Eshbayev et al., 2024). Meanwhile, other research findings suggest that the adoption of technology itself does not lead to sustainable benefits because organizational alignment and strategy fit matter more (Ciliberto et al., 2024; Eriksson et al., 2023). Thus, the application of the industry 4.0 concept may help to increase the efficiency of lean processes, however, if companies do not have specific environmental indicators, sustainability goals, and organizational routines, then its ecological benefits may be insufficient.

Where technical readiness differs, the importance of integration becomes apparent. For example, the presence of infrastructure, digital literacy, institutional support, and access to relevant technologies may affect digital green initiatives in rural and agricultural contexts (Qi & You, 2024). This proves that the integration of digital, green, and lean capabilities is much more complicated and implies factors such as organizational learning, human resources, governance, and strategic alignment.

The research lacks theoretical elaboration of the underlying capability-building mechanisms involved in these interactions, even though this synergistic potential is clearly evident. There are many publications, which measure such outcomes as carbon footprint, green total factor productivity, or innovation performance without explaining in detail how firms develop their capabilities to align their digital investments with environmental and lean initiatives. The influence of lean management on the choice of technologies, implementation strategies, and sustainability performance measurement also lacks adequate research. It means that future research must develop dynamic models describing the interplay between the above-mentioned variables at different periods of time.

Theme 3: Trade-Offs and Implementation Problems of the Lean Digital Economy and Green Development

There are no guarantees of positive outcomes of the integration of lean management, digitization and green development. Although these three aspects may work synergistically, they may also cause some implementation problems. Although digitization goes along with sustainability and efficiency, there is still an adverse effect on the environment related to data processing, energy use, hardware production, and electronics. Thus, digital transformation cannot be considered sustainable on its own as it is possible to say that environmental impacts of digital transformation depend on development, implementation, use, governance and evaluation of technologies (Ciocoiu, 2011; de Pablos, 2024).

There is also a similar problem in lean management where excessive concentration on cost savings and efficiency may overlook some social and environmental consequences outside of the actual manufacturing process where improvement of a certain operational process may move consumption of resources or environmental costs to another stage of the supply chain. As green development broadens performance consideration to environmental effects during the whole life cycle of goods, this aspect is extremely important.

Contradictory views on the significance of the trade-offs exist in the literature. In accordance with one view, digital technologies may bring some environmental benefits due to the improved efficiency of allocation and utilization of resources using automation, monitoring, prediction and optimization (Eshbayev et al., 2024; Pop et al., 2023). The more critical approach mentions rebound effects which consist in growth of production and consumption as well as fall in prices due to efficiency improvements. These contradictions emphasize the importance of considering environmental performance together with lean and digital ones.

Organisational competence and scale also affect implementation issues. Big businesses could have easier access to funding, technology infrastructure, specialised knowledge, and data capabilities. Financial limits, a lack of digital skills, infrastructural constraints, organisational reluctance, and challenges integrating new technology with current procedures are all potential challenges for SMEs (Eriksson et al., 2023). Therefore, the shift to a lean digital economy is not just a technology problem; it also involves organisational competencies, worker development, and institutional support.

Another major obstacle is the fragmentation of policies. Sustainability, industrial change, digital competitiveness, and environmental protection are often handled by different legal and policy frameworks. Organisations may find it challenging to match technology investment with environmental goals as a result of this fragmentation, which can lead to contradictory

incentives (Adarina et al., 2020; Blieva et al., 2020). Determining whether lean digital efforts promote system-wide sustainability or just shift environmental loads across organisational and supply-chain borders is further hampered by the lack of established multidimensional evaluation measures.

These results suggest that integrated evaluation frameworks should replace isolated evaluations of particular trade-offs in future research. Operational effectiveness, digital resource needs, lifecycle environmental consequences, organisational preparedness, social results, and institutional circumstances should all be taken into account concurrently by such frameworks. This would make it possible to determine more precisely if integrating digital, green, and lean capabilities results in a net sustainability advantage.

Theme 4: Future Research Agendas and Emerging Directions

The intersection of digital capabilities, green development, and lean management offers a significant research priority for the future, especially with regard to conceptual integration, empirical validation, organisational capability development, and policy design. Establishing more precise conceptual boundaries between related concepts like Lean 4.0, Sustainability 4.0, Green Digital Economy, and Digital Green Transformation is the top goal. It is now challenging to create cumulative theoretical knowledge and compare findings across fields due to inconsistent nomenclature and overlapping meanings. Therefore, future research should specifically examine the relationships between lean practices, digital capabilities, green innovation, and sustainability results while elucidating their various roles.

The integrated relationship's empirical confirmation is the second priority. Previous research has examined the connections between the development of the digital economy and green growth using structural modelling, productivity-frontier estimating, and spatial econometrics (Chen et al., 2024; Xu et al., 2023; Zheng et al., 2023). However, very few studies look at digital capabilities, green development, and lean methods all at once. Multilevel empirical models that link firm-level operational practices with technical capabilities, supply-chain impacts, institutional contexts, and wider environmental outcomes should be developed in future study.

Third, longitudinal and comparative studies should receive more focus. While service sectors, public organisations, SMEs, developing markets, and cross-sectoral ecosystems are still relatively understudied, the information that is now available is mostly centred in manufacturing and industrial contexts (Ciliberto et al., 2024; Vilaça et al., 2026). While cross-national studies might show how institutional and policy settings affect the efficacy of integrated lean, digital, and green initiatives, longitudinal research could ascertain if benefits brought about by lean digital transformation are maintained over time.

Fourth, the organisational and human resources needed to maintain integration should be investigated in future studies. Sustainable change cannot be produced by digital technologies on their own. The effectiveness of converting technology investments into operational and environmental advantages may depend on a number of factors, including digital skills, organisational culture, leadership, learning capacities, change management, and governance procedures (de Pablos, 2024). The relationship between technology adoption and organisational change would be strengthened by paying more attention to these issues.

Lastly, more synergy between policy and governance research is needed. The environmental effects of digital infrastructures, energy use, electronic waste, data governance, and uneven access to technology should all be addressed by regulatory frameworks in addition to fostering digital innovation and competitiveness. Instead of seeing sustainability and technology policies as distinct areas, more integrated policy approaches might link digital transformation with environmental and social goals (Adarina et al., 2020; Limna, 2026).

All things considered, the research suggests that the future of the lean digital economy is found in the strategic and systematic integration of lean practices, digital technology, and green initiatives rather than in their independent progress. Therefore, whether digitalisation increases efficiency or if digital technologies promote green growth is not the only crucial subject for future study. Instead, whether digital transformation produces results that are economically competitive, operationally efficient, and ecologically sustainable depends on how lean management, digital capabilities, and green development interact. In addition to strengthening the theoretical underpinnings of the lean digital economy, answering this question would give companies and policymakers looking to accomplish sustainable digital transformation with useful advice.

Critical Discussion

Through the provision of a detailed analytical review of the important trends, controversies, and research problems that exist in the field, the Critical Discussion section goes deeper into the analysis of the literature than the mere literature review. This critical discussion involves evaluating the existing body of knowledge based on four dimensions of analysis rather than only summarizing the results that have already been obtained: the topics where the literature agrees, the disagreements among academics, the existing research gaps, and the practical implications for theory, future research, and practice. In addition to offering a broader understanding of the state of the literature, this systematic approach also allows identifying areas of agreement, conceptual controversies, limitations, and opportunities for extending research knowledge.

Agreements in the Literature

There is a general agreement among academics in the literature that integration of digital transformation, lean management, and sustainable development is a key strategy for enhancing the organizational effectiveness and addressing larger issues in economics and environment. The research on lean management stresses the optimization of the business processes, creation of value, waste reduction, and continuous improvement as the keyways to achieve higher levels of operational performance (Bhamu & Singh Sangwan, 2014; Womack et al., 1990). Likewise, the research on digital transformation stresses the importance of new digital technologies in helping organizations to improve their decision making, reorganize their processes, and create new values using data (Vial, 2019). Specialists in the sphere of green development have common views about the need for combining technical advances and operational effectiveness with environmental concerns in order to stimulate sustainable economic development (Dyllick & Muff, 2016; Hart, 1995).

However, as the relation between lean digital transformation and green development requires a systemic change in the organizational capabilities, institutions and strategy rather than just technical integration, it is important to investigate the apparent consensus in more detail. Based

on the prior research, the extent to which digitization can contribute to sustainable outcomes depends on the way how technologies are incorporated in the company operations and sustainability strategy (Vial, 2019). In a similar fashion, if the company pays more attention to the cost reduction than the creation of ecological value, then lean can increase efficiency while producing limited environmental gains (Bhamu & Singh Sangwan, 2014). Hence, the consensus in the research should be viewed conditionally as the strategic integration of lean thinking, digital innovations and sustainability principles produces positive results. As a result, by highlighting the importance of the alignment of technological, operational and environmental capabilities, this perspective goes beyond the current theoretical ones.

Disagreements

Even though the potential gains from the integration of digital technology, lean methods and green development are widely recognized, there is a great deal of controversy in the literature on their actual impact and nature. According to some researchers, the digital transformation contributes to sustainability by providing opportunities for more efficient manufacturing, more effective monitoring and smarter use of resources (Vial, 2019). However, other points of view state that digitalization can lead to the increasing dependency on resource-intensive infrastructure, higher energy consumption and generation of additional electronic waste, all of which can have unexpected environmental effects. In the same way, the views on lean management differ. Some scholars think that lean promotes sustainability due to its ability to eliminate waste while the others believe that traditionally lean management approach concentrates on efficiency and productivity without considering other aspects (Bhamu & Singh Sangwan, 2014; Dyllick & Muff, 2016). It proves that rather than being generally positive, the connection between digitalization, lean management and green development largely depends on the context.

The contradictions identified in the literature reflect some fundamental disagreements regarding the perception of modern economy in terms of sustainability and progress. While the long-term resilience of ecological systems and the outcome of inclusive development are not discussed often, most of the existing research evaluates digital and lean initiatives using productivity, cost reductions and efficiency metrics. This brings up the issue of a theoretical limitation since efficiency improvements do not necessarily bring about lasting changes without the presence of adaptations in stakeholder involvement, business model, and governance (Hart, 1995). Thus, the need for more complex frameworks which would consider not only technological perspective but also interactions between organizational strategies, institutional context, and sustainability aims is justified by the disagreements within the academic community.

Gaps

While the topics of lean management, digital transformation and sustainability have been widely researched, it is necessary to admit that there is a certain number of gaps regarding their interrelations. Modern studies tend to examine these areas separately, leading to the appearance of a fragmented body of information concerning the combined impact of digital capabilities and lean management on green development outcomes. While sustainability studies usually pay separate attention to environmental performance and responsible resource management, research on digital transformation mostly concentrate on organizational changes, technological innovations, and competitive advantages (Vial, 2019; Dyllick & Muff, 2016). Likewise, studies

on lean management have traditionally paid attention to manufacturing efficiency and not to its more comprehensive role for sustainable economic growth (Bhamu & Singh Sangwan, 2014). Thus, there is a lack of empirical evidence regarding the combined impact of lean digital approach and its contribution to social, economic and environmental results in various industries and countries.

Firstly, the main theoretical and methodological gap is associated with the lack of coordinated empirical research. There is only partial knowledge regarding the process through which digital technologies increase the efficiency of lean practices and thus affect the trajectory of sustainable development. Currently, there is no understanding whether lean digital transformation is successful in relation to organizational competencies, regulatory framework, infrastructural readiness and human capital. Moreover, it is necessary to mention that there is no sufficient information concerning how these changes can help to reach macroeconomic goals such as sustainable growth, productivity increases and sustainable industrial development since many studies use firm level perspective. Therefore, multidisciplinary research methods involving operations management, digital economy perspectives, and sustainability theories are required.

Implications

Several noteworthy implications can be deduced from the evaluation of the current literature with respect to theory, research, and practice. From the perspective of theory, the findings indicate that in the future lean management, digital transformation, and green development should not be regarded as separate bodies of knowledge. Rather, such concepts need to be viewed as interconnected components of a unified transformation paradigm in which environmental responsibility, technology, and operational excellence complement each other. Through highlighting the importance of incorporating organisational, technical, and sustainability capabilities to achieve sustainable and competitive outcomes, the above approach will facilitate the expansion of existing theories, such as resource-based view (Hart, 1995), by encouraging scholars to develop multidimensional models of organisations considering sustainability impacts and performance improvements.

Practically, the literature underscores the need for the development of comprehensive strategies that would ensure the positive contribution of digital innovation into sustainable development. The former should be seen through the lens of responsible resource management, innovation, and resilience rather than automation or efficiency alone. Furthermore, to ensure the broad engagement in emerging digital economy, policymakers should foster workforce development, innovation with a sustainability focus, and digital infrastructure (Bukht & Heeks, 2017). Lastly, for technology innovation to lead to sustainable and just economic growth, it is essential for firms, governments, and scholars to collaborate to apply the principles of lean management, digital transformation, and green development.

Recommendations and Future Directions

Findings of the current narrative review clearly indicate that coordinated efforts at the level of practice, policy, and research are essential for the successful integration of lean principles, digital transformation, and green development. Although the literature available at the moment points at significant possibilities for improvement in terms of organisational efficiency, sustainability performance, and organisational resilience as well as the persistent challenges

associated with technology implementation, organisational capabilities, governance, and variations across contexts, organisations need relevant guidance, supportive institutional and regulatory frameworks, and further academic research to address the abovementioned problems and improve both theoretical and empirical knowledge base. For this reason, the following recommendations are offered in three related directions: proposals for further research, recommendations for policy and organisational use, and recommendations for practice.

Recommendations for Practice

Practitioners must use a more comprehensive strategy that strikes a balance between operational effectiveness, technical advancement, and sustainability results in order to integrate principles, digital transformation, and green development. By strategically utilising digital capabilities to promote waste reduction, resource optimisation, and environmentally conscious decision-making, organisations should go beyond considering technology only as instruments for automation and cost reduction. To maximise the value produced by digital transformation efforts, practitioners are urged to build skills in areas like data analytics, process innovation, and continuous improvement (Vial, 2019). Adoption of methods should also take into account social and environmental aspects in addition to more conventional performance metrics like cost effectiveness, productivity, and quality (Dyllick & Muff 2016). Because of this, managers must create performance metrics that account for both the effects of sustainability and operational excellence.

Additionally, practitioners should understand that organisational preparedness, workforce competencies, and cultural adaption are just as important to lean digital transformation as technology investment. Through programs for participatory improvement and ongoing skill development, employees should be actively participating in transformation activities. Employee engagement, leadership commitment, and organisational learning capacities have a greater impact on lasting gains than technology adoption alone, according to prior implementation studies (Bhamu & Singh Sangwan 2014). Organisations should thus create change management plans that match transformation initiatives with sustainability goals and people skills. A strategy like this may boost resilience, promote creativity, and guarantee that lean digital practices provide long-term benefits rather than immediate efficiency advantages.

Recommendations for Policy or Organizational Use

Organisational and policy frameworks need to be strengthened to ensure that sustainable digital economies are promoted. In order to ensure that organisations, including small and medium sized enterprises, are able to take part in digital transformation processes, it is essential for policymakers to focus on investing in infrastructure, innovation ecosystems, and workforce development initiatives. Studies on the digital economy suggest that significant barriers to inclusive growth can be caused by uneven access to skills, infrastructure, and information (Bukht & Heeks 2017). Consequently, human capital development, digital literacy, and sustainability innovation are the priorities of government interventions rather than availability of technology.

One of the critical aspects of corporate governance and decision making within organisations is the necessity of ensuring alignment of transformation projects and sustainability responsibilities. Organisations need to have sustainability-oriented digital strategies that

consider the impact of adoption of new technologies on the environment through their use of energy, consumption of resources and lifecycle effects. Following a resource-based view, firms can obtain a competitive advantage by developing capabilities that at the same time contribute to environmental sustainability and business performance (Hart, 1995). To create integrated approaches and promote long term sustainability, organisational leadership needs to encourage collaboration between technology experts, sustainability experts and operational managers. These strategies not only reduce chances of negative environmental impact resulting from technological innovations but also allow promoting digital transformations.

Future Research Directions

Future studies should create comprehensive theoretical and empirical frameworks that would outline the manner in which digital transformation and lean practices help to meet the goals of green development. Even though little research exists on the interaction between the components of this framework as an integrated approach in various organisational and economic contexts, existing literature has provided some valuable insight into both areas. Future research should explore the mediators and moderators such as organisational capabilities, institutional support, technology readiness, workforce skills and regulations that affect the effectiveness of digital solutions. Longitudinal analysis could be quite helpful in studying transformation process dynamics and efficiency gains leading to financial and environmental benefits (Vial, 2019).

The impact of lean digital economies on national and industrial scales should also be considered in future research in addition to firm-level analysis. Understanding the influence of contextual variables on the interplay between digitization, productivity, and sustainability can be gained through comparative research across industries and countries. Researchers should consider developing evaluation frameworks that take into account not only performance metrics but also the social, environmental, and economic dimensions. Such approaches will enhance the comprehension and provide practitioners and policymakers with the necessary data to develop sustainable digital transformation strategies. Future research can contribute to the creation of resilient, inclusive, and environmentally friendly digital economy by closing those knowledge gaps.

Conclusion

By the integration of existing research across the abovementioned interrelated fields, this narrative review has analyzed the relationship between the principles, digital transformation, and green development. The analysis underlined the fact that emergence of digital economy is not merely an issue of technological change; it is rather a result of a broader shift in the approach to value creation, resource management, and sustainable growth. As was found from the research, digital technologies provide organizations with the ability to become more agile and capable of making data-driven decisions and innovate, while lean principles offer a framework for efficiency improvement through waste elimination and continuous improvements (Bhamu & Singh Sangwan 2014; Vial, 2019). Proper combination of these approaches with sustainability can lead to responsible resource usage and sustainable long-term development (Dyllick & Muff 2016).

The contribution of this literature review is the perspective which brings together three previously disconnected streams of research in the areas of sustainable development, digital

transformation, and operational excellence. The report then considers the issues as distinct disciplines, pointing out their inseparable connection and the importance of developing institutional and organizational capacities for sustainable results of digital innovation. According to Hart (1995) and Vial (2019), substantial changes require alignment of capabilities, human resources, governance structures, and sustainability strategy; mere adoption of technologies is not enough. This study contributes to the advancement of deep understanding of the potential of lean digital ecosystems for the promotion of sustainable economic development through the identification of areas of convergence, divergence, research gaps, and practical implications. Further studies should explore the connections through research, cross-sectoral comparisons, and dynamic frameworks reflecting the dynamism of digital and green changes.

Limitations

It is crucial to consider several limitations of the narrative review when interpreting the outcomes it produces, although it provides an overview of recent data. First of all, the breadth of the literature search process, including the selection of databases, time period of publications, and available scientific resources, has an effect on the review. Contributions beyond the selected scope can provide alternative insights regarding the interrelation of lean management tools, digitalization, and sustainable development, no matter how hard one tries to collect the contributions. Besides, the literature is still distributed unevenly in terms of sectors, with industrial and high-tech firms being better studied than service sectors, governmental organizations, and emerging economy situations. Sectoral mismatch may prevent the generalizability of existing knowledge across various organizational contexts.

Secondly, the scope of the reviewed literature is limited due to the conceptual complexity of the topic. It is hard to distinguish clear theoretical boundaries as the concepts of transformation, sustainability of Industry 4.0, green innovation, and operational excellence are being applied in overlapping ways. Inconsistencies of the interpretations may occur because of the usage of diverse definitions, measurement approaches, and perspectives in different scientific works. Besides, because of the nature of a narrative review, which involves analysis based on synthesis and interpretation of the previous research rather than statistics, the perception of themes and their associations is inevitably biased. However, future research may complement these outcomes by means of systematic reviews, meta-analysis, and empirical validation, although narrative reviews present opportunities for theory building and development (Vial, 2019).

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- Acknowledgements:** The authors would like to express their sincere gratitude to the Faculty of Business and Management, Universiti Teknologi MARA (UiTM), Kedah Campus, Malaysia, for providing the academic environment, resources, and institutional support necessary for the completion of this research. The authors also appreciate the valuable support, insights, and constructive feedback provided by colleagues and peers throughout the development of this manuscript.
- Funding Statement:** No Funding. This research did not receive any specific financial support from any funding agency, government body, commercial organization, or other external source.
- Conflict of Interest Statement:** The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed to the development of the manuscript and have reviewed and approved the final version for submission to the Advanced International Journal of Business, Entrepreneurship and SMEs (AIJBES).
- Ethics Statement:** This study is a narrative literature review and did not involve human participants, animals, interviews, surveys, experiments, or the collection of personal or sensitive data. Therefore, ethical approval and informed consent were not required. The authors confirm that the research was conducted in accordance with accepted principles of academic integrity, responsible research conduct, and ethical publishing standards.
- Author Contribution Statement:** All authors contributed to the development and completion of this manuscript. Noris Fatilla Ismail was responsible for the conceptualization, development of the review framework, literature search and synthesis, manuscript preparation, and overall coordination of the study. Chua Chy Ren contributed to the literature review, analysis and synthesis of relevant studies, manuscript development, and critical revision. Siti Muliana Samsi contributed to the literature review, interpretation and synthesis of the findings, critical review, and refinement of the manuscript. All authors contributed to the critical revision of the manuscript, read and approved the final version, and agreed to be accountable for the content of the work.
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