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Identification of Factors Affecting the Feasibility of Lean Production Toward Sustainability in the Iranian Automotive Industry

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A B S T R A C T

Given the environmental, economic, and managerial challenges within the Iranian automotive industry, the transition toward sustainable lean production has gained significant attention as a key strategic solution. This study aims to identify the factors influencing the feasibility of implementing lean production toward sustainability in the Iranian automotive sector, in order to analyze its multidimensional aspects and propose an optimal pathway for sustainable development in this industry. This research is applied in terms of purpose and qualitative in terms of methodology. The statistical population consisted of university faculty members and expert professionals in the Iranian automotive industry. A theoretical sampling method was adopted, and 15 experts were selected for semi-structured interviews. Data collection was conducted through semi-structured interviews, and data analysis was performed using thematic analysis. The results indicated that the feasibility of sustainable lean production in the Iranian automotive industry depends on four main dimensions: technological, managerial, environmental, and economic–social. Within each of these dimensions, several components were identified, including the adoption of advanced technologies, lean management strategies, reduction of environmental pollutants, and the creation of economic and social value. These dimensions directly influence production optimization and the enhancement of sustainability in the automotive industry. Developing sustainable lean production in the Iranian automotive sector requires a comprehensive and integrated approach that encompasses technological, managerial, environmental, and economic–social dimensions. Success in this direction necessitates macro-level industrial and economic policymaking supported by governmental incentives, investment in smart technologies, and strengthened environmental commitments. The findings of this study can assist policymakers and industry stakeholders in formulating effective strategies for sustainable production.

Keywords: *Lean production, sustainability, automotive industry, advanced technologies, lean management, thematic*

1. Introduction

The automotive industry is widely regarded as a strategic backbone of national industrial development due to its extensive value chain linkages, employment potential, and capacity to diffuse advanced production and management technologies across other sectors (Feyzpour & Radmanesh, 2012). In emerging economies, this sector is also a key arena where tensions between cost competitiveness, quality requirements, and sustainability pressures are acutely experienced (Mohammadi et al., 2015). In Iran, the automotive industry operates under the combined constraints of economic sanctions, macroeconomic instability, and structural inefficiencies, which deeply affect access to technology, capital, and inputs (Rezai, 2023). At the same time, rising environmental concerns, resource constraints, and regulatory expectations have placed sustainable production high on the policy agenda, pushing manufacturers to seek models that simultaneously reduce waste, improve productivity, and enhance environmental and social performance (Safaei Qadikalai & Hosin Bar, 2016; Shari'at et al., 2017). Within this context, lean production oriented toward sustainability is increasingly seen as a strategic pathway for revitalizing the competitiveness and legitimacy of the Iranian automotive sector (Mohaghar et al., 2021; Taheri Zadeh & Abbasi, 2020).

Lean manufacturing emerged from the Toyota Production System as a coherent philosophy and set of practices aimed at eliminating all forms of waste in production while creating value from the customer's perspective (Womack & Jones, 2021). Empirical studies have demonstrated that lean bundles—such as just-in-time, total productive maintenance, standardized work, and continuous improvement—are strongly associated with improvements in cost, quality, flexibility, and delivery performance when they are implemented in a consistent, system-wide manner (Bhamu & Singh Sangwan, 2021; Shah & Ward, 2023). However, the effectiveness of lean is highly context dependent, shaped by institutional conditions, organizational culture, and strategic priorities at firm and industry levels (Ang et al., 2015; Schneider et al., 2014). For automotive manufacturers in Iran, where legacy systems, capacity constraints, and volatility in demand and supply are prevalent, transferring textbook lean tools without a deeper understanding of enabling factors can result in fragmented or symbolic implementation rather than genuine process transformation (Ismailpour et al., 2013; Safaei Qadikalai & Hosin Bar, 2016).

Over the last two decades, the lean paradigm has progressively converged with sustainability thinking, giving rise to concepts such as "lean and green" and "sustainable lean production" (Dora et al., 2022; Jabbour et al., 2023). Research has shown that many lean practices—such as waste reduction, defect prevention, and process flow optimization—create natural synergies with environmental performance by decreasing resource consumption and emissions (Dora et al., 2022; Ferrazzi et al., 2025). Recent cross-sector investigations using methods such as fuzzy DEMATEL highlight that lean practices can significantly improve environmental indicators when strategically configured as part of an integrated sustainability program rather than implemented in isolation (Ferrazzi et al., 2025). At the same time, systematic reviews of lean and sustainable supply chain management underscore that the environmental and social benefits of lean are neither automatic nor guaranteed; rather, they depend on how practices are embedded within broader supply chain relationships, governance mechanisms, and organizational learning processes (Jabbour et al., 2023; Rabetino et al., 2015).

The digital transformation of manufacturing—often summarized under the label of Industry 4.0—adds another layer of complexity and opportunity to the lean–sustainability nexus (Frank et al., 2022). Advanced technologies such as cyber-physical systems, Internet of Things (IoT), big data analytics, and artificial intelligence enable real-time monitoring, predictive maintenance, and more precise resource management, which can significantly enhance both lean performance and environmental outcomes (Dora et al., 2022; Frank et al., 2022). Recent studies point to the emergence of relational marketing and digital management models that integrate lean manufacturing concepts with data-driven customer orientation and platform-based ecosystems, particularly in highly competitive and digitalized markets (Садченко et al., 2024). At the same time, applications of lean principles are expanding beyond traditional factory settings to services such as healthcare and dental clinics, demonstrating that lean can be used as an effective approach for improving operational efficiency and quality across sectors, including in technically intensive and customer-centric environments (Затулкин, 2023). These developments suggest that a contemporary understanding of lean in the automotive industry must account not only for classical process-oriented tools, but also for digitalization capabilities and data-enabled decision-making (Frank et al., 2022; Kao, 2022).

Despite these global trends, the implementation of lean and sustainable production in developing-country contexts is shaped by specific institutional, structural, and resource-related constraints. Studies on internal factors influencing the growth and performance of small and medium enterprises emphasize the importance of managerial capabilities, access to finance, human resource skills, and quality of internal processes for successful adoption of advanced management practices (Aidis, 2021; Ghosh & Kwan, 2019). Research on socio-economic structures and actors in industrial clusters highlights how network relationships, local governance, and knowledge spillovers condition the diffusion of new production paradigms, including lean and sustainability-oriented initiatives (Chittithaworn, 2019; Lekhanya, 2015; Sukwadi et al., 2013). From a regional perspective, institutional quality, regulatory frameworks, and developmental policies can significantly mediate how firms respond to competitive pressure and environmental challenges (Andrei & Rodríguez-Pose, 2017). These insights are particularly relevant for Iran's automotive ecosystem, where institutional volatility, infrastructural gaps, and fragmented policy measures complicate long-term strategic planning and investment in new production systems (Rezai, 2023; Taheri Zadeh & Abbasi, 2020).

In parallel, the sustainability literature stresses that corporate-level environmental and social initiatives must be coordinated with functional-level strategies in operations, logistics, and supply chain management in order to achieve meaningful outcomes (Singh et al., 2015). Sustainable supplier relationship management and environmentally conscious technology adoption are increasingly recognized as critical mechanisms for extending sustainability efforts beyond organizational boundaries (Rabetino et al., 2015; Schneider et al., 2014). In the automotive context, this means that lean and sustainable production cannot be fully realized without alignment between internal process improvements and upstream and downstream partners, including component suppliers, logistics providers, and aftermarket services (Jabbour et al., 2023; Sukwadi et al., 2013). However, empirical evidence from many developing economies suggests that limited bargaining power, information asymmetries, and short-term survival pressures often hinder such coordinated efforts and constrain the scope of sustainability-oriented collaboration (Aidis, 2021; Ghosh & Kwan, 2019).

Within Iran, a growing body of research has started to examine sustainable production and competitive advantage in the manufacturing sector, including in automotive-related industries. Studies on sustainable production in private manufacturing companies and plastic parts producers have proposed conceptual frameworks and structural models that integrate environmental, economic, and social criteria, often using meta-synthesis and interpretive structural modeling to identify key drivers and interrelationships (Safaei Qadikalai & Hosin Bar, 2016; Shari'at et al., 2017). Other work has focused on improving production performance in the context of a "resistance economy," highlighting the importance of productivity enhancement, waste reduction, and local resource utilization as strategic responses to external constraints (Feyzpour & Radmanesh, 2012; Taheri Zadeh & Abbasi, 2020). At the firm level, investigations into quality cost modeling and operational efficiency in automotive spare parts manufacturers underline the need for systematic approaches to quality management and cost control as prerequisites for adopting lean and sustainable practices (Ismailpour et al., 2013).

More specifically, research on production and operations strategies in Iran's automotive companies has underscored the role of strategic alignment and integrated management systems in building sustainable competitive advantage (Mohaghar et al., 2021). Studies on sustainable production in food and agricultural sectors likewise demonstrate that economic sustainability is closely linked to efficient resource use, risk management, and institutional support, suggesting that similar logics may apply in the automotive industry (Mohaghar et al., 2021; Mohammadi et al., 2015). At a broader economic level, analyses of the causes and consequences of Iran's economic crisis emphasize structural vulnerabilities, financial constraints, and institutional deficiencies that directly affect industrial investment, technology acquisition, and supply security (Rezai, 2023). These conditions make it difficult for automotive firms to commit to long-term lean and sustainability programs without a clear understanding of the critical internal and external factors that enable or inhibit such transformations (Safaei Qadikalai & Hosin Bar, 2016; Taheri Zadeh & Abbasi, 2020).

At the global frontier, methodological developments such as network data envelopment analysis and two-stage efficiency assessment have been used to disentangle managerial and operational efficiency in complex organizations, offering tools for evaluating how lean and sustainability initiatives translate into performance outcomes across multiple stages and units (Hwang & Kao, 2022; Kao, 2022). These approaches suggest that lean and sustainable production should be conceptualized not merely as a set of isolated tools, but as multi-dimensional systems that interact with financial, environmental, and organizational subsystems. For Iran's automotive sector, this implies the need to identify and structure the key technical–operational, economic–financial, environmental, and organizational–cultural dimensions that collectively shape the feasibility of transitioning toward lean and sustainable production (Dabbagh & Soltan Mohammadi, 2021; Jabbour et al., 2023).

Nonetheless, despite the richness of the international and national literature, several gaps remain. First, many studies on lean manufacturing focus on performance outcomes without systematically unpacking the underlying components and dimensions that determine the feasibility of lean when it is explicitly oriented toward sustainability in a specific industrial and institutional context (Bhamu & Singh Sangwan, 2021; Shah & Ward, 2023). Second, while there is emerging research on sustainable production models in Iran, these investigations tend to address particular sectors, sets of practices, or methodological tools and do not always provide an integrated conceptual model that links technical and operational practices with economic, environmental, and organizational–cultural enablers in the automotive industry (Dabbagh & Soltan Mohammadi, 2021; Safaei Qadikalai & Hosin Bar, 2016; Shari'at et al., 2017). Third, the dynamic interplay between lean practices, digital technologies, and sustainability outcomes, although well documented in some advanced economies, has not been fully explored in the context of Iranian automotive manufacturers facing severe resource and institutional constraints (Ferrazzi et al., 2025; Frank et al., 2022; Садченко et al., 2024).

Addressing these gaps requires a context-sensitive, exploratory approach capable of capturing the nuanced perceptions of industry experts and academic specialists regarding the factors that enable or hinder lean production toward sustainability. Qualitative, theme-based methodologies are particularly suited to uncovering latent structures, interdependencies, and priority patterns among technical, economic, environmental, and organizational–cultural elements in complex, crisis-prone environments (Dabbagh & Soltan Mohammadi, 2021; Ismailpour et al., 2013). By systematically identifying and structuring these factors into coherent components and dimensions, it becomes possible to provide both policymakers and practitioners with a conceptual roadmap for designing targeted interventions, aligning organizational strategies, and sequencing investments in technology, human resources, and supply chain capabilities (Rabetino et al., 2015; Schneider et al., 2014; Singh et al., 2015).

Therefore, the aim of this study is to identify and conceptualize the key factors influencing the feasibility of lean production toward sustainability in the Iranian automotive industry across technical–operational, economic–financial, environmental, and organizational–cultural dimensions.

2. Methods and Materials

The present study is applied in terms of purpose and qualitative in terms of its approach, situated within the qualitative research paradigm and employing thematic analysis as the primary strategy for in-depth data collection and interpretation. The statistical population consisted of academic experts specializing in production and operations management, as well as senior and mid-level managers in the Iranian automotive industry. A purposive sampling method was used for selecting participants, and the processes of data collection (interviews) and preliminary analysis were conducted simultaneously until theoretical saturation was achieved. Theoretical saturation was specifically reached after conducting and analyzing the twelfth interview; at this point, the researcher determined that no new concepts, codes, or categories were emerging from the data and that subsequent interviews merely reiterated and confirmed prior findings. However, to ensure the adequacy of the data and validate the saturation point, three additional interviews were conducted, and upon the continued absence of new insights, the sampling process was concluded with a total of 15 experts.

The primary data collection instrument was semi-structured interviews which, after full transcription, were analyzed based on Strauss and Corbin's (1998) three-stage coding procedure. In the first stage, open coding, each interview was examined line by line and initial concepts or raw codes (such as "waste reduction" or "use of artificial intelligence") were extracted from the text with the purpose of fracturing the data and identifying all possible units of meaning. Subsequently, in the axial coding stage, these open codes were compared based on conceptual similarities and organized into broader categories or components; for example, codes related to process improvement were placed under the category of "production efficiency." Finally, in the selective coding stage, by establishing relationships among the axial categories, the "core category" or main dimensions of the study were formed. In this step, the twelve identified components were integrated into four final dimensions—"technical and operational," "economic and financial," "environmental," and "organizational and cultural"—which constitute the final conceptual model of the study.

To ensure the validity and reliability of the findings, several key strategies were employed. Triangulation of data sources was achieved by interviewing two distinct groups of experts (academic and industrial). Member checking was performed by presenting a summary of findings to three interviewees and obtaining their confirmation. Finally, the coding and analysis processes were continuously reviewed by supervisory faculty through peer debriefing sessions, reducing potential researcher bias and strengthening the scientific rigor of the results.

3. Findings and Results

To guarantee the scientific rigor and dependability of the findings derived from the interview analysis, several actions were undertaken within the framework of the four criteria of trustworthiness in qualitative research. The table below summarizes these criteria and the strategies employed in this study, followed by a detailed explanation of each.

Table 1

Strategies Used to Ensure Research Trustworthiness

Trustworthiness Criterion	Equivalent in Quantitative Research	Brief Definition	Strategies Used in This Study
Credibility	Internal validity	Ensuring that the findings accurately represent participants' perspectives.	• Data source triangulation: interviews with two groups of experts (university faculty and industrial managers). • Member checking: providing a summary of findings to three interviewees and obtaining confirmation.
Transferability	External validity	Providing sufficient contextual detail to allow readers to judge applicability to other settings.	• Thick description: offering detailed accounts of the research context, participant characteristics, and data collection and analysis processes.
Dependability	Reliability	Ensuring stability and consistency of the research process over time.	• Audit trail: transparent and comprehensive documentation of all research stages, from initial design to final analysis and coding.
Confirmability	Objectivity	Ensuring that findings are grounded in the data rather than researcher bias.	• Peer debriefing: review and approval of coding and theme extraction processes by supervisory professors. • Maintaining a chain of evidence: enabling traceability of each final theme to initial codes and direct interview quotations.

1. **Credibility:** To ensure that the interpretations provided were aligned with the actual viewpoints of the experts, two key measures were taken. First, by employing data source triangulation, interviews were conducted with two distinct yet complementary groups (university professors with deep theoretical knowledge and managers in the automotive industry with extensive practical experience). This enabled the researcher to examine the phenomenon from multiple angles and achieve a comprehensive and balanced understanding. Second, a member-checking strategy was implemented; following the initial analysis and extraction of the main themes, a summary of findings was sent to three experts who had participated in the interviews (one university professor and two industrial managers), asking them to verify alignment with their perspectives. The received feedback, which confirmed the accuracy of the interpretations, significantly strengthened the credibility of the findings.
2. **Transferability:** The goal of qualitative research is not statistical generalization but rather providing deep insights that others may transfer to their own contexts. To facilitate this, the strategy of thick description was employed. Throughout various sections of the article—particularly in the methodology—the characteristics of participants, the selection process, specific conditions of the Iranian automotive industry as the research setting, and the data analysis procedure were described in detail. This transparency enables readers to compare the conditions of this study with their own contexts and decide on the applicability of the findings.

3. **Dependability:** To ensure that the research process was logical, coherent, and replicable, a detailed audit trail was established. All stages—including recorded interview audio files, their full transcriptions, interview notes, the step-by-step process of open coding, grouping codes into concepts during axial coding, and the eventual formation of final dimensions during selective coding—were thoroughly documented and archived. These records make the research process transparent to any external reviewer and guarantee process stability.
4. **Confirmability:** To minimize potential researcher bias and ensure that findings emerged directly from the data, two measures were adopted. First, the coding and data analysis processes were continuously discussed and reviewed in peer-debriefing sessions with supervisory professors, which helped refine and validate interpretations. Second, by maintaining a chain of evidence, each of the final dimensions and components of the model can be easily traced back to initial codes and specific quotations from interviewees, demonstrating the objectivity of the findings and their grounding in the raw data.

Table 2

Classification of the Identified Codes of the Learning Phenomenon in the Form of Main Categories or Main Phenomena

Identified Codes	Experts	Frequency
Reduction of production cycle time	P1, P3, P4, P5, P7, P13, P14	7
Process optimization	P1, P2, P8, P9, P11, P13, P15	7
Waste reduction	P1, P2, P3, P4, P5, P6, P7, P14	8
Optimal use of resources	P1, P2, P3, P4, P5, P6, P10, P12, P14	9
Increased equipment efficiency	P1, P2, P3, P4, P5, P8, P14, P15	8
Use of quality standards	P2, P6, P7, P8, P9, P10, P11, P15	8
Reduction of production errors	P1, P2, P3, P6, P7, P8, P11, P14	8
Process quality control	P1, P2, P6, P7, P8, P9, P10, P12, P14	9
Product quality monitoring	P1, P3, P4, P5, P7, P9, P12, P13	8
Customer satisfaction	P1, P2, P8, P9, P10, P11, P14	7
Use of artificial intelligence	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10	10
Robotics in production	P1, P2, P3, P4, P5, P6, P10, P12, P14	9
Digitalization	P1, P3, P4, P5, P7, P9, P12, P13	8
Internet of Things (IoT)	P1, P2, P8, P9, P10, P11, P14	7
Big data analytics	P1, P2, P8, P9, P10, P11, P14	7
Reduction of raw material costs	P1, P2, P3, P4, P5, P8, P14, P15	8
Reduction of production costs	P2, P6, P7, P8, P9, P10, P11, P15	8
Optimization of energy consumption	P1, P2, P3, P6, P7, P8, P11, P14	8
Waste reduction	P1, P2, P6, P7, P8, P9, P10, P12, P14	9
Increased capital productivity	P1, P3, P4, P5, P7, P9, P12, P13	8
Research and development (R&D)	P1, P2, P8, P9, P10, P11, P14	7
Investment in modern equipment	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10	10
Development of technological infrastructure	P1, P2, P3, P4, P5, P6, P10, P12, P14	9
Increased competitive capability	P1, P3, P4, P5, P7, P9, P12, P13	8
Support for technology-based startups	P1, P2, P8, P9, P10, P11, P14	7
Stable supply of raw materials	P1, P2, P8, P9, P10, P11, P14	7
Optimization of procurement processes	P1, P2, P3, P4, P5, P8, P14, P15	8
Reduction of delivery time	P2, P6, P7, P8, P9, P10, P11, P15	8
Integration with suppliers	P1, P2, P3, P6, P7, P8, P11, P14	8
Use of ERP systems	P1, P2, P6, P7, P8, P9, P10, P12, P14	9
Reduction of water consumption	P1, P3, P4, P5, P7, P9, P12, P13	8
Reduction of energy consumption	P1, P2, P8, P9, P10, P11, P14	7
Reduction of toxic material usage	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10	10
Optimization of raw material consumption	P1, P2, P3, P4, P5, P6, P10, P12, P14	9
Reduction of environmental pollutants	P1, P3, P4, P5, P7, P9, P12, P13	8
Reuse of waste	P1, P2, P8, P9, P10, P11, P14	7
Low-waste production processes	P1, P2, P8, P9, P10, P11, P14	7

Green waste management	P1, P2, P3, P4, P5, P8, P14, P15	8
Optimization of recycling processes	P2, P6, P7, P8, P9, P10, P11, P15	8
Reduction of carbon emissions	P1, P2, P3, P6, P7, P8, P11, P14	8
Use of recycled materials	P1, P2, P6, P7, P8, P9, P10, P12, P14	9
Modular design	P1, P3, P4, P5, P7, P9, P12, P13	8
Optimization of fuel consumption	P1, P2, P8, P9, P10, P11, P14	7
Increased durability of parts	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10	10
Development of electric and hybrid vehicles	P1, P2, P3, P4, P5, P6, P10, P12, P14	9
Flexible organizational culture	P1, P3, P4, P5, P7, P9, P12, P13	8
Employee training	P1, P2, P8, P9, P10, P11, P14	7
Enhancement of technical skills	P1, P2, P8, P9, P10, P11, P14	7
Encouragement of innovation	P1, P2, P3, P4, P5, P8, P14, P15	8
Knowledge management in the organization	P2, P6, P7, P8, P9, P10, P11, P15	8
Top management support	P1, P2, P3, P4, P5, P8, P14, P15	8
Formulation of long-term strategies	P2, P6, P7, P8, P9, P10, P11, P15	8
Allocation of sufficient financial resources	P1, P2, P3, P6, P7, P8, P11, P14	8
Lean performance monitoring	P1, P2, P6, P7, P8, P9, P10, P12, P14	9
Incentive policies for lean production	P1, P3, P4, P5, P7, P9, P12, P13	8
Increased employee awareness of sustainability	P1, P2, P8, P9, P10, P11, P14	7
Promotion of lean thinking	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10	10
Strengthening teamwork	P1, P2, P3, P4, P5, P6, P10, P12, P14	9
Effective interdepartmental communication	P1, P3, P4, P5, P7, P9, P12, P13	8
Incentive system for continuous improvement	P1, P2, P8, P9, P10, P11, P14	7

As Table 2 shows, the experts in the 15 interviews referred to a wide range of factors in response to the question. In order to summarize and identify the main categories (codes), the concepts identified are presented in Table 3. By comparing the various concepts (codes), it is possible to discover more shared areas among them, which allows the classification of similar concepts within common categories. The outcome of this stage of the process is the formation of components.

Table 3

Axial Codes (Identified Concepts) Derived from Interviews with Experts (Axial Coding)

Row	Axial Code	Open Coding
1	Production productivity	Reduction of production cycle time
		Process optimization
		Waste reduction
		Optimal use of resources
		Increased equipment efficiency
2	Quality management	Use of quality standards
		Reduction of production errors
		Process quality control
		Product quality monitoring
		Customer satisfaction
3	Advanced production technologies	Use of artificial intelligence
		Robotics in production
		Digitalization
		Internet of Things (IoT)
		Big data analytics
4	Cost reduction	Reduction of raw material costs
		Reduction of production costs
		Optimization of energy consumption
		Waste reduction
		Increased capital productivity
5	Investment in innovation	Research and development (R&D)
		Investment in modern equipment
		Development of technological infrastructure
		Increased competitive capability

		Support for technology-based startups
6	Supply chain management	Stable supply of raw materials
		Optimization of procurement processes
		Reduction of delivery time
		Integration with suppliers
		Use of ERP systems
7	Reduction of natural resource consumption	Reduction of water consumption
		Reduction of energy consumption
		Reduction of toxic material usage
		Optimization of raw material consumption
		Reduction of environmental pollutants
8	Recycling and waste management	Reuse of waste
		Low-waste production processes
		Green waste management
		Optimization of recycling processes
		Reduction of carbon emissions
9	Sustainable product design	Use of recycled materials
		Modular design
		Optimization of fuel consumption
		Increased durability of parts
		Development of electric and hybrid vehicles
10	Change management and continuous improvement	Flexible organizational culture
		Employee training
		Enhancement of technical skills
		Encouragement of innovation
		Knowledge management in the organization
11	Managerial commitment to lean production	Top management support
		Formulation of long-term strategies
		Allocation of sufficient financial resources
		Lean performance monitoring
		Incentive policies for lean production
12	Sustainable organizational culture	Increased employee awareness of sustainability
		Promotion of lean thinking
		Strengthening teamwork
		Effective interdepartmental communication
		Incentive system for continuous improvement

At this stage, the common aspects of the components derived from the previous stages were identified and, based on their similarities, were organized into broader and more limited categories. In the first step, numerous themes were obtained, which, through integration and analysis using an iterative process of data analysis, led to the reduction of the total set of initial codes into fewer codes, such that, in order to avoid redundancy, all repeated or similar initial codes that were conceptually very close were placed within a single set and formed concepts that constituted the categories. The results of this stage are presented in Table 4.

Table 4

Main Dimensions Identified (Selective Coding)

Row	Selective Dimension	Axial Code	Open Coding
1	Technical and operational dimension	Production productivity	Reduction of production cycle time
			Process optimization
			Waste reduction
			Optimal use of resources
			Increased equipment efficiency
		Quality management	Use of quality standards
			Reduction of production errors
			Process quality control
			Product quality monitoring
			Customer satisfaction

		Advanced production technologies	Use of artificial intelligence
			Robotics in production
			Digitalization
			Internet of Things (IoT)
			Big data analytics
2	Economic and financial dimension	Cost reduction	Reduction of raw material costs
			Reduction of production costs
			Optimization of energy consumption
			Waste reduction
			Increased capital productivity
		Investment in innovation	Research and development (R&D)
			Investment in modern equipment
			Development of technological infrastructure
			Increased competitive capability
			Support for technology-based startups
		Supply chain management	Stable supply of raw materials
			Optimization of procurement processes
			Reduction of delivery time
			Integration with suppliers
			Use of ERP systems
3	Environmental dimension	Reduction of natural resource consumption	Reduction of water consumption
			Reduction of energy consumption
			Reduction of toxic material usage
			Optimization of raw material consumption
			Reduction of environmental pollutants
		Recycling and waste management	Reuse of waste
			Low-waste production processes
			Green waste management
			Optimization of recycling processes
			Reduction of carbon emissions
		Sustainable product design	Use of recycled materials
			Modular design
			Optimization of fuel consumption
			Increased durability of parts
			Development of electric and hybrid vehicles
4	Organizational and cultural dimension	Change management and continuous improvement	Flexible organizational culture
			Employee training
			Enhancement of technical skills
			Encouragement of innovation
			Knowledge management in the organization
		Managerial commitment to lean production	Top management support
			Formulation of long-term strategies
			Allocation of sufficient financial resources
			Lean performance monitoring
			Incentive policies for lean production
		Sustainable organizational culture	Increased employee awareness of sustainability
			Promotion of lean thinking
			Strengthening teamwork
			Effective interdepartmental communication
			Incentive system for continuous improvement

A total of 60 indicators, organized into 12 components (production productivity, quality management, advanced production technologies, cost reduction, investment in innovation, supply chain management, reduction of natural resource consumption, recycling and waste management, sustainable product design, change management and continuous improvement, managerial commitment to lean production, and sustainable organizational culture) and 4 dimensions (technical and operational, economic and financial, environmental, and organizational and cultural), were considered by the researcher to ensure sufficient adequacy for selecting the main categories for examining the responses related to the research questions.

In the first stage of data analysis, more than 60 distinct open codes were extracted from the interview transcripts, each representing a raw and initial concept from the experts' perspectives. The axial coding process transformed these scattered concepts into 12 key components by uncovering semantic relationships among them. For example, the analysis showed that seemingly different concepts such as "reduction of production cycle time," "optimal use of resources," and "increased equipment efficiency" all converged on a common point: the effort to optimize tangible outputs on the production line. This internal connection led to the formation of the axial category "production productivity." Similarly, the relationship among codes such as "use of artificial intelligence," "robotics in production," and "Internet of Things (IoT)" was strong enough to give rise to the distinct conceptual category of "advanced production technologies." This pattern-finding process was essentially the first step in reducing data complexity and moving from the descriptive level to the analytical level, during which the underlying structure in the experts' viewpoints gradually became apparent.

In the next step, during selective coding, the analysis focused on the interrelationships among the 12 components themselves in order to derive a broader overarching structure. This analysis showed that the components do not function as isolated islands but rather cluster into larger groups with a shared internal logic. For instance, it became clear that components such as "production productivity," "quality management," and "advanced technologies" are all related to the core architecture of operations and production engineering (how the product is made), and this deep connection led to the emergence of the "technical and operational dimension." On the other hand, components such as "cost reduction," "investment in innovation," and "supply chain management" shared a common economic and business logic aimed at organizational survival and competitiveness, thereby forming the "economic and financial dimension." This process represented an analytical leap from identifying "what" (the components) to understanding "higher-order categories" (the dimensions).

Ultimately, the selective coding process reached its peak by uncovering systematic relationships among the four final dimensions and creating the integrated conceptual model of the study. The analyses showed that these four dimensions are in a reciprocal and dynamic relationship. For example, investment in the "technical dimension" (such as digitalization) directly affects improvements in the "economic dimension" (cost reduction) and the "environmental dimension" (reduced energy consumption). However, the most important finding at this stage was the identification of the central and enabling role of the "organizational and cultural dimension." The data clearly indicated that without "managerial commitment" and a "culture of continuous improvement," any effort in the other three dimensions would remain ineffective. This finding transformed the model from a four-part list into an integrated system in which the organizational dimension acts as the foundation and infrastructure upon which the sustainability and success of the other dimensions depend.

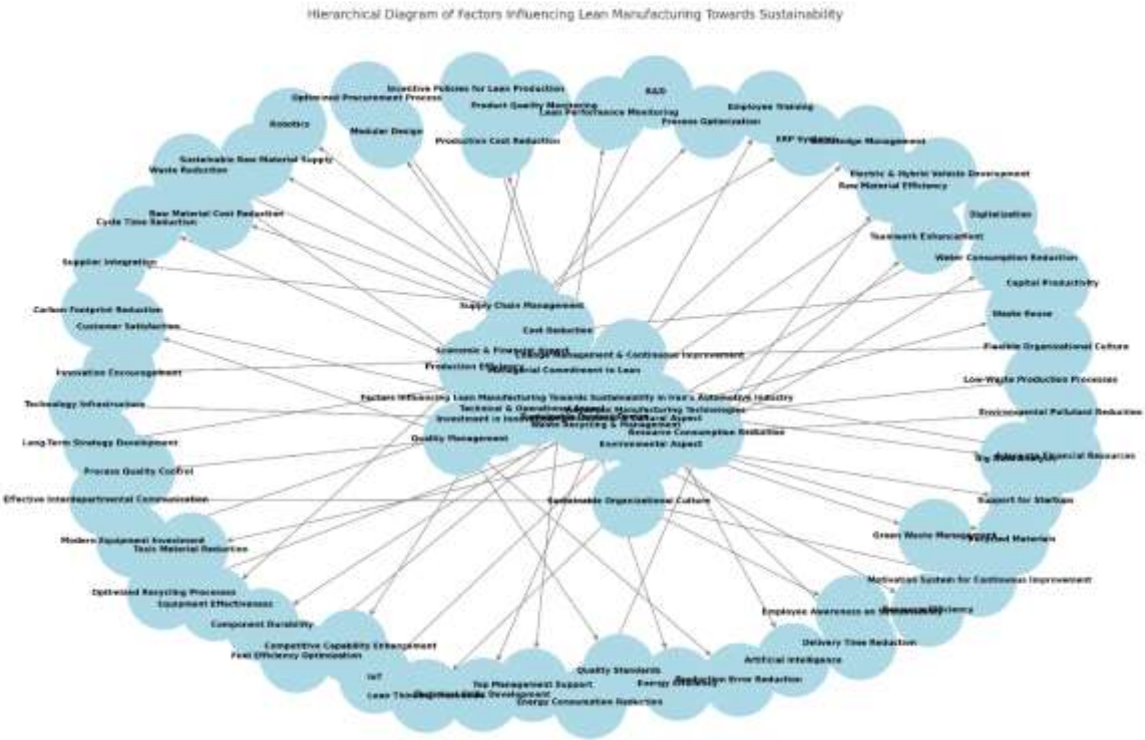
The results of this study are meaningfully aligned with the global literature on "lean and sustainable production" and, in a sense, subject that literature to examination in a new context. The "technical and operational dimension," which emphasizes waste reduction and process optimization, is a direct reflection of the classical lean production principles introduced by Womack and Jones (2021). The "environmental dimension," with its focus on reducing resource consumption and managing waste, is fully consistent with the "lean and green production" paradigm, which theorizes the synergy between operational productivity and environmental responsibility. Similarly, the "economic and financial dimension," which addresses cost reduction and enhanced competitive capability, supports the arguments of researchers who consider lean production a key competitive strategy, including Shah and Ward (2023). Finally, the "organizational and cultural dimension" as an enabling factor reinforces the findings of Liker (2020) and Jabbour et al. (2023), who have consistently emphasized the critical role of leadership, culture, and change management in the successful implementation of modern production systems.

Rather than rejecting existing theories, this study primarily confirms and localizes them within a unique context. The main innovation of this research lies in demonstrating that, although these four dimensions are well established in the global literature, their weight and priority differ under the specific conditions of the Iranian industry. The findings clearly highlight that, in a business environment affected by economic sanctions and macro-level instability, the "economic and financial dimension" and the "organizational and cultural dimension" shift from being mere "success factors" to "prerequisites for survival." While a European company might initiate lean projects with a focus on environmental aspects, in Iran the primary drivers remain "reduction of production costs" and "stable supply of raw materials." By demonstrating this context-specific prioritization, the study extends the global theory of "sustainable lean production," transforming it from a generic model into an adaptive strategic framework that shows how the implementation pathway must be localized to fit environmental pressures.

Based on the components and indicators identified by the participants, the proposed research model was designed:

Figure 1

Model for identifying factors influencing the feasibility of lean production toward sustainability in the Iranian automotive industry



4. Discussion and Conclusion

The findings of this study indicate that the feasibility of implementing lean production toward sustainability in the Iranian automotive industry is shaped by twelve core components that cluster into four overarching dimensions: technical–operational, economic–financial, environmental, and organizational–cultural. These results confirm that lean production is not merely a collection of tools but a multi-layered system that interacts simultaneously with technological readiness, financial stability, environmental responsibility, and cultural–managerial capabilities (Womack & Jones, 2021). The strong alignment between productivity-related codes—such as cycle-time reduction, resource optimization, and equipment efficiency—and the literature underscores that minimizing waste and maximizing value creation remain foundational pillars of lean philosophy (Shah & Ward, 2023). This coherence suggests that despite contextual constraints, Iranian manufacturers perceive lean-related productivity improvements in ways consistent with global best practices.

The identification of "quality management" as a central technical component reflects the well-established assertion that lean performance is directly influenced by quality assurance and defect prevention mechanisms (Bhamu & Singh Sangwan, 2021). The experts' emphasis on standardization, process control, and error reduction mirrors the systematic frameworks proposed in classical and contemporary lean studies, where quality stability is considered a prerequisite for waste elimination (Womack & Jones, 2021). Moreover, the emergence of advanced technologies—including artificial intelligence, IoT, robotics, and big data analytics—as key enablers illustrates the sector's awareness of Industry 4.0's transformative potential. This is consistent with findings showing that digital capabilities enhance algorithmic precision, decision-making accuracy, and predictive maintenance, all of which strengthen lean outcomes (Frank et al., 2022). The alignment with global industry patterns is also reinforced by studies demonstrating the synergistic impact of digital transformation on lean and sustainability performance across manufacturing sectors (Ferrazzi et al., 2025; Садченко et al., 2024).

The economic–financial dimension emerged as a significant driver of lean feasibility, reflecting the structural pressures faced by Iranian automotive firms. Cost reduction through energy optimization, minimizing waste, stabilizing supply chains, and investing in innovation aligns closely with studies noting that financial resilience is a critical determinant of sustainable competitiveness in manufacturing contexts with high environmental turbulence (Mohaghar et al., 2021). The clustering of components such as supply chain integration, raw material security, and procurement optimization parallels empirical findings suggesting that supply-side vulnerabilities can undermine lean performance by disrupting flow, increasing working capital requirements, and amplifying variability (Rabetino et al., 2015). This is particularly notable in contexts where sanctions and macroeconomic instability, as described in national economic analyses, directly affect material access, import channels, and liquidity (Rezai, 2023). Thus, the strong presence of economic motivational factors reinforces the reality that Iranian automotive firms often pursue lean not as a strategic enhancement but as a survival mechanism.

Additionally, the study found that investment in innovation—through R&D, modern equipment, and infrastructure upgrades—plays a pivotal role in enabling sustainable lean transitions. This observation is consistent with research highlighting how innovation capacity supports the adoption of eco-efficient technologies, energy-saving techniques, and modular design strategies (Aidis, 2021; Dora et al., 2022). The literature on industrial clusters similarly emphasizes that innovation-driven linkages and knowledge flows contribute to competitive upgrading and operational modernization (Chittithaworn, 2019). In this sense, the experts' perspectives reflect an understanding that long-term sustainability cannot be achieved solely by operational optimization; rather, it requires transformational investments that reposition firms within technologically dynamic global markets (Frank et al., 2022).

The results also reveal that the environmental dimension—comprising natural resource conservation, waste minimization, green waste management, and sustainable product design—forms a coherent cluster. This strongly aligns with the global shift toward integrating environmental management principles into lean frameworks (Jabbour et al., 2023). The congruence is particularly visible in the identification of reducing toxic materials, lowering emissions, using recycled content, and optimizing fuel efficiency as central practices that bridge lean and ecological objectives. Prior work demonstrates that environmental-oriented lean initiatives not only reduce operational waste but also enhance brand reputation and regulatory compliance (Schneider et al., 2014; Singh et al., 2015). The experts' focus on electric and hybrid vehicle development resonates with international trends in automotive sustainability and further confirms that environmental pressures are stimulating technological innovation (Ghosh & Kwan, 2019). These results collectively illustrate that environmental sustainability is not perceived as a peripheral consideration but rather an integrated pillar within the lean production ecosystem.

Perhaps the most striking insight from this study is the prominence of the organizational–cultural dimension. The analysis shows that managerial commitment, long-term strategic orientation, resource allocation, workforce development, and a culture of continuous improvement are viewed as essential enablers for implementing lean sustainably. This finding aligns strongly with previous studies that emphasize the indispensable role of leadership, employee engagement, and organizational learning in shaping lean system maturity (Dabbagh & Soltan Mohammadi, 2021; Lekhanya, 2015). The emergence of this dimension as a foundational layer also echoes global findings that cultural transformation is a determinant of lean success above and beyond technical interventions (Andrei & Rodríguez-Pose, 2017). Continuous improvement systems, teamwork structures, and knowledge management mechanisms identified by the experts support the argument that cultural infrastructure determines whether lean tools become deeply embedded or remain ceremonial (Safaei Qadikalai & Hosin Bar, 2016). Moreover, studies in service and clinical environments show that organizational culture consistently mediates the effectiveness of lean practices across diverse sectors (Затулкин, 2023).

Interestingly, the results indicate that organizational–cultural components in Iran play an even more critical role than those reported in many international studies. This heightened importance appears to be driven by structural institutional constraints, resource limitations, and contextual complexities unique to the Iranian environment. Literature on institutional influences suggests that in regions with weaker governance structures or unstable economic systems, internal cultural coherence becomes a compensatory mechanism for ensuring organizational performance and resilience (Andrei & Rodríguez-Pose, 2017). The experts' emphasis on leadership support, employee empowerment, and sustained awareness-building around sustainability further demonstrates that cultural alignment acts as a stabilizing mechanism that anchors long-term operational initiatives in volatile environments.

This study also reinforces the notion that lean sustainability is a systemic and interconnected phenomenon. The experts repeatedly emphasized that improvements in the technical dimension—such as digitalization or quality enhancement—directly influence environmental and economic outcomes. This observation is consistent with research showing that technological and operational interventions generate cascading effects across financial, environmental, and strategic domains (Hwang & Kao, 2022; Kao, 2022). For example, energy optimization not only lowers costs but also supports environmental compliance; likewise, digital transformation enhances process visibility, which strengthens both quality performance and resource efficiency. The ability of lean practices to generate multi-domain benefits has been widely documented, reinforcing the systemic perspective revealed by this study (Dora et al., 2022; Ferrazzi et al., 2025).

Finally, the study contributes novel insights by contextualizing lean sustainability within Iran's macroeconomic and institutional landscape. Economic challenges such as volatility in supply chains, financial constraints, and limited technology import channels mean that lean adoption is often reactive and necessity-driven rather than proactive and innovation-driven. This mirrors findings from studies on SMEs in developing contexts, where internal conditions and socio-economic structures significantly influence the uptake of modern management practices (Aidis, 2021; Sukwadi et al., 2013). The Iranian automotive sector's prioritized focus on cost reduction, raw-material security, and operational continuity reiterates previous observations that sustainability pathways in constrained environments tend to diverge from those in advanced industrial economies (Mohammadi et al., 2015; Rezai, 2023). The results also validate arguments that sustainable production models must be adapted to local pressures and institutional realities rather than imported wholesale from foreign contexts (Shari'at et al., 2017; Taheri Zadeh & Abbasi, 2020).

This study was qualitative in nature and relied on expert interviews, which inherently limits the generalizability of the findings. The sample size, though appropriate for qualitative methods, may not fully capture the diversity of perspectives across all segments of Iran's automotive supply chain. Additionally, given the rapidly evolving technological and economic environment, the identified factors may shift over time as new digital tools, regulatory changes, and competitive pressures emerge. The reliance on participants' subjective interpretations also introduces the possibility of response bias, particularly in organizational and cultural assessments.

Future research could employ mixed-methods or quantitative approaches to validate and prioritize the identified components across broader samples. Comparative studies between automotive firms in Iran and those in other developing economies could illuminate similarities and context-specific divergences in lean sustainability pathways. Longitudinal research designs would also be valuable for tracking how economic instability, technological adoption, and environmental pressures reshape lean feasibility over time. Finally, exploring the role of digital transformation as a mediator between lean practices and sustainability outcomes would enrich theoretical understanding.

Practitioners should focus on strengthening organizational culture and leadership commitment as foundational enablers for sustainable lean transformation. Investment in technological infrastructure and workforce skill development should be approached strategically and aligned with long-term operational goals. Firms should also design integrated systems that link technical improvements with economic and environmental objectives, ensuring that lean initiatives generate cross-functional value. Strengthening supplier collaboration and establishing resilience-oriented procurement strategies can further enhance sustainability outcomes in volatile environments.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

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