

Lean as a System of Learning Systems

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Abstract— This viewpoint article develops an architected framework of learning in lean enterprises by integrating Fujimoto’s evolutionary learning capabilities perspective, Imai’s Kaizen model, and Argyris and Schön’s organizational learning framework. Through theoretical synthesis, the paper reconceptualizes lean as a dynamic system of learning systems that supports stabilization, incremental improvement and strategic renewal. The resulting framework positions lean transformation as a recursive process that fosters generative change, cultural adaptation, and long-term competitiveness. This integrative perspective provides practitioners with a diagnostic and developmental tool for overcoming stagnation in lean initiatives and designing more robust learning architectures, advancing a holistic, capability-based view of sustained lean growth.

Keywords—lean, learning, system-of-systems

I. INTRODUCTION

Lean was first described by [1] as a means of achieving world-class quality and productivity in manufacturing. It was later popularized by [2] as a superior approach to managing a business and continues to gain interest from both practitioners and academics alike [3]. Lean can be seen as an attempt to generalize and replicate the performance lessons from Toyota – outside the company, the industry and the country [4]. However, many attempts to implement lean continue to fail [5]. At the same time, as a continuously evolving business phenomenon, our understanding of lean also continues to develop [6]. For example, what to many began simply as a set of tools and best practices for operational excellence [7] has progressed to a holistic management philosophy [8] and more recently a complete education system [9]. What really sets Toyota apart from its competitors, is that it has “learned to learn” [10].

As such, delving deeper into the learning dimension of lean, [11] presents an organizational learning component to explain the evolution of lean over time. More recently, [12] attributes much of the continued lean failure to a lack of awareness regarding the significance of learning when embarking on lean initiatives – both at the organization and enterprise / supply chain level. [13] also emphasizes that the development of a learning-to-learn capability is critical for achieving the true promise of lean. Although 20 years prior, [14] suggested that becoming lean involves becoming a learning organization via constant reflection and continuous improvement, the strategic importance of organizational- and enterprise-wide learning for lean success remains overlooked.

One possible cause for such a high rate of lean failure is the reluctance to understand lean as a learning system, or indeed what might be comprehended as a complete system of learning systems. To explore this idea, this research adopts a system-of-systems (SoS) perspective as an analytical lens. The term SoS appears frequently across engineering and management literature, and its definition has been formalized

within systems engineering through ISO/IEC/IEEE 21839, which provides a widely recognized standard definition. However, its application as an analytical lens in organizational and management studies remains limited, and interpretations of SoS vary across disciplinary contexts [15]. In this investigation, the definition of [16] is adopted, which describes SoS as a configuration of independent yet interacting systems that collectively exhibit capabilities not achievable by any constituent system alone.

The following characteristics are often associated with an SoS. Importantly, not all characteristics need to be present in every instance; rather, they collectively describe the nature of typical SoS arrangements [17]:

- **operational and managerial independence.** Each component system can function and be governed independently while also contributing to the broader whole.
- **geographic or functional distribution.** Reflects the decentralized nature of constituent systems.
- **emergent behaviour.** The integrated whole produces outcomes or learning dynamics not predictable from the parts in isolation; and
- **evolutionary development.** Both the constituent systems and the overarching SoS evolve over time rather than being designed as a single, fixed architecture.

These characteristics emphasize that an SoS does not represent hierarchical control but rather interdependence, autonomy, and emergent capability, making it a useful lens for analysing complex learning arrangements in lean enterprises. As such, the following research question is adopted to guide the study:

How does a system-of-systems lens reshape our understanding of the learning systems within lean firms?

To address the research question, this article sets out to theorize on the learning attributes of lean by synthesizing three seminal works: Firstly, the important work of [18], which presents the development of evolutionary learning capabilities as a key to Toyota’s success; second, the pivotal work of [19] which suggests Kaizen as the key to Japan’s competitive success; and third, we draw on the groundbreaking work of [20] which distinguishes between single- and double-loop learning and has inspired further scholars to explore the significance of triple-loop learning [21].

The paper is presented as follows: in the next section the research design (theory synthesis) is described, while in section three an overview of the synthesis preparation is presented, wherein the relevant theories are summarised. Section four presents the results of the synthesis, which involved comparing the theories for points of convergence. In

section five the implications of the theory synthesis process are discussed, before conclusions are drawn and areas for future research identified in section six.

II. RESEARCH DESIGN

To explore lean as a system of learning systems, this paper adopts a process of theorizing [22] and applies theory synthesis, which “compares and weaves together specific, related theories of interest” [23]. [24] sees theorizing as “the process through which a theory is created, from the first feeble hunch to the final theory, presented in print to the reader” (p. vii). As such, the study adopts a three-phased approach to theory synthesis – namely *synthesis preparation*, *synthesis*, and *synthesis refinement* – with the aim of achieving conceptual integration across multiple theoretical perspectives from distinct intellectual traditions [25]. Such synthesis aims to provide an enhanced understanding of lean as a business phenomenon, by linking previously unconnected research streams.

III. SYNTHESIS PREPARATION: THEORETICAL BACKGROUND

This chapter prepares the ground for an integrative synthesis of three influential but distinct theoretical traditions, selected on the basis of their scholarly influence and conceptual complementarity across levels of learning, to develop a unified view of lean as a system of learning systems: Fujimoto’s (1999) evolutionary learning capabilities perspective, Imai’s (1986) Kaizen model, and Argyris and Schön’s (1974) organizational learning framework. While these works arise from different scholarly lineages, they converge on a common concern: how organizations learn to sustain performance, improve processes, and adapt over time. Leveraging this shared emphasis on learning, the chapter extracts and recontextualizes core constructs from each framework as building blocks for a coherent, SoS model of lean transformation.

A. Fujimoto’s (1999) evolutionary learning capabilities perspective

[18] presents an evolutionary perspective of capability development at Toyota and offers a three-level model consisting of routinized manufacturing capability, routinized learning capability, and evolutionary learning capability. Whereas *routinized manufacturing capability* refers to the ability to maintain a steady state with stable performance, *routinized learning capability* refers to the ability to change the manufacturing system to improve its functionality. *Evolutionary learning capability* is defined as a firm’s ability to cope with a complex process of capability-building and affects the other capabilities themselves. This capability is of highest importance as it allows a firm to outperform its rivals in dynamic conditions characterized by high uncertainty, identifying new market opportunities through reinterpreting environmental signals, experimenting with alternative strategic directions, and recombining existing capabilities into novel configurations to support firm growth.

B. Imai’s (1986) Kaizen model

Imai’s Kaizen model [19] encompasses maintenance, Kaizen, and innovation. At the foundational level, *maintenance* refers to preserving current standards through stable processes, disciplined execution, and adherence to established procedures. Building on this base, *Kaizen* represents continuous, small-step improvement driven by

frontline problem solving, cross-functional collaboration, and iterative refinement of work practices. At the highest level, *innovation* involves more radical, discontinuous changes that challenge existing assumptions and restructure processes or systems altogether.

C. Argyris and Schön’s (1974) organizational learning framework

[20] distinguishes between different depths of learning based on how organizations detect and respond to problems. *Single-loop learning* involves correcting errors by adjusting actions without questioning the underlying norms, goals, or assumptions that guide behaviour. In contrast, *double-loop learning* requires reflection on and revision of these deeper governing values, enabling more fundamental shifts in policies, strategies, or mental models. Some scholars have extended this logic to *triple-loop learning* [26], referring to a meta-level inquiry in which organizations reconsider and redesign the overarching learning architecture itself, allowing them not only to question their governing values but also to redefine how they engage with and adapt to changing external environments. The framework positions learning as a recursive, inquiry-driven process through which organizations not only refine their actions but also reshape the underlying frameworks that determine how they interpret and respond to challenges, both internally and in relation to evolving market and societal conditions.

IV. THEORY SYNTHESIS: RESULTS

This section presents the theoretical synthesis of the Lean System of Learning Systems (L-SoLS).

TABLE I. SYNTHESIZING LEAN AS A SYSTEM OF LEARNING SYSTEMS

	Fujimoto (1999)	Imai (1986)	Argyris & Schön (1974)
System 1: Learning to Stabilize	Routine Manufacturing Capabilities: the ability to maintain a steady state with stable performance	Maintenance: activities directed toward maintaining current technological, managerial and operating standards	Single-loop Learning: “we learn to maintain the field of constancy by learning to design actions that satisfy existing governing variables”
System 2: Learning to Improve	Routine Learning Capabilities: the ability to change the manufacturing system to improve functionality	Kaizen: small improvements made in the status quo as a result of ongoing efforts	Double-loop Learning: “we learn to change the field of constancy ... changes the governing variables (the “settings”) of one’s programs and causes ripples of change to fan out”
System 3: Learning to Adapt	Evolutionary Learning Capabilities: a firm’s ability to cope with a complex process of capability building and affects the other capabilities themselves	Innovation: radical improvements in the status quo (as a result of a large investment in new technology and / or equipment)	Triple-loop Learning*: “when the essential principles on which the organization is founded come into discussion - involving ‘the development of new principles, with which an organization can proceed to a subsequent phase’”.

* though triple-loop learning has clearly been inspired by Argyris and Schön, it does not arise explicitly in their published works [26].

V. SYNTHESIS REFINEMENT: DISCUSSION

The aim of this paper was to synthesize three theoretical traditions into a single recursive SoS architecture. This section refines that synthesis by clarifying the theoretical structure of the L-SoLS framework (Fig. 1) and specifies the relationships among the three systems. Contemporary insights from *The Lean Strategy* [27] are also used to elaborate its conceptual implications, using the Toyota Production System (TPS) as a reference model that concretizes the L-SoLS framework in an established industrial management context.

At first glance, the L-SoLS framework may appear as a simple, hierarchical maturity model. However, the synthesis reveals something more structurally complex: lean emerges as an SoS composed of three nested but interdependent learning systems.

System 1 (*Learning to Stabilize*) concerns the organization's ability to stabilize and reliably reproduce existing capabilities. It corresponds to maintaining performance within an established capability trajectory by ensuring that work is executed consistently and deviations are rapidly detected and corrected. From the perspective of Takashi Fujimoto, this reflects routinized manufacturing capability, where stable performance is achieved through disciplined execution of well-defined processes. Similarly, in Masaaki Imai's framework, this aligns with maintenance, which preserves current standards and prevents deterioration.

The primary problem type addressed at this level is executional deviation: instances where actual performance diverges from defined standards. Learning therefore takes the form of single-loop adjustment, in which actions are corrected without questioning underlying assumptions or system design. Operationally, System 1 is instantiated through mechanisms such as standardized work, visual management, and daily management routines. These practices create the conditions for process stability, transparency, and rapid feedback, ensuring that deviations are visible and actionable.

Within the broader L-SoLS architecture, System 1 plays a foundational role. By stabilizing performance, it provides the necessary signal clarity for higher-order learning. Without stable standards, it becomes difficult to distinguish meaningful problems from random variation, thereby undermining both improvement and adaptation efforts.

System 2 (*Learning to Improve*) concerns the organization's ability to systematically improve and refine existing capability trajectories. Rather than simply maintaining performance, this system focuses on identifying and resolving the underlying causes of recurring problems, thereby enhancing the functionality and efficiency of established processes. In Fujimoto's terms, this corresponds to routinized learning capability, defined as the ability to deliberately modify the production system to improve its performance. In parallel, Imai characterizes this mode as Kaizen, involving continuous, incremental improvements driven by structured problem-solving and frontline engagement.

The dominant problem type at this level is process limitation (i.e., persistent gaps between desired and actual performance), that cannot be resolved through simple adherence to standards. Addressing such problems requires questioning aspects of the existing process design, assumptions, or parameters. As such, learning at this level

aligns with double-loop learning, in which underlying assumptions within a given operational frame are examined and revised. However, this occurs within the boundaries of an existing capability trajectory; the fundamental direction of the system remains intact.

System 2 is operationalized through routines such as A3 problem-solving, root cause analysis, and Toyota Kata. These mechanisms enable organizations to iteratively refine processes, update standards, and develop greater problem-solving capability among employees. Within the L-SoLS framework, System 2 plays a critical intermediary role. It transforms operational instability into structured learning and ensures that performance improvements are systematically embedded. However, because it operates within an existing trajectory, it does not by itself address deeper questions of strategic direction or environmental alignment.

System 3 (*Learning to Adapt*) concerns the organization's ability to adapt to changing environments through evolutionary capability development and strategic renewal. From an evolutionary learning capability viewpoint (as developed by Takashi Fujimoto), organizations develop the capacity to navigate uncertainty through what can be described as multipath system emergence. Rather than optimizing a single trajectory, firms explore and cultivate multiple potential capability paths, for example, alternative technologies, product architectures, or market positions. Over time, these paths are selectively reinforced or abandoned based on their alignment with environmental conditions. This process enables organizations not only to respond to change, but to reconfigure the underlying structure.

Complementing this perspective, Imai's distinction between Kaizen and innovation clarifies the nature of change at this level. Whereas Kaizen (System 2) operates through incremental improvement within an existing system, innovation represents discontinuous change that restructures the system itself. In this sense, System 3 is not an extension of improvement activity, but a qualitatively different mode of learning that involves redefining technological trajectories, value propositions, and / or business domains.

Empirically, System 3 becomes visible through shifts such as transitions between technological paradigms (e.g., from internal combustion engines to hybrid or battery-electric systems) or expansion into new or adjacent markets. These activities reflect not only strategic decision-making, but experimentation at the level of system configuration, where alternative futures are explored in parallel before being selected and scaled. Within the broader L-SoLS architecture, System 3 governs the selection and reconfiguration of capability trajectories, while Systems 1 and 2 operate within those trajectories. This distinction is critical: whereas System 2 improves performance along a given path, System 3 determines which paths are pursued, created, or abandoned.

Evaluating the three systems against the SoS characteristics further justifies the framework's architectural claim. Each system exhibits operational and managerial independence (System 1 through local routines, System 2 through improvement structures and System 3 through strategic planning processes), while geographic or functional distribution is also reflected in the decentralized nature of each system's mechanisms across work cells, departments, organizations and / or enterprises, respectively.

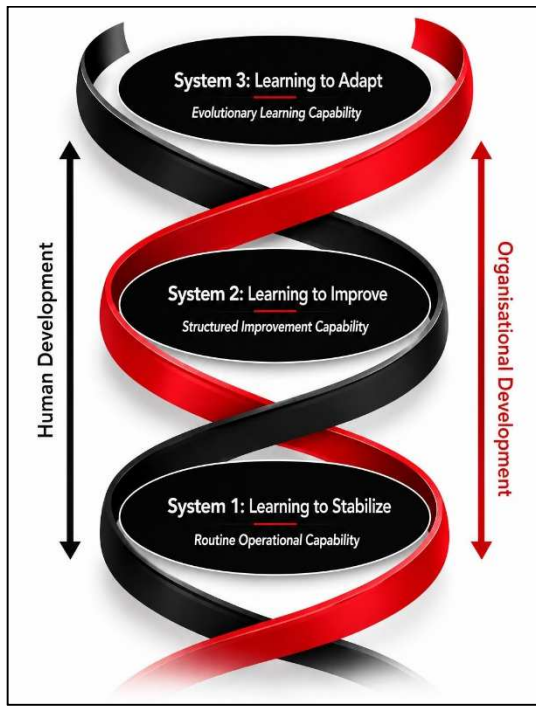


Fig. 1. Lean System of Learning Systems (Source: author)**

Emergent behavior arises from the recursive interaction among the three systems, while evolutionary development is evident in the dynamic co-evolution of all three systems over time. Taken together, the three systems satisfy the defining SoS characteristics, thereby justifying the SoS framing over a simpler hierarchical or maturity model interpretation. This is a critical characteristic of the model in that the three systems do not represent successive stages of development. They operate simultaneously and recursively. System 2 presupposes the stability of System 1 to expose meaningful problems. System 3 presupposes the reflexivity of System 2 to surface and question governing assumptions. In turn, insights from System 3 cascade downwards intra-organizationally (and indeed outwards inter-organizationally), reshaping improvement routines and operational standards and growing the business. It is this recursive interaction that distinguishes L-SoLS from linear capability models. Lean is not the accumulation of tools or routines; on the contrary, it is the structured coupling of learning mechanisms across interdependent levels of abstraction.

This distinction clarifies an enduring paradox in lean practice: organizations may excel at systems 1 and 2 yet fail to adapt strategically. The L-SoLS framework explains this not as inconsistency but as imbalance. Continuous improvement does not automatically produce evolutionary renewal. System 2 learning improves performance within a frame; System 3 learning revises the frame itself. The synthesis therefore differentiates incrementalism from evolution without opposing them. Evolutionary capability is not a break from lean logic but its extension to a higher order of reflexivity.

The results also challenge the common dichotomy between efficiency and adaptability. In the L-SoLS framework, operational stability (System 1) is not the enemy of innovation; it is its precondition. Without stable standards, meaningful deviation cannot be detected. Without disciplined routines, experimentation cannot be evaluated. Conversely, excessive emphasis on stability suppresses higher-order

learning. When System 1 dominates, lean efforts degenerate into rigid standardization exercises. When System 2 dominates without System 3 oversight, organizations risk localized optimization detached from strategic direction. The theoretical synthesis thus reframes lean as a dynamic equilibrium among learning systems. The health of the architecture depends on maintaining productive tension across all three systems.

An additional layer of reinforcement to refine this theoretical synthesis comes from contemporary lean scholarship, particularly *The Lean Strategy* [27], which describes lean transformation as the deliberate alignment of daily operational stability, structured problem-solving, and strategic exploration. The account provides practice-based grounding for the recursive dynamics articulated in the L-SoLS framework: daily management stabilizes work and makes problems visible (System 1), problem-solving capability develops people and improves processes (System 2), and strategy emerges as a learning process in which assumptions are tested, principles revisited, and new directions explored (System 3). In this view, lean leadership is not the administration of tools but the stewardship of a learning architecture, linking local learning to strategic renewal through mechanisms such as standardized work and visual management, A3 management, Obeya, and Hoshin Kanri.

To move the L-SoLS framework towards greater empirical accessibility, Table II proposes illustrative observable indicators for each of the three learning systems. These indicators are not intended as definitive measurement instruments (such development would require further empirical work), but rather as preliminary anchors that allow researchers and practitioners to begin distinguishing System 1, System 2, and System 3 activities in real organizational settings.

The Lean Strategy [27] also demonstrates how the Toyota Production System (TPS) orients around these three learning systems: from building in stability to succeed every day (system 1), to deepening technical mastery for solving more technical problems (system 2), to realigning product offerings for increasing customer satisfaction through better product-market fit [28] (system 3). Thus, TPS acts as a reference model for the L-SoLS framework, serving as a concrete, practice-proven instantiation of the three nested learning systems (Fig. 2).

TABLE II. ILLUSTRATIVE OBSERVABLE INDICATORS FOR L-SOLS

	Observable indicators / lean mechanisms
System 1: Learning to Stabilize	Creation and adherence to standardized work; 5S; consistent use of visual controls (e.g., daily management boards); realization of stable performance
System 2: Learning to Improve	Use of JIT and Jidoka to surface problems (kanban and andon); frequency and quality of structured problem-solving cycles; use of A3 management; changes to standard work; root-cause analysis and reduction of root-cause recurrence; cross-functional participation in improvement activity
System 3: Learning to Adapt	Revision of strategic assumptions and governing principles; leadership engagement in reflective forums (e.g., Obeya); evidence of Hoshin Kanri driving system-level redesign; new capability configurations emerging from strategic review; multi-path system emergence

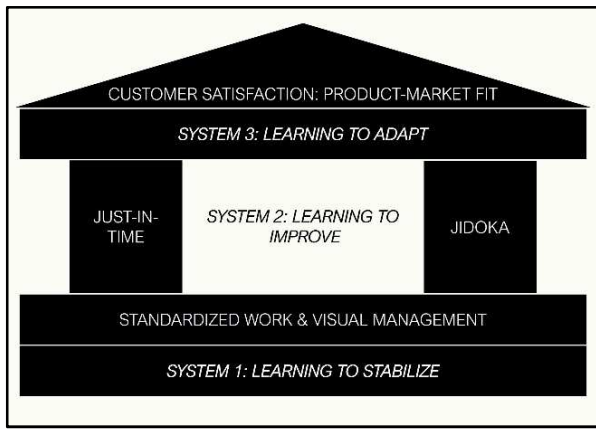


Fig. 2. TPS as a reference model for L-SoLS (Source: author)

Through developing and refining this theoretical synthesis, lean can be repositioned conceptually. It is neither a toolkit, nor a cultural philosophy alone. Neither is it a static production system. Rather, lean becomes a deliberately architected system of nested learning systems that together generate evolutionary capability. Thus, the distinctive feature of mature lean organizations is not merely operational excellence but the institutionalization of reflexivity across the three learning systems.

This evolutionary development is precisely what distinguishes a mature lean enterprise from one that has merely implemented lean tools. Taken together, the three systems can be interpreted as addressing qualitatively different classes of organizational problems: executional deviation (System 1), process design limitations (System 2), and strategic or environmental misalignment (System 3).

This distinction reinforces the analytical value of the L-SoLS framework as a structured architecture for problem definition and resolution across systems. As such, the three systems also satisfy the key SoS characteristics of operational independence, managerial independence, emergent behaviour, and evolutionary development, thereby justifying the SoS framing rather than a much simpler hierarchical or maturity model interpretation.

This reframing of lean also addresses long-standing debates in lean scholarship. By grounding lean within an explicit system of learning systems architecture, the L-SoLS framework clarifies how lean can simultaneously sustain basic stability, incremental improvement and periodic reinvention. It provides a structural explanation for why some organizations reproduce lean superficially while others develop enduring adaptive capacity for long-term growth.

VI. CONCLUSION

This paper set out to reframe our understanding of lean as a system of learning systems. A plethora of misconceptions exist as lean has been diversely interpreted as a production system, a set of tools, a philosophy, and indeed a culture. Each interpretation captures part of its reality but fails to explain its long-term adaptive power. Through theoretical synthesis, this article advances a different claim.

A. Theoretical Contributions

This theorizing piece makes four primary contributions to theory. Firstly, it reconceptualizes lean from a socio-technical production system to an SoS learning architecture (the SoS perspective describes the structural composition of lean, while

the notion of a learning architecture captures its intentional design). This ontological shift elevates lean from operational methodology to institutional design for sustained learning. Secondly, it integrates three major theoretical traditions into a coherent L-SoLS framework, aligning standardization capability, improvement capability, and adaptive capability with distinct but interdependent learning systems. This synthesis clarifies how incremental, developmental and generative learning coexist within lean organizations. Third, it resolves the perceived tension between lean's incrementalism and the need for strategic innovation. Evolutionary capability emerges not as a departure from lean but as its highest-order expression. Finally, it reframes lean maturity as a balance among nested systems rather than the adoption of discrete tools or practices. This provides a more robust theoretical basis for studying lean transformation in the future.

B. Implications for Practice

For practitioners, the research has direct implications. Organizations pursuing lean should design explicitly for three interlocking learning systems:

1. Mechanisms that stabilize and standardize operations (E.g., standardized work and visual management).
2. Routines that institutionalize improvement from operational disruptions revealed by JIT and Jidoka (E.g., Kanban, Andon, and A3 Management).
3. Forums and structures that periodically question and redesign governing principles (E.g., Obeya and Hoshin Kanri).

Transformation efforts that neglect any of these systems risk imbalance. Tool-driven initiatives often strengthen System 1 without developing System 2 reflexivity. Continuous improvement programs may deepen System 2 while leaving strategic assumptions unexamined. Conversely, innovation programs disconnected from operational discipline may fail to institutionalize learning. Lean leadership, therefore, becomes the stewardship of a learning architecture rather than the deployment of methods.

C. Limitations and Future Work

This article is conceptual. As such, the L-SoLS framework remains a theoretical synthesis requiring empirical validation. Moreover, generative or triple-loop learning remains conceptually contested, suggesting further work may be needed to operationalize observable indicators of System 3 activity. As such, future research should examine how the three learning systems can be empirically identified and measured, how imbalance among systems can be used to diagnose and predict transformation failure, and how evolutionary learning manifests across industries and institutional contexts. The role of leadership behaviors in sustaining recursive coupling among systems should also be explored. Comparative longitudinal case studies would be particularly valuable in testing the framework. Finally, while the L-SoLS framework is currently grounded in a manufacturing context and illustrated through TPS, it is proposed that the underlying learning architecture defined by stabilization, improvement, and adaptation would be applicable across any organizational setting in which standards can be defined, deviations detected, and governing assumptions revised - including service, healthcare, and public sector contexts.

D. Concluding Remarks

Lean is not merely a method for operational excellence, nor is it simply a philosophy of waste reduction. When viewed through an SoS lens, it becomes clear that lean is a deliberately architected, recursive arrangement of nested learning systems that cultivate evolutionary capability development. Organizations do not become adaptive by adopting tools, they become adaptive by designing the conditions under which learning emerges, accumulates, and transforms. Properly understood, lean provides precisely such an architecture: one that integrates operational stability, structured improvement, and generative renewal into a coherent system of learning systems. In addressing the RQ *How does a system-of-systems lens reshape our understanding of the learning processes within lean firms?* this synthesis shows that lean should not be interpreted as a static production system but as a system of learning systems spanning the creation and maintenance of standards, continuous improvement, and strategic reinvention. Ultimately, lean is best conceived as an institutional learning architecture for defining and resolving problems at progressively higher levels of abstraction, from execution to product and process improvement to strategic renewal.

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**An AI-based image generation tool (DALL·E) was used to render Fig. 1 from the conceptual design.

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