



Universidad de Oviedo

Integrating Lean Manufacturing, Industry 4.0, and Circular Economy

A Digital Green Lean Framework for Culture and Leadership
Transformation in Process Manufacturing

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Presentation Structure

Section 1: Introduction (frames the questions)

Section 2: Theoretical Foundation

Section 3: Methodology (three studies, three methods)

Section 4: Studies and their original contribution

Section 5: Synthesis (DGL framework, tensions)

Section 6: Conclusion (closing the loop, contribution, boundaries, falsifiability, implications)



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Section 1: Introduction (frames the question)

What this thesis asks:

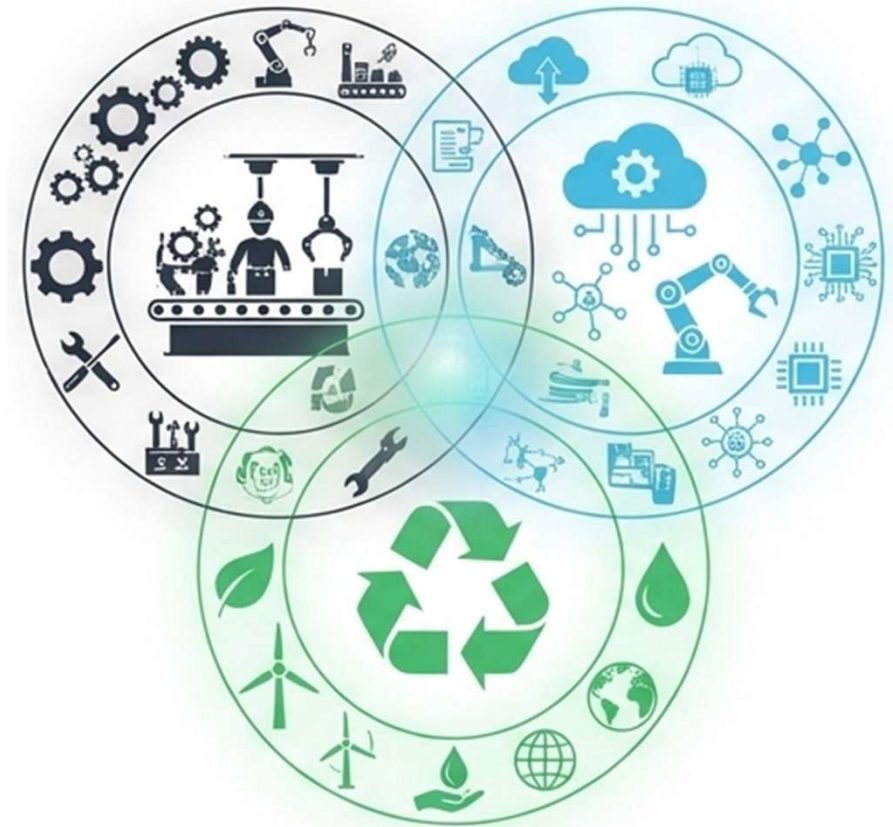
AIM...

...to develop and provide exploratory empirical corroboration for an integrated framework, Digital Green Lean, that explains how Lean Culture and Lean Leadership must transform to accommodate Industry 4.0 and Circular Economy models in process manufacturing?

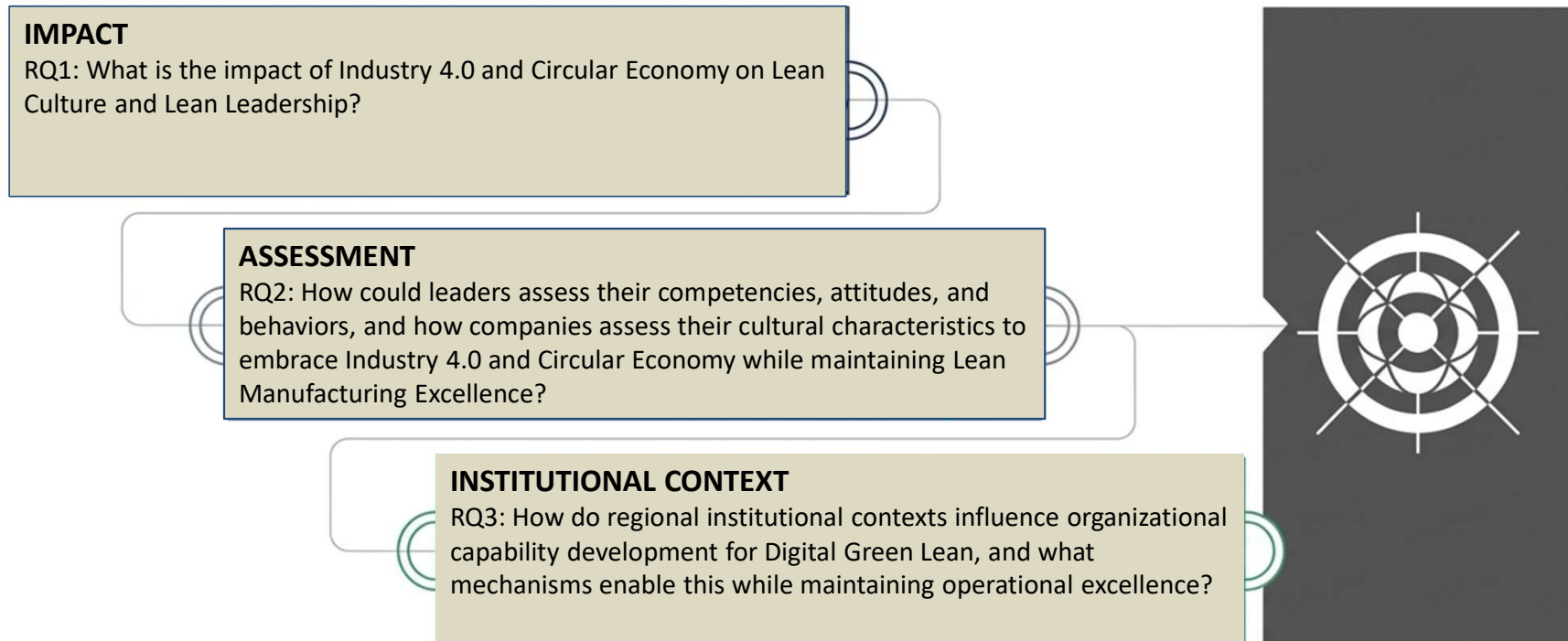
Asking how,
not
whether...?

Focused on
Culture &
Leadership

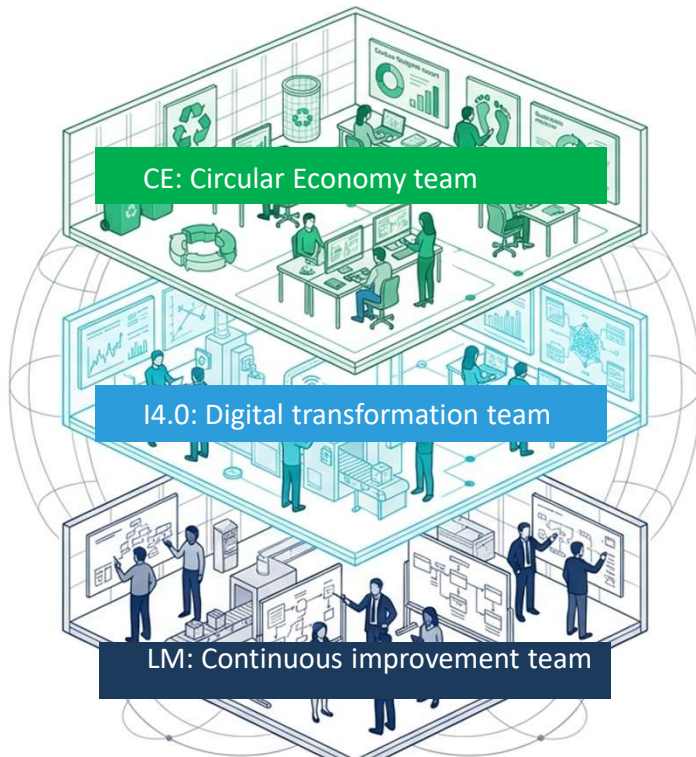
Lean (OpEx)
is a must



What this thesis asks? Research Framework



When walking into a process manufacturing shopfloor today...



Three Teams working in parallel Three transformations

Each one funded and heavily resourced

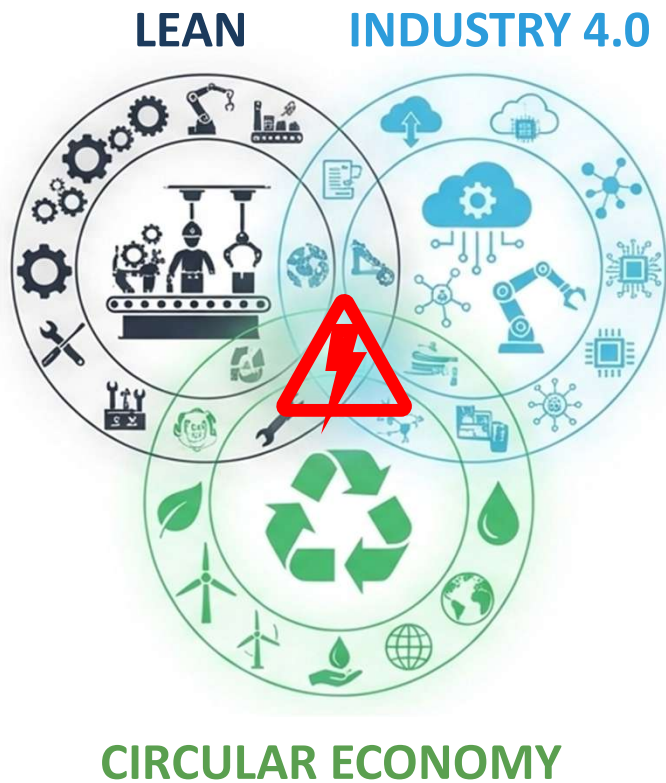
Each one proven and delivers organizational benefits

Each one has its own committee and organizational logic

None of them structurally coordinated

The key to triple integration is not technology. It is organizational logic

Three paradigms, one intersection point



TRILEMMA

Process Manufacturers face simultaneous, non-negotiable pressures to be efficient, digital, and circular

CONFLICT

Each paradigm is coherent, imposes distinct, sometimes contradictory operational demands with the other two

GAP

Existing literature treats integration as a tools problem and ignores the culture and leadership transformation required to manage triple integration, without sub-optimizing the system



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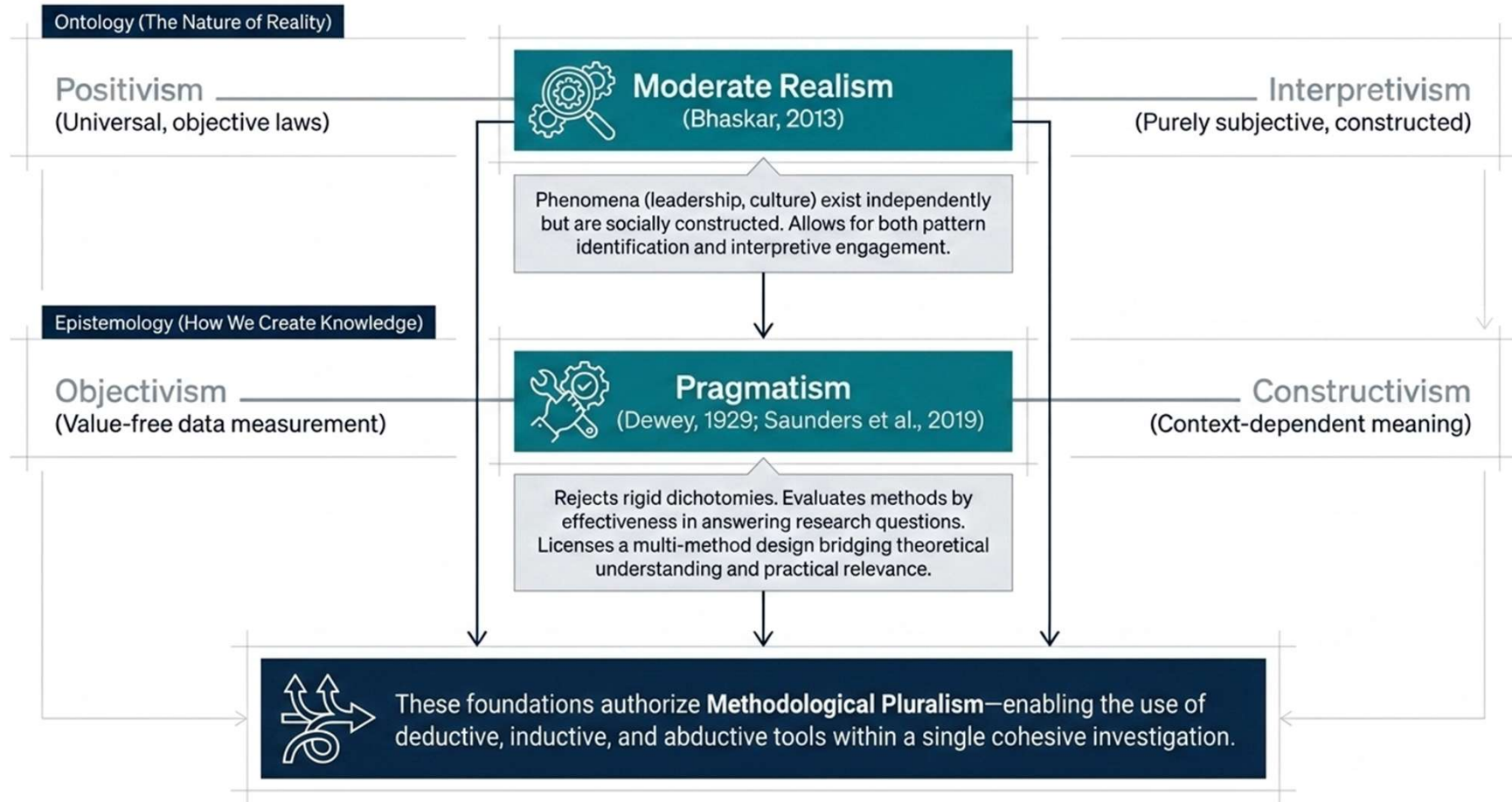
Section 2: Theoretical Foundation

The sociotechnical divergence, defining tensions...

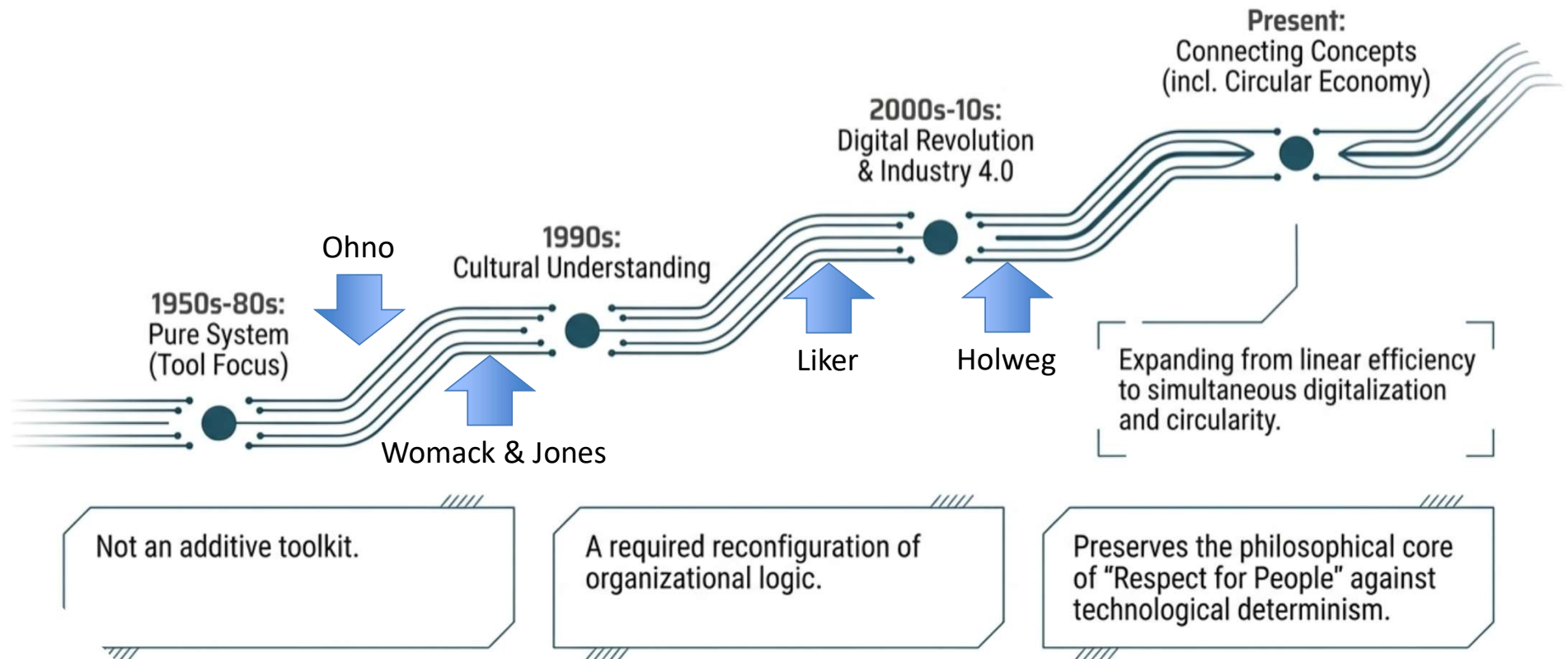
	Lean	I4.0	CE
Primary Goal	Process Stability & Flow	Speed & Customization	Resource Decoupling
Process Logic	Linear Waste Reduction	Dynamic Reconfiguration	Extended Value Loops
Data Utilization	Visual Management / Historical	Algorithmic / Predictive	Lifecycle Tracking
Leadership Paradigm	Supervisor coaching at the Gemba	Data-driven experimentation	Ecosystem orchestration

Different goals, logics and leaders. Stacking them does not integrate them.

Philosophical positioning: Ontological and Epistemological Stance



Theoretical positioning: DGL as the 4th evolution of Lean

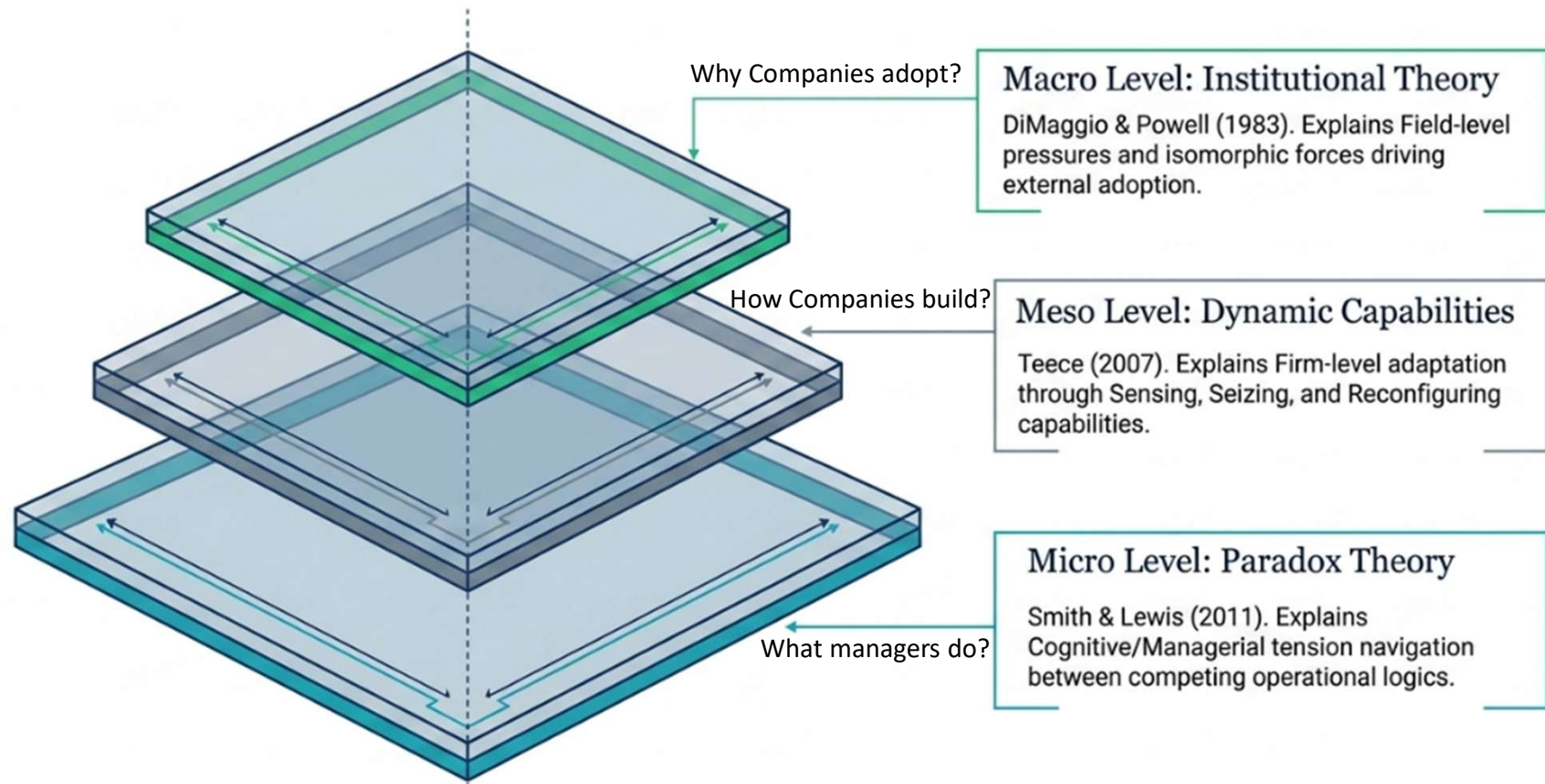




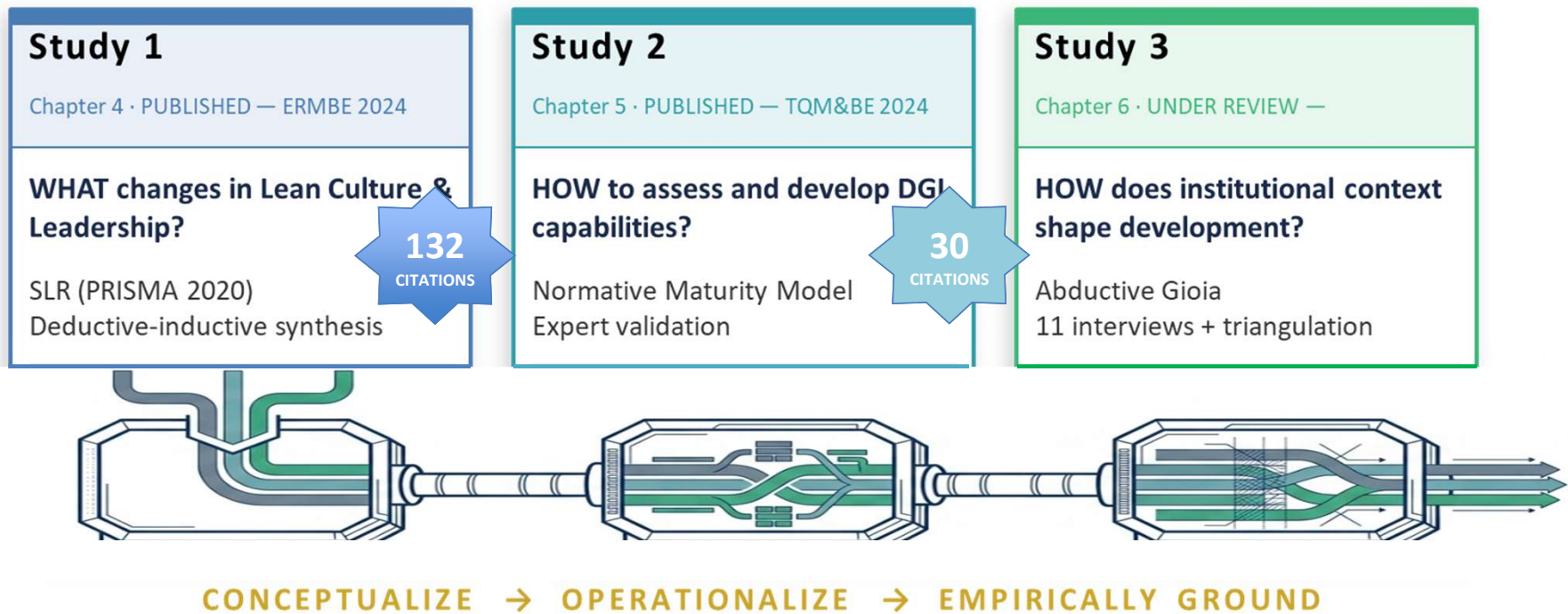
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Section 3: Methodology (three studies, three methods)

The triple layer theoretical architecture



Three studies, three methods, one architecture

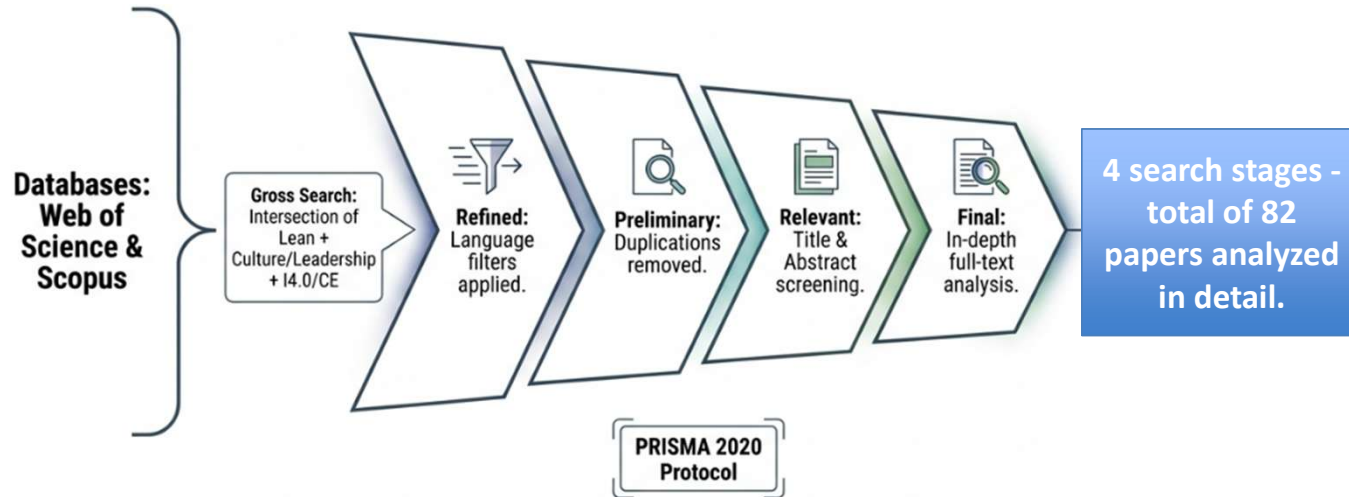




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Section 4: Studies and their original contribution

Systematic Literature Review



LEAN CULTURE

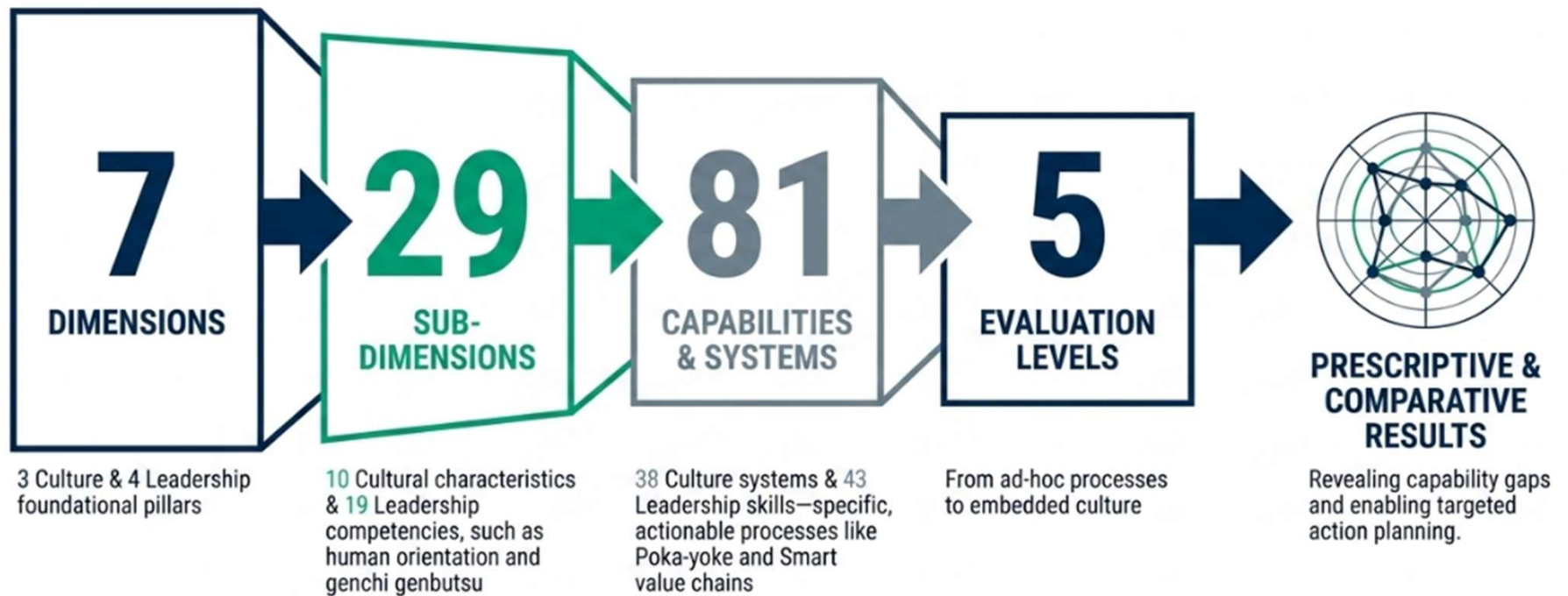
10 characteristics
*3 cultural dimensions
(Values & Principles, Customer centric, OpEX)*

LEAN LEADERSHIP

19 competencies
*4 capability families
(Customer oriented, Personal Development, Lean Principles, Performance Driven)*

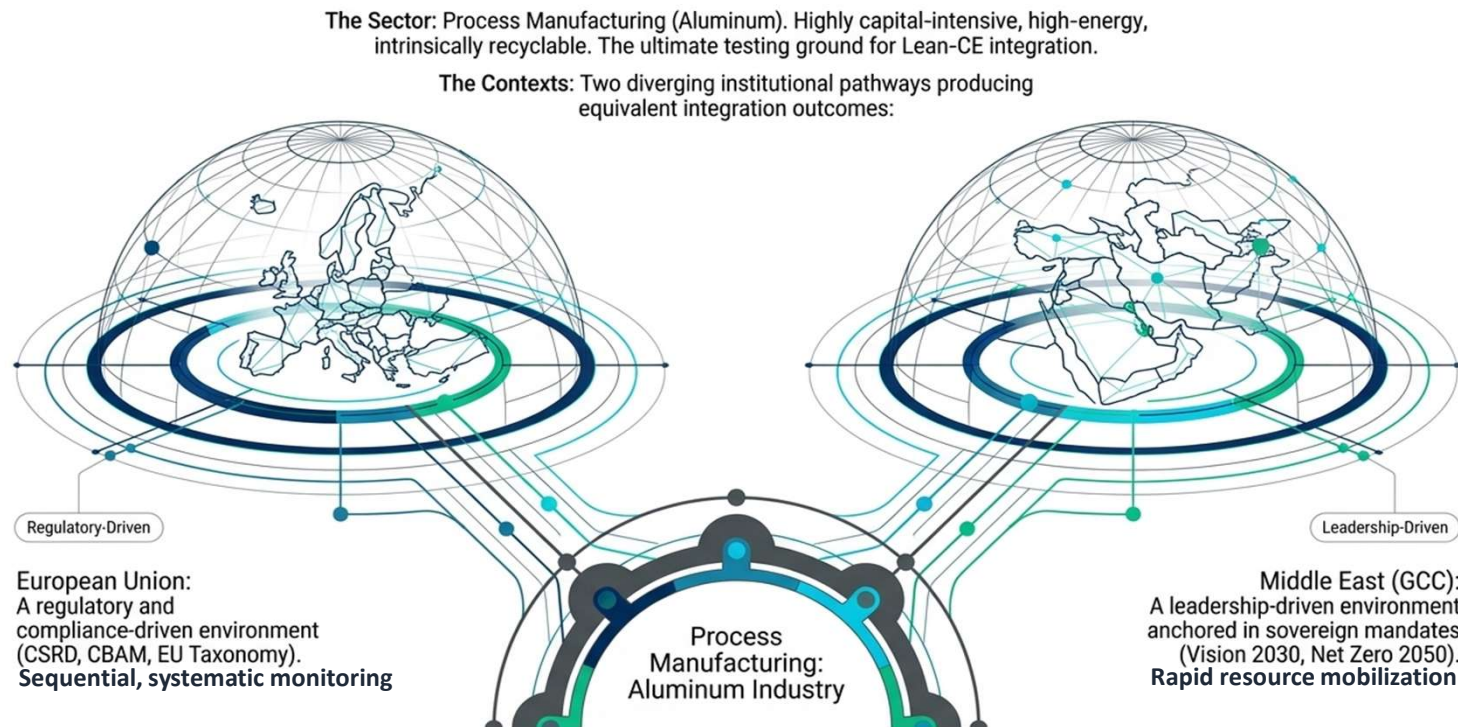
DEDUCTIVE/INDUCTIVE - Existing competencies must be reconceptualized — not merely adopted

DGL Maturity Model



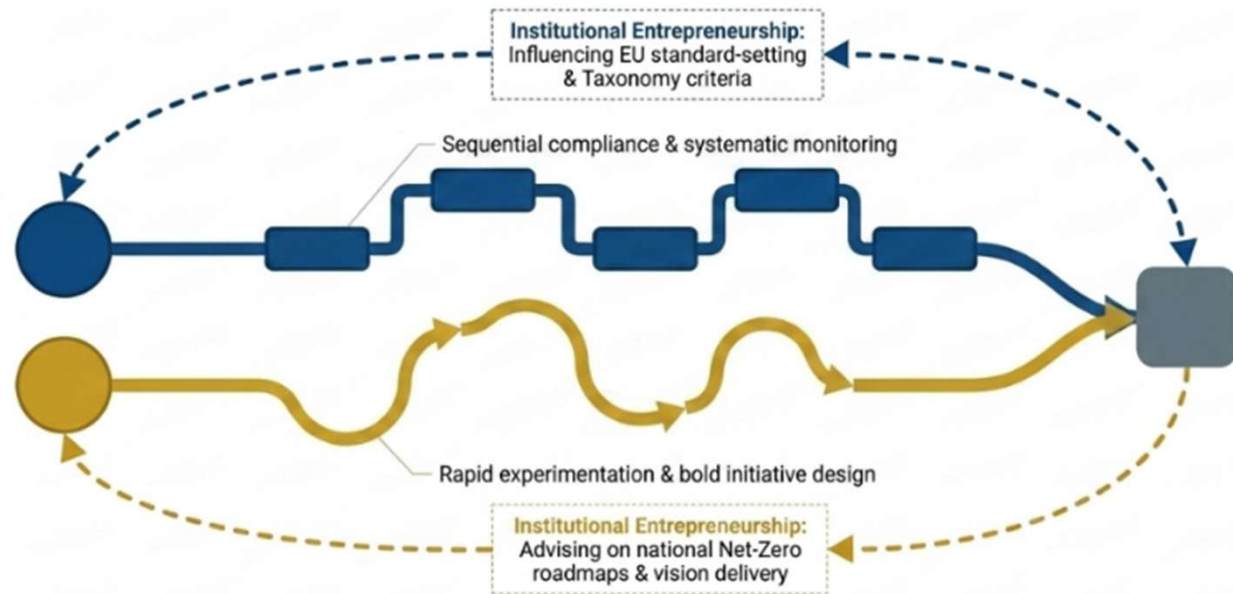
Level 5 is asymptotic — a diagnostic tool, not an EFQM-style certification trap

Two contexts, one sector



Abductive Gioia · 11 interviews · 68 first order codes · 4 aggregate dimensions · saturation · informant triangulation
· Quality: Lincoln & Guba Trustworthiness

Institutional Pathway Equivalence



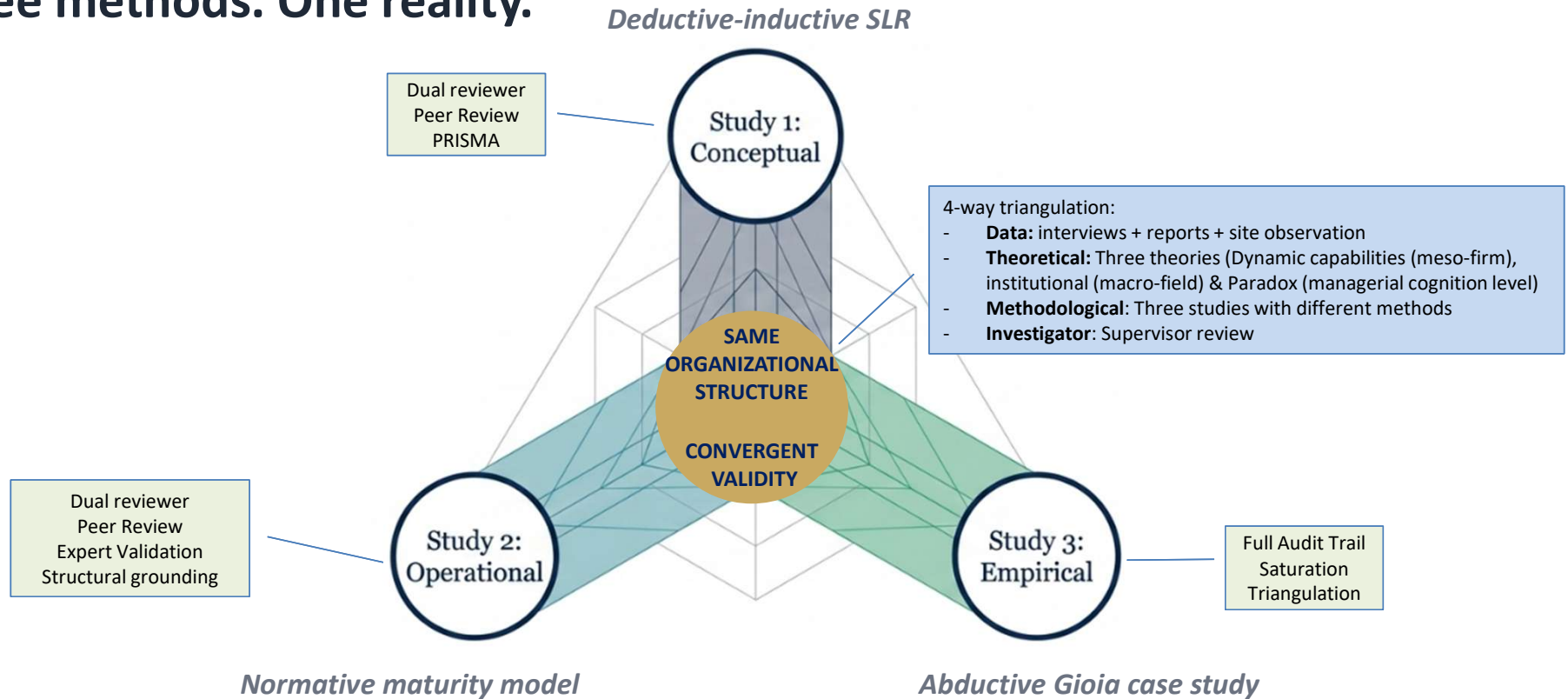
OUTCOME:
COMPARABLE
DGL
CAPABILITIES

4 Dimensions

Regional Institutional context
Org. Capability Development
Stakeholder Driven Transformation
Cultural Adaptation processes

Divergent Institutional pathways produce equivalent operational outcomes. Furthermore, the mechanism is bidirectional: Organizations are shaped by their institutional context, and in turn, actively shape it when operating at Levels 4 & 5

Three methods. One reality.



If organization's reality was purely socially constructed, 3 methods + 3 data sets would have produced 3 disconnected results...

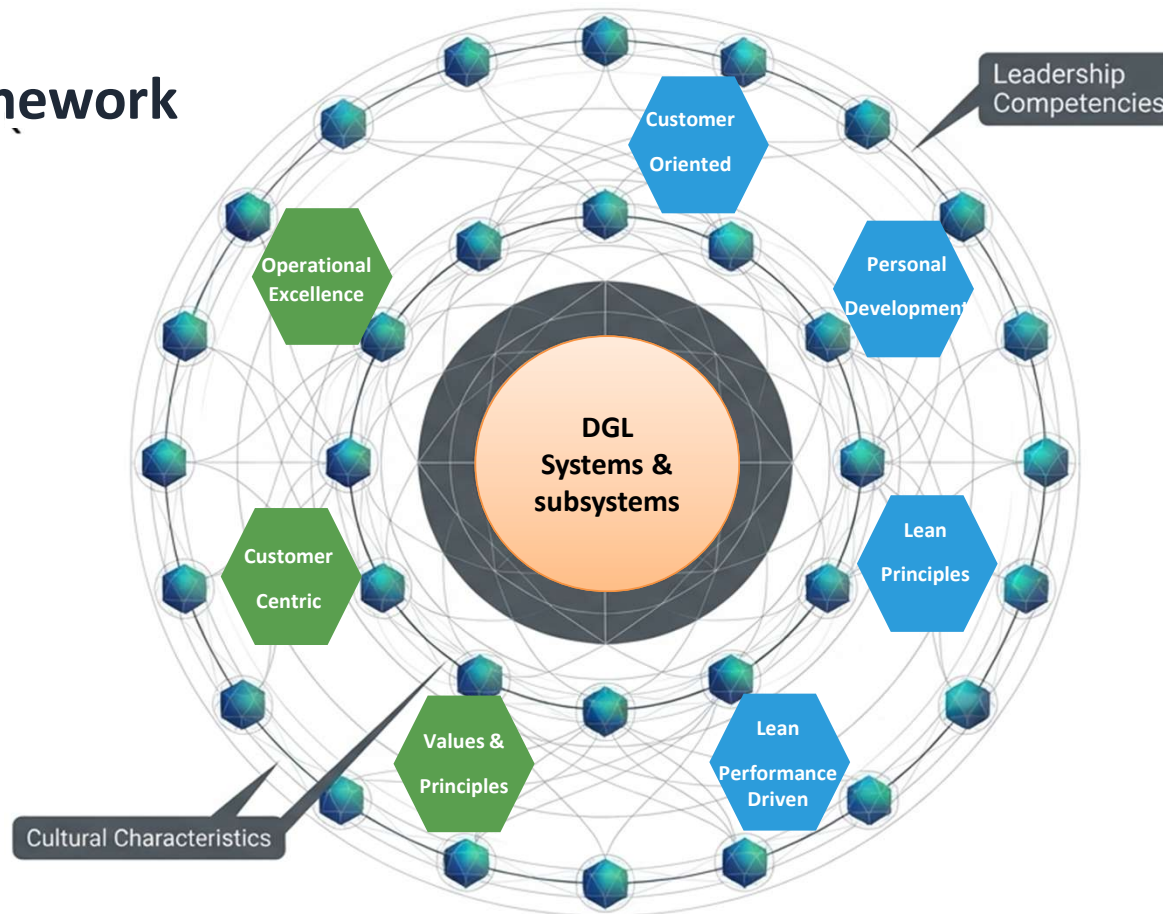
...the proof of ontological moderate realism.



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Section 5: Synthesis (DGL framework, tensions)

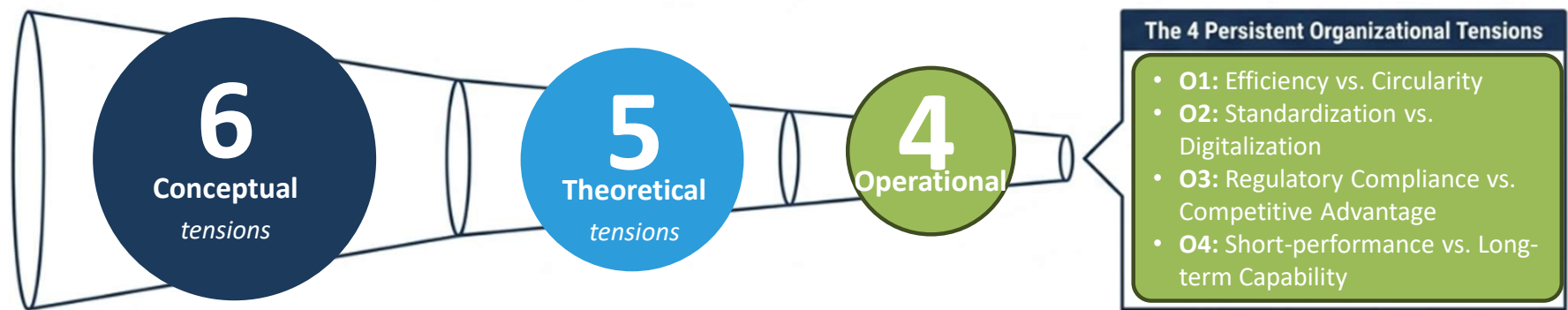
The DGL framework



***Not a new toolkit. A new sociotechnical framework. Culture & Leadership First.
Avoids similar original problems TPS went through (Hines et al., 2025).***

From conceptual to operational tensions

An abductive pipeline — refinement, not loss



DGL: Four operational tensions to be navigated, not resolved

01

Efficiency vs. Circularity

- Linear waste reduction collides with closed-loop variability
- The most disruptive tension. Lean optimizes linear throughput. CE demands reverse logistics and closed material loops that inherently introduce variance
- DGL Navigation: Circular Heijunka, cultural acceptance of sub-optimization

02

Standardization vs. Digitalization

- Visible standards collide with algorithmic opacity
- Lean stability requires reduced variance and standard work. I4.0 demands dynamic reconfiguration and rapid experimentation
- DGL Navigation: Augmented genchi genbutsu, algorithmic stewardship, layered jidoka, nested PDCA

03

Regulatory Compliance vs Competitive Advantage

- Risk-management framing collides with opportunity framing
- Dual framing · institutional entrepreneurship vs global and local governance
- DGL Navigation: institutional entrepreneurship, global-local governance

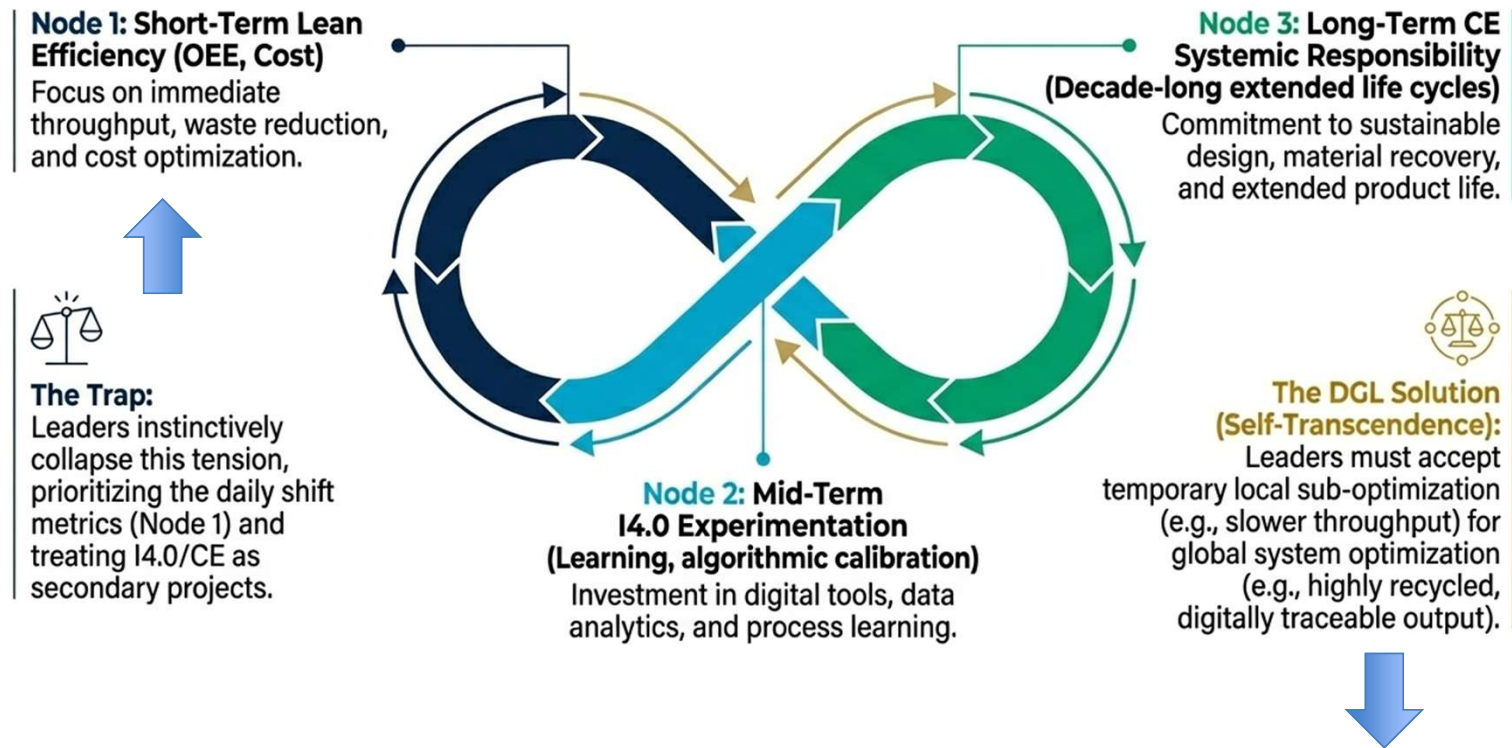
04

Short-term performance vs. Long-term capability

- Quarterly accountability collides with long term capability
- Lean kaizen logic is incremental. CE adoption and I4.0 transformation sometimes require step-change redesign that disrupts standard work
- DGL Navigation: paradox-aware hoshin kanri, ambidextrous capability development, decoupling performance metrics

DGL sustains competing logics without premature resolution.

Productive paradox management





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Section 6: Conclusion (closing the loop, contribution, boundaries, falsifiability, implications)

Where we started — where we land

AIM

The thesis question

*"How must Lean organizational culture and leadership capabilities transform to implement Industry 4.0 and Circular Economy simultaneously, **without sacrificing operational excellence**?"*



Lean becomes an **enabling platform** for fourth-generation **Digital Green Lean** — not replaced but reconceptualized as the core for digital and circular transformation.

RQ1

IMPACT

Chapter 4

What is the impact of Industry 4.0 and Circular Economy on Lean Culture and Lean Leadership?

Three patterns: reinforcement of core competencies, **modification** of shopfloor practices , **reconceptualization** of the framework. I4.0 extends Lean logic; CE challenges its linear assumption.

RQ2

ASSESSMENT

Chapter 5

How could leaders assess their competencies, attitudes and behaviors to embrace I4.0 and CE while maintaining Lean Manufacturing Excellence?

A developmental journey, asymptotic at Level 5, not certifiable
5 maturity levels × 7 dimensions × 29 subdimensions × 81 capabilities.

RQ3

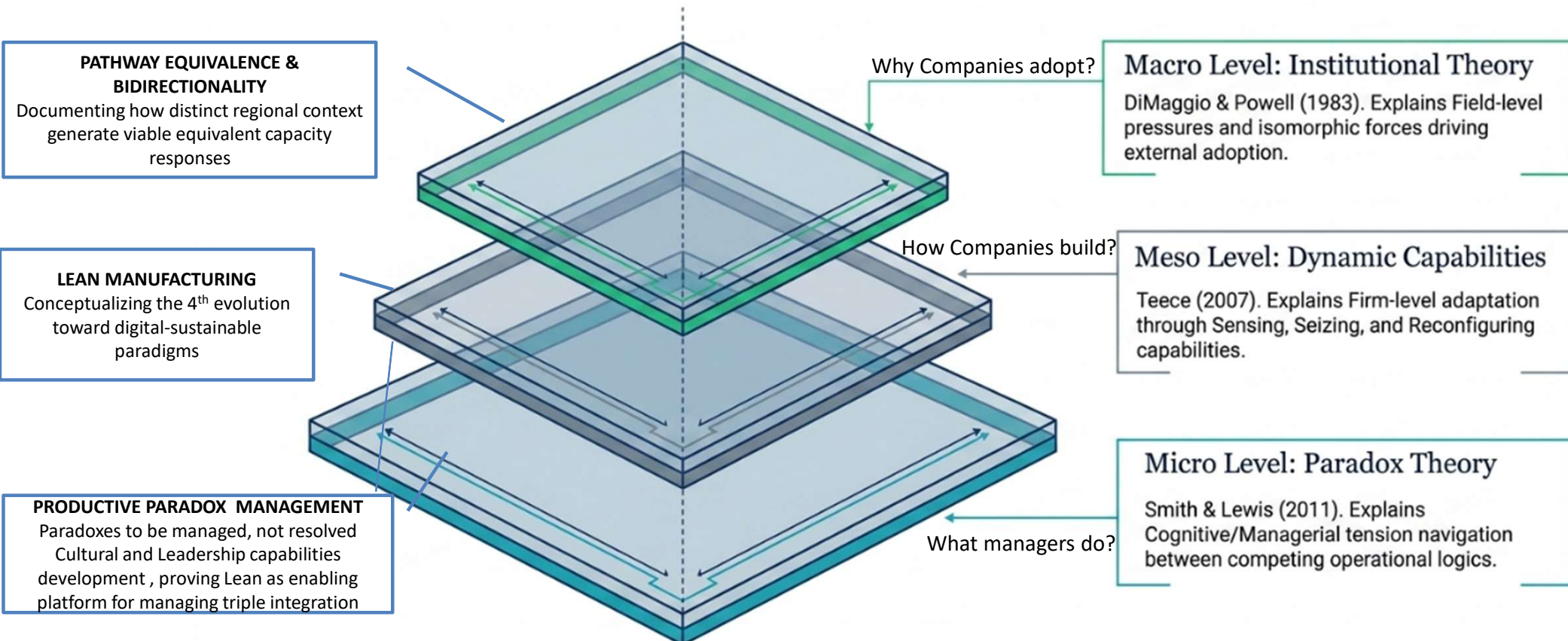
INSTITUTIONAL
CONTEXT

Chapter 6

How do regional institutional contexts influence organizational capability development for DGL, and what mechanisms enable this while maintaining operational excellence?

Institutional pathway equivalence: Different institutional pressures, equivalent operational outcomes.
Mechanism is **bidirectional**: institutions shape firms AND firms reshape institutions at Levels 4–5.

Three literature streams advanced



Lean is the enabling platform for digital integration and circular economy, regardless of the institutional context.

DGL as a validated middle-range theory (Robert K. Merton 1949 & 1968)

It's Bounded – It Shows Mechanism – It's testable.

1

DGL is an organizational capability, not a technical system.

It must be developed, not procured. No purchase order builds it.

2

Capability development is sequential and parallel.

Lean foundations are necessary, but I4.0 and CE must evolve concurrently.

3

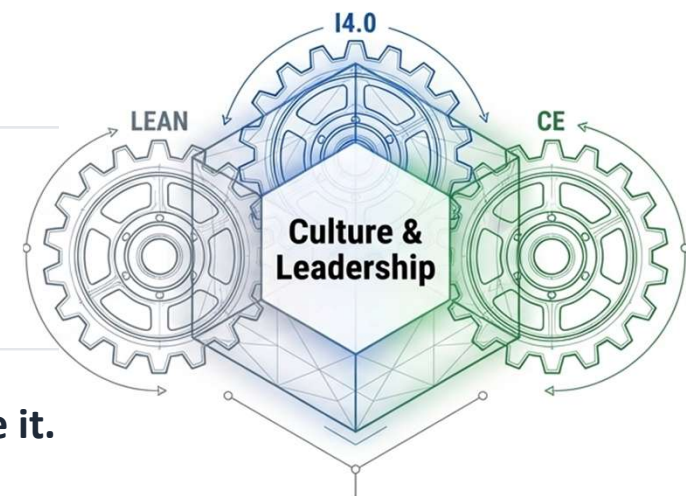
Organizations don't just absorb institutional pressure, they shape it.

Institutional entrepreneurship is required at maturity Levels 4 and 5.

4

Tensions are navigated by leaders, not resolved by systems.

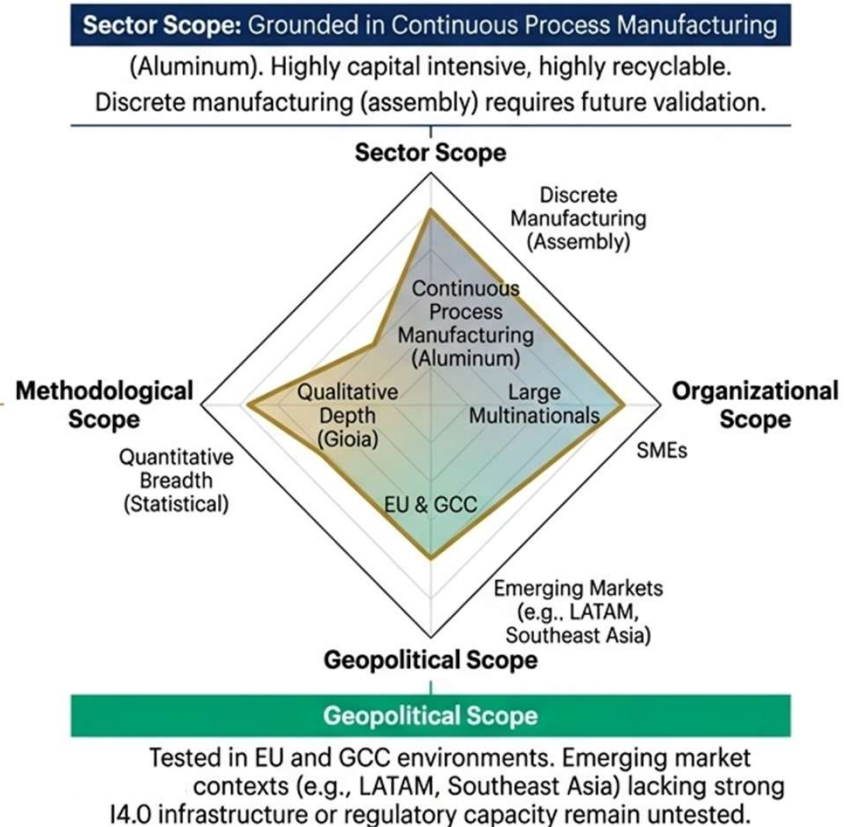
Self-transcendence is the cognitive mechanism: leaders must tolerate temporary local sub-optimization for systemic gain. This capability is itself developable across maturity Levels 4 and 5.



What this thesis does not claim

Methodological Scope:

Qualitative depth (Gioia method) prioritized over quantitative breadth.
Statistical generalization of the 81 capabilities requires future psychometric validation.



Organizational Scope:

Focused on Large Multinationals. SME dynamics—with different resource constraints and stakeholder pressures—are excluded.

Honest boundaries make the framework testable — and define the future research agenda.

If any of these were true, DGL would be false



Trigger 1: Unchanged Lean is Sufficient

If studies prove I4.0 and CE integrate flawlessly using traditional 1990s Lean leadership competencies, DGL's core premise of structural evolution is false.



Trigger 2: Zero Performance ROI

If longitudinal tracking shows organizations at DGL Level 5 perform no better operationally or sustainably than those at Level 2, the maturity model lacks prescriptive validity.



Trigger 3: Process-Manufacturing Lock-in

If the 4 aggregate dimensions completely fail to replicate in discrete manufacturing (e.g., automotive assembly), DGL is a sector-specific anomaly, not a generalizable framework.

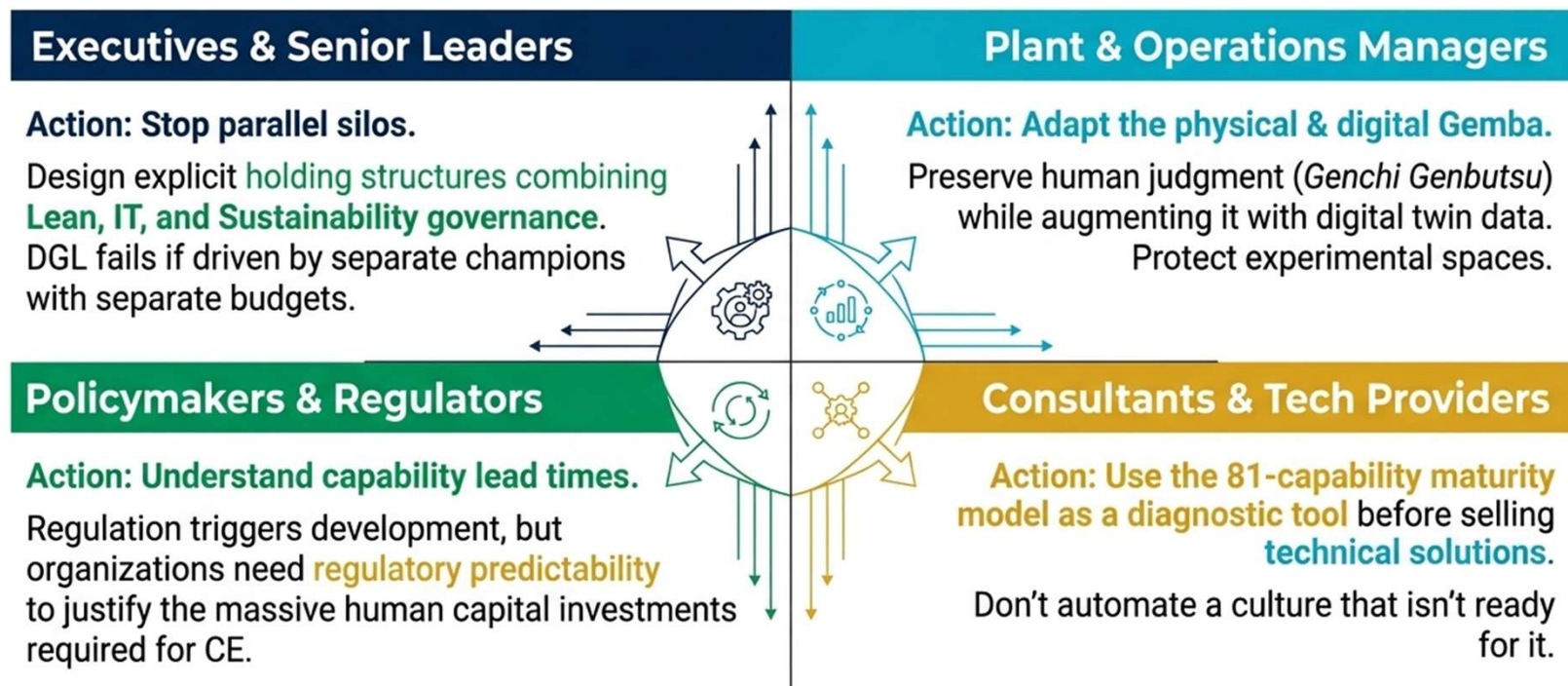


Trigger 4: Conceptual Redundancy

If DGL can be proven to be fully subsumed by existing frameworks (like EFQM Sustainability or Industry 5.0 policy papers), its originality is invalidated.

A robust theory must be falsifiable. These four conditions are open invitations to disconfirm.

Different audiences. Different actions.



This Thesis offers a framework, DGL, with a middle-range theory of integration through productively managed organizational tensions, where Lean Manufacturing becomes its enabling platform. DGL is the fourth generation of Lean

With gratitude

TO THE TRIBUNAL

Prof. Dr. Pilar González Torre, Prof. Dr. Marta Fernández Barcala, Prof. Dr. José Moyano Fuentes, Prof. Dr. Juan Antonio Marín García and Prof. Dr. Jorge Vivares Vergara — for the time, the rigor and the seriousness of your reading.

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TO MY PARENTS AND MY WIFE

For believing in this long before there was any evidence it would conclude — and for waiting, with grace, while it did.

I now welcome your questions and your conversation.