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Toward the Theoretical Foundations of Industry 6.0: A Framework for AI-Driven Decentralized Manufacturing Control

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Abstract

This study advances toward establishing the theoretical foundations of Industry 6.0 by developing a comprehensive framework that integrates artificial intelligence (AI), decentralized control systems, and cyber–physical production environments for intelligent, sustainable, and adaptive manufacturing. The research employs a tri-modal methodology (deductive, inductive, and abductive reasoning) to construct a theoretical architecture grounded in five interdependent constructs: advanced technology integration, decentralized organizational structures, mass customization and sustainability strategies, cultural transformation, and innovation enhancement. Unlike prior conceptualizations of Industry 6.0, the proposed framework explicitly emphasizes the cyclical feedback between innovation and organizational design, as well as the role of cultural transformation as a binding element across technological, organizational, and strategic domains. The resulting framework demonstrates that AI-driven decentralized control systems constitute the cornerstone of Industry 6.0, enabling autonomous real-time decision-making, predictive zero-defect manufacturing, and strategic organizational agility through distributed intelligent control architectures. This work contributes foundational theory and actionable guidance for transitioning from centralized control paradigms to AI-driven distributed intelligent manufacturing control systems, establishing a conceptual foundation for the emerging Industry 6.0 paradigm.

Keywords: Industry 6.0; theoretical foundations; AI-driven control systems; decentralized manufacturing; cyber-physical systems; intelligent automation; Industrial Internet of Things; smart manufacturing; sustainable production; mass customization; manufacturing paradigm

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1. Introduction

Establishing the theoretical foundations of Industry 6.0 requires understanding how the convergence of artificial intelligence (AI) and cyber–physical control systems is fundamentally transforming industrial manufacturing, driving evolution beyond established paradigms toward unprecedented levels of intelligent automation and sustainable production. Recent decades have witnessed accelerated industrial transformation through various evolutionary stages, culminating in the emerging concept of Industry 6.0 [1]. Following the digital transformation of Industry 4.0 [2], characterized by cyber–physical systems integration and intelligent automation, and the human-centric approach of Industry 5.0 [3], which emphasizes collaborative human–machine interaction and sustainability-oriented manufacturing, Industry 6.0 represents the next evolutionary paradigm that fully integrates AI-driven control systems with sustainable production environments [4]. Importantly, Industry 5.0 should not be understood as a concluded paradigm but as an ongoing research and policy agenda with early industrial implementations. In this respect, our framework positions Industry 6.0 as an emerging and complementary paradigm that extends, rather than replaces, the principles of Industry 5.0. Industry 6.0 represents the cognitive manufacturing paradigm where knowledge is transformed into autonomous "thought-like" decision-making capabilities through AI-driven systems that exhibit cognitive functions such as learning, reasoning, and adaptive problem solving. Unlike the data-centric approach of Industry 4.0 or the knowledge-collaborative focus of Industry 5.0, Industry 6.0 establishes cognitive manufacturing systems capable of autonomous strategic thinking, operating within cyclical feedback loops between technological cognition, organizational intelligence, strategic adaptation, cultural evolution, and continuous innovation. This cognitive dimension, combined with the cyclical interdependence of constructs rather than linear technological advancement, constitutes the paradigm's distinguishing theoretical foundation and primary contribution to manufacturing theory.

Originality and Contribution of the Framework

The originality of the proposed framework lies in how it advances beyond existing Industry 4.0 and 5.0 conceptualizations. Whereas Industry 4.0 has largely been framed around cyber–physical integration and centralized digital efficiency, and Industry 5.0 has focused on human–machine collaboration and sustainability awareness, our framework introduces two key contributions. First, it highlights the cyclical feedback loops across technological, organizational, strategic, cultural, and innovation constructs, moving away from linear or siloed representations that dominate previous models. Second, it identifies cultural transformation as a binding element that systematically connects all dimensions, rather than treating culture as a background condition or maturity stage.

These contributions position Industry 6.0 not as a replacement but as a theoretical extension of previous paradigms, integrating dispersed elements of the literature [1,3,5] into a coherent and systemic architecture. This integrated approach, illustrated in Table 1 and further developed in the conceptual models, underscores the novelty of our contribution to both academic debate and managerial practice.

Industry 6.0 can be understood as a cognitive manufacturing paradigm in which AI-driven systems and distributed control architectures transform knowledge into autonomous and adaptive decision-making capabilities. The model is cyclical and interdependent: advanced technology integration (AI and IIoT) reconfigures organizational structures (decentralization), enables strategies that combine mass customization and sustainability, requires continuous cultural transformation, and fosters proactive innovation. Innovation, in turn, feeds back into technology and organizational structures, closing the loop.

Unlike prior conceptualizations that emphasize primarily techno-centric [6] or human-centric [7] and sustainability-oriented [8] perspectives, our definition explicitly stresses the systemic feedback loops and the binding role of cultural transformation as distinctive contributions. This working definition also provides the interpretative lens for Table 1, which summarizes how Industry 6.0 extends and integrates the main epistemological, organizational, and strategic features of Industry 4.0 and 5.0.

Table 1. Distinctive Characteristics Across Industrial Paradigms.

Dimension	Industry 4.0	Industry 5.0	Industry 6.0
Epistemological Foundation	Data collection and processing	Information to knowledge transformation	Knowledge to cognitive "thought"
Primary Focus	Operational efficiency through digitalization	Human–machine collaborative knowledge	Cognitive manufacturing systems
Decision-Making	Data-driven with human oversight	Knowledge-based human–machine collaboration	Autonomous cognitive decision-making
Organizational Structure	Traditional hierarchies with digital tools	Enhanced collaboration within existing structures	Cognitively enabled decentralized architectures
Strategic Orientation	Cost reduction and efficiency	Customization with sustainability awareness	Cognitive mass customization–sustainability integration
Cultural Foundation	Process optimization culture	Human-centric collaborative values	Continuous cognitive transformation
Innovation Pattern	Technology-driven improvements	Collaborative knowledge innovation	Autonomous cognitive innovation loops
Theoretical Novelty	CPS and IoT integration	Human-centricity in knowledge work	Cyclical cognitive feedback between all constructs

This transformation toward intelligent control systems and decentralized manufacturing architectures [9] aligns with the growing need for organizational resilience, adaptation to rapid change, and flexible responses to external disruptions, as demonstrated by the COVID-19 pandemic [10]. The pandemic served as a catalyst for Industry 6.0 advancement, exposing vulnerabilities in traditional manufacturing control systems and highlighting the critical importance of cyber–physical systems capable of autonomous decision-making [11]. The imperative to respond rapidly to supply chain disruptions and dynamic market conditions has accelerated the integration of artificial intelligence and Industrial Internet of Things (IIoT) technologies to create more resilient and adaptive manufacturing ecosystems. These enabling technologies, foundational in Industry 4.0 [12] and 5.0 [13], have evolved in Industry 6.0 to enable predictive analytics, autonomous optimization, and real-time adaptability, establishing a robust foundation for sustainable long-term manufacturing resilience [14].

This research addresses the growing need for intelligent and adaptive control architectures in modern manufacturing environments. Building on the technological foundations of Industry 4.0 [15] and the human-centric principles of Industry 5.0 [16], the proposed framework explores how artificial intelligence, and decentralized decision-making can converge to create resilient, sustainable, and highly customized production systems. By focusing on distributed control, predictive optimization, and real-time adaptability, this study positions Industry 6.0 as an evolutionary step that integrates advanced technologies with organizational and cultural transformation, offering a structured approach to guide both academic inquiry and industrial practice.

Industry 6.0 fundamentally redefines manufacturing paradigms, moving beyond the standardized mass production of the 20th century and transcending the limited customization capabilities of Industry 4.0 and 5.0 [5]. The paradigm prioritizes mass customization integrated with sustainability principles, compelling organizations to develop strategies that seamlessly combine operational flexibility with environmental responsibility. Contemporary consumers, increasingly conscious of environmental impacts, demand personalized products that align with sustainability imperatives [17]. Manufacturing organizations must consequently adopt intelligent control systems that optimize efficiency and customization while minimizing environmental footprint, making circular production and responsible resource management integral components of smart manufacturing strategies [18].

A defining characteristic of Industry 6.0 is its commitment to achieving zero-defect manufacturing environments through predictive analytics and AI-enabled quality control systems, extending and revolutionizing the quality objectives of previous industrial paradigms [19]. This ambitious goal necessitates advanced integration of monitoring technologies, cyber–physical systems, and predictive algorithms that proactively eliminate defects while optimizing product quality and sustainability outcomes [20]. The zero-defect approach compels organizations to fundamentally restructure both production processes and organizational architectures, creating more dynamic, responsive systems focused on continuous improvement and autonomous optimization. This comprehensive transformation represents a strategic paradigm shift that embraces integrated quality and sustainability management through AI-driven control systems, positioning Industry 6.0 as the cornerstone of modern intelligent manufacturing strategies [21].

Despite extensive literature documenting Industry 4.0 and 5.0 impacts, three critical theoretical gaps persist that justify the cognitive manufacturing paradigm of Industry 6.0. First, existing frameworks treat technological, organizational, strategic, and cultural dimensions as independent variables rather than cyclically interdependent constructs enabled by cognitive systems. Second, while AI and cyber–physical systems have been extensively studied as data processors (4.0) and knowledge enablers (5.0), their evolution toward cognitive "thought-like" capabilities that fundamentally reconfigure organizational DNA remains theoretically underdeveloped [22]. Third, the integration of mass customization and sustainability as mutually reinforcing strategic imperatives, enabled by cognitive decision-making systems rather than competing human-managed objectives, lacks a theoretical foundation. These gaps necessitate a comprehensive cognitive manufacturing framework that explicates the cyclical relationships between constructs, positioning cultural transformation as the binding element that enables continuous cognitive organizational evolution [23]. Additionally, although zero-defect concepts have been discussed in manufacturing literature, limited research has investigated the long-term organizational and cultural implications of implementing AI-driven zero-defect environments on strategic transformation and innovation capabilities [24].

The lack of a standardized definition of Industry 6.0 reinforces the motivation for this study. Existing works offer heterogeneous and sometimes conflicting descriptions [1,13,20], with some emphasizing techno-centric perspectives and others human-centric or sustainability-driven orientations. In this fragmented landscape, developing a coherent theoretical foundation becomes essential for guiding both academic debate and managerial practice. Our framework does not attempt to impose a definitive definition of Industry 6.0; rather, it integrates dispersed elements into a systemic and cyclical architecture that clarifies how technologies, strategies, and cultural drivers interact to form a distinct industrial paradigm.

Given these gaps, the following research questions arise:

- RQ1: How does Industry 6.0 influence the structure and strategy of industrial organizations?
- RQ2: What organizational structures are best suited to support the decentralized decision-making and integration of advanced technologies foreseen by Industry 6.0?
- RQ3: How can organizations develop strategies that effectively balance mass customization and sustainability within the Industry 6.0 model?
- RQ4: What are the cultural and strategic implications of a zero-fault environment, and how does it affect continuous innovation and incremental improvement in industrial organizations?

2. Methodology

This research adopts a systematic and epistemologically rigorous methodology, integrating deductive [25], inductive [26], and abductive [27] reasoning across distinct phases to build a comprehensive theoretical framework for Industry 6.0.

In the deductive phase, we developed research propositions from an extensive review of literature covering Industry 4.0 and 5.0 paradigms, as well as emerging contributions on Industry 6.0 [28]. Key theoretical constructs and principles were identified to shape initial assumptions about organizational, cultural, and technological changes.

The inductive phase involved analyzing systematic reviews and recent empirical studies to detect gaps in the existing knowledge base [29]. We clustered these gaps into thematic areas such as (i) cultural implications of zero-defect manufacturing, (ii) the integration of sustainability into control systems, and (iii) decentralized decision-making in AI-driven environments. From these clusters, additional propositions were formulated to address overlooked or underexplored aspects.

Finally, the abductive phase connected these constructs into a unified theoretical model [30]. Abduction was operationalized through inference-to-the-best-explanation: iterative cycles of reasoning linked empirical anomalies and conceptual gaps to new theoretical relationships. For instance, the absence of explicit cultural considerations in zero-defect literature was abductively explained by integrating a construct on cultural transformation. This process strengthened the internal logic of the framework by aligning theoretical insights with emerging industrial practices.

Overall, this tri-modal reasoning approach ensures that the proposed model is both conceptually rigorous and grounded in empirical relevance. Deduction provided theoretical grounding, induction revealed knowledge gaps, and abduction allowed for the creative integration of constructs into a holistic model of Industry 6.0.

3. Industry 4.0 to 6.0: Theoretical Foundations and Strategic Adaptations

3.1. Moving from Industry 4.0 to 6.0

The progression from Industry 4.0 to Industry 6.0 reflects profound changes in technological integration, organizational design, and strategic orientation. Industry 4.0 introduced cyber–physical systems (CPSs) and the Internet of Things (IoT), creating a foundation for digital automation and efficiency gains [31]. However, decision-making largely remained centralized, limiting flexibility and responsiveness [32]. As a result, the potential benefits of these new technologies for agility and adaptability were not fully realized [33]. Industry 5.0 expanded this paradigm by emphasizing human–machine collaboration, personalization, and initial steps toward sustainability [34]. Yet, structural change was modest, with organizations maintaining traditional hierarchies that restricted agility [35,36]. Based on these findings and comparisons, the following considerations can be made:

- P1: *The integration of cyber–physical systems and IoT in Industry 4.0 laid the foundation for digital automation but maintained centralized organizational structures and strategies focused on efficiency [31,32].*
- P2: *The transition to Industry 5.0 introduced human–machine collaboration, improved personalization capabilities, and began to incorporate sustainability, but without significant changes to organizational structures [34,36].*

By contrast, Industry 6.0 [5] builds on these advances with the integration of artificial intelligence (AI) and the Industrial Internet of Things (IIoT) to enable autonomous systems and decentralized decision-making [37]. Business strategy is reoriented around the dual imperatives of mass customization and sustainability [38,39]. Based on these observations and comparisons, the following propositions can be formulated:

- P3: *The evolution towards Industry 6.0 involves significant technological advances with AI and IIoT enabling autonomous systems, requiring decentralized organizational structures to fully exploit these technologies [5,37].*
- P4: *In Industry 6.0, the business strategy focuses on mass customization and sustainability as central objectives, building on the personalization of Industry 5.0 and addressing the limitations of efficiency-focused strategies of Industry 4.0 [38,39].*

Crucially, Industry 6.0 requires a cultural transformation that embeds continuous improvement and sustainability as organizational values [40]. In our framework, cultural transformation is not addressed as a generic change initiative but as a structural binding construct that systematically connects technological integration, decentralized organizational forms, strategic orientation, and innovation. Unlike Industry 4.0 and 5.0 maturity models, where culture is treated as an enabling factor or peripheral dimension [41], Industry 6.0 positions cultural transformation as both an outcome of cognitive manufacturing (e.g., zero-defect learning environments, sustainability-driven values) and a precondition for its consolidation. This cultural dimension, functioning as the connective tissue of the paradigm, also enables organizations to leverage advanced analytics and autonomous systems to drive proactive, data-driven innovation [42]. Based on the above findings and comparisons, we can state the following:

- P5: *Cultural change is essential in Industry 6.0, fostering a culture of continuous improvement and sustainability values, moving beyond the process optimization culture of Industry 4.0 and the human-centric focus of Industry 5.0 [40,43].*
- P6: *Innovation in Industry 6.0 will be proactive and data-driven, enabled by advanced analytics and autonomous systems, leading to continuous improvement in strategy and technology adoption [42].*

This set of propositions highlights where our framework advances beyond existing conceptualizations: the cyclical feedback between innovation (P6 $\rightarrow$ C5) and organizational/technological design (C1, C2) and the role of cultural transformation (P5 $\rightarrow$ C4) as a structural connector. These features constitute the main theoretical novelty of our approach.

3.2. Technological Integration in Industry 6.0

Technological integration is a core element of Industry 6.0, characterized by the implementation of advanced technologies such as artificial intelligence (AI) [44] and the Industrial Internet of Things (IIoT) [45], alongside a strong commitment to sustainability across the entire production cycle. These systems drive improvements in operational efficiency and expand flexibility, enabling organizations to respond quickly to market shifts and environmental challenges [46].

Industry 4.0 focused on digitization and automation using cyber–physical systems and IoT, aiming to create smart factories that increase productivity and efficiency [47]. Although AI and IoT were introduced to automate workflows and enable data collection, human decision-making remained central, and sustainability was not yet a priority [48]. With Industry 5.0, there was a clear convergence between technological sophistication and human critical thinking [49]. This development led to more customized products [50], and while sustainability entered the conversation, it was not fully integrated into operational frameworks [51].

Industry 6.0 marks a decisive shift. It embeds autonomous and intelligent resource management into a holistic, sustainability-focused approach [52]. Artificial intelligence enables systems to learn from data and make independent decisions, enhancing precision and reducing the need for human intervention [53]. The IIoT supports real-time data acquisition, allowing equipment within Industry 6.0 environments to act autonomously [54].

Continuous monitoring helps organizations track operations, identify areas for improvement, and anticipate challenges. This methodology ensures efficient and agile solutions are prioritized [55].

Sustainability integration within the Industry 6.0 framework represents a significant progression from prior practices [56]. A defining feature of Industry 6.0 is its explicit attention to the environmental consequences of technology adoption [57]. Utilizing AI and IIoT, organizations monitor and optimize energy use, resource allocation, and waste reduction in real time [58]. This supports alignment with ecological goals, encourages more efficient resource management, helps reduce carbon footprints, and strengthens competitive positioning [59]. For example, lowering energy consumption per unit output not only boosts efficiency but also enhances the corporate image among consumers and stakeholders who increasingly value sustainability [60]. Drawing from these analyses and comparisons, the following propositions can be stated:

- P7: *Compared to previous paradigms, the combination of advanced technologies such as AI and IIoT in Industry 6.0 promotes predictive optimization and intelligent automation, significantly improving the operational efficiency and flexibility of industrial organizations through autonomous decision-making systems [44,45].*
- P8: *Integrating sustainable practices through AI and IIoT in Industry 6.0 enables organizations to balance mass customization with environmental responsibility, strengthening strategic positioning and corporate reputation beyond what was achieved in Industry 4.0 and Industry 5.0 [56,58].*

Siemens' Amberg factor (Siemens Digital Enterprise, Available online: https://www.siemens.com/global/en/company/stories/industry/electronics-digitalenterprise-futuretechnologies.html; accessed on 29 August 2025) demonstrates cognitive manufacturing, where AI autonomously adjusts production based on real-time quality predictions. By analyzing control point data, the system anticipates defects and proactively modifies processes, enabling strategic decisions about scheduling, resources, and quality without human input.

3.3. Organizational Structure Adaptations

In Industry 6.0, adapting organizational structures is crucial. Companies need flexible frameworks that enable rapid responses to market dynamics and evolving consumer demands. Within a connected manufacturing environment, decentralized decision-making and adaptable organizational forms are essential for competitiveness [61]. In Industry 4.0, firms mainly retained conventional hierarchies, relying on automation and digitalization to enhance efficiency. However, decision-making mostly remained centralized [62]. While these systems improved operations, they were not designed to address swift market transitions [63]. Industry 5.0 brought greater collaboration between humans and machines, creating a more adaptive work context, yet control often stayed centralized, limiting true organizational agility [64].

Industry 6.0 advances these developments by favoring decentralization as a structural strategy for responding more efficiently to market fluctuations. This enables organizations to react more promptly to changing conditions, as localized decision-making shortens response times [65]. With the integration of AI and IIoT, business units can access real-time data, allowing autonomous decisions independent of central management and enhancing overall system responsiveness [66].

To align with shifting consumer expectations and the growing importance of sustainable practices, companies must further restructure themselves in Industry 6.0 [67]. While previous paradigms improved efficiency and customization, Industry 6.0 demands agility to support advanced customization and sustainable resource management. This shift involves adapting processes to enable mass customization and sustainable production models [68]. Using advanced technologies to collect detailed data on consumer preferences, organizations can deliver tailored products while maintaining environmental responsibility [69].

As a result, decentralized and dynamic structures empower organizations to meet market needs more rapidly, promoting continuous innovation and efficient supply chain management, which surpasses the capabilities of earlier industrial paradigms [70]. Based on these findings and comparisons, the following proposition can be stated:

- P9: *Compared to the more hierarchical structures of Industry 4.0 and the limited flexibility of Industry 5.0, the decentralized organizational structures of Industry 6.0 increase the agility of companies, enabling them to respond more quickly and flexibly to market fluctuations and local operating conditions through autonomous decision-making [61,62].*
- P10: *Structural adaptation to market dynamics and specific consumer preferences through Industry 6.0 enables organizations to implement mass customization models and sustainable resource management, exceeding the levels of customization and adaptability achievable in Industry 4.0 and Industry 5.0 [67,69].*

The Haier RenDanHeYi model (RenDanHeYi management model, Available online: https://www.rendanheyi.com/; accessed on 29 August 2025) illustrates decentralized cognitive architecture, where independent business units use AI and machine learning to analyze market data and make strategic decisions. Each unit acts as a "cognitive enterprise," autonomously handling product customization, supplier selection, and sustainability, showing how decentralization enhances competitiveness through cognitive capabilities.

3.4. Strategic Shifts

Industry 6.0 demands significant strategic adjustments, placing mass customization and sustainable long-term planning at the center of business models [71]. This shift requires organizations to redefine their production and market strategies, not only to meet evolving consumer expectations but also to establish sustainability as a core strategic objective [72]. Mass customization is a crucial element in Industry 6.0, as it compels companies to revise both their manufacturing processes and marketing approaches [73]. As consumer preferences increasingly focus on personalized solutions, organizations are required to serve individual needs while preserving operational efficiency [37]. Achieving this level of customization involves strategies that balance flexibility with scalability, allowing companies to adapt rapidly to changing consumer demands [21]. Moreover, marketing must also evolve to communicate individualized value effectively, positioning customization as a key differentiator and enhancing customer experience, which is now central to competitiveness [74].

Another strategic priority in Industry 6.0 is long-term sustainable planning, which extends the concept of sustainability beyond emissions reduction to encompass the entire product lifecycle and promote circular economy practices [45]. This approach emphasizes responsible resource management and considers both the environmental and social impacts of production activities [75]. The integration of AI and IIoT enables real-time monitoring and optimization of processes, which allows companies to minimize waste and continually improve resource efficiency. Sustainability, therefore, becomes a proactive responsibility throughout the value chain, encouraging collaboration with suppliers and partners who are also committed to sustainable practices [76]. As a result, Industry 6.0 supports investments in technologies and business processes that ensure responsible resource management and foster a sustainability-oriented corporate culture. This orientation, in turn, enhances resilience and long-term competitiveness [77].

Ultimately, Industry 6.0 guides organizations toward strategies that integrate personalization with sustainability. This dual focus transforms production and marketing models to align with the requirements of a more resilient and sustainable economy. Such a foundation enables modern organizations to thrive in increasingly dynamic markets. Based on these findings, we can state:

- P11: *Mass customization, enabled by the integration of AI and IIoT in Industry 6.0, requires a business strategy that balances operational flexibility and scalability, enhancing the ability of companies to respond to dynamic consumer preferences [21,69].*
- P12: *Integrating sustainability as a guiding principle of business strategy in Industry 6.0 fosters long-term value creation by promoting responsible resource management practices and a sustainability-oriented supply chain [45,75,76].*

Nike's cognitive manufacturing platform (Nike Willy Wonka factory: https://about.nike.com/en/stories/nike-spaces-sports-design-innovation-performance) leverages AI to optimize both product personalization and sustainability. By processing customer data alongside environmental factors like material use and emissions, the system autonomously balances customization with eco-friendly practices, illustrating how cognitive systems can harmonize individual preferences and environmental goals.

3.5. Challenges and Opportunities

Industry 6.0 is fundamentally oriented towards achieving a zero-defect manufacturing environment. This paradigm shift presents significant opportunities but also introduces notable challenges. A primary challenge lies in the cultural transformation required within organizations [39]. Unlike previous industrial paradigms where quality control was often reactive, Industry 6.0 emphasizes proactive, data-driven quality assurance. Such an approach fosters continuous improvement and supports incremental innovation [56]. Autonomous systems and real-time data analytics play a central role by enabling predictive quality management. These technologies allow companies to prevent defects before they occur, rather than simply correcting them after production. This shift leads to reduced waste and lower operational costs, while making production processes more resilient. Potential issues are identified and addressed early, minimizing disruption [78]. To fully realize these benefits, organizations must embrace a culture that prioritizes ongoing quality enhancement. Teams should be empowered to make informed decisions using real-time data [79]. This empowerment is essential for the agility and adaptability that Industry 6.0 requires, enabling decision-making at the operational level. Furthermore, the establishment of a zero-defect environment highlights the transition from static to dynamic quality management. In this context, quality is seen not just as a matter of compliance, but as a strategic objective that continuously drives innovation and adaptability [37]. Organizations are encouraged to cultivate a culture of incremental improvement, leveraging data to refine processes and respond swiftly to evolving market needs [1]. This cultural evolution enhances operational agility and strengthens customer trust and brand reputation, aligning with the overarching aims of Industry 6.0, particularly its commitment to sustainability. Recent contributions also highlight how AI and blockchain are being applied to quality management [16] and how neural network models can predict equipment faults in real time [17], reinforcing the role of predictive analytics in achieving zero-defect environments. Drawing upon these findings and comparisons, it is possible to affirm that:

- P13: *Implementing a zero-defect manufacturing environment in Industry 6.0 requires significant cultural changes that promote a culture of continuous quality and incremental improvement that supports continuous innovation within industrial organizations [24,79].*

- P14: *Establishing a zero-defect environment in Industry 6.0 strategically impacts organizations by promoting data-driven decision-making and proactive quality management, thereby increasing organizational agility and resilience [19,20].*

As an illustrative example of cognitive zero-defect cultural transformation, Toyota's advanced quality systems (Toyota Production System, Available online: https://global.toyota/en/company/vision-and-philosophy/production-system/; accessed on 29 August 2025) highlight how AI-driven predictive quality management can reshape an organization's approach from reactive problem solving to proactive quality assurance. Employees collaborate with cognitive systems that continuously analyze quality patterns, recommend process enhancements, and autonomously implement minor adjustments. This integration fosters a shift from traditional human-centered continuous improvement (kaizen) to a collaborative dynamic between human insight and machine intelligence, supporting the pursuit of zero-defect outcomes.

To enhance transparency and strengthen the theoretical grounding of our framework, Appendix A provides a detailed mapping between each proposition (P1–P14) and the corresponding references, clarifying how prior studies informed and supported the formulation of each proposition.

4. Towards Industry 6.0: Conceptual Models

This section presents theoretical models to clarify the transition from Industry 4.0 to Industry 6.0, highlighting major phases and changes. Building on earlier propositions (P1–P6), these models structure the analysis of technological, organizational, strategic, and cultural evolution. An evolutionary model outlines the main stages, while a conceptual model for Industry 6.0 examines key factors such as advanced technology, decentralized organization, mass customization, sustainability, cultural shifts, and innovation. The section concludes with practical guidelines for organizations moving toward Industry 6.0, aiming for clarity and analytical rigor.

4.1. Evolutionary Model from Industry 4.0 to Industry 6.0

The evolutionary model from Industry 4.0 to 6.0 depicts industrial transformation as a network of connected paradigms, each with five main elements: technology, organizational structure, business strategy, culture, and innovation (Figure 1). It should be noted that elements such as AI, IIoT, sustainability, and mass customization have appeared in earlier industrial paradigms, particularly Industry 4.0 and 5.0. However, in Industry 6.0, these components are not treated as isolated or incremental extensions but are reconfigured into a cyclical, self-reinforcing system. The novelty of the model lies in the feedback loops and in the cultural transformation that binds these elements together, making them operate as interdependent drivers of resilience and adaptability. These components shape every phase, showing that progress is both linear and qualitative, with interdependent relationships. Transition is driven primarily by technological advances. For instance, Industry 4.0 introduced IoT and Cyber–Physical Systems, enabling automation and digitalization to improve efficiency and cut costs.

As Industry 5.0 emerges, human–machine integration deepens with collaborative robotics and AI enabling more adaptable and customized production. This phase is marked by agile manufacturing that meets specific customer needs. Industry 6.0 brings fully autonomous, intelligent networks powered by advanced AI and IIoT, closely linking technology, sustainability, and organizational agility for higher efficiency.

Organizational structures evolve from centralized hierarchies in Industry 4.0 to greater internal collaboration in 5.0, facilitated by improved technological communication. In 6.0, organizations adopt decentralized structures that enable rapid decision-making at operational levels through real-time data access. The model reflects this with interconnected influences between technology and organizational components, underlining the importance of decentralization.

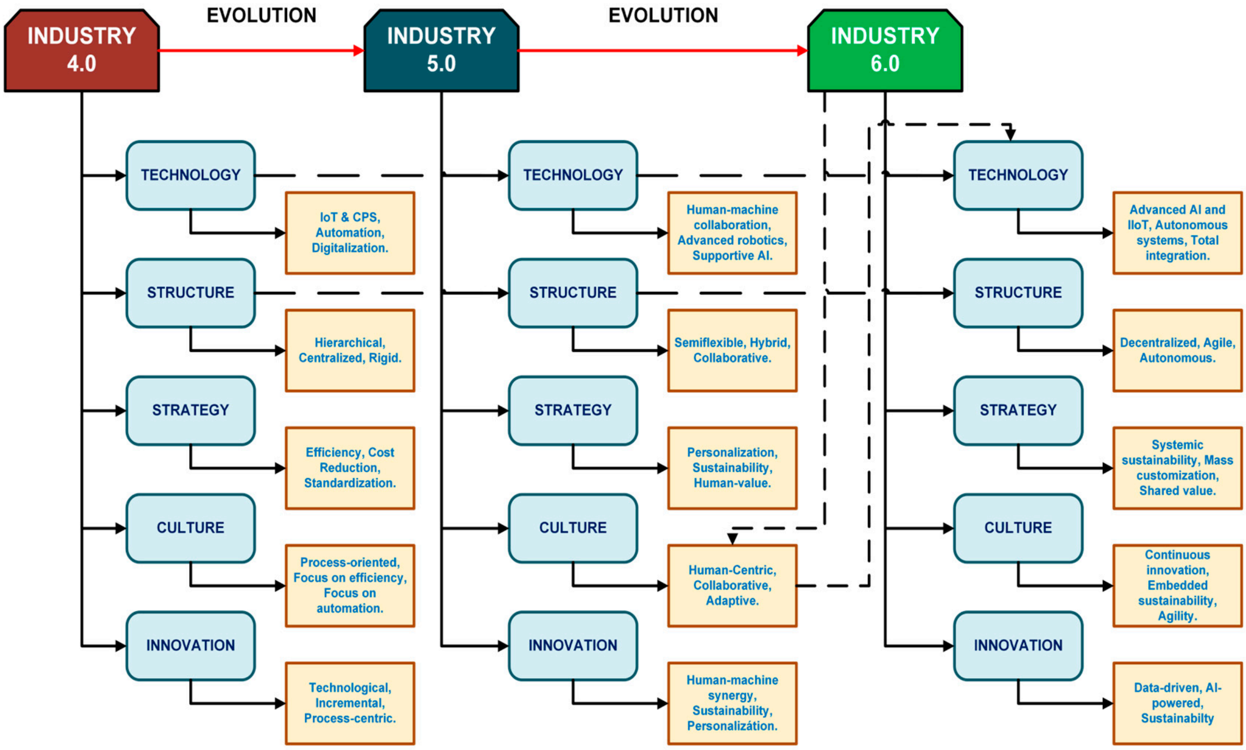

Figure 1. Graphical model for moving from Industry 4.0 to Industry 6.0 (Source: author's elaboration).

Strategically, Industry 4.0 focuses on efficiency and standardization, while 5.0 shifts toward customization and innovation, though sustainability remains secondary. By Industry 6.0, mass customization and sustainability take center stage, with strategies geared toward tailored solutions and responsible practices. Organizational culture transitions from process optimization to continuous improvement and proactive innovation, supporting adaptability and resilience in the face of constant technological change.

To summarize the main changes in technology, structure, strategy, culture, and innovation across the three industrial paradigms, Table 2 presents six Knowledge Insights that illustrate the evolution from Industry 4.0 to Industry 6.0, corresponding to propositions P1 to P6 discussed earlier in Section 3.1.

Table 2. Knowledge Insights on the evolution from Industry 4.0 to Industry 6.0.

Proposition	Knowledge Insights	Explanatory Notes
P1	Industry 4.0 relies on cyber–physical systems (CPS) and IoT for digital automation but maintains centralized structures.	This insight emphasizes the technological advancements of Industry 4.0, focusing on automation through CPS and IoT, but highlights that organizational structures remain centralized, limiting flexibility and agility.
P2	Industry 5.0 emphasizes human–machine collaboration and early sustainability integration, with minimal structural changes.	This insight underscores the shift towards human-centered technologies in Industry 5.0, integrating collaborative robots and AI, while suggesting that the organizational structure remains largely intact.

Table 2. *Cont.*

Proposition	Knowledge Insights	Explanatory Notes
P3	Industry 6.0 uses AI and IIoT to enable autonomous systems, requiring decentralized structures for agility and responsiveness.	The key difference in Industry 6.0 is the integration of fully autonomous systems, where decentralized decision-making structures are critical to ensure responsiveness and adaptability to rapid market changes.
P4	In Industry 6.0, business strategies prioritize mass customization and sustainability, overcoming prior efficiency-focused models.	This insight highlights how Industry 6.0 overcomes the limits of traditional efficiency-driven models, focusing on sustainable, tailored products that meet customer-specific demands while reducing environmental impact.
P5	A cultural shift is essential in Industry 6.0, fostering continuous improvement and integrating sustainability across the organization.	The cultural transformation in Industry 6.0 is critical to maintaining an innovation-driven environment. Sustainability becomes ingrained not just as a product feature, but as a core organizational value.
P6	Innovation in Industry 6.0 is proactive and data-driven, using advanced analytics and autonomous systems for continuous improvement.	Innovation in Industry 6.0 is rooted in advanced analytics and AI-driven systems, enabling real-time data collection and predictive analytics to drive continuous improvement in processes, products, and business strategies.

4.2. Conceptual Model from Industry 4.0 to Industry 6.0

The conceptual model of industrial evolution from Industry 4.0 to 6.0 is based on six propositions and six knowledge insights (see Table 1), highlighting key changes shown in Figure 2. It covers not just technology, but also the development of organizations, strategies, and cultures. P1 explains that cyber–physical systems (CPS) and IoT-enabled digital automation in Industry 4.0 without shifting away from centralized structures or efficiency-driven strategies. P2 notes that Industry 5.0 has increased human–machine collaboration, customization, and sustainability efforts, yet centralization remains dominant and sustainability is often seen as an add-on rather than a core strategy.

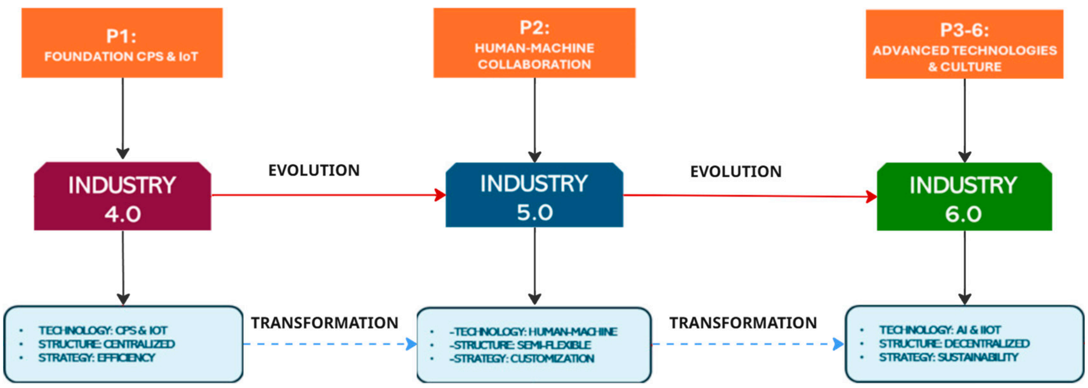

Figure 2. Conceptual model for moving from Industry 4.0 to Industry 6.0 (Source: author's elaboration).

The propositions P3 to P6 outline the distinctive features of Industry 6.0 compared to earlier paradigms. P3 highlights the central role of artificial intelligence and IIoT, which enable autonomous systems and require decentralized structures, thus increasing agility and responsiveness. P4 focuses on business strategies integrating mass customization with sustainability. P5 emphasizes the importance of ongoing cultural transformation, with sustainability established as a core value. Finally, P6 shows that innovation in Industry 6.0 is proactive and data-driven, fostering technological development and the ability to anticipate market trends. The conceptual model illustrates a network in which changes in any component affect the entire system, demonstrating the need for a systemic and integrated approach to fully unlock the benefits of Industry 6.0.

4.3. Conceptual Model of Industry 6.0

The conceptual model of Industry 6.0, as illustrated in Figure 3, presents an interconnected and dynamic structure based on Propositions P7 to P14 detailed in Sections 3.2–3.5. This model integrates Artificial Intelligence (AI) and the Industrial Internet of Things (IIoT), which together drive significant transformations as highlighted in Propositions P7 and P8. Relationships within the model are depicted using solid and dashed arrows. Solid arrows indicate direct links and main propositions, whereas dashed arrows represent feedback loops and indirect influences among components.

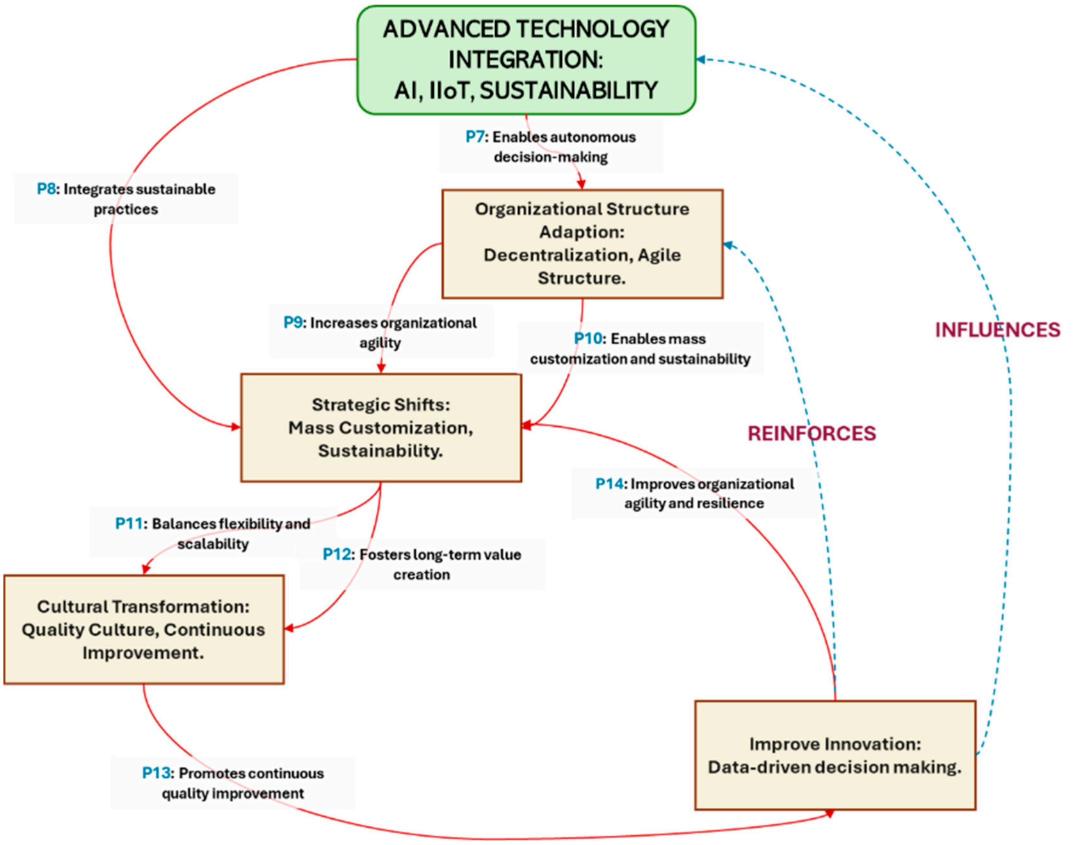

Figure 3. Conceptual model of Industry 6.0 (Source: author's elaboration).

At the core of Industry 6.0 lies Advanced Technology Integration. Here, AI and IIoT form the foundation for systems capable of autonomous decision-making and predictive optimization. Proposition P7 demonstrates how these technologies support organizational adaptation and enable intelligent automation for data-driven decision-making. AI facilitates continuous machine learning and adaptation, while IIoT connects devices and systems, enabling real-time communication and information exchange. Proposition P8 explains how technological integration supports strategic renewal, combining sustainable practices with the capacity for mass customization. Advanced technologies facilitate the collection and analysis of extensive consumer and operational data. This supports strategies that merge personalized product offerings with operational efficiency and environmental stewardship. As a result of technological advancement, organizations increasingly adopt decentralized and agile structures. Once these structures are implemented, companies gain greater flexibility and responsiveness, as described in Propositions P9 and P10. Proposition P9 clarifies that decentralization enables faster adaptation to market changes, allowing business units to make decisions based on localized data. This capability improves organizational agility and responsiveness to shifts in consumer preferences or market conditions. Proposition P10 highlights that flexible organizational design supports the delivery of customized products while managing resources sustainably. Decentralization also encourages collaboration across departments and organizational levels, fostering innovation and resource efficiency. This approach ensures that specific customer needs are met without compromising the overall sustainability objectives of the enterprise.

The Industry 6.0 model is grounded in strategic change facilitated by advanced technologies and decentralized organizational structures. Propositions P11 and P12 outline how organizations develop strategies that enhance adaptability to consumer demands. Proposition P11 examines how business strategy shapes the balance between customization and efficiency, emphasizing the importance of quickly adapting products and services to customer requirements while maintaining high levels of productivity. Proposition P12 addresses the integration of sustainability into core business practices, supporting the creation of long-term value. Organizations now adopt sustainable approaches not only to comply with environmental standards but also to respond to increasing consumer expectations for social and environmental responsibility. This strategic orientation enhances a firm's competitive position and strengthens its reputation.

Cultural transformation is a critical component of the model, focusing on ongoing quality improvement. Proposition P13 demonstrates how attention to quality encourages innovation and fosters a culture of continuous advancement. Such a culture motivates personnel to develop new ideas, experiment with novel solutions, and collaborate across organizational boundaries. Proposition P14 details how strategic modifications can enhance a company's responsiveness to market changes, technological developments, and evolving customer needs, thereby ensuring sustained competitiveness. The Industry 6.0 conceptual model highlights a complex network of interrelated and circular connections among its components. Solid arrows represent direct and immediate relationships, while dashed arrows indicate feedback loops and longer-term influences.

1. Feedback from Innovation to Organizational Structure: Innovation is not only influenced by organizational structure but in turn can stimulate structural changes. For example, new ideas or technologies may require internal reorganization to be implemented effectively.
2. Feedback from Innovation to Technology Integration: Innovation can lead to the development or adoption of new technologies, further fueling the cycle of technological advancement.

These interconnections ensure that the system remains in a state of ongoing transformation, fostering an adaptive and resilient organizational ecosystem. Each element of the model both influences and is influenced by the others, highlighting the importance of approaching Industry 6.0 as an integrated system. The distinction between continuous and dashed arrows clarifies the nature of the transformations: direct relationships represent immediate and intentional impacts, while feedback loops reflect longer-term effects resulting from ongoing interactions among system components. The model's strength lies in its circular and synergistic structure. Digital and sustainable transformation arises not from isolated changes, but from the dynamic interplay among all components. This integrated perspective is essential for fully leveraging the value of Industry 6.0, as it enables organizations to innovate, remain agile, and pursue sustainability in a highly competitive environment.

5. Building Theory for Industry 6.0

The development of a theoretical framework for Industry 6.0 is essential for understanding and guiding the transition to this new industrial paradigm. In this section, we apply a theory-building methodology [80] to construct a comprehensive theoretical model that synthesizes the main components and their interconnections, as identified in propositions P1–P14 from the previous sections. Theory building is a systematic process for formulating a coherent and robust theory by defining key constructs, establishing relationships among them, and integrating these elements into a unified conceptual model [81]. This approach enables the logical organization of complex ideas, making it easier to understand the relevant phenomena and serving as a foundation for future research and practical applications [82]. A construct is a key theoretical concept central to the study's focus. In Industry 6.0, constructs stem from propositions P1–P14, reflecting major technological, organizational, strategic, and cultural changes. These include technology integration, decentralized structures, personalization and sustainability strategies, cultural shifts, and innovation enhancement. Identifying these constructs requires analyzing and synthesizing the main ideas from each proposition.

- C1. Advanced Technology Integration emerges from the propositions that highlight the importance of technologies such as Artificial Intelligence (AI) and Industrial Internet of Things (IIoT) in enabling autonomous systems and improving operational efficiency (P3, P7, P8).
- C2. Decentralized Organizational Structures are identified as necessary to take full advantage of new technologies and increase organizational agility, as discussed in propositions P3, P9, and P10.
- C3. Mass Personalization and Sustainability Strategies are derived from propositions that emphasize the importance of balancing operational flexibility, personalization, and environmental responsibility (P4, P11, P12).
- C4. Cultural Transformation is a construct that emerges from the need to foster a culture of continuous improvement and integrate sustainability values, as described in P5 and P13.
- C5. Boosting Innovation is identified as a key element to drive continuous improvements in technology strategy and adoption, based on propositions P6 and P14.

In the process of developing a theoretical framework, once the constructs have been defined, we proceed as follows:

1. Elaboration of Relationships: It is necessary to establish how these constructs interact with one another, identifying causal or mutually influential relationships.
2. Formulation of the Theoretical Model: The next step involves integrating the constructs and relationships into a coherent structure that represents the phenomenon under study.
3. Theoretical Validation: The model should then be validated by linking it to existing literature. This entails discussing how the model contributes to the field of study and what implications it holds.
4. Implications and Future Perspectives: It is important to explore the practical consequences of the model and identify potential avenues for further research.

This approach establishes a strong theoretical framework for Industry 6.0, clarifying changes in industry and offering guidance to organizations shifting to the new paradigm. It explains how advanced technologies, structures, strategies, culture, and innovation shape adaptive, sustainable systems. The next section defines main concepts, outlines their relationships, and introduces an integrated Industry 6.0 model, relating it to literature and emphasizing its practical value.

5.1. Processing Construct Relationships

The identified constructs represent the fundamental elements of Industry 6.0. To gain a comprehensive understanding of the way these elements interact and influence industrial transformation, it is imperative to establish the causal relationships and mutual influences that exist between them.

- C1. Advanced Technology Integration → C2. Decentralized Organizational Structures. Advanced Technological Integration (C1) functions as a catalyst for the transformation of organizational structures. The implementation of technologies such as AI and the Industrial Internet of Things (IIoT) enables autonomous systems and data-driven decision-making in real time. This capability necessitates and encourages the development of decentralized organizational structures (C2), as evidenced by propositions P3, P7, and P9. The implementation of advanced technologies enables operational departments to make autonomous decisions, thereby reducing the necessity for centralized control and increasing organizational agility.
- C2. Decentralized Organizational Structures → C3. Mass Personalization and Sustainability Strategies. The implementation of Decentralized Organizational Structures (C2) directly influences Mass Personalization and Sustainability Strategies (C3). As previously discussed in Propositions P4, P10, P11, and P12, the decentralization of organizational structures allows for greater operational flexibility, enabling the organization to quickly adapt to dynamic consumer preferences and implement sustainable practices. Autonomous business units can tailor products and services to local needs, thereby balancing efficiency and environmental responsibility.
- C3. Mass Personalization Strategies and Sustainability → C4. Cultural Transformation. The implementation of Mass Personalization and Sustainability Strategies (C3) necessitates a comprehensive cultural transformation (C4). Propositions P5, P12, and P13 illustrate the necessity of an organizational culture that fosters continuous improvement, innovation, and the adoption of sustainable values to effectively implement strategies focused on personalization and sustainability. The corporate culture must transform to align with these novel strategic objectives, necessitating a culture that fosters continuous learning and adaptability.
- C4. Cultural Transformation → C5. Boosting Innovation. Cultural transformation (C4) is a prerequisite for the empowerment of innovation (C5). An innovation-oriented culture, as delineated in Propositions P6 and P14, cultivates the germination of novel concepts and the incorporation of nascent technologies. The promotion of values such as creativity, collaboration, and openness to change within the organization stimulates proactive, data-driven innovation, which is essential for maintaining a competitive advantage in Industry 6.0.
- C5. Enhancing Innovation → C1. Advanced Technology Integration and C2. Decentralized Organizational Structures. The enhancement of innovation (C5) generates a positive feedback loop with advanced technological integration (C1) and decentralized organizational structures (C2). The continued development and adoption of new technologies is a consequence of sustained innovation, which in turn drives further integration of technology (P6). Moreover, it may necessitate modifications to organizational structures to facilitate the implementation of novel innovative processes and systems (P14), thereby establishing a virtuous cycle of continuous improvement and adaptation.

5.2. Building the Integrated Theoretical Model

By integrating the identified constructs and their relationships, the Integrated Theoretical Model of Industry 6.0 is outlined (Figure 4). This model illustrates a dynamic and interconnected system where each component influences the others, generating a continuous cycle of transformation and improvement. The model shows that successfully adopting Industry 6.0 requires a holistic approach. In this perspective, technology, organizational structure, business strategy, culture, and innovation are all interdependent elements that must be aligned for organizations to thrive in the new industrial context. The transformation process begins with the integration of advanced technologies (C1), which forms the foundation of Industry 6.0. The introduction of tools such as artificial intelligence (AI) and the industrial Internet of Things (IIoT) enables the creation of autonomous systems and the optimization of processes based on prediction. These technologies support intelligent automation, allowing machines to execute complex tasks independently of human intervention. They can adapt and learn from experience by using sophisticated machine learning algorithms. Furthermore, these systems facilitate real-time data analytics, as the IIoT makes it possible to collect and process significant amounts of operational data, improving visibility and control. Advanced analytics also support data-driven decisions, with AI helping organizations reduce errors and increase overall efficiency. This phase is crucial because it provides the technical foundation needed for further transformation. For organizations to fully capitalize on the potential of Industry 6.0, they must ensure the effective integration of advanced technologies. The adoption of these technologies also makes it necessary to adapt organizational structures accordingly.

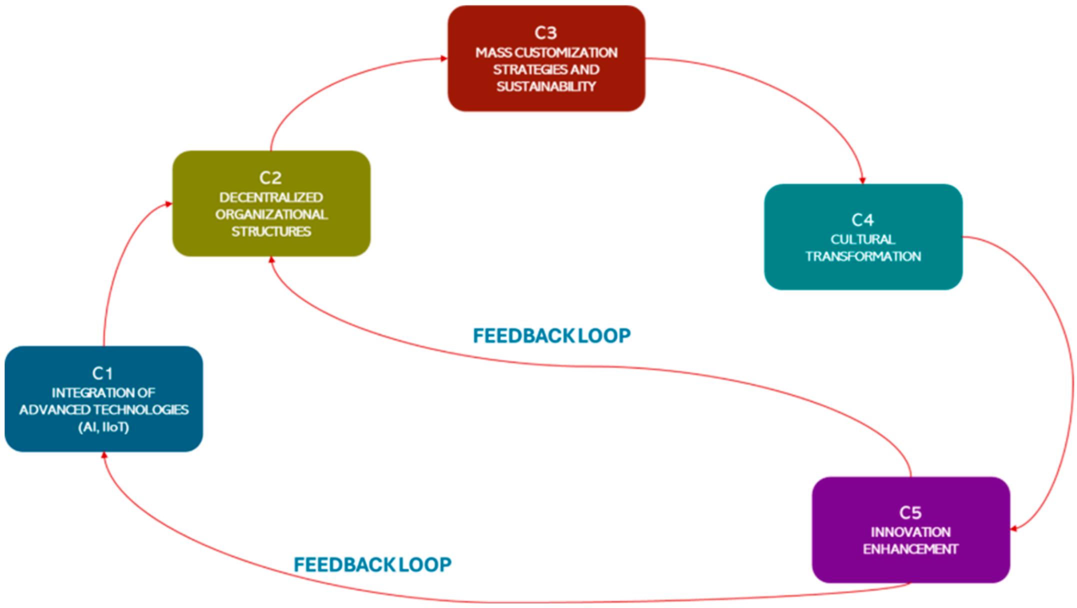

Figure 4. Industry 6.0 theoretical model (Source: author's elaboration).

The emergence of decentralized organizational structures (C2) directly results from the need to leverage operational autonomy. These structures allow departments and teams to make rapid, informed decisions based on local data, thereby increasing organizational agility. By reducing hierarchical levels, companies can respond more swiftly to market changes. Furthermore, the flatter organizational setup encourages collaboration, facilitates information sharing, and supports cross-functional innovation. The decentralization process is enabled by technologies introduced in the initial stage, which provide the tools necessary for effective communication and autonomous process management.

Establishing appropriate organizational structures makes it possible to implement Mass Personalization and Sustainability Strategies (C3). This involves using data-driven and technology-enabled mass customization, offering personalized products and services on a large scale without increasing costs. At the same time, sustainability is integrated into all operational aspects, from resource management to product design. These strategies address the evolving expectations of consumers, who increasingly desire personalized offerings and demonstrate heightened environmental awareness. Adopting such strategies helps companies differentiate themselves in the market and generate long-term value.

To implement these strategies successfully, it is essential to transform organizational routines and mindsets. Employees should be encouraged to seek continuous improvement in processes and products, while the company's mission and values must reflect sustainability and a commitment to innovation. Company culture serves as the binding element that supports both technological advancements and changes in work practices. When organizational culture is transformed, it leads to further enhancement of innovation (C5). At this stage, the company not only responds to change but also anticipates trends and drives innovation within its sector. A data-driven approach enables the organization to identify new opportunities and optimize operations. Developing innovative solutions empowers the company to create advanced products, services, and business models. This, in turn, provides a competitive advantage and sustains the cycle of transformation. The model incorporates a feedback loop that connects innovation enhancement (C5) with advanced technology integration (C1) and decentralized organizational structures (C2). This loop implies that the introduction of new technologies stimulates further adoption and supports business operations; changes in organizational structure align with the introduction of innovative technologies and strategies, potentially requiring additional structural adjustments; organizational culture evolves to support new initiatives while maintaining a focus on ongoing improvement and innovation. This continuous process ensures that the company remains adaptable and resilient, capable of responding to market challenges and opportunities. The graphical representation of the Integrated Theoretical Model, shown through a circular or spiral diagram (Figure 4), illustrates the cyclical and progressive nature of this process. The constructs (C1–C5) are presented sequentially, with direct relationships indicated by arrows.

- C1 is a prerequisite for C2. The implementation of advanced technological integration necessitates the establishment of decentralized organizational structures.
- C2 → C3: Decentralized structures facilitate the adoption of mass personalization and sustainability strategies.
- C3 → C4: The implementation of these strategies facilitates cultural transformation.
- C4 → C5: Cultural transformation drives the empowerment of innovation.
- C5 → C1/C2: Enhancing innovation generates new technological developments and necessitates further organizational adaptations, thereby closing the feedback loop.

The feedback arrows underscore the influence of each stage on the others, creating an interactive and self-reinforcing system.

5.3. Theoretical Validation of the Model

The integrated theoretical model of Industry 6.0 is grounded in several established management theories, connecting traditional concepts with the requirements of contemporary industrial change. According to Contingency Theory [83], organizations should adapt their structures to match technological and environmental conditions. Within this model, Advanced Technological Integration (C1) calls for Decentralized Organizational Structures (C2) to fully realize the potential of new technologies, reflecting the contingency approach. The Resource-Based View [84] highlights that organizations gain a competitive edge by cultivating resources that are rare and difficult to imitate. In our framework, Advanced Technology Implementation (C1) and Innovation Enhancement (C5) serve as such strategic resources. Dynamic Capabilities Theory [85] stresses the importance of developing the ability to respond quickly to changes. Our model shows that decentralized structures (C2) and a focus on cultural transformation (C4) are central to building these capabilities. Principles from Organizational Learning Theory [86] are visible in the Cultural Transformation (C4) and Innovation Enhancement (C5) components, which together foster a culture of ongoing learning and innovation. Systems Theory [87] views organizations as interconnected entities. The model illustrates this by showing how technology (C1), organizational structure (C2), strategy (C3), culture (C4), and innovation (C5) interact and influence one another. Transformational Leadership Theory [88] emphasizes the role of leaders in driving organizational change. In the context of Industry 6.0, effective leadership is crucial to ensuring successful cultural transformation (C4). Stakeholder Theory [89] advocates for considering the interests of all stakeholders. The model addresses this through mass personalization and sustainability strategies (C3), which account for the needs of customers, communities, and the environment. Porter's Competitive Advantage Theory [90] is reflected in the use of advanced technologies (C1) and innovation (C5) to differentiate and optimize organizational performance. The model incorporates these elements through constructs C1, C2, and C3. The framework's complexity arises from its dynamic and adaptive nature, enabling organizations to evolve in response to change through feedback loops that connect the various constructs. Knowledge Management Theory [91] is also present in the Innovation Enhancement (C5) and Cultural Transformation (C4) components, demonstrating the critical role of knowledge management in promoting continuous innovation. Finally, our model not only aligns with these foundational theories but also integrates them to support the effective adoption of Industry 6.0. It demonstrates how technology, structure, strategy, culture, and innovation are interrelated and collectively enhance organizational adaptability.

5.4. Final Theoretical Contribution

The ultimate theoretical contribution of this study is the formulation of a central theoretical proposition that encapsulates the core tenets of the integrated model of Industry 6.0. This proposition emphasizes the interdependence of constructs and the cyclical nature of transformation. The final theoretical assertion is as follows:

- *Success in Industry 6.0 is not achieved merely through the adoption of advanced technologies or the implementation of new strategies but emerges from a cyclical and interdependent transformation wherein Advanced Technological Integration (C1) reconfigures Organizational Structures (C2), which in turn enable and are reshaped by Mass Personalization and Sustainability Strategies (C3). This dynamic process initiates a profound Cultural Transformation (C4) that elevates Innovation (C5) from an operational function to an intrinsic strategic capability. This enhanced innovation further fuels technological integration and organizational evolution, establishing a virtuous cycle that redefines the organization's identity and operational essence, making agility, resilience, and sustainability not just objectives but fundamental components of its DNA.*

This proposition encapsulates the essence of the model, emphasizing that success in Industry 6.0 is contingent upon the synergistic effect of all identified components, rather than the result of isolated changes. Each construct is intimately connected and mutually reinforcing:

Advanced Technology Integration (C1) serves as the initial catalyst, enabling new operational capabilities through technologies like AI and IIoT. However, to fully realize its potential, it requires Decentralized Organizational Structures (C2) that allow for agility and rapid decision-making at all levels. Decentralized Organizational Structures (C2) facilitate the implementation of Mass Personalization and Sustainability Strategies (C3), empowering autonomous units to tailor products and services to local needs while balancing efficiency with environmental responsibility. The effectiveness of these strategies (C3) hinges on a Cultural Transformation (C4) that fosters a culture of continuous improvement, innovation, and the integration of sustainability values throughout the organization. This Cultural Transformation (C4) propels Innovation Enhancement (C5), stimulating the generation of new ideas and the adoption of emerging technologies, which are essential for maintaining a competitive advantage. Innovation Enhancement (C5) creates a positive feedback loop by driving further Advanced Technology Integration (C1) and necessitating additional adaptations in Decentralized Organizational Structures (C2), thereby perpetuating the cycle of continuous improvement and adaptation.

This cyclical and interdependent model underscores that success in Industry 6.0 requires a holistic approach where technological advancements, organizational restructuring, strategic initiatives, cultural shifts, and innovation practices are aligned and mutually reinforcing. By embracing this integrated framework, organizations can navigate the complexities of the modern industrial landscape, fostering agility, resilience, and sustainability [92] essential for long-term success.

This proposition captures the essence of the model, highlighting that the success of Industry 6.0 depends on the synergistic interaction of all its components rather than isolated changes. Each construct is closely linked and reinforces the others. Advanced Technology Integration (C1) acts as the primary catalyst, providing new operational capabilities through technologies such as AI and IIoT. However, its full potential is realized only when supported by Decentralized Organizational Structures (C2), which enable agility and timely decision-making throughout the organization. These decentralized structures also facilitate the adoption of Mass Personalization and Sustainability Strategies (C3), empowering autonomous units to respond to local needs while balancing efficiency and environmental stewardship.

The effectiveness of these strategies (C3) depends on a genuine Cultural Transformation (C4), which nurtures continuous improvement, innovation, and the integration of sustainability values at every level. This cultural evolution (C4) drives Innovation Enhancement (C5), supporting the development of new ideas and the implementation of emerging technologies, which are essential for maintaining competitiveness. Innovation Enhancement (C5) then reinforces the cycle by promoting further Advanced Technology Integration (C1) and prompting new adaptations in Decentralized Organizational Structures (C2), ensuring ongoing improvement and organizational flexibility. This cyclical and interdependent approach demonstrates that Industry 6.0 requires a comprehensive framework, where advancements in technology, organizational changes, strategic initiatives, cultural development, and innovation practices are aligned and mutually supportive. By adopting this integrated perspective, organizations can effectively address the challenges of the contemporary industrial environment, strengthening agility, resilience, and sustainability as core elements for long-term success.

To this end, our proposed framework distinguishes itself from previous approaches by moving beyond a focus on standalone technological enablers, such as multi-agent [7] or digital twin integration [8], and instead embeds these elements within a systemic, cyclical perspective in which feedback loops and cultural transformation play a central role.

6. Discussion of Results

This section discusses the theoretical study's results in relation to the research questions. The integrated Industry 6.0 model developed here highlights essential technological, organizational, strategic, and cultural changes for this emerging industrial paradigm. To ground the theoretical contribution in emerging industrial practice, we included several illustrative cases throughout the analysis. For instance, Siemens' Amberg factory demonstrates cognitive quality control, where AI autonomously adjusts production parameters in real time. The Haier RenDanHeYi model exemplifies decentralized organizational architectures that empower independent units with cognitive decision-making capabilities. Nike's cognitive manufacturing platform illustrates how AI can harmonize personalization and sustainability, while Toyota's predictive quality systems show how zero-defect principles can reshape organizational culture. These examples, while not exhaustive, support the plausibility of the proposed framework by showing how elements of Industry 6.0 are already materializing in advanced manufacturing contexts.

Response to RQ1: How does Industry 6.0 influence the structure and strategy of industrial organizations?

Our findings indicate that Industry 6.0 reconfigures both organizational architecture and business strategy. Advanced technologies such as AI and IIoT (C1) act as catalysts for decentralization (C2), enabling real-time decision-making and enhanced agility. Strategic orientation shifts toward balancing mass customization and sustainability (C3), ensuring that organizations can deliver tailored products without compromising environmental responsibility [35,36]. Importantly, the model emphasizes that cultural transformation (C4) underpins these changes, embedding adaptability and continuous improvement across the enterprise. This holistic transformation surpasses prior frameworks that treated these domains separately, underscoring our contribution of a systemic, cyclical design. In particular, cultural transformation is not addressed as a generic change process but as a structural binding construct that continuously connects technology, organization, strategy, and innovation, distinguishing Industry 6.0 from previous maturity-oriented models.

Response to RQ2: What organizational structures are best suited to support the decentralized decision-making and integration of advanced technologies envisaged by Industry 6.0?

The results highlight decentralized organizational structures (C2) as most effective for leveraging the potential of Industry 6.0. These structures empower teams with autonomy, supported by real-time information from AI-driven control systems (C1). In practice, distributed additive manufacturing offers a clear example: local production cells autonomously adjust printing parameters, reducing reliance on central supervision and enhancing responsiveness. Such emerging practices confirm that decentralization, when combined with advanced technology, generates resilience and operational agility beyond what centralized structures can provide [62]. Similar directions are noted in recent studies where multi-agent systems are adopted to coordinate distributed manufacturing tasks [7] and digital product passport frameworks are integrated with digital twins to enable decentralized control [8].

Distributed additive manufacturing networks demonstrate cognitive decentralization by allowing local nodes to autonomously manage printing, material use, and quality control. These nodes adapt in real time to conditions like humidity and temperature, while inter-node communication ensures global quality and sustainability.

Response to RQ3: How can organizations develop strategies that effectively balance mass customization and sustainability within the Industry 6.0 model?

The model suggests that the balance between personalization and sustainability (C3) can be achieved by integrating advanced analytics with decentralized decision-making. AI and IIoT support mass customization while simultaneously optimizing resource use and minimizing waste [55]. This dual focus is increasingly evident in sectors such as predictive maintenance, where localized teams use machine learning insights to anticipate equipment failures and intervene proactively. By reducing downtime and avoiding unnecessary resource consumption, firms demonstrate how personalized service delivery and sustainable practices can reinforce each other within Industry 6.0 environments. This is consistent with neural-network-based approaches to fault prediction [17] and Six Sigma applications enhanced by AI [16], which demonstrate how data-driven systems can embed resilience and sustainability into industrial operations.

Cognitive predictive maintenance systems balance customization and sustainability by using machine learning to schedule maintenance for each machine, optimizing resources facility-wide. These systems learn each machine's operation, predict the best times for intervention, and coordinate activities to reduce downtime and environmental impact.

Response to RQ4: What are the cultural and strategic implications of a zero-fault environment and how does it affect continuous innovation and incremental improvement in industrial organizations?

Achieving a zero-defect environment requires a cultural transformation (C4) that prioritizes quality, innovation, and preventive approaches over reactive corrections [21]. Strategically, this transformation strengthens innovation (C5), as predictive quality systems encourage experimentation and cross-functional collaboration. By embedding zero-defect objectives within organizational culture, firms move from static compliance to dynamic improvement, creating environments where incremental learning and radical innovation coexist. This cultural embedding distinguishes our model from prior accounts that largely treated zero-defect as a technological or operational goal rather than a cultural and strategic imperative.

Furthermore, this study addresses several gaps in existing literature:

1. This study investigates the impact of Industry 6.0 on organizational structures, with a focus on decentralization that enables distributed decision-making and the assimilation of new technologies.
2. In contrast to Industry 4.0 and 5.0, our framework positions sustainability as a core component, guiding organizations toward balancing mass customization with ecological responsibility.
3. We highlight necessary cultural transformations for achieving zero-defect environments, which are crucial for fostering sustained innovation and organizational resilience.
4. The theoretical model presented combines aspects of technology, organizational architecture, strategy, culture, and innovation, providing both actionable recommendations and fresh perspectives for management scholars and practitioners.

7. Conclusions

This study develops a conceptual framework for Industry 6.0, positioning it as an emerging paradigm that integrates advanced technologies, decentralized organizational forms, mass customization, sustainability, and innovation into a systemic and cyclical model. By highlighting the binding role of cultural transformation, the framework clarifies how technology, organization, strategy, and innovation are continuously connected and reinforced, moving beyond the linear or siloed representations of Industry 4.0 and 5.0.

The contribution of this research is threefold. First, it provides a clear working definition of Industry 6.0, addressing the current fragmentation in the literature. Second, it introduces propositions (P1–P14) that establish a theoretically grounded foundation for further inquiry. Third, it illustrates the plausibility of the framework through emerging industrial cases such as Siemens, Haier, Nike, and Toyota.

Several limitations must also be acknowledged. The applicability of the framework may be constrained in highly regulated industries, and SMEs may face barriers due to resource constraints and limited digital infrastructures. Moreover, the emphasis on cultural transformation presupposes organizational readiness that may vary across contexts, making diffusion uneven.

Overall, this research advances the debate on the future of manufacturing by framing Industry 6.0 as an adaptive and context-sensitive paradigm. Rather than replacing Industry

4.0 and 5.0, it provides an integrative lens for understanding how cognitive manufacturing, cultural transformation, and systemic feedback loops can drive more resilient, sustainable, and innovative industrial ecosystems. Thus, Industry 6.0 emerges not as a prescriptive blueprint but as a conceptual lens for rethinking how manufacturing systems can evolve toward greater resilience, sustainability, and cognitive adaptability.

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Appendix A Proposition–Reference Mapping

Proposition	Key Reference	Contribution of the Cited Works
P1	[32,37]	These works establish the foundational role of CPS and IoT in Industry 4.0, enabling digital automation but retaining centralized and efficiency-oriented structures.
P2	[34,36]	These studies on Industry 5.0 emphasize human–machine collaboration and sustainability awareness, but note limited changes in organizational structure, supporting the transition argument.
P3	[5,37]	Literature on AI and IIoT demonstrates how autonomous systems drive the need for decentralized organizations, showing a step beyond 4.0 and 5.0.
P4	[38,39]	These contributions highlight the strategic importance of mass customization and sustainability, positioning them as central objectives for Industry 6.0.
P5	[40,43]	Cultural change is discussed as a driver of innovation and sustainability in industrial transitions, but without systemic integration—our proposition builds on and extends these insights.
P6	[42]	This work stresses the shift toward proactive, data-driven innovation enabled by advanced analytics, aligning with our view of continuous innovation in Industry 6.0.
P7	[44,45]	These studies document how AI/IIoT integration improves efficiency and flexibility, forming the basis for Industry 6.0's predictive optimization and autonomous decision-making.
P8	[56,58]	Research on sustainable practices in advanced manufacturing shows how AI/IIoT can reconcile customization and environmental goals, supporting our proposition.
P9	[61,62]	Decentralization and agility are emphasized in these works, demonstrating how distributed structures enhance responsiveness compared to hierarchical models.
P10	[67,69]	These papers show how adaptation to market dynamics and consumer preferences requires new structural models, validating the Industry 6.0 approach.
P11	[21,69]	These contributions discuss how AI and IIoT enable scalable customization strategies, supporting the balance of flexibility and scalability proposed in P11.
P12	[45,75,76]	Sustainability as a strategic imperative is emphasized here, particularly the role of supply chains and responsible resource management in long-term value creation.
P13	[24,79]	These studies explore zero-defect manufacturing and cultural change for quality, underlining the organizational and cultural shifts required for implementation.
P14	[19,20]	These works provide evidence of predictive quality and defect prevention as strategic levers, showing their role in resilience and agility.2

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