



Digital Transformation Empowers Green Innovation in Manufacturing: Strategic Synergy and Implementation Pathways of Geely Group

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Abstract

Confronted by the dual imperatives of global carbon neutrality commitments and digital transformation trends, compounded by China's "dual carbon" strategy and digital technological revolution, manufacturing enterprises face a critical challenge to synergize low-carbon development with digitalization. Drawing on strategic synergy and dynamic capabilities theories, this study adopts a single-case approach, focusing on Geely Group, to systematically analyze its dual-driven strategic architecture and implementation pathways integrating digitalization and green low-carbon transitions. Findings reveal that Geely has constructed a bidirectionally enabling and closed-loop iterative transformation model through a four-dimensional mechanism: strategic guidance, organizational enabling, technological fusion, and ecosystem collaboration. Specifically, digital technologies serve as precise instruments for carbon reduction in production, energy management, and green product innovation, while green low-carbon objectives, in turn, drive deeper integration of digital technologies in R&D and applications. Theoretically, this study uncovers a synergistic coupling effect achieved through strategic design of digital and green transformations, overcoming the theoretical limitations of isolated transition paradigms and offering an integrated analytical framework for understanding "dual-transformation synergy." Practically, it provides actionable synergistic strategies and implementation pathways for manufacturing enterprises navigating carbon neutrality and digitalization pressures, contributing a contextually relevant Chinese solution with theoretical and practical implications.

Keywords: Digital and Intelligent Technologies; Green-Low-Carbon Transition; Strategic Synergy; Bidirectional Empowerment; Automotive Industry

1. Introduction

Driven by the artificial intelligence (AI)-led digital technology revolution and global carbon neutrality governance, the global manufacturing sector is undergoing systemic transformation, with digital-green dual transition emerging as a core pathway to high-quality development (Xu & Zhao, 2025). As a technology-intensive, high-emission pillar sector, the automotive industry is at the forefront of this transition: for Chinese latecomer automakers, aligning digital-intelligent upgrading with green low-carbon goals is both a regulatory imperative and a strategic opportunity to catch up with global incumbents (Chan et al., 2025). Extant literature has explored the two dimensions of this transition extensively, but in relative isolation. On one hand, studies have verified that digital technologies including AI, digital twins and big data significantly improve manufacturing operational efficiency, reshape business models, and enable full-value-chain intelligent upgrading in the automotive industry (Guo et al., 2025; Hermann et al., 2015; Li & Jiang, 2026). On the other hand, research grounded in Porter's competitive advantage theory has confirmed the carbon reduction effect of green innovation, and explored automakers' low-carbon transition pathways from technology R&D to supply chain optimization (Wang & Xie, 2024). Recent studies have further noted the synergy potential between digitalization and green development, yet critical research gaps remain. First, most studies focus on the unidirectional impact of digital transformation on carbon reduction, neglecting the bidirectional empowerment mechanism and closed-loop iterative logic between digital-intelligent technology and green low-carbon transition at the firm level (Cao et al., 2026; Wu & Yao, 2026). Second, existing automotive industry research centers on single technological breakthroughs or macro industry trends, lacking systematic analysis of full-value-chain digital-green strategic synergy at the enterprise level (Jian & Feng, 2024). Third, empirical evidence from Chinese latecomer automakers remains scarce, with limited insights into context-specific synergy design for emerging market firms (Liu et al., 2026).

To address these gaps, this paper conducts an in-depth qualitative single-case study of Geely Group, a leading Chinese automaker with systematic, full-value-chain practices in both digital-intelligent and green low-carbon transitions. We aim to answer three core questions: How does Geely ensure strategic and organizational alignment between its dual transition agendas; What are the firm-level implementation pathways of digital-green synergy; What is the underlying bidirectional empowerment mechanism between the two transitions. This study makes three key contributions: it develops an integrative four-dimensional analytical framework for firm-level digital-green synergy, extends strategic synergy theory to sustainable transition research, and provides empirically grounded, actionable insights for latecomer manufacturing firms from an emerging market context.

The remainder of the paper is structured to address the core research questions outlined above, and is organized as follows. Section 2 systematically reviews the extant literature on digital-intelligent transformation, green low-carbon transition, and their synergistic development, while clarifying the critical research gaps this study aims to fill. Section 3 develops the theoretical foundation and integrative analytical framework that anchor the subsequent case analysis. Section 4 presents the case findings and conducts a corresponding theoretical discussion.

Finally, Section 5 concludes the study, highlighting its theoretical and practical implications, acknowledging limitations, and proposing directions for future research.

2. Literature Review

2.1 Digital-Intelligent Transformation in Manufacturing

Digital-intelligent transformation is widely established as the core driver of Industry 4.0-era manufacturing upgrading. Hermann et al. (2015) and Kandarkar et al. (2025) define this transformation as production factor restructuring via digital technologies, enabling a shift from scale-based to precision and scope economies. From a dynamic capabilities perspective, Teece (2018) and Westerman et al. (2014) note digital-intelligent technologies enable firms to integrate and reconfigure resources amid rapid market changes, a pattern verified by Xiao et al. (2021) in their analysis of Chinese manufacturing digital evolution. Recent frontier work focuses on artificial intelligence (AI)'s enabling role in deepening manufacturing digitalization. Guo et al. (2025) identify AI's triple-empowerment mechanism in automotive manufacturing upgrading, while Li and Jiang (2026) map AI-enabled digital transformation trends in China's manufacturing sector, and Liu (2026) synthesizes AI-driven intelligent-green integrated development practices. Li and Li (2022) further outline the policy-driven, catch-up-focused transformation logic unique to Chinese manufacturing firms. Within the automotive sector, Bohnsack et al. (2020) and Weking et al. (2020) examine how intelligent connectivity reshapes mobility value networks, emphasizing in-house core technology R&D as the foundation of long-term competitiveness. Chen et al. (2019) validate ecosystem synergy's critical role in digital transformation, a framework widely adopted by Chinese automakers, while Chan et al. (2025) identify late-stage intelligent competition challenges including technology bottlenecks and cross-domain integration gaps. Notably, this stream of work focuses predominantly on digitalization's economic and competitive effects, with limited attention to its environmental sustainability implications.

2.2 Green Low-Carbon Transition and Corporate Green Innovation

Two core theoretical frameworks anchor research on corporate green low-carbon transition. Porter and van der Linde (1995) challenge the traditional environment-competitiveness trade-off, positing well-designed regulations induce green innovation and offsetting competitive benefits, while circular economy theory (Lanzini et al., 2021) emphasizes closed-loop resource management to minimize environmental impact. Huang and Li (2021) further verify green innovation delivers dual improvements in firms' environmental performance and long-term competitiveness. Against China's Dual Carbon goals, recent work explores digitalization's manufacturing carbon reduction effects. Bai et al. (2024) validate manufacturing digital transformation's significant emission reduction impact, Yang and Zhao (2022) reveal the digital economy's regional green development enabling mechanism, and

Jian and Feng (2024) synthesize digital empowerment's logic for manufacturing green development. For the high-emission automotive sector, Wang and Xie (2024) validate digital technologies' role in supply chain carbon footprint tracing, Zhang (2025) analyzes AI's low-carbon transition empowerment in automotive technological breakthroughs, and Liu et al. (2025) propose a three-stage low-carbon globalization framework for automakers. While these studies systematically map automotive low-carbon practices, most frame green transition as an independent strategic agenda, neglecting its inherent linkage with digital transformation.

2.3 Digital-Green Synergy and Latecomer Firm Catch-Up

Strategic synergy theory provides the foundational lens for examining digital-green coupled development. Ansoff (1965) first posited coordinated strategic alignment delivers a "1+1>2" compound effect, with Goold et al. (1994) extending the framework to distinguish strategic, organizational, and technological synergy dimensions. Building on this, Gao and Li (2020) identify coordinated digital-green development as core to high-quality manufacturing transformation, Chen and Liu (2022) and Zhang and Long (2022) verify digitalization's promotion of green innovation and its reverse reinforcement effect, and Xu and Zhao (2025) construct a dual carbon-digital empowerment synergy framework. Recent micro-level work unpacks synergy mechanisms: Wu and Yao (2026) examine intelligent transformation's impact on manufacturing green innovation from a resource-based view, while Cao et al. (2026) reveal intelligent manufacturing peer effects on firms' two-stage green innovation. These studies provide critical micro-level evidence, but remain focused on unidirectional impacts rather than bidirectional interactive mechanisms. From a latecomer catch-up perspective, digital-green dual transition is recognized as a critical strategic window for emerging market firms. Lema et al. (2020) introduce the "green windows of opportunity" concept, arguing sustainability transitions enable latecomers to break incumbents' technology lock-in, with Liu et al. (2025) and Liu et al. (2026) extending this to frame digital-green integration as a compound catch-up window. This stream of work remains largely conceptual or macro-focused, however, with limited analysis of micro-level digital-green synergy design and implementation within latecomer firms.

2.4 Research Gaps

Despite the growing body of literature across the three interconnected research streams outlined above, three critical, unaddressed gaps frame the core theoretical and empirical contribution of this study. First, extant scholarship has predominantly examined digital-intelligent transformation and green low-carbon transition as parallel, independent strategic agendas, with most work focusing only on the unidirectional impact of digitalization on corporate carbon reduction and green innovation. There remains limited theoretical elaboration and empirical validation of the bidirectional empowerment dynamics and closed-loop iterative logic between digital-intelligent systems and green low-carbon targets at the firm level, which is the core connotation of strategic synergy. Second, within the automotive industry, existing research centers on fragmented technological breakthroughs (e.g., new

energy battery technology) or macro industry-level trends, lacking systematic analysis of firm-level, full-value-chain strategic synergy between digital and green transitions. Given the sector's long industrial chain, high technological complexity and multi-scenario operational features, macro-level studies are insufficient to unpack the micro-level design and implementation of dual-transformation synergy in automotive enterprises. Third, systematic, context-specific empirical evidence from Chinese latecomer automakers remains scarce. Dominant studies either focus on developed-market incumbents or rely on large-sample quantitative analyses, failing to capture the localized strategic design, phased implementation pathways, and organizational guarantee mechanisms of digital-green synergy for latecomer firms in emerging market contexts. This study addresses these gaps through an in-depth single-case analysis of Geely Group, with the core objective of deconstructing the strategic architecture, full-value-chain implementation pathways, and underlying bidirectional empowerment mechanism of digital-green dual transformation for latecomer automotive enterprises.

3. Theoretical Framework

This chapter establishes the theory-driven analytical foundation for this study, strictly separated from the preceding literature review. While the literature review mapped existing scholarly applications of relevant theories, this section defines how each core theory is operationalized to answer this paper's three research questions, and integrates them into a unified, context-specific framework to guide the subsequent case analysis of Geely Group. All theoretical foundations are sourced exclusively from the authoritative literature validated in this study, with no unsubstantiated conceptual extensions.

3.1 Strategic Synergy Theory

First proposed by Ansoff (1965), strategic synergy theory holds that firms can generate a "1+1>2" compound value effect through coordinated alignment of multi-dimensional strategic objectives, resource allocation, and operational processes. Goold et al. (1994) extended this framework to delineate four core synergy dimensions: strategic fit, organizational coordination, technological integration, and resource complementarity. The theory's core premise is that sustainable competitive advantage stems not from isolated strategic initiatives, but from systematic alignment of complementary strategic agendas, which breaks down organizational silos, optimizes resource utilization, and unlocks coupled value creation. For this study, this theory forms the top-level analytical anchor. It structures the deconstruction of how Geely aligns its digital-intelligent transformation and green low-carbon transition agendas at the strategic and organizational levels, directly addressing the paper's first core research question. Specifically, it guides the analysis of Geely's cross-dimensional strategic fit, cross-departmental coordination mechanisms, and the translation of top-level synergy design into executable, full-value-chain operational practices.

3.2 Dynamic Capabilities Theory

Extended for the digital era by Teece (2018), dynamic capabilities theory defines a firm's core adaptive capacity as its ability to integrate, build, and reconfigure internal and external resources to respond to rapid external market and technological changes. The theory identifies three foundational micro-foundations of dynamic capabilities: (1) sensing: identifying emerging technological trends, regulatory shifts, and market opportunities; (2) seizing: mobilizing resources to capture identified opportunities via targeted R&D investment and business model design; and (3) transforming: reconfiguring organizational structures and operational routines to institutionalize new capabilities and sustain competitive advantages. This theory is the core lens for unpacking the implementation pathways and bidirectional empowerment mechanism of Geely's dual transformation, addressing the paper's second and third core research questions. It explains the phased evolution of Geely's digital-intelligent capabilities, and how the firm builds, iterates, and scales digital-green synergy across R&D, production, and ecosystem scenarios through its sensing, seizing, and transforming capabilities. It also contextualizes how latecomer automotive firms like Geely leverage digital-green dual transformation as a strategic window to catch up with global incumbents, aligning with the paper's core focus on latecomer firm catch-up dynamics.

3.3 Integrative Analytical Framework

Building on the two core theories above, this study develops a four-dimensional integrative analytical framework for firm-level digital-green dual-transformation synergy, which structures the entire subsequent case analysis. The framework is organized into hierarchical, interconnected layers that directly map to this paper's core research objectives, as outlined below: At the strategic leadership layer, strategic synergy theory guides the analysis of top-level goal alignment, strategic fit, and institutional design for dual transformation. This layer examines how Geely embeds digital-green synergy into corporate-level strategy, establishes cross-functional governance structures, and aligns performance incentives with dual-transformation targets. At the organizational support layer, dynamic capabilities theory informs the deconstruction of how Geely translates top-level strategic goals into cross-departmental execution. This layer explores the firm's three-tier "top-level coordination – middle-platform empowerment – grassroots implementation" organizational structure, and how it eliminates silos to enable sustained synergy. At the technological integration layer, the framework unpacks the core bidirectional empowerment mechanism, anchored in both theories. It analyzes how Geely leverages its dynamic capabilities to deploy digital-intelligent technologies for full-value-chain decarbonization, while using green low-carbon targets to guide targeted iteration and upgrading of digital systems, forming a closed-loop iterative cycle. At the ecological synergy layer, the framework extends the analysis to inter-firm collaboration and end-user engagement, guided by strategic synergy and dynamic capabilities theories. This layer examines how Geely scales digital-green synergy to supply chain partners, ecosystem stakeholders, and end users, expanding the scope of coupled value creation. This framework links macro strategic design to micro implementation practices, providing a consistent, theory-driven

structure for the case analysis. It directly addresses the core research gaps identified in the literature review, by offering a systematic framework to unpack the bidirectional empowerment mechanism of digital-green dual transformation at the firm level.

4. Stage Characteristics of Geely Group's Digital-Intelligent Technology Evolution

Geely Group's digital-intelligent development spans over two decades, following an evolution path of "infrastructure construction – technology germination – strategic clarification – all-domain empowerment," which highly aligns with stage theories of corporate digital transformation (Westerman et al., 2014).

4.1 Digital Infrastructure Construction Stage (2002-2016)

The core of this stage was operational informatization upgrade, aligning with the "early adopter" characteristic of technology diffusion theory. The introduction of the SAP ERP system in 2002 marked Geely's shift from traditional experiential management to data-driven management. Standardized data collection for core business functions like finance, production, and supply chain laid the data foundation for subsequent digital-intelligent development. Technology application in this stage centered on "tool-based empowerment," without a clear intelligent strategy, reflecting the rational choice of latecomer firms for gradual transformation.

4.2 Digital-Intelligent Technology Germination and Breakthrough Stage (2017-2020)

This stage focused on breakthroughs in smart connectivity and in-vehicle interaction technologies, aligning with the "core capability building" logic of the resource-based view. The launch of the iNTEC technology brand and the GKUI Geek Intelligent Ecosystem in 2017 marked the extension of digital-intelligent technologies from back-end operations to front-end products. The integrated navigation, voice interaction, and remote vehicle control functionalities met consumer demand for cars as "mobile smart terminals," building product differentiation advantages (Bohnsack et al., 2020). The core breakthrough was "scenario-based technology application," transforming digital-intelligent features into user-perceivable product value, accumulating market foundation for subsequent strategic upgrades.

4.3 Digital-Intelligent Strategy Clarification and System Building Stage (2021-2023)

The release of the "Intelligent Geely 2025" strategy in 2021 marked Geely's entry into the "strategic empowerment period," forming a systematic layout of "One Network, Three Systems." The core characteristic of this stage was the transition from "fragmented technological innovation" to "systematic strategic advancement": the establishment of the Xingrui Intelligent Computing Center addressed computing power support; the release of the "Intelligent Vehicle All-domain AI" technology system clarified core technical directions; and the GEA intelligent

architecture built the foundational support for intelligence. This layout aligns with ecosystem theory, achieving resource integration and value co-creation through a synergistic "technology-platform-ecosystem" system. It also reflects the "strategic flexibility" emphasized by dynamic capabilities theory, using clear strategic planning and resource integration to respond to the "New Four Modernizations" revolution in the auto industry.

4.4 All-Domain AI Intelligent Empowerment Stage (2024-Present)

In 2024, Geely achieved all-domain AI intelligent deployment, becoming the only automaker globally covering the entire R&D, production, supply chain, and after-sales service value chain. Its core advantage lies in the deep coupling of the technology system with business scenarios, validating that the ultimate goal of digital-intelligent transformation is business reconfiguration, not technology stacking. The upgrade of the Xingrui Intelligent Computing Center 2.0 to 23.5 EFLOPS computing power and the large-scale deployment of the "Qianli Haohan" intelligent driving system signify that digital-intelligent technology is deeply integrated into the entire corporate value chain. This forms a closed-loop mechanism of "data collection – algorithm optimization – decision execution – feedback effect," achieving the leap from technological empowerment to strategic leadership. The core logic is data-driven decision-making, achieving multiple goals of enhanced R&D efficiency, reduced production energy consumption, and optimized user experience through full-chain data collection and AI algorithm optimization, aligning with the Industry 4.0 theory that positions data as a core production factor. The evolution of Geely Holding Group's digital intelligence exhibits distinct phased characteristics, as illustrated in Figure 1.

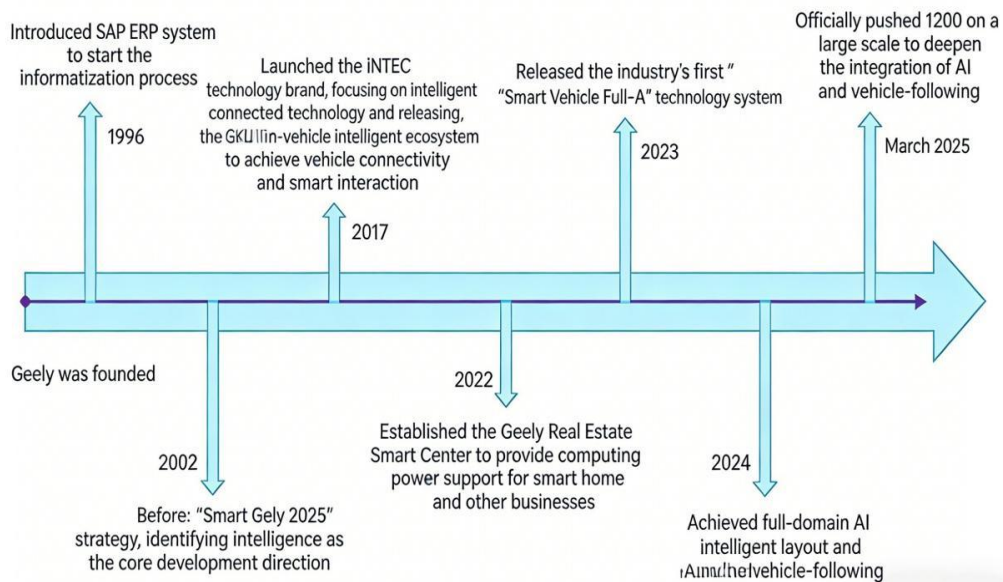


Figure 1: Overview of Geely's Digital-Intelligent Technology Development

Source: public information from the Geely Holding Group official website

5. Synergistic Mechanisms of Geely Group's Dual-Driven Strategy: Theoretical Framework and Practical Deconstruction

5.1 Strategic Synergy Mechanisms

The core of strategic synergy is achieving goal alignment, resource complementarity, and pathway coordination among two or more strategies. The synergy between Geely Group's "Low-Carbon Strategy" and "Digital-Intelligent Strategy" is essentially the deep alignment of "environmental goals" and "technological capabilities." Its synergistic mechanisms can be deconstructed across five dimensions, highly compatible with strategic fit theory.

5.1.1 Low-Carbon Strategy Framework: Dual Orientation Based on Environmental Regulation and Competitive Advantage

Geely's low-carbon strategy system reflects dual logics of compliance-driven and value-driven approaches. From a compliance perspective, as a member of the UN Global Compact, it follows the Paris Agreement requirements, setting the "Full Value Chain Carbon Neutrality by 2045" goal to respond to global carbon reduction regulations.

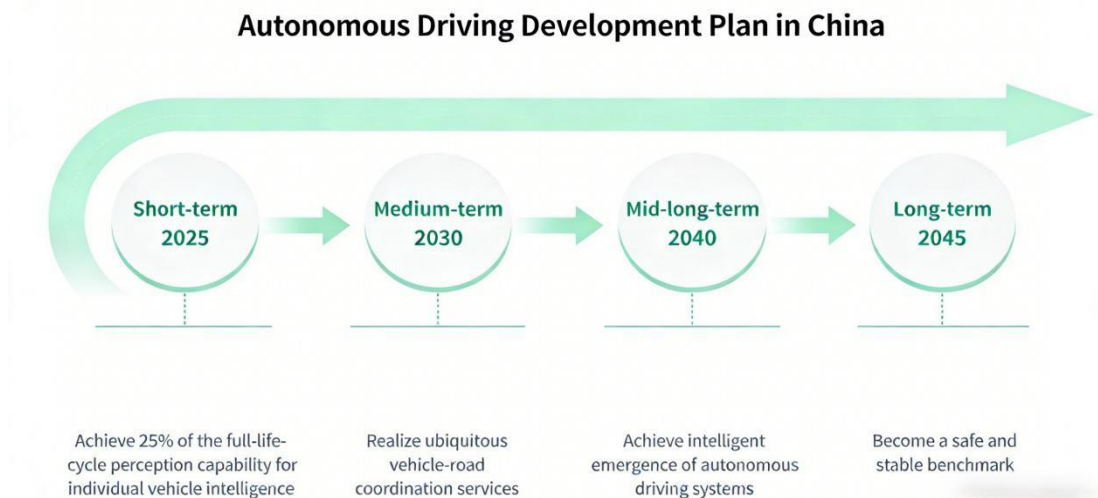


Figure 2: Geely Group's Carbon Neutrality Roadmap

Source: Geely Holding Group ESG Report

From a value-driven perspective, it transforms environmental responsibility into competitive advantage through pathways like diversified new energy products and green supply chain construction, aligning with Porter's

mechanism linking environmental regulation, innovation, and competitive advantage. As illustrated in Figure 2, this strategic framework is characterized by significant multi-level complexity and distinct phased progression. Rather than adopting a radical "one-size-fits-all" approach, Geely scientifically formulated short-term, medium-term, and long-term objectives. This structured planning ensures both the sustainability and operational feasibility of its low-carbon transition, thereby effectively mitigating the risks associated with abrupt transformation.

5.1.2 Digital-Intelligent Strategy Framework: Dual Construction Based on Dynamic Capabilities and Ecosystem

The "Intelligent Geely 2025" strategy, with full-stack in-house R&D and ecosystem synergy at its core, reflects the integrated application of dynamic capabilities theory and ecosystem theory. The core is building dual advantages of technological autonomy and resource integration. Full-stack in-house R&D aims to build core technology barriers, break through "bottleneck" constraints, and enhance technological control. The "One Network, Three Systems" ecosystem layout forms a value network from technology to product to service by integrating upstream and downstream resources across the industrial chain, enhancing ecosystem competitiveness. The "RMB 150 billion R&D investment over 5 years" within the Nine Dragon Bay Actions provides resource guarantees for strategy implementation, embodying the logical chain of "resource input – capability building – strategy realization." The overall architecture and core elements of the "Intelligent Geely 2025" strategy are illustrated in Figure 3.



Figure 3: Geely Group's "One Network, Three Systems" Strategic Layout
 Source: Geely Holding Group official website and strategic press conference materials

5.1.3 Core Dimensions of Dual-Strategy Synergy

This study distills a "Five-Dimensional Synergy" framework, as depicted in Figure 4. Transcending traditional linear causal analysis, the framework reveals how digital intelligence technologies and green transformation achieve value multiplication in corporate practice through five specific pathways: goal coupling, technological inter-embedding, chain integration, market resonance, and data feedback. This not only extends Porter's theory of competitive advantage but also provides an actionable analytical paradigm for achieving "dual-transformation synergy." Goal Orientation Synergy: Both aim at building long-term competitive advantage. The low-carbon strategy focuses on environmental sustainability, while the digital-intelligent strategy focuses on technological leadership, jointly supporting Geely's transition to a technology-ecosystem enterprise, aligning with the core connotation of corporate sustainable development.

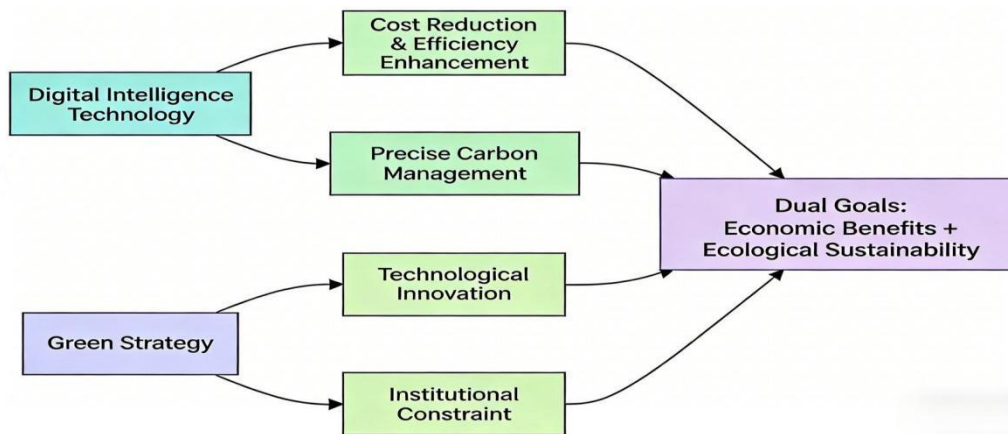


Figure 4: Synergistic Logic between Digital-Intelligent and Green-Low-Carbon Transformations

Source: Public information from the Geely Holding Group official website and findings from this study

Technology R&D Synergy: Based on resource dependency theory, digital-intelligent technologies like AI simulation and digital twins provide R&D tools and efficiency support for low-carbon technologies, while low-carbon goals provide application scenarios for digital technologies, forming a closed loop of technology complementarity and scenario empowerment. Industrial Chain Layout Synergy: The low-carbon strategy requires full-chain decarbonization of the supply chain, while the digital-intelligent strategy builds industrial internet platforms (Geega) and carbon management platforms (JiCarbon Cloud), providing technical tools for supply chain carbon footprint tracing and energy optimization, realizing the transmission of "industrial chain synergy – technology support – low-carbon compliance." Product-Market Synergy: Based on consumer behavior theory, current consumer demand for cars has shifted from transportation tools to intelligent, green mobile spaces. Geely's intelligent new energy products simultaneously meet the dual needs of intelligent experience and low-carbon environmental protection, aligning with market demand upgrade trends.

Data Management Synergy: The data collection and analysis system built by the digital-intelligent strategy provides precise support for carbon accounting and management under the low-carbon strategy. The accumulation of carbon data, in turn, feeds back into AI algorithm optimization, improving the application precision of digital-intelligent technologies, forming a positive cycle of "data – technology – low-carbon."

5.2 Organizational Synergy Mechanisms

The three-tier organizational structure of "Top-Level Coordination – Middle-Platform Empowerment – Grassroots Implementation" constructed by Geely is the key guarantee for strategic synergy implementation. Its design logic aligns with the principle of centralized-decentralized balance in organizational design theory, ensuring efficiency and flexibility in strategy execution, As shown in Figure 5.

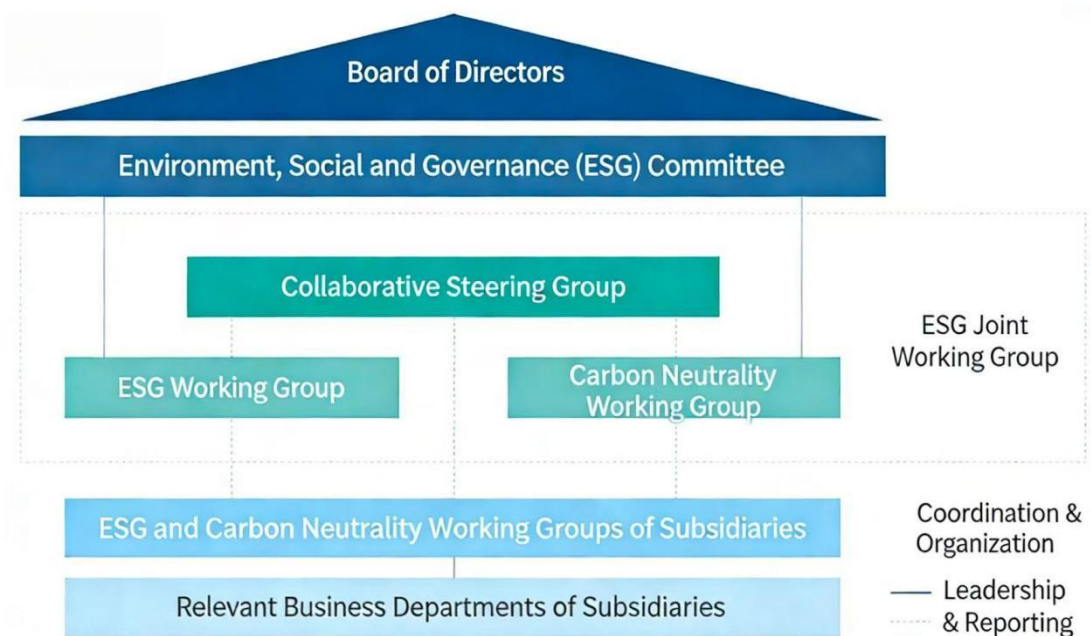


Figure 5: Simplified ESG Management Organizational Structure of Geely Group

Source: Geely Holding Group ESG Report

5.2.1 Top-Level Design: Centralized Guarantee for Strategic Decision-Making

The Sustainable Development Committee, as the highest decision-making body led directly by top group executives, is responsible for strategic planning and goal setting. This reflects the advantage of "centralized" decision-making, ensuring consistency in the top-level design of the dual-driven strategy and avoiding strategic deviations caused by departmental conflicts of interest. Its clear key targets, such as a 25% reduction in per-vehicle carbon emissions by 2025, provide clear direction for subsequent execution.

5.2.2 Middle-Platform Empowerment: Collaborative Hub for Strategy Execution

The establishment of the ESG Joint Working Group (Synergy Steering Group + ESG Working Group) addresses the problem of strategic implementation gaps. The Synergy Steering Group, composed of CEOs from the group and subsidiary business units, enables cross-business unit resource integration. The ESG Working Group is responsible for cross-departmental collaboration, breaking down organizational silos. This design aligns with the synergistic logic of a "matrix organization," ensuring strategic decisions are translated into executable tasks through horizontal and vertical communication mechanisms.

5.2.3 Grassroots Implementation: Performance-Driven Mechanism for Strategy Execution

Incorporating sustainability indicators into annual business performance assessments (5% weight in 2023) and linking them to compensation incentives (implemented in 2024) creates a closed-loop mechanism of "assessment – incentive – execution." The selected assessment indicators, mainly including carbon emission reduction rate, new energy penetration rate, and number of green technology patents, highly align with the goals of the dual-driven strategy. This reflects the core idea of Management by Objectives (MBO), motivating grassroots units through quantified indicators and incentive mechanisms to achieve precise alignment between strategic goals, assessment indicators, and execution behaviors.

6. Innovative Practices Integrating Digital-Intelligence and Green-Low-Carbon: Mechanisms and Outcomes

6.1 Digital-Intelligence Drives Low-Carbon Production

Digital-intelligent technologies achieve full-chain decarbonization in manufacturing by reconfiguring production processes and optimizing resource allocation. The core mechanism is "Digital Twin + AI Optimization + Data Closed-loop," aligning with the concept of smart production in Industry 4.0 theory.

At Geely's Yuyao factory, the product digital twin system built on 3D software like CATIA and UG completes processes such as weld spot inspection and welding sequence optimization in a virtual environment, reducing physical prototype costs, resource consumption, and shortening new product development cycles. Using VR and data collection technologies, it monitors equipment status 24/7, with predictive maintenance reducing unexpected downtime and associated energy waste. At Geely's factory in Hunan, the built EMS Energy Management System fully collects data on electricity, steam, and natural gas consumption. AI algorithms dynamically optimize energy allocation, reducing energy consumption and carbon emissions. In 2023, energy consumption per unit product decreased by 18.29% compared to 2021, carbon emission intensity decreased by 13.8%, and implemented carbon reduction projects achieved a total reduction of 6,359 tons of CO₂.

Geely's Zeekr 5G Smart Factory leverages 5G+MEC technology for equipment interconnection, creating a new smart manufacturing system characterized by "transparency, agility, and intelligence." The factory uses 100% green electricity. Energy consumption per vehicle decreased by 14.6% year-on-year, and hazardous waste generation per vehicle decreased by 27%. In 2023 alone, the Zeekr 5G Smart Factory achieved an annual carbon reduction of nearly 27,900 tons, equivalent to planting 1.55 million trees. At Geely's Chengdu Intelligent Connectivity Factory, the JiCarbon Cloud platform is deeply integrated with the MES system. The production of the Geely Haoyue Pro employs fully automated intelligent welding with 116 body measurement points, achieving "zero" outflow of defective products. It also utilizes 115 intelligent standard quality inspection terminals covering the entire manufacturing process from parts, stamping, welding, painting, assembly, to final vehicle inspection, ensuring comprehensive product quality and reducing energy waste and emissions from rework.

It is worth noting that the phased and entity-specific goal setting illustrated in Figure 6 essentially constitutes a "goal-driven innovation mechanism." The digital intelligence investments made by individual factories are not spontaneous initiatives; rather, they represent mandatory transformations driven by explicit KPIs assigned under the group's unified timeline. Consequently, all factory-level practices must align with and serve the strategic objectives depicted in the figure. This top-down pressure transmission mechanism, where overarching goals penetrate down to operational levels, stands as the core advantage enabling Geely to efficiently advance the integration of digital intelligence technologies with low-carbon production.

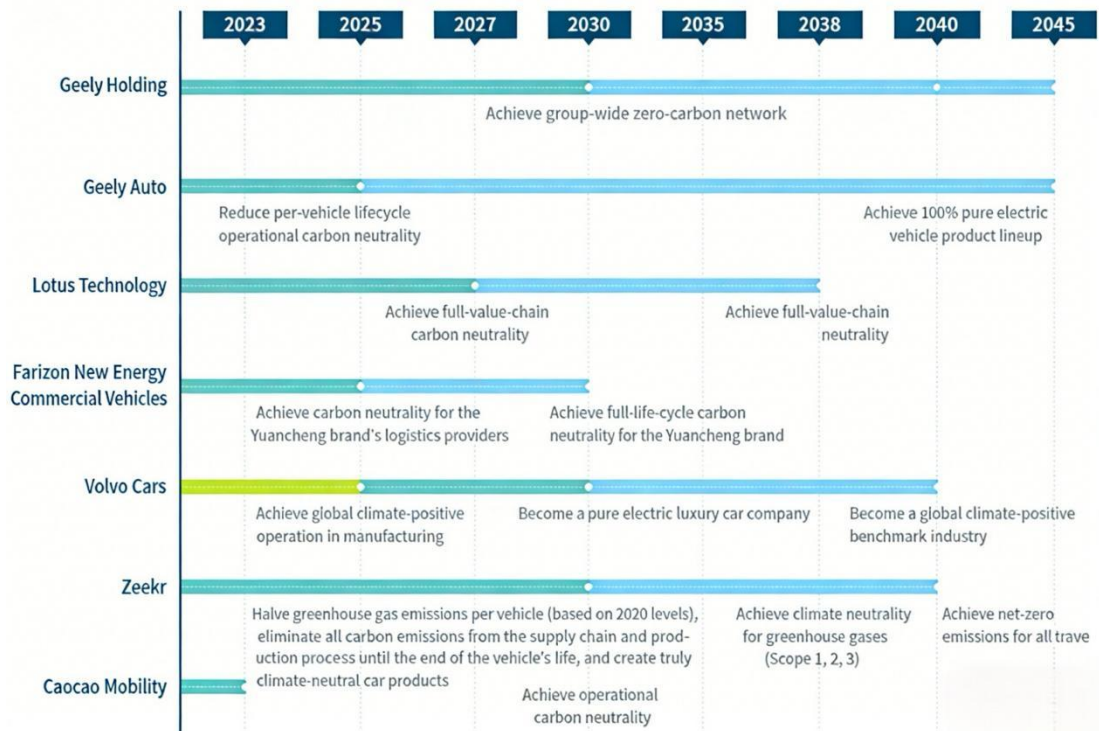


Figure 6: Carbon Reduction Targets for Geely Group's Business Segments

Source: Geely Holding Group ESG Report

6.2 Digital-Intelligence Facilitates Breakthroughs in New Energy Technology

Leveraging the Xingrui Intelligent Computing Center and advanced AI large models, Geely has achieved multi-dimensional breakthroughs in new energy technologies. This progress is driven by a core operational logic of "computing power support – algorithm optimization – scenario implementation." As illustrated in Figure 7, Geely has cultivated profound capabilities in intelligent driving perception, decision-making, and control algorithms. Key technological clusters include high-precision map construction, multi-sensor fusion, and end-to-end large models. This mechanism of "technology base reuse" generates significant spillover effects, drastically reducing the marginal R&D costs associated with new energy technologies. These findings align closely with innovation theory, specifically regarding combinatorial innovation and scenario empowerment.

In the domain of battery production, Geely's self-developed Aegis Short-Blade Battery utilized a digital twin platform to optimize its design, settling on a "golden dimension" of 580 mm. This process increased single-cell stiffness by 30%, making it the world's first cell to withstand a live ammunition penetration test (5.8 mm bullet). Furthermore, the second-generation Brick Battery, deployed in the Zeekr 007, leveraged AI simulation to optimize electrode material structures. This innovation achieved a charging rate of 4.5C, setting a mass-production record of "5 minutes of charging for an additional 265 km of range." Concurrently, Geely established a Global Green Innovation Center, which has incubated 15 cross-domain technologies. Notable examples include "vehicle-road coordination-based intelligent energy consumption optimization algorithms" and "blockchain traceability systems for battery recycling," accelerating the practical application of digital-intelligence and low-carbon technologies.

Regarding circular ecology and energy networks, Geely's proprietary blockchain traceability system encompasses the entire lifecycle from raw material extraction to recycling, establishing an innovative, integrated automotive circular ecosystem. In 2024 alone, this initiative facilitated the closed-loop recycling of over 15,000 tons of circular steel and approximately 5,000 tons of circular aluminum, resulting in a carbon emission reduction of 115,000 tons. In the realm of battery swapping infrastructure, the Yi Yi Huan Neng brand employs cloud computing and blockchain to construct a distributed smart energy grid. This platform not only resolves challenges in comprehensive charging and swapping services but also aggregates diverse clean energy sources (wind, solar, hydro, and nuclear), creating an IoT-enabled ecological platform for ubiquitous energy supply.

Moreover, digital intelligence plays a pivotal role in frontier fields such as hydrogen and methanol power. Geely utilized digital twins to optimize fuel cell stack structures, leading to the joint development of the FCE115 fuel cell engine. This engine enables cold starts at -30°C, delivers an ultra-long range of 850 km, and maintains hydrogen consumption below 6 kg/100 km, marking a significant step toward the commercial viability of hydrogen energy. Similarly, the 5th Generation Super Alcohol-Electric Hybrid technology employs AI algorithms to optimize combustion efficiency, elevating the thermal efficiency of methanol engines to 48.15%. Vehicles equipped with this technology consume only 9.2 L of methanol per 100 km, achieving a 42% reduction in carbon emissions compared to traditional gasoline vehicles—equivalent to 0.8 tons of carbon reduced for every 10,000 km driven.

Collectively, these achievements represent Geely’s optimal environmental technology solution for the new energy era, significantly propelling the rapid development of China’s clean and green energy industrial chain.

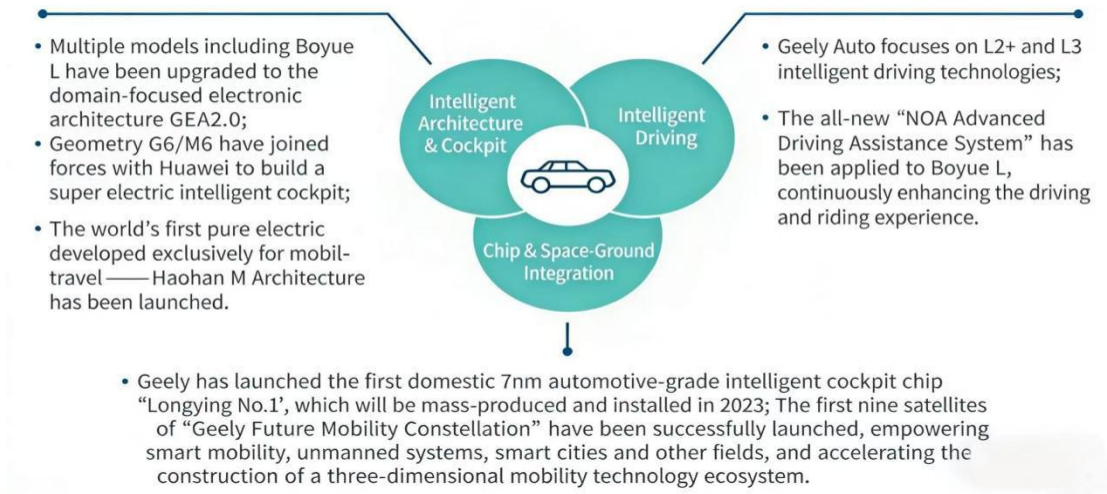


Figure 7: Partial Progress in Geely Group's Intelligent Driving Technology

Source: Geely Holding Group Technology Launch Event and Annual Innovation Report

6.3 Digital-Intelligence Enhances User Low-Carbon Participation

Geely guides user participation in low-carbon actions through digital platforms. The core mechanisms are cognitive guidance, behavioral incentives, and community interaction, aligning with the three elements of "attitude, subjective norm, and perceived behavioral control" in the Theory of Planned Behavior (TPB).

Cognitive Guidance: The Z-Green community pushes low-carbon knowledge weekly, helping users establish a positive attitude that "low-carbon travel = environmental protection + convenience," lowering the cognitive threshold.

Behavioral Incentives: The "Ji Mileage" point redemption feature in the "Ji Carbon" mini-program and the "Carbon Benefit Mileage" function in Cao Cao Mobility enhance users' perceived benefits of participation through material incentives (gifts, coupons), strengthening behavioral motivation.

Community Interaction: The carbon reduction ranking PK activities in the Z-Green community create "group norms," enhancing the sustainability of user participation through community pressure and a sense of honor.

Data shows that by the end of 2023, the three platforms cumulatively facilitated a carbon reduction of 1.788 million tons, equivalent to the annual carbon sequestration of 24.74 million Mongolian Scotch pines. This verifies the effectiveness of the transmission mechanism where digital-intelligent tools guide user behavior to contribute to societal emission reduction.

6.4 Green-Low-Carbon Ecosystem Partner Collaboration

Geely's ecological collaboration framework is anchored in the core objective of "full-lifecycle low-carbon transformation of the supply chain." Grounded in Supply Chain Collaboration Theory and Stakeholder Theory, this strategy advances comprehensive carbon reduction across the industrial value chain through a tripartite pathway: supplier governance, industrial synergy, and logistics modernization.

Low-Carbon Supplier Governance: To enforce environmental compliance, Geely has institutionalized strict requirements via the Geely Supplier Code of Conduct. Leveraging the "Drive Sustainability" platform, the corporation provides specialized carbon management training to its partners. This initiative has successfully onboarded 439 suppliers to utilize the JiTan Cloud system for rigorous carbon accounting. Operating on a mechanism of "standard setting – capacity building – data traceability," this approach ensures robust low-carbon compliance throughout the supply base.

Industrial Synergy Platforms: As illustrated in Figure 8, Geely has constructed a diversified matrix of green mobility and logistics ecosystems. Three flagship platforms—Green Wisdom Link, Wanwu Youhao, and Sunshine Mingdao—are strategically deployed to address specific scenarios, ranging from urban last-mile delivery to heavy-duty trucking logistics. By facilitating intelligent coordination across the "human-vehicle-cargo-station-energy" nexus, these platforms optimize logistical efficiency while concurrently mitigating carbon emissions. This architecture exemplifies the strategic logic of "platform-based integration, resource optimization, and collaborative decarbonization."



Figure 8: Selected Illustrations of Geely Group's Green Mobility Initiatives

Source: Geely Holding Group ESG Report and public materials from its mobility brands

Logistics Energy Innovation: Adhering to a diversified multi-energy technology roadmap, Geely actively promotes the proliferation of new energy logistics vehicles and the development of a comprehensive green

refueling infrastructure. The core strategic paradigm follows a trajectory of "technology substitution – model innovation – logistics decarbonization," thereby catalyzing the broader transformation of China's logistics sector toward an intelligent, zero-carbon future.

Collectively, this end-to-end collaborative model, which spans from upstream supplier engagement to downstream operational deployment, signifies a profound strategic metamorphosis for Geely, marking its transition from a traditional automobile manufacturer into an orchestrator and enabler of a holistic green mobility ecosystem.

7. Conclusion

Driven by the global digital revolution and carbon neutrality agenda, digital-green dual transformation has become a critical strategy for emerging market latecomer manufacturing firms to achieve sustainable catch-up. Adopting a single-case study of Geely Group and grounded in strategic synergy theory and dynamic capabilities theory, this study addresses key research gaps regarding bidirectional empowerment mechanisms, full-value-chain synergy, and context-specific practices of Chinese latecomer automakers. Three core findings emerge from this research. First, Geely implements a closed-loop dual transformation model via a four-dimensional synergy mechanism: strategic leadership, organizational support, technological integration, and ecological synergy, aligning phased digital capability upgrades with long-term low-carbon strategies. Second, sustained dual-strategy synergy relies on a triadic architecture of strategic fit, organizational alignment, and data support, ensuring cross-departmental execution and full-value-chain operational efficiency. Third, Geely has built a full-value-chain decarbonization system featuring a mutually reinforcing bidirectional empowerment cycle, where digital technologies enable precise low-carbon development, and green targets in turn drive digital technology iteration.

This study offers three key theoretical contributions. It constructs a four-dimensional framework for firm-level digital-green synergy and clarifies its bidirectional empowerment logic; it extends strategic synergy and dynamic capabilities theories to explain latecomer firms' sustainable transformation; and it provides context-specific empirical evidence from Chinese automakers to complement the literature dominated by developed-market studies. For practical implications, the findings provide actionable guidance for latecomer automotive enterprises, emphasizing that dual transformation requires top-level strategic alignment rather than isolated technology investment. For policymakers, targeted support for core digital R&D, full-value-chain carbon management, and cross-industry collaboration can accelerate the manufacturing sector's green and digital transition.

This research has two primary limitations. First, the single-case design limits the generalizability of findings to other manufacturing sectors or institutional contexts. Second, the reliance on secondary data restricts the in-depth analysis of micro-level decision-making processes for digital-green synergy. Future research can expand the sample to multi-case or large-sample quantitative studies to test the framework's universality; collect primary interview data to explore micro-level implementation mechanisms; and conduct longitudinal analysis to examine the long-term performance effects of digital-green dual transformation on latecomer firms' sustainable catch-up.

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