System Dynamics and Environmental Constraints: How CEOs Are Redefining Strategy for Sustainable Corporate Transformation

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Abstract

Based on exploring how the application of System Dynamics Modelling (SDM), combined with an increased awareness of environmental constraints, influences strategic decision-making among corporate executives pursuing sustainability transformation. Drawing upon the principles of systems thinking and environmental frameworks such as the Planetary Boundaries and Limits to Growth, the study investigates how executives adapt to complex, dynamic challenges that transcend traditional business metrics. Using qualitative data from in-depth interviews with five CEOs across diverse sectors, this research identifies common themes around how leaders perceive ecological limits and systemic feedback, and how this shapes long-term strategy formation.

Furthermore, the study integrates quantitative simulation using the World3 model to demonstrate the systemic impacts of corporate decisions on pollution, resource depletion, and industrial output over time. The findings suggest that CEOs who are informed by systems thinking, and environmental thresholds are more likely to engage in strategic foresight, invest in resilience, and redefine corporate success beyond short-term profit. The paper contributes to the field by demonstrating the practical relevance of SDM in bridging the gap between theoretical sustainability imperatives and executive-level decision-making. It also offers a conceptual framework for integrating SDM with sustainability governance, highlighting the potential for more adaptive, long-term strategic planning in the face of ecological disruption.

Keywords: System Dynamics Modelling (SDM), Corporate Sustainability Strategy, Systems Thinking, Environmental Constraints, Executive Decision-Making

JEL R11, R58, Q58

Introduction

The accelerating environmental crises of the 21st century—climate change, biodiversity loss, and natural resource depletion—have rendered traditional business models increasingly obsolete. In a global economy shaped by finite ecological boundaries, corporations are under intensifying pressure to move beyond short-term profit maximisation and address the broader societal and environmental consequences of their operations. While awareness of sustainability has grown markedly in recent years, a gap persists between strategic intent and meaningful organisational transformation. This disjuncture is often rooted in a failure to appreciate the systemic nature of environmental challenges, which are non-linear, interconnected, and time dependent.

A growing body of research suggests that effective corporate sustainability transformation requires a paradigm shift in how organisations conceptualise value, risk, and long-term viability. Central to this shift is the adoption of systems thinking—a holistic approach that recognises the dynamic interplay between business activity and planetary systems. Within this context, System

Dynamics Modelling (SDM) emerges as a powerful methodological tool, capable of simulating the feedback loops, delays, and causal structures that shape environmental and organisational outcomes over time.

This study investigates how the integration of SDM and a heightened awareness of environmental constraints influence the strategic behaviour of corporate leaders. Specifically, it explores how CEOs interpret and respond to ecological limits—such as those defined by the Planetary Boundaries framework—and how this awareness informs long-term strategic planning. Drawing upon qualitative interviews with five CEOs from diverse sectors, alongside simulations using the World3 model, this paper offers insights into how decision-makers perceive sustainability not merely as compliance, but as a core strategic imperative.

The research contributes to the discourse on corporate sustainability by bridging quantitative systems modelling with executive-level cognition and leadership. In doing so, it advances a conceptual model of strategic transformation that is responsive to both regulatory frameworks and the biophysical realities that underpin corporate operations.

The paper is guided by the following research question:

How does the application of System Dynamics Modelling and awareness of environmental constraints shape CEOs' strategies for corporate sustainability transformation?

General Background

Systems thinking has emerged as a critical lens through which corporations can address the complexity of sustainability. Pioneered by scholars such as Donella Meadows (2008), Peter Senge (1990), and Russell Ackoff (1981), systems thinking recognises that organisations are embedded within larger socio-ecological systems and that interventions in one part of the system can have unintended consequences elsewhere. This holistic approach is particularly suited to understanding the interdependence between economic activities, environmental degradation, and long-term viability.

Meadows' *Thinking in Systems* (2008) articulates foundational elements of systems thinking, including feedback loops, time delays, and leverage points. Her earlier work, *The Limits to Growth* (Meadows, Meadows, Randers, & Behrens, 1972), introduced the World3 System Dynamics model, which warned that unchecked industrial and population growth could lead to ecological collapse within a finite planetary system. Contemporary studies continue to affirm the model's predictive validity (Branderhorst, 2020; Turner, 2014).

System Dynamics Modelling (SDM), developed by Forrester and popularised by Meadows and Sterman (2000), provides a quantitative framework to simulate complex systems over time. In the context of corporate sustainability, SDM enables organisations to assess the long-term impacts of decisions related to resource use, pollution, capital investment, and regulation. Using causal loop diagrams (CLDs), stock-and-flow structures, and scenario testing, SDM allows business leaders to visualise how feedback mechanisms shape sustainability trajectories (Sterman, 2000).

Beyond its technical function, SDM facilitates strategic foresight by surfacing systemic risks and helping organisations identify effective leverage points. When deployed within a corporate context, it enables executives to assess how small, targeted interventions can trigger broader, long-term transformation.

Environmental Limits: Planetary Boundaries and Limits to Growth

The Planetary Boundaries framework, introduced by Rockström et al. (2009), defines the biophysical limits within which humanity must operate to maintain Earth's stability. It identifies nine Earth system processes—such as climate regulation, biodiversity, and biogeochemical flows—of which at least four have already exceeded their safe thresholds (Steffen et al., 2015). These breaches highlight the urgency for corporations to develop sustainability strategies that are ecologically informed.

This framework builds upon the foundational insights of *Limits to Growth* (Meadows et al., 1972), which modelled the consequences of exponential growth in a world of finite resources. Raworth's (2017) "Doughnut Economics" further refines this discourse by arguing that economic systems must operate between a social foundation and an ecological ceiling, thus ensuring human well-being without breaching environmental limits.

Together, these models suggest that respecting environmental constraints is not only an ethical necessity but also a strategic imperative. They form a compelling basis for corporate leaders to embed environmental thresholds into core decision-making processes and to develop strategies that ensure long-term viability and resilience.

CEO Strategic Cognition and Environmental Awareness

The influence of systems thinking and environmental limits on corporate strategy ultimately depends on how these ideas are understood and acted upon by organisational leaders. Strategic cognition—the ways in which CEOs interpret information, evaluate risks, and anticipate outcomes—has been identified as a key factor in driving sustainability-oriented decision-making (Hahn, Preuss, Pinkse, & Figge, 2014).

Empirical research shows that leaders who adopt a systems perspective are more likely to embrace long-term thinking and see sustainability as an opportunity rather than a constraint (Busch, Bauer, & Orlitzky, 2016). They are also more likely to align corporate objectives with global frameworks such as the Sustainable Development Goals (United Nations, 2015) and the EU's Corporate Sustainability Reporting Directive (European Commission, 2021).

Nevertheless, structural barriers persist. Traditional performance metrics, such as quarterly earnings and shareholder returns, can undermine long-term sustainability planning. In this context, SDM provides a critical counterbalance. By modelling long-range scenarios, SDM helps executives to visualise delayed consequences and reinforce the value of early, preventative action (Sterman, 2000).

Whiteman, Walker, and Perego (2013) argue that awareness of ecological boundaries—such as carbon emissions or land-system change—can directly shape how executives allocate capital, set priorities, and evaluate performance. The EU's "double materiality" concept, now embedded in sustainability reporting regulation, reflects this perspective by requiring firms to account for both the external and internal dimensions of environmental risk (EFRAG, 2022).

Ultimately, the convergence of SDM, systems thinking, and environmental awareness within the executive domain offers a framework for deep, strategic transformation—provided that corporate leaders are willing to challenge conventional assumptions and embrace a more adaptive, long-term view.

Theoretical Framework

This study's theoretical framework integrates three interdependent strands of scholarship: systems thinking, System Dynamics Modelling (SDM), and environmentally informed corporate governance. Together, these perspectives offer a robust foundation for examining how corporate leaders conceptualise sustainability challenges and formulate strategy in response to ecological constraints.

Systems thinking provides the conceptual architecture for understanding corporations not as isolated entities but as components within broader ecological, regulatory, and economic systems. As articulated by Meadows (2008) and Senge (1990), systems thinking emphasises feedback loops, delays, non-linear causality, and interdependencies—features that characterise sustainability challenges. Unlike reductionist models, systems thinking acknowledges that interventions can generate ripple effects across complex, adaptive systems.

Within this paradigm, corporate leaders are encouraged to identify leverage points—places within a system where small changes can lead to significant outcomes (Meadows, 1999). For sustainability strategy, this involves shifting attention from surface-level compliance to root causes, long-term dynamics, and systemic innovation. Systems thinking thus not only facilitates holistic analysis but also redefines leadership roles in addressing environmental and social risks.

System Dynamics Modelling (SDM), as developed by Forrester and operationalised in the *Limits to Growth* studies (Meadows et al., 1972), extends systems thinking into a simulation environment. SDM enables the mapping and quantification of feedback-rich systems, making it possible to test strategic scenarios under varying assumptions of resource use, pollution, capital allocation, and policy intervention (Sterman, 2000).

In this study, the World3 model provides a conceptual and analytical tool for simulating the interactions between corporate behaviour, environmental constraints, and long-term outcomes. By incorporating variables such as industrial output, sustainability investment, and regulatory pressure, SDM reveals how seemingly incremental corporate actions can produce significant systemic effects—both beneficial and detrimental.

Moreover, SDM supports strategic foresight by helping CEOs visualise delayed consequences, rebound effects, and trade-offs across time horizons. In doing so, it serves as a bridge between abstract sustainability principles and concrete strategic choices, offering data-driven guidance on navigating environmental complexity.

The concept of environmental constraints is grounded in two major frameworks: the *Limits to Growth* model and the Planetary Boundaries framework (Rockström et al., 2009). Both underscore the reality that human activity, including corporate operations, is bounded by the finite capacity of Earth's life-support systems. These ecological thresholds—climate stability, biosphere integrity, and resource cycles—constitute hard limits beyond which socio-economic collapse becomes increasingly probable (Steffen et al., 2015).

The Planetary Boundaries framework, in particular, offers scientific metrics for identifying when economic activity exceeds ecological safe zones. For corporate strategists, these boundaries function as non-negotiable guardrails that must inform investment, innovation, and reporting decisions. Failure to operate within these thresholds poses reputational, regulatory, and existential risks to business continuity.

The research suggests that when CEOs internalise such constraints—conceptually and strategically—they are more likely to transition from a compliance mindset to one of adaptive transformation. Environmental awareness becomes not simply a matter of reporting, but of reimagining how value is created, sustained, and distributed across stakeholders.

Bringing these elements together, the proposed theoretical model suggests that the application of SDM, underpinned by systems thinking and informed by ecological limits, enables CEOs to redesign strategy toward long-term sustainability.

In this framework:

- Systems thinking provides the worldview,
- SDM offers the technical modelling capability,
- Planetary boundaries set the environmental parameters, and
- Strategic cognition acts as the executive interface translating insight into action.

The integrated approach positions corporate sustainability not as an isolated initiative but as an evolving, systems-responsive process. It further implies that CEOs who adopt this model are more likely to lead effective, long-term transformations capable of balancing profitability, resilience, and environmental stewardship.

Methodology

A sequential explanatory design was employed, beginning with qualitative data collection through in-depth interviews, followed by quantitative systems modelling to simulate sustainability scenarios. This design enables a layered exploration of the research question, examining both how CEOs perceive and articulate sustainability constraints, and how those perceptions align—or conflict—with systemic outcomes under SDM projections.

Qualitative Method: CEO Interviews and Thematic Analysis

A qualitative, interpretive approach was employed to investigate how corporate executives conceptualise and operationalise sustainability under emerging environmental constraints. The study focused on five CEOs from diverse industries—civil engineering, logistics, finance, manufacturing, and construction—each occupying the highest decision-making role within their respective organisations.

Participant Selection

The CEOs were selected purposefully to ensure a range of sectoral perspectives, particularly from high-impact or mixed-environmental-footprint industries. The sample included: a large Belgian construction firm recognised as a market leader in sustainability practices; a smaller Hungarian construction company; a UK-based logistics corporation engaged in low-emission transport innovation; a global European manufacturing firm producing industrial water pumps; and a Hungarian investment bank selected for its involvement in sustainable finance portfolios. This diversity allowed for cross-contextual insights into sector-specific challenges and strategic thinking.

A core line of inquiry examined executive understanding and preparedness for evolving policy landscapes, particularly the Corporate Sustainability Reporting Directive (CSRD) and the EU Green Deal. Respondents shared their views on how these frameworks affect disclosure practices, compliance requirements, and long-term strategic planning.

The interviews probed the tensions CEOs experience between immediate operational goals and long-term sustainability objectives. Executives were asked to reflect on how short-term financial metrics and shareholder expectations impact their ability to make forward-looking investments.

Participants were invited to identify perceived feedback loops, systemic risks (e.g., supply chain disruptions, climate-induced market shifts), and high-leverage intervention points within their business models. These discussions helped uncover whether and how systems thinking is integrated into strategic planning.

Data Collection

Semi-structured interviews were conducted in October 2024, each lasting between 60 and 75 minutes. Open-ended questions explored the CEOs' views on environmental constraints, systems thinking, sustainability regulation, organisational transformation, and the role of modelling in strategic planning. All interviews were audio-recorded, transcribed verbatim, and anonymised to protect participant confidentiality. Informed consent was obtained from all participants in accordance with ethical guidelines.

Data Analysis

Thematic analysis was conducted manually using Microsoft Excel. Codes were developed inductively through repeated readings of the transcripts, allowing key patterns to emerge from the data. A comparative cross-case matrix was created to synthesise findings across the five participants, structured around five core thematic categories: (1) recognition of environmental constraints, (2) systems thinking, (3) regulatory influence, (4) organisational barriers, and (5) modelling practices. Educational background, governance structures, and sectoral context were considered during interpretation to better understand underlying divergences.

While the formal six-step process of Braun and Clarke (2006) was considered, the analysis ultimately followed a simplified, yet rigorous, thematic approach suitable for manual implementation. This included iterative refinement of themes and coding clusters, consistent with common principles of interpretive qualitative research. Direct quotations were paraphrased to maintain anonymity while preserving conceptual meaning.

This approach enabled the identification of shared narratives, as well as points of tension or divergence in how CEOs interpret sustainability and attempt to operationalise it within complex organisational and regulatory landscapes.

Each interview followed a flexible but consistently themed protocol, allowing for both comparative analysis and individual depth. Conversations were conducted either in person or via secure video conferencing platforms, depending on participant availability and location. Interview durations ranged from 60 to 90 minutes. All interviews were recorded—with participant consent—and subsequently transcribed for qualitative analysis using thematic coding techniques.

Quantitative Method: System Dynamics Modelling (SDM)

The System Dynamics simulation employed in this study is based on the World3 model, a refined version of the global systems model originally developed at the Massachusetts Institute of Technology (MIT) under the leadership of Jay W. Forrester. While the initial model was published in *The Limits to Growth* (Meadows, Meadows, Randers, & Behrens, 1972), the World3 version was subsequently enhanced by Donella Meadows and colleagues in later updates of the book (1992; 2004) to reflect new data, policy developments, and system feedback.

The World3 model is designed to simulate the long-term interactions between population growth, industrial output, natural resource use, environmental pollution, and capital investment.

It offers a dynamic framework for testing how different strategic and policy choices impact global sustainability over multi-decade timeframes.

The research used SDM to model scenarios across different corporate decision pathways:

- Business-as-usual (BAU)
- Early sustainability investment
- Delayed response to environmental pressure
- High-regulation and low-regulation futures

Year	Resource Stock (R) (CO2 (Ton))	Industrial Output (IO)	Pollution (Pol) CO2/year 5 tons CO2 per 10,000 EUR (IO)	Sustainability Investment (SI) EUR/Year 5%/AR	Pollution Reduction Efficiency (Pol) CO2/year 0.05 tons per 1000 EUR Invested in Sustainability	Regulatory Compliance (RC) % of regulatory fulfillment
2017	1000000	€ 1,000,000.00	5.0	€ 150,000.00	2.50	80.0%
2018	950000	€ 1,050,000.00	525.0	€ 157,500.00	7.50	82.3%
2019	897500	€ 1,102,500.00	551.3	€ 165,375.00	7.88	84.6%
2020	842375	€ 1,157,625.00	578.8	€ 173,643.75	8.27	87.1%
2021	784493.75	€ 1,215,506.25	607.8	€ 182,325.94	8.68	89.7%
2022	723718.4375	€ 1,276,281.56	638.1	€ 191,442.23	9.12	92.4%
2023	659904.3594	€ 1,340,095.64	670.0	€ 201,014.35	9.57	95.3%
2024	592899.5773	€ 1,407,100.42	703.6	€ 211,065.06	10.05	98.3%
2025	522544.5562	€ 1,477,455.44	738.7	€ 221,618.32	10.55	101.5%
2026	448671.784	€ 1,551,328.22	775.7	€ 232,699.23	11.08	104.8%
2027	371105.3732	€ 1,628,894.63	814.4	€ 244,334.19	11.63	108.3%
2028	289660.6419	€ 1,710,339.36	855.2	€ 256,550.90	12.22	112.0%
2029	204143.674	€ 1,795,856.33	897.9	€ 269,378.45	12.83	115.8%
2030	114350.8577	€ 1,885,649.14	942.8	€ 282,847.37	13.47	119.9%

Figure 1. System Dynamics Modelling

Created by the Author from a Pilot Case

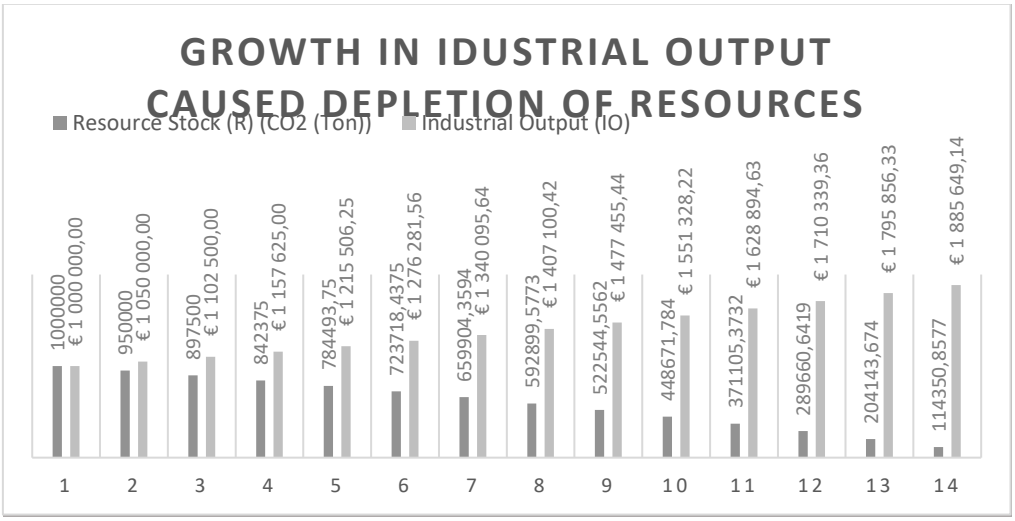

Figure 2. Industrial Growth causing Natural Resource Depletion on the Planet with Finite Resources

Source: Created by the Author based on System Dynamics Modelling in Excel 2024

Causal loop diagrams and stock-and-flow structures were used to visualise how sustainability initiatives affected pollution, capital decay, and industrial decline over time.

These outputs helped evaluate the systemic implications of the strategic patterns identified in the interviews.

All participants have given informed consent, and data collection followed ethical protocols approved by the relevant university authority. Interviewees were anonymised, and no company-specific confidential information was disclosed. SDM simulations were theoretical and not based on proprietary business data.

Limitations

Several limitations should be acknowledged in the context of this research. First, the relatively small sample size (n = 5) constrains the generalisability of the interview findings. While the participants were selected to represent a cross-sectoral view and to maximise depth through semi-structured conversations, the findings should be interpreted as indicative rather than exhaustive. The insights are valuable for thematic exploration but do not claim statistical representativeness.

Second, the use of the World3 model, though theoretically grounded and well-established in macro-scenario modelling, poses limitations when applied to firm-level strategic contexts. Its design is suited to simulating global ecological and economic trends rather than capturing the granularity of sector-specific or enterprise-specific decision-making. As such, its integration in this research serves more as a heuristic and framing tool than as a precise forecasting engine.

Third, there was considerable variability in participants' familiarity with systems thinking and System Dynamics Modelling (SDM). While some CEOs demonstrated a nuanced understanding of feedback loops and dynamic complexity, others approached sustainability in more conventional or compartmentalised ways. This variation may have influenced the alignment between the interview data and the theoretical constructs of SDM.

Fourth, the quality and interpretive value of simulation outputs are inherently limited by the assumptions embedded within the models. Factors such as input variable ranges, scenario framing, and temporal scope can significantly influence results. Caution must be exercised in drawing firm conclusions from such models, particularly in executive decision-making contexts.

Results

CEO Interview Findings (Thematic Analysis)

Thematic analysis of five semi-structured interviews provided insight into how CEOs from different sectors are engaging with sustainability-related challenges and constraints, revealing notable variation in strategic interpretations and responses.

Recognition of Environmental Constraints

All five CEOs acknowledged environmental degradation—including climate change, biodiversity loss, and resource depletion—as pressing issues with strategic implications for their organisations. However, the framing of these issues varied. Three CEOs referenced environmental factors primarily as regulatory or financial risks, while two approached them as framed concerns in terms of long-term enterprise value and stewardship obligations to future generations. One CEO from the Belgian construction sector explicitly linked ecological degradation to business model

transformation, highlighting the materiality of resource scarcity in future-proofing the firm. Conversely, the Hungarian construction CEO viewed sustainability primarily through client expectations and reputational dynamics rather than ecological thresholds.

Systems Thinking and Complexity Awareness

Explicit engagement with systems thinking concepts—such as feedback loops, interdependence, and dynamic complexity—was limited to two participants. Only two CEOs demonstrated familiarity with feedback loops, interdependencies, and non-linear outcomes—primarily those in engineering-intensive sectors (civil engineering and manufacturing). Others expressed an intuitive understanding of complexity, often referencing sustainability as "connected" or "cross-cutting," but did not use systemic language or tools explicitly. A common challenge was the compartmentalisation of sustainability into discrete operational initiatives rather than its treatment as an interconnected system influencing organisational performance and long-term resilience.

Regulatory Influence and Strategic Alignment

All participants cited EU-level regulations—particularly the Corporate Sustainability Reporting Directive (CSRD), the EU Taxonomy, and Green Deal objectives—as significant drivers of organisational change. Most indicated that increased formalisation of internal sustainability functions and improved alignment with external stakeholders. However, concerns were raised regarding the speed of regulatory evolution, the administrative burden of compliance, and uncertainties around interpretive guidance. The CEO of the investment bank stressed the transformative potential of sustainable finance regulations, noting their capacity to redirect capital flows and influence corporate behaviour.

Organisational Barriers and Change Management

Despite formal endorsement of sustainability at the executive level, all CEOs reported encountering organisational friction in translating sustainability ambition into practice. Common obstacles included short-term financial incentives, middle-management resistance, and skills gaps related to ESG metrics and implementation. Several participants noted that while sustainability had been integrated into strategic documents, operationalisation remained uneven across departments and initiatives. Governance structures also varied: some firms had established sustainability committees at board level, while others lacked formal oversight mechanisms. The need for stronger internal capacity-building, revised KPIs, and clearer accountability structures was frequently emphasised.

Modelling Practices and Future Forecasting

While none of the CEOs employed formal SDM techniques, several organisations had adopted scenario analysis or climate risk tools to varying extents, often through consultancy support.
However, interest in scenario planning and climate-risk forecasting was evident, particularly from the manufacturing and logistics sectors. These firms had engaged external consultants or used in-house tools for carbon tracking and transition planning. The conceptual principles of SDM—such as feedback effects, stock-flow relationships, and long-range simulation—were generally unfamiliar. This suggests a gap between the growing awareness of systemic risks and the analytical capabilities currently employed within firms.

Simulation Insights

To complement the qualitative findings, the system dynamics model was used to simulate long-term outcomes under different sustainability transformation scenarios. This modelling exercise was not designed to mirror any one company in the study, but rather to test the implications of delayed versus proactive sustainability investment, under environmental and regulatory constraints similar to those raised in the interviews.

Three primary scenarios were explored:

Business-as-Usual (BAU) with Minimal Sustainability Investment

The trajectory demonstrates how incrementalism, even when aligned with basic regulatory compliance, fails to mitigate systemic collapse when resource and pollution limits are ignored. The model projects that under such conditions, resource depletion and pollution levels exceed planetary boundaries by mid-century, leading to sharp declines in industrial output, life expectancy, and capital availability post-2040. This scenario aligns with several CEOs' concerns about "doing the minimum" under compliance-driven sustainability strategies. It also reflects the short-term incentive structures that were identified as barriers in the interview findings.

Delayed Sustainability Transition

In this simulation, sustainability investment begins around 2030, triggered by intensifying regulatory pressure, climate crises, and rising public demand. While outcomes are more favourable than the BAU pathway, the delay results in significant overshoot of ecological thresholds—particularly in terms of CO_2 concentration and biodiversity loss—before partial recovery occurs. The ecological overshoot in this scenario exemplifies the risks of deferred strategic action—a pattern reflected in interviews where sustainability was acknowledged but not fully embedded operationally. Industrial capital stabilises only after 2070, and human well-being indicators temporarily decline. This mirrors the strategic lag identified in interviews, where CEOs acknowledged the importance of sustainability but admitted to operational inertia and internal resistance.

Early, Proactive Transition (2025 Onset, Strong Governance)

This scenario introduces a robust, integrated sustainability strategy from 2025, including shifts toward circular economy practices, emissions reduction, sustainable finance alignment, and stakeholder-driven innovation. Under these assumptions, planetary boundaries are approached but not exceeded. Industrial output stabilises, and population well-being indicators improve modestly over the long term. This scenario models the ambition of companies already investing in sustainability transformation, such as the Belgian construction firm and the manufacturing company in this study. It also illustrates the potential strategic advantage of systems thinking and early adaptation—areas currently underutilised by most participants.

Interpretation and Integration with Qualitative Data

The World3 outcomes echo the patterns observed in the interviews, illustrating how different timing and intensity of sustainability interventions can significantly influence long-term viability under ecological and regulatory constraints. While the CEOs showed increasing awareness of sustainability's importance, only a minority were taking comprehensive, forward-looking action

aligned with the proactive scenario. The lack of familiarity with modelling tools in the interview sample contrasts with the powerful forecasting insights generated by SDM in this simulation.
Taken together, the interviews and modelling suggest that stronger anticipatory capabilities and systemic tools may enhance the strategic responsiveness of firms facing accelerating sustainability pressures.

Conclusion

This study has examined how the application of System Dynamics Modelling (SDM) and the awareness of environmental constraints shape CEOs' strategies for corporate sustainability transformation. By integrating qualitative insights from executive interviews with systems-level simulations using the World3 model, the research provides a nuanced perspective on the cognitive and structural enablers—and inhibitors—of sustainable strategic leadership.

The findings suggest that while a growing number of CEOs recognise the material risks posed by ecological degradation and regulatory change, there remains a substantial gap between this awareness and the adoption of systemically grounded decision-making tools. Interviewed executives articulated a broad strategic vision for sustainability but often faced structural inertia, short-term reporting pressures, and limited exposure to formal systems methodologies such as SDM. Nevertheless, evidence of intuitive systems thinking—particularly in recognising feedback loops and leverage points—suggests fertile ground for further development.
Simulations using the World3 model reinforced the value of early, systems-informed interventions. Scenarios characterised by proactive sustainability investment and regulatory alignment produced markedly more stable outcomes than those delayed by structural or strategic inertia. These findings affirm the hypothesis that SDM, when integrated into strategic leadership practice, enhances an organisation's capacity for long-term resilience and ecological alignment.

From a theoretical standpoint, the study advances an integrative model in which systems thinking, ecological constraint recognition, and strategic cognition converge to support sustainability transformation. Practically, it calls for broader dissemination of SDM within executive circles and greater institutional support for embedding systems-based approaches into strategic planning, governance, and scenario analysis.

Future research may further explore how sectoral differences affect systems adoption, and how organisational culture influences the receptivity of CEOs to systems tools and sustainability imperatives. By advancing both understanding and application, this study contributes to the ongoing shift from fragmented corporate responsibility to integrated, systems-oriented transformation.

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Company, Position, Education	**Innovative Large Construction Company, Belgium, CEO, MA in Ecology**	**Investment Bank, Hungary, CEO & Chairman of the Board, MBA Business, Economics**	**Logistics Company, UK, CEO, BA in Logistics and Transportation**	**Multinational Manufacturing Company, Italy, CEO, MA in Economics**	**Civil Engineering Company, Hungary, Chairman, MBA Business Economics**
Themes of Thematic Analysis	**CEO 1 Insights**	**CEO 2 Insights**	**CEO 3 Insights**	**CEO 4 Insights**	**CEO 5 Insights**
SYSTEMS THINKING AND CORPORATE SUSTAINABILITY		**SYSTEMS THINKING AND CORPORATE SUSTAINABILITY**		**SYSTEMS THINKING AND CORPORATE SUSTAINABILITY**	
Familiarity with Systems Thinking	Aware but not frequently used. It causes disagreements in the boardroom.	Vaguely aware, uses elements intuitively in decision-making.	Emphasis on interconnectedness in operations to balance efficiency and environmental impact	Systems thinking critically, it requires a comprehensive interconnected view beyond organisational boundaries.	Familiar, not applying systems thinking due to decision-making speed.
Application to Sustainability Challenges	Acknowledges value but short-term profit pressures dominate.	Intuitive understanding, quick fixes are often preferred.	Practical sustainability initiatives to address both environmental impact and community relations.	Broader consideration of the environmental system is fundamental.	Sees it as long-term responsibility but challenges with owners' perspectives.
Environmental, Social, and Economic Systems	Environmental factors: equipment choices; social factors: CSR and employee well-being.	Considers ESG as an overarching strategy driven by profitability.	Limited resources and capacity for comprehensive systems mapping.	Embracing all parts of ESG	Focused on employee wellbeing and environmental considerations.
Challenges of Systems Thinking	Time is the major constraint, and decisions need to be made quickly.	Challenges include limited understanding and strategic tools.	Time and cost involved in mapping and modelling.	External stakeholder engagement and education are necessary but challenging	Time-consuming process, difficult to implement.
CHANGE MANAGEMENT MODELS AND CORPORATE TRANSFORMATION		**CHANGE MANAGEMENT MODELS AND CORPORATE TRANSFORMATION**		**CHANGE MANAGEMENT MODELS AND CORPORATE TRANSFORMATION**	
Change Management Approaches	Change management models not widely used; ownership commitment is key.	Focus on leadership and people, outside push.	Communication as a primary tool in promoting change, with limited use of formalised models like Kotter's or TQM.	A flexible, consultation-based approach to change management.	Leadership commitment is essential, owners' vision drives change.
Use of Specific Models	Not using them.	Believes models like Kotter's and TQM are theoretical.	Importance of employee buy-in for effective transformation.	Stakeholders buy-in is a major challenge, particularly in fostering internal commitment to sustainability goals.	Not using models directly, hired consultants.
Obstacles in Sustainable Transition	Lack of formalized action steps and need for ownership commitment.	People are key drivers, lack of formal models.	Ongoing assessment and stakeholder engagement for sustained progress.	External and internal communication.	Ownership commitment is key, communication across levels.
Continuous Improvement	Keeping stakeholders engaged and maintaining momentum is a challenge.	Leadership and CSR budgets drive continuous improvement.	Helps us stay accountable and responsive to emerging challenges or opportunities.	Dedicated ESG resources enhance improvement, commitment to institutionalising sustainability.	Constant engagement and monitoring needed.
MERGING SDGs WITH PLANETARY BOUNDARIES		**MERGING SDGs WITH PLANETARY BOUNDARIES**		**MERGING SDGs WITH PLANETARY BOUNDARIES**	

Alignment with SDGs	SDGs are considered but seen pessimistically, with financial system constraints.	SDGs important but profitability is still the driver.	Targeted alignment, focused on reducing environmental impact, responsible production.	Long-term alignment with the SDGs, underscored by regulatory frameworks.	Pessimistic about long-term viability without external pressure.
Interconnectedness of SDGs and Planetary Boundaries	The company does not focus heavily on the Planetary Boundaries framework.	SDGs and profitability drive actions; innovation only if profitable	Acknowledgement of planetary boundaries, with proactive steps towards reducing environmental impact.	Integrate directly and believes that the holistic thinking is important for positive impact.	Doesn't directly integrate planetary boundaries, uses SDGs for structure.
Integration into Business Strategy	External consultants are needed to integrate sustainability frameworks.	Doesn't use planetary boundaries actively, but SDGs are useful for customers	Financial and logistical barriers to scaling sustainable initiatives.	Integration of planetary boundaries is aspirational but requires navigating complex trade-offs.	Implemented SDGs but with external help.
Challenges in Balancing Growth and Planetary Boundaries	No shareholders make long-term planning easier but still challenging.	Challenges include low profit in sustainable investments	Scaling up sustainability efforts without compromising efficiency and costs is challenging	Balancing sustainability with market affordability is a challenge.	Challenges include long-term thinking without shareholder pressure.
EU REGULATORY FRAMEWORK		**EU REGULATORY FRAMEWORK**		**EU REGULATORY FRAMEWORK**	
Adapting to EU Regulations	Currently adapting with external help; complex compliance requirements.	Compliance mainly because it is must, not for true innovation	Adjustment to EU regulations as a complex but necessary adaptation.	Regulatory compliance reflects a strategic approach to aligning operations with EU sustainability mandates.	Working with external consultants, finds regulations complex.
Challenges with Double Materiality	Concept is not fully understood; knowledge gap hinders progress.	Struggles with regulations due to profit-focused culture.	Double materiality poses challenges, particularly for SMEs with limited resources.	Double materiality is challenging but seen as essential for balancing regulatory compliance.	Still unclear about double materiality and compliance.
Impact on Innovation	Regulations have pushed sustainability, but leadership commitment is crucial.	Not optimistic about SMEs under simplified frameworks.	Regulations promote visibility but add to operational workload.	EU regulations pose operational challenges but create opportunities for sustainable innovation, accountability.	Started early with voluntary self-declaration, but regulations pushed innovation.
SMEs and Simplified Frameworks	Expects resistance and challenges for SMEs to adapt to simplified frameworks.	SMEs will struggle with compliance.	SMEs may still struggle with the administrative burden.	SMEs may still struggle with the administrative burden.	Sees resistance in SMEs; complexity of compliance.
Other Regulatory Initiatives	Government leadership is key to the enforcement of new sustainability laws.	Lobbying and lack of government support are major obstacles.	Thinks governmental leadership is key for regulatory success.	Having a Specialised team to ensure compliance.	Thinks governmental leadership is key for regulatory success.
CHALLENGES AND OPPORTUNITIES FOR TRANSFORMATION		**CHALLENGES AND OPPORTUNITIES FOR TRANSFORMATION**		**CHALLENGES AND OPPORTUNITIES FOR TRANSFORMATION**	
Obstacles to Long-term Transformation	Lack of knowledge and interest are major barriers to sustainability transformation.	Always comes down to profit maximalisation.	Financial strain as a core obstacle to sustainable transformation.	Balancing sustainability with market affordability presents a major obstacle.	Lack of knowledge and interest are biggest obstacles.
Opportunities from Regulations and Frameworks	Once compliant, the company expects to benefit in multiple ways.	No opportunity yet; regulations seen as costs.	Leveraging sustainability as a competitive advantage to attract environmentally conscious clients.	Sustainability an opportunity, emphasising long-term growth over immediate profitability.	Sees benefits once compliant, but compliance is costly.

Managing Trade-offs	Long-term planning is easier due to ownership structure.	No long-term planning due to profitability focus.	Balanced approach to reconcile immediate profitability with long-term sustainability.	Long-term sustainability goals are prioritised, showing alignment with a future-focused corporate vision.	Long-term planning easier without shareholder pressure.
Measuring Progress	Still at the beginning, progress measured by profit.	Still measuring success with profit, not sustainability.	Regular measurement of environmental metrics to track and enhance sustainability efforts.	Evolving metrics underscore a commitment to refining sustainability measures.	Measuring success still focused on profit, progress is but on the way.
KEY TAKEAWAYS		**KEY TAKEAWAYS**		**KEY TAKEAWAYS**	
	1. Financial Incentives: Despite a willingness to invest in sustainability, the CEO 1 highlights how financial barriers and a lack of market incentives hinder deeper transformation. 2. Employee Buy-in: Getting employees on board with sustainability is a recurring challenge, signalling the need for stronger engagement or change management models. 3. Scaling Innovations: A core issue is the difficulty in scaling sustainable solutions, particularly in construction, where solutions like biobased materials are still limited. 4. Regulatory Impact: EU regulations are both an opportunity and a burden. While they increase visibility, they also require extensive internal work	1. Short-term Financial Focus: CEO 1 and 2 emphasises financial considerations as the main driver behind sustainability efforts, but with less optimism about the long-term benefits of sustainability initiatives. 2. Superficial Integration of Sustainability Frameworks: While the company aligns with the SDGs on paper, it is primarily motivated by external factors such as customer demand and shareholder expectations, rather than a deep commitment to planetary boundaries. 3. Regulatory Burden: Compliance with EU regulations is seen as burdensome and counterproductive to innovation, particularly in financial services where profitability is prioritized. 4. Resistance to Long-term Planning: CEO 2 candidly admits that long-term planning is not viable under his leadership, given the corporate and shareholder focus on short-term returns.	1. Financial Barriers: Although CEO 3 is committed to sustainability, financial constraints limit the ability to scale up initiatives like alternative fuel vehicles. 2. Employee Engagement: Securing employee buy-in remains a recurring challenge, reinforcing the need for a culture that values sustainability at all levels. 3. Scaling Innovations: High upfront costs and limited infrastructure pose difficulties in expanding sustainable practices, such as the use of electric vehicles. 4. Regulatory Impact: EU regulations provide a framework for transparency and visibility in sustainable practices but require additional resources for compliance.	1. Financial Incentives and Trade-offs: CEO 4 highlights the challenge of balancing financial viability with sustainability, especially in markets where increased costs could limit access to essential products. 2. Stakeholder Engagement and Communication: Achieving internal and external stakeholder buy-in is a recurring theme, underlining the importance of effective communication and education in sustainability transformation. 3. Scaling Sustainable Solutions Globally: Similar to previous interviews, CEO 4 identifies scaling as a key challenge, especially in regions with limited financial capacity. 4. Regulatory Influence on Corporate Strategy: EU regulations are both a constraint and an opportunity, helping the company focus on sustainable innovation but requiring extensive internal adaptation.	1. Change Management: Formal models like Kotter's and TQM are not used in practice by the CEO 5 company, and ownership commitment is emphasised as the key driver for sustainability transitions. 2. Sustainability Frameworks: External consultants play a critical role in helping the company integrate sustainability frameworks like the SDGs and EU regulations. 3. Regulatory Impact: EU regulations push companies toward sustainability, but the complexity of compliance is a major challenge, especially in understanding new concepts like double materiality. 4. Long-term Thinking: As a third-generation business, the Group is in a better position to adopt long-term sustainability strategies, but short-term profit still dominates decision-making.

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