Normatively Framed System Dynamics (NFSD): A Progressive Architecture for Integrating Strategic Sustainability Planning with System Dynamics

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1. Introduction

Sustainability transitions require long-term planning under deep uncertainty, multiple interacting stakeholders, and complex feedback structures. System Dynamics (SD) provides powerful methods for understanding such complexity through systems thinking, causal loop diagrams (CLDs), stock-and-flow modelling, and simulation. These methods have contributed substantially to analysing dynamic behaviour and exploring alternative future scenarios.

However, sustainability planning introduces an additional challenge. Before analysing how a system behaves, planners must first determine what constitutes a desirable future and how the boundaries of the analysis should be defined. While System Dynamics provides sophisticated methods for analysing system behaviour, it generally leaves these normative questions outside the modelling framework.

Strategic sustainability planning faces the complementary challenge. The Framework for Strategic Sustainable Development (FSSD) provides a scientifically developed normative sustainability definition together with a structured planning procedure for identifying strategic transition pathways. However, the FSSD itself contains only limited support for analysing dynamic system structures and testing alternative transition scenarios.

This paper therefore investigates the following question:

Can System Dynamics be complemented with explicit normative framing to better support strategic sustainability planning?

2. System Dynamics in Strategic Planning

System Dynamics has developed into a comprehensive field for analysing complex systems through iterative learning. It combines qualitative systems thinking with quantitative System Dynamics modelling to improve strategic decision making.

At the qualitative level, causal loop diagrams (CLDs) support understanding of system structure, feedback relationships and policy resistance. When additional insight is required, quantitative stock-and-flow models allow alternative scenarios to be simulated, revealing delays, accumulations and unintended consequences that are difficult to identify intuitively.

The resulting strategic planning process can therefore be viewed as a learning cycle in which structural understanding, modelling and implementation continuously improve one another (Figure 1).

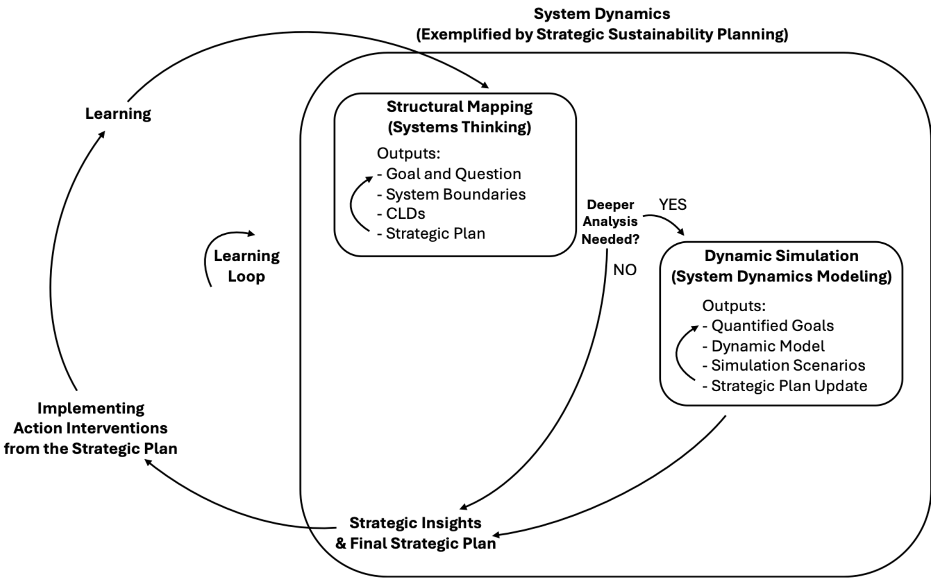

Figure 1. System Dynamics in Strategic Sustainability Planning. *How System Dynamics supports a strategic planning learning loop with strategic insights and strategic plans through progressively deeper analysis from structural mapping (with Systems Thinking) to dynamic simulation (with System Dynamics Modelling.*

Although this approach provides powerful analytical capabilities, sustainability planning introduces one additional question:

How should the desired future state guiding the modelling process be defined?
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Without explicit normative guidance, sustainability goals, system boundaries and policy evaluation criteria may become inconsistent or case dependent.

3. Adding Explicit Normative Framing

Could an explicit normative planning layer be introduced before structural analysis begins?

In this paper the normative framing is illustrated using the Framework for Strategic Sustainable Development (FSSD). The FSSD defines sustainability through eight Sustainability Principles (SPs) that serve as boundary conditions for a sustainable society rather than prescribing specific technological solutions. These principles are operationalized through the ABCD planning procedure (Figure 2):

A. Awareness and Vision
B. Baseline Assessment
C. Creative Solutions
D. Strategic Prioritization

The ABCD procedure supports backcasting from success by first defining a sustainable future before identifying strategic interventions capable of moving the current system towards that future.

Rather than replacing System Dynamics, this normative planning process complements it by clarifying the desired direction of change before structural analysis begins.

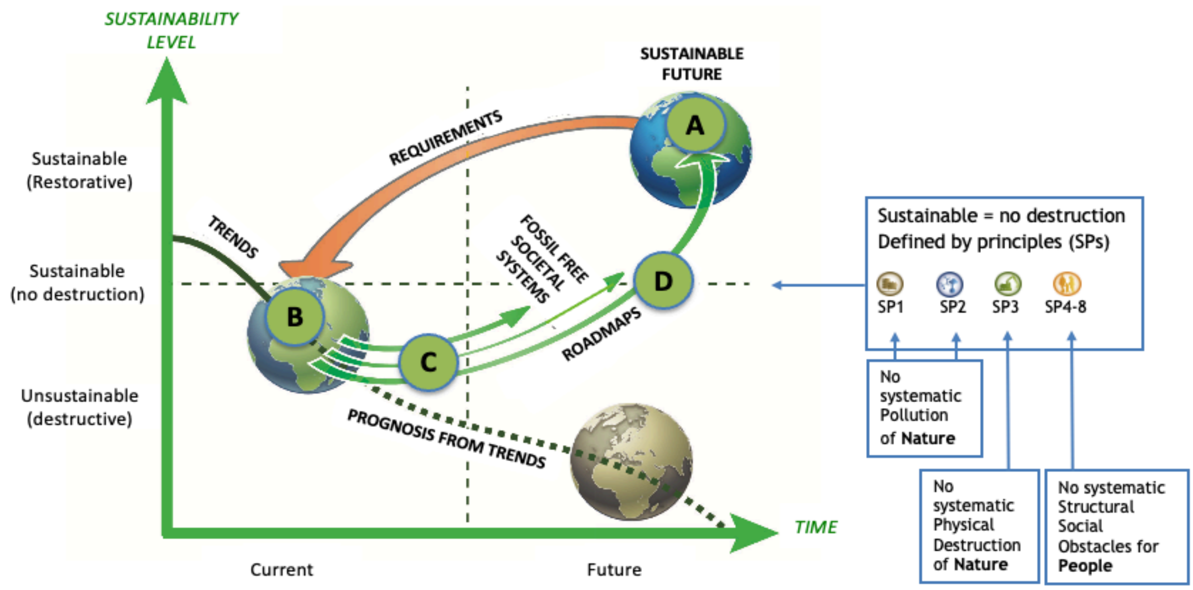

Figure 2. The ABCD process and the SPs of the FSSD. *How the current unsustainable society is on a trend towards further unsustainability and destruction while a desirable fossil free and restorative sustainable future is defined (normatively framed) by eight Sustainability Principles (SPs) (step A) and puts requirements on the current situation (step B) to define new incentives and action interventions (step C) that are combined into strategic plans (or roadmaps) that can reach sustainability (step D) (based on an illustration by Stefan Borell).*

4. Normatively Framed System Dynamics (NFSD)

Together these observations suggest a structured integration between explicit normative planning and progressively deeper System Dynamics analysis. The central contribution of this paper is the NFSD architecture, which proposes that explicit normative framing should precede structural and dynamic analysis. In this paper, sustainability constitutes the normative planning objective and the FSSD provides the explicit normative framing.

The process of the NFSD begins by defining sustainability and developing strategic transition plans through the FSSD. These strategic outputs then guide systems thinking through causal loop diagrams. If qualitative analysis proves insufficient, quantitative System Dynamics modelling can subsequently be introduced to evaluate alternative transition pathways.

Rather than prescribing simulation in every situation, NFSD introduces increasingly sophisticated analytical refinement only when additional insight is strategically justified.

The architecture therefore consists of successive analytical layers (Figure 3):

- explicit normative framing
- strategic transition planning
- qualitative structural mapping
- quantitative dynamic simulation
- implementation
- organisational learning

Importantly, the analytical layers should not be interpreted as separate sequential methodologies. Instead, they represent progressively deeper analytical iterations of the same principle-based strategic planning process. Each analytical layer revisits and refines the same ABCD planning process using progressively deeper analytical methods. Rather than replacing the previous layer, it refines the vision

(A), current reality assessment (B), intervention design (C) and strategic prioritization (D) using progressively deeper analytical methods.

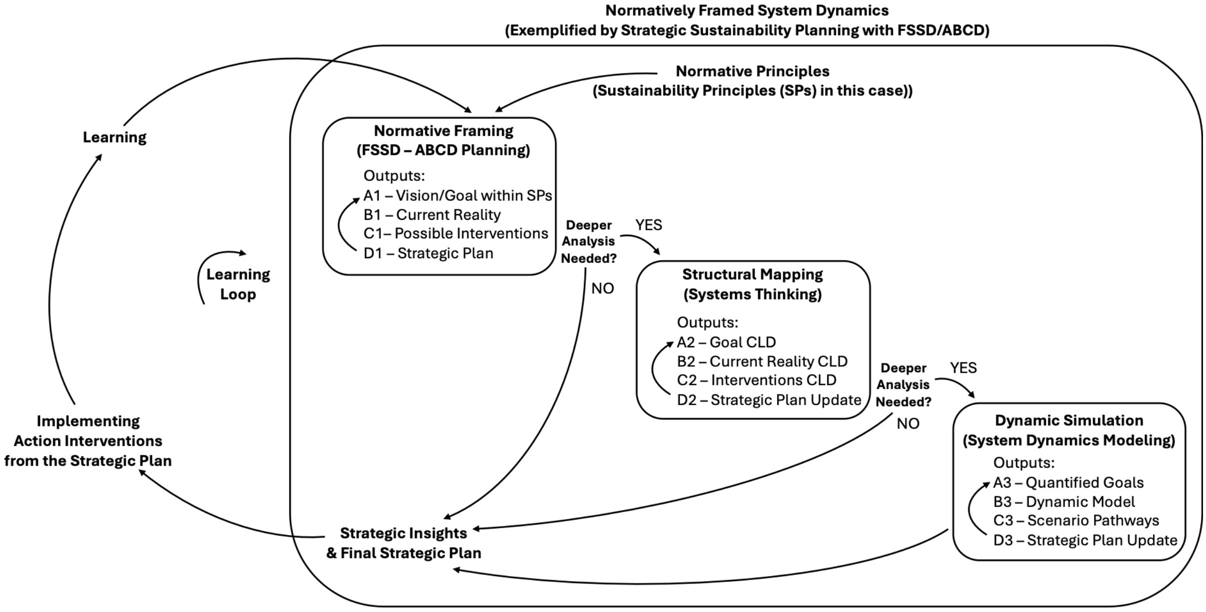

Figure 3. Normatively Framed System Dynamics (NFSD) Architecture. *The same principle-based strategic planning process is progressively revisited and refined through structural mapping and dynamic simulation whenever additional insight is strategically justified. Strategic insights from each stage guide the development of strategic plans that are then further implemented and refined in the iterative learning loop.*

This progressive deepening allows strategic planning to remain proportionate to the complexity of the decision problem while maintaining a consistent sustainability direction throughout the analysis.

5. Illustration through a Practical Case

The proposed architecture has emerged through more than two decades of conceptual and applied research and is illustrated here through a practical case of regional electromobility planning in Sweden.

The GreenCharge Southeast project illustrates the progressively deepening workflow proposed by NFSD. The planning process began with principle-based strategic planning using the FSSD and the ABCD procedure. The resulting planning process was then revisited through progressively deeper structural mapping, where causal loop diagrams refined the vision (A), the current reality assessment (B), and the strategic interventions (C/D). Finally, these refined structural insights informed the development of a System Dynamics model used to further evaluate and improve the strategic roadmap (Figure 4).

This practical case demonstrates how normative framing, structural analysis and simulation can operate within one coherent planning architecture.

The purpose of the case illustration is not to evaluate the transport system itself but to demonstrate the successive analytical phases of the NFSD architecture.

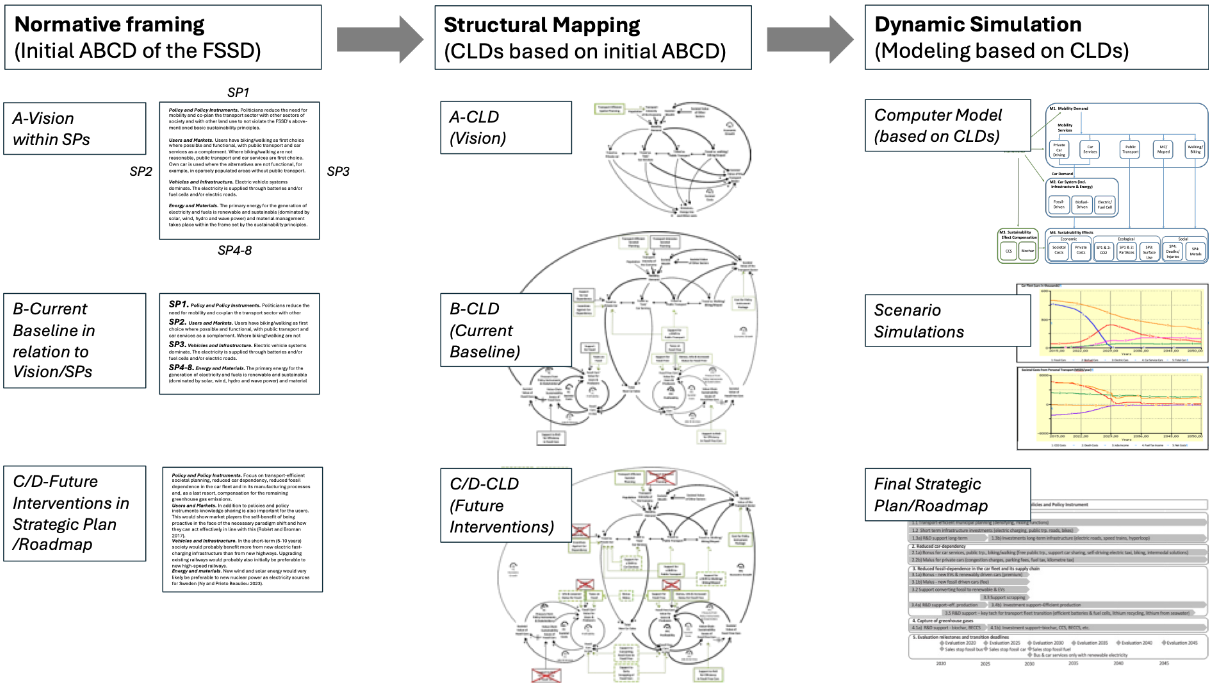

Figure 4. Progressive refinement of the same strategic planning process in the GreenCharge Southeast case through increasingly deeper analytical methods.

6 Discussion

Summary of findings

The analysis suggests that the answer to the research question is affirmative. System Dynamics can indeed be complemented by explicit normative framing through the proposed NFSD architecture.

The NFSD suggests that explicit normative framing should precede structural and dynamic analysis whenever the purpose is strategic sustainability planning. Planning begins with normative framing, in this case provided through strategic sustainability planning based on the FSSD. If strategic reasoning indicates that deeper understanding is required, structural mapping using systems thinking tools is introduced. If further insight into system behaviour is needed, system dynamics modelling can then be applied to explore dynamic consequences and evaluate alternative transition pathways. This means that rather than replacing earlier analytical stages, each successive layer revisits and refines the same strategic planning process using progressively deeper analytical methods.

The proposed architecture contributes to System Dynamics in three principal ways:

1. NFSD introduces explicit normative framing into strategic planning without modifying the analytical methods of System Dynamics itself.
2. NFSD organizes qualitative systems thinking and quantitative simulation within one progressively deepening methodological framework.
3. NFSD provides a conceptual architecture within which future methodological developments can be organised consistently.

Critical Assessment

First, the effectiveness of NFSD depends on the quality and legitimacy of the normative principles used to frame the analysis. In this paper, the sustainability principles of the FSSD serve as the normative foundation. However, alternative normative frameworks could potentially be used in other application domains, and the choice of such principles may influence the framing of system boundaries and the interpretation of model results.

Second, much like for its ‘parent approaches’ (FSSD and SD), the effectiveness of the NFSD architecture also depends upon the topic knowledge and methodological skill of the planning team that uses it. This can however be at least partially dealt with given that the methodological support of the NFSD is stronger than for either of the two parent approaches.

Third, even though early conceptualizations and practical cases have emerged over the past two decades the new formalized version of the architecture has so far been illustrated primarily through conceptual reasoning and a single sustainability transition case. Although this case demonstrates the practical feasibility of the three-phase analytical process, further empirical applications are needed to evaluate how NFSD performs across different planning contexts.

Conclusions and Wider Consequences

Although illustrated here through sustainability planning using the FSSD, NFSD represents a more general planning architecture. Any explicit normative framework could potentially provide the initial framing before structural and dynamic analysis. NFSD may therefore contribute more broadly to strengthening the role of System Dynamics in strategic planning under explicit societal goals.

Future Research

The present paper introduces only the conceptual architecture.
Future work is currently operationalizing successive analytical layers of the architecture through dedicated methodological developments in (i) strategic sustainability indicator development, (ii) leverage point analysis based on causal loop diagrams, and (iii) detailed System Dynamics modelling and simulation.