Systems Thinking in Supply Chain Management

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Background

- Systems thinking is an approach to problem solving that looks at problems, not in isolation, but rather in the context of the larger system
- When working with an organizational structure, like a supply chain, this system includes the people, processes, resources and environment that work together to create a successful outcome
- This presentation will look at the application of system thinking to supply chain management

Principles of Systems Thinking

Systems Thinking

Systems thinking is concerned with understanding or intervening in problem situations, based on the principles and concepts of the systems paradigm

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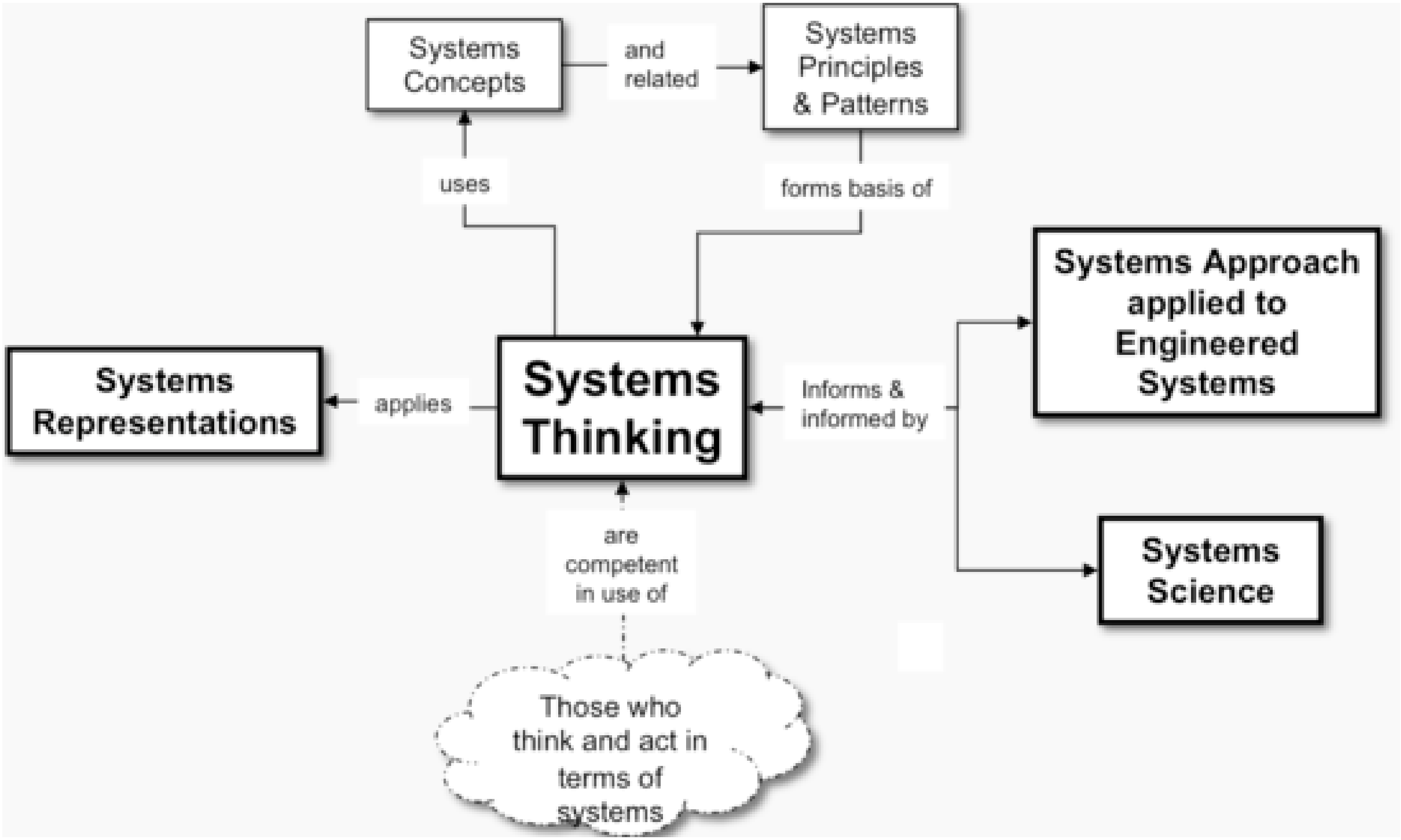
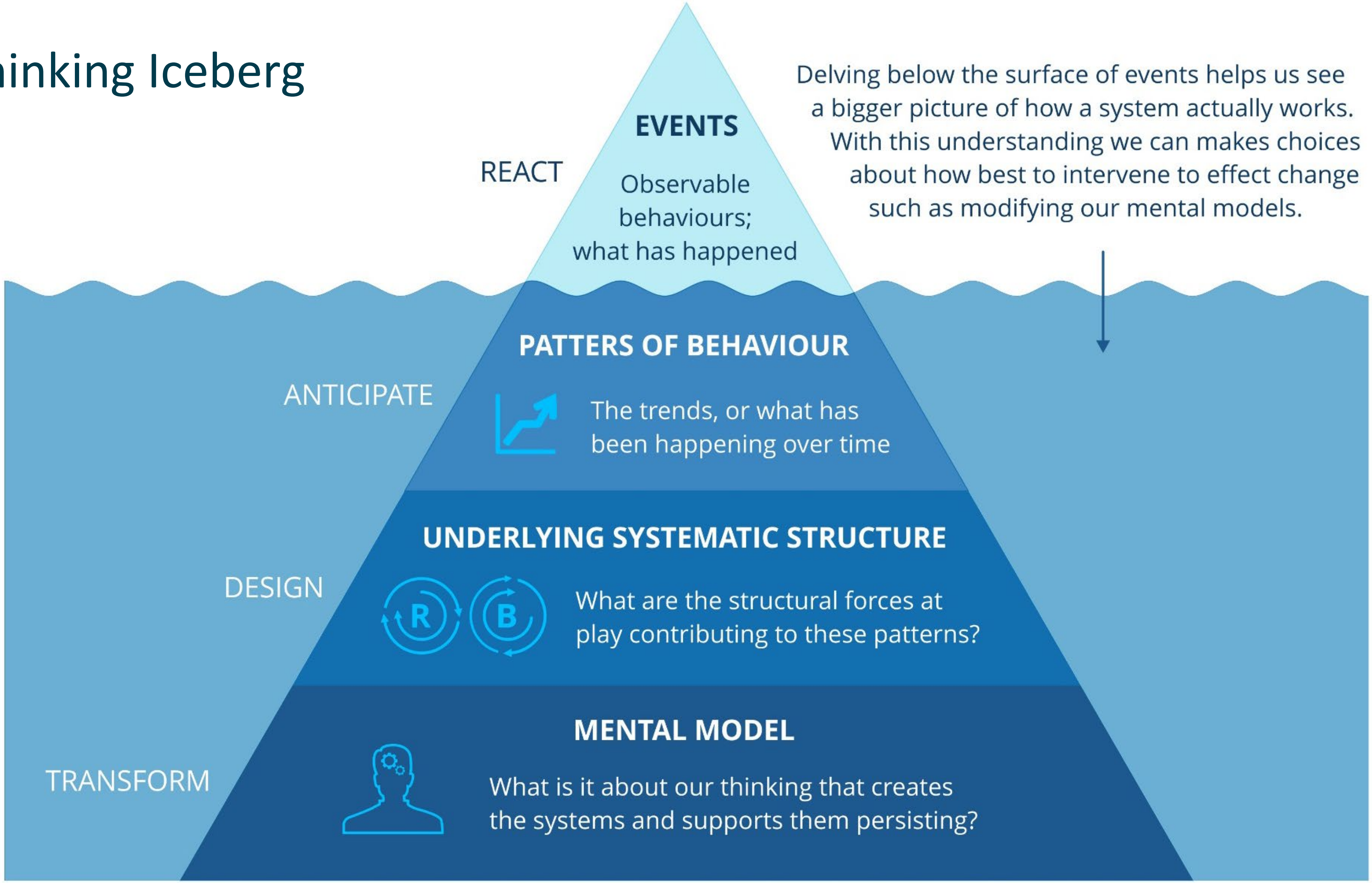
Systems thinking considers the similarities between systems from different domains in terms of a set of common systems concepts, principles and patterns



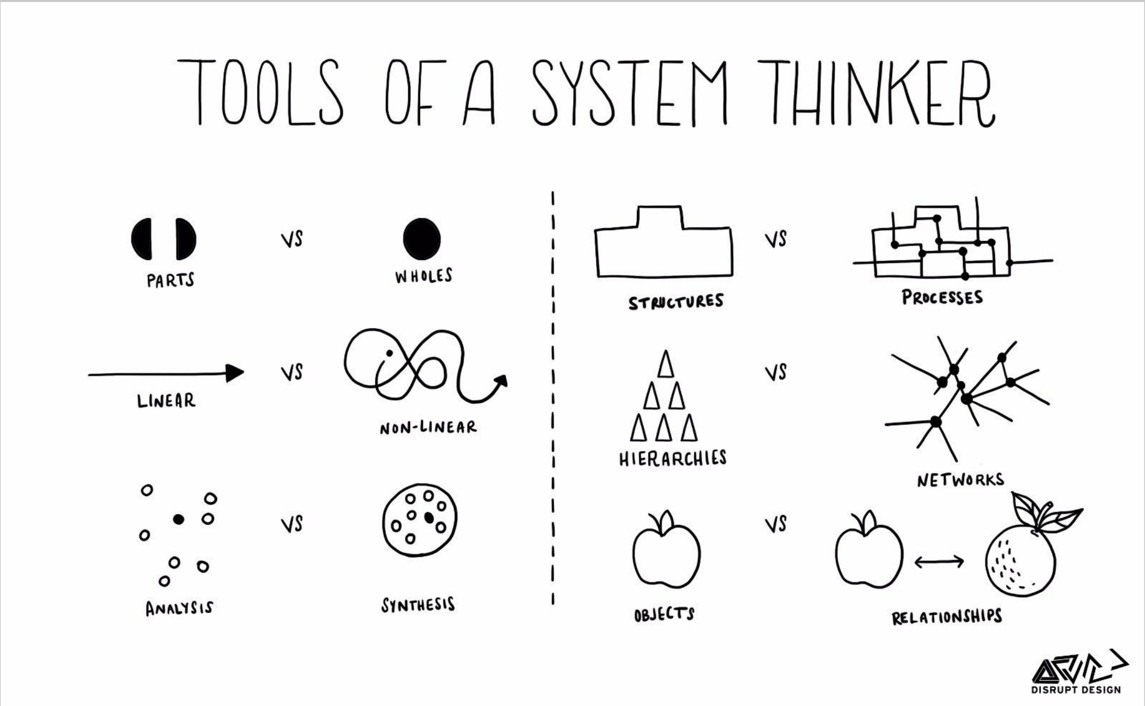
INCOSE Systems Engineering Handbook

Systems Thinking Iceberg



Developing a Systems Thinking Mindset Requires 4 Skills

- ***Exploring boundaries*** – understanding the inclusion, exclusion and marginalization of stakeholders and issues that concern them
- ***Appreciating multiple perspectives*** – how and why stakeholders frame issues in different ways
- ***Understanding relationships*** – networks of interconnections within and across systems
- ***Thinking in terms of systems themselves*** – organized wholes with properties that cannot be anticipated by analyzing any one part of the system in isolation



Principles of Systems Thinking (1 of 2)

Abstraction	A focus on essential characteristics is important in problem solving because it allows problem solvers to ignore the nonessential, thus simplifying the problem. (Sci-Tech Encyclopedia 2009; SearchCIO 2012; Pearce 2012)
Boundary	A boundary or membrane separates the system from the external world. It serves to concentrate interactions inside the system while allowing exchange with external systems. (Hoagland, Dodson, and Mauck 2001)
Change	Change is necessary for growth and adaptation, and should be accepted and planned for as part of the natural order of things rather than something to be ignored, avoided, or prohibited (Bertalanffy 1968; Hybertson 2009).
Dualism	Recognize dualities and consider how they are, or can be, harmonized in the context of a larger whole (Hybertson 2009)
Encapsulation	Hide internal parts and their interactions from the external environment. (Klerer 1993; IEEE 1990)
Equifinality	In open systems, the same final state may be reached from different initial conditions and in different ways (Bertalanffy 1968). This principle can be exploited, especially in systems of purposeful agents.
Holism	A system should be considered as a single entity, a whole, not just as a set of parts. (Ackoff 1979; Klir 2001)
Interaction	The properties, capabilities, and behavior of a system are derived from its parts, from interactions between those parts, and from interactions with other systems. (Hitchins 2009 p. 60)
Layer Hierarchy	The evolution of complex systems is facilitated by their hierarchical structure (including stable intermediate forms) and the understanding of complex systems is facilitated by their hierarchical description. (Pattee 1973; Bertalanffy 1968; Simon 1996)
Leverage	Achieve maximum leverage (Hybertson 2009). Because of the power versus generality tradeoff, leverage can be achieved by a complete solution (power) for a narrow class of problems, or by a partial solution for a broad class of problems (generality).
Modularity	Unrelated parts of the system should be separated, and related parts of the system should be grouped together. (Griswold 1995; Wikipedia 2012a)

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Principles of Systems Thinking (2 of 2)

Network	The network is a fundamental topology for systems that forms the basis of togetherness, connection, and dynamic interaction of parts that yield the behavior of complex systems (Lawson 2010; Martin et al. 2004; Sillitto 2010)
Parsimony	One should choose the simplest explanation of a phenomenon, the one that requires the fewest assumptions (Cybernetics 2012). This applies not only to choosing a design, but also to operations and requirements.
Regularity	Systems science should find and capture regularities in systems, because those regularities promote systems understanding and facilitate systems practice. (Bertalanffy 1968)
Relations	A system is characterized by its relations: the interconnections between the elements. Feedback is a type of relation. The set of relations defines the network of the system. (Odum 1994)
Separation of Concerns	A larger problem is more effectively solved when decomposed into a set of smaller problems or concerns. (Erl 2012; Greer 2008)
Similarity/ Difference	Both the similarities and differences in systems should be recognized and accepted for what they are. (Bertalanffy 1975 p. 75; Hybertson 2009). Avoid forcing one size fits all, and avoid treating everything as entirely unique.
Stability/ Change	Things change at different rates, and entities or concepts at the stable end of the spectrum can and should be used to provide a guiding context for rapidly changing entities at the volatile end of the spectrum (Hybertson 2009). The study of complex adaptive systems can give guidance to system behavior and design in changing environments (Holland 1992).
Synthesis	Systems can be created by choosing (conceiving, designing, selecting) the right parts, bringing them together to interact in the right way, and in orchestrating those interactions to create requisite properties of the whole, such that it performs with optimum effectiveness in its operational environment, so solving the problem that prompted its creation (Hitchins 2008: 120).
View	Multiple views, each based on a system aspect or concern, are essential to understand a complex system or problem situation. One critical view is how concern relates to properties of the whole. (Edson 2008; Hybertson 2009)

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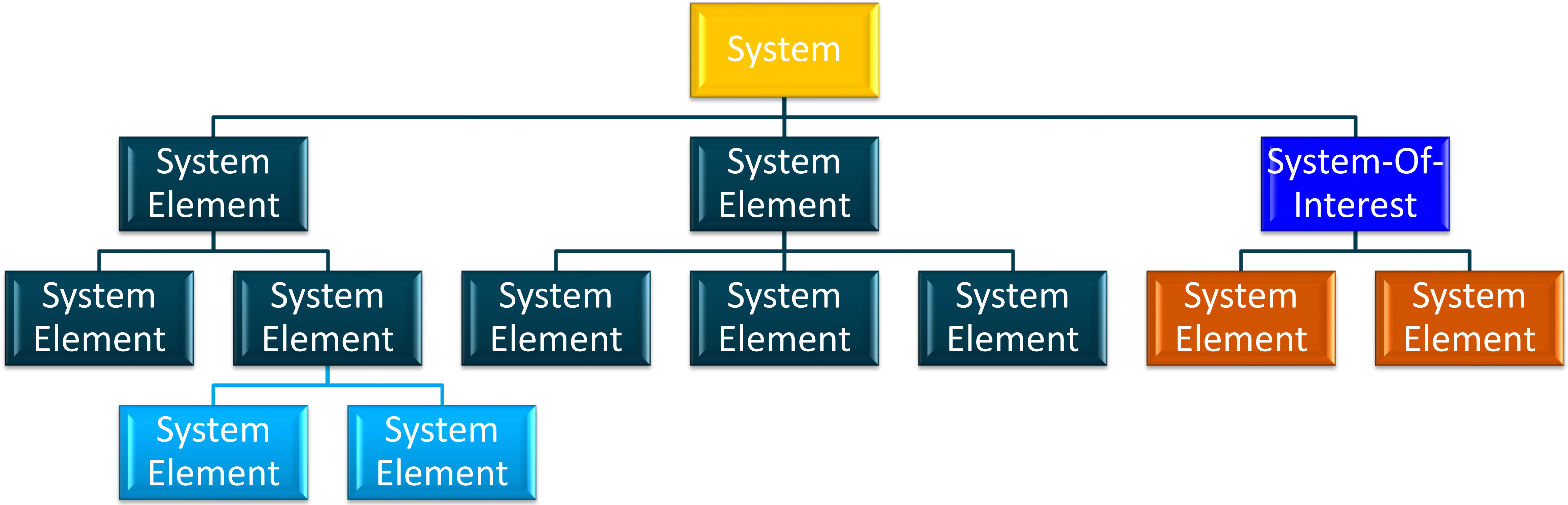
Systems Thinking

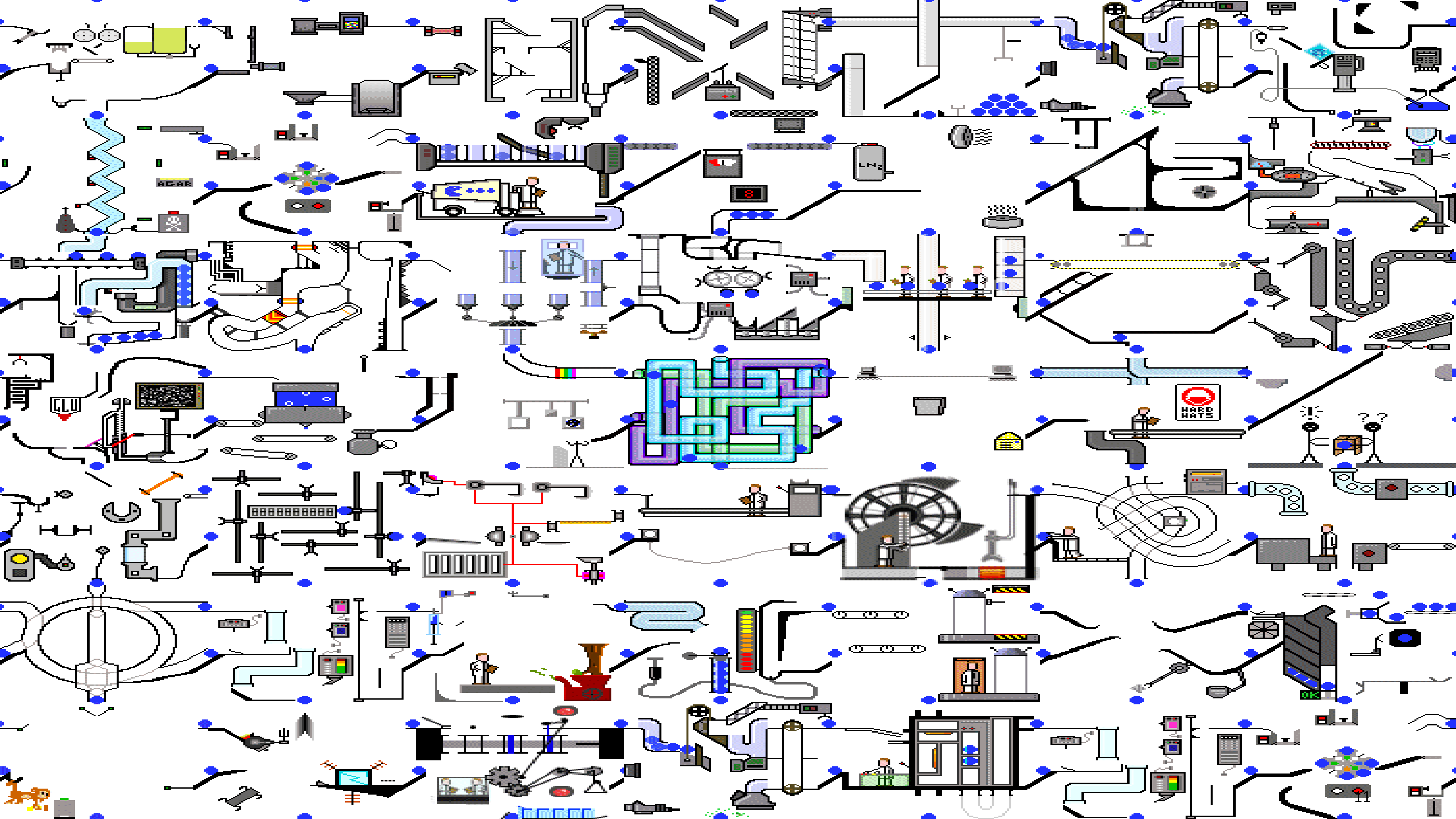
A holistic approach to analysis that focuses on the way that a system's **constituent parts interrelate** and how systems **work over time** and **within the context of larger systems**

Key concepts:

- **Hierarchy** – Systems are composed of smaller subsystems
- **Complexity** – Creates unknown (and sometimes undesirable) emergent behavior
- **Emergent behavior** – Properties of the system result from the both the components and their interactions

Hierarchy - System-of-Interest, System Element

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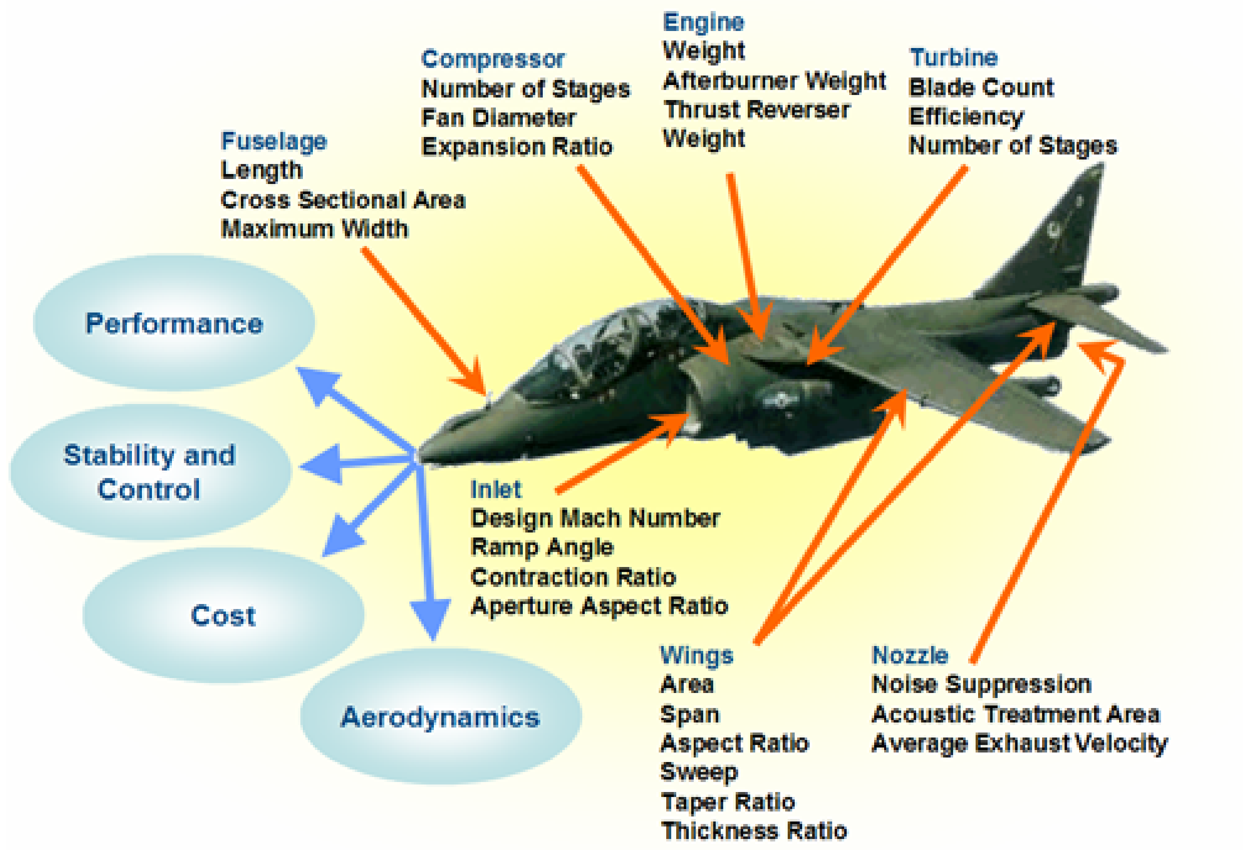
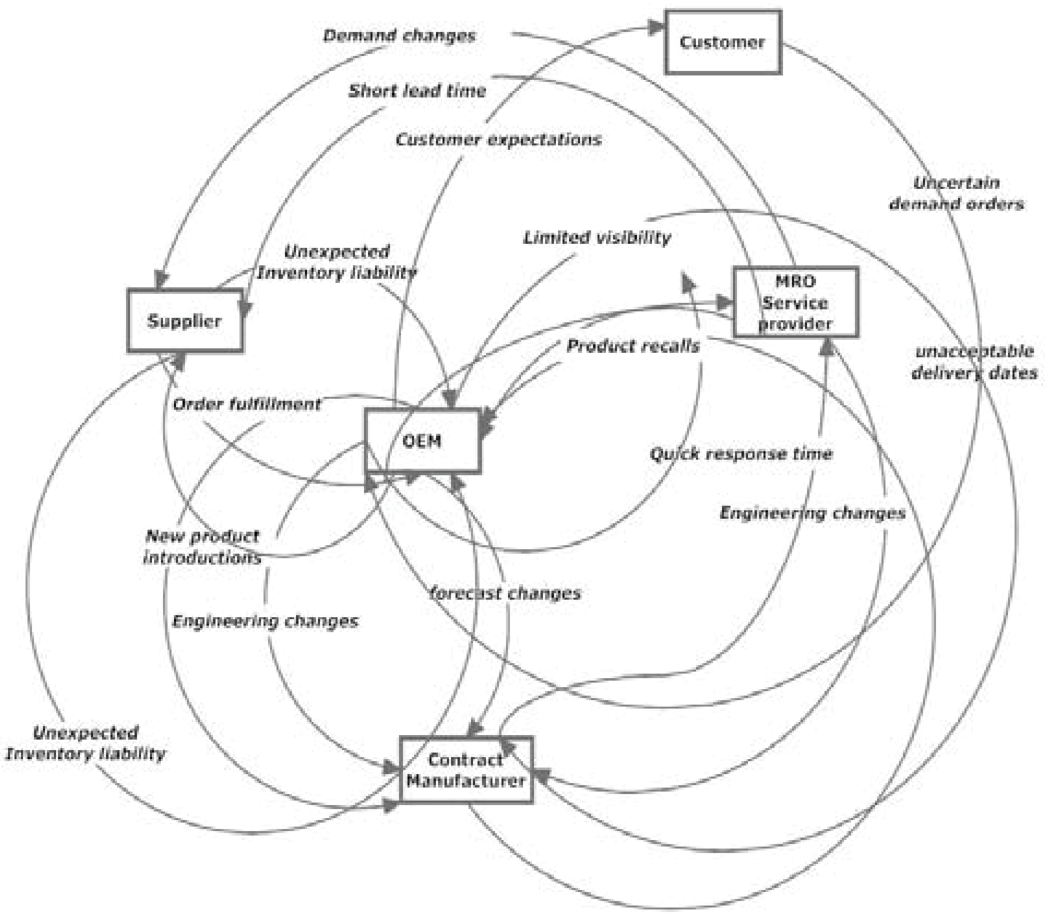
Emergent Behavior
Properties of the system result from both the components and their interactions



Systems Thinking Applied to Supply Chain Management

Characteristics of a Supply Chain Management System

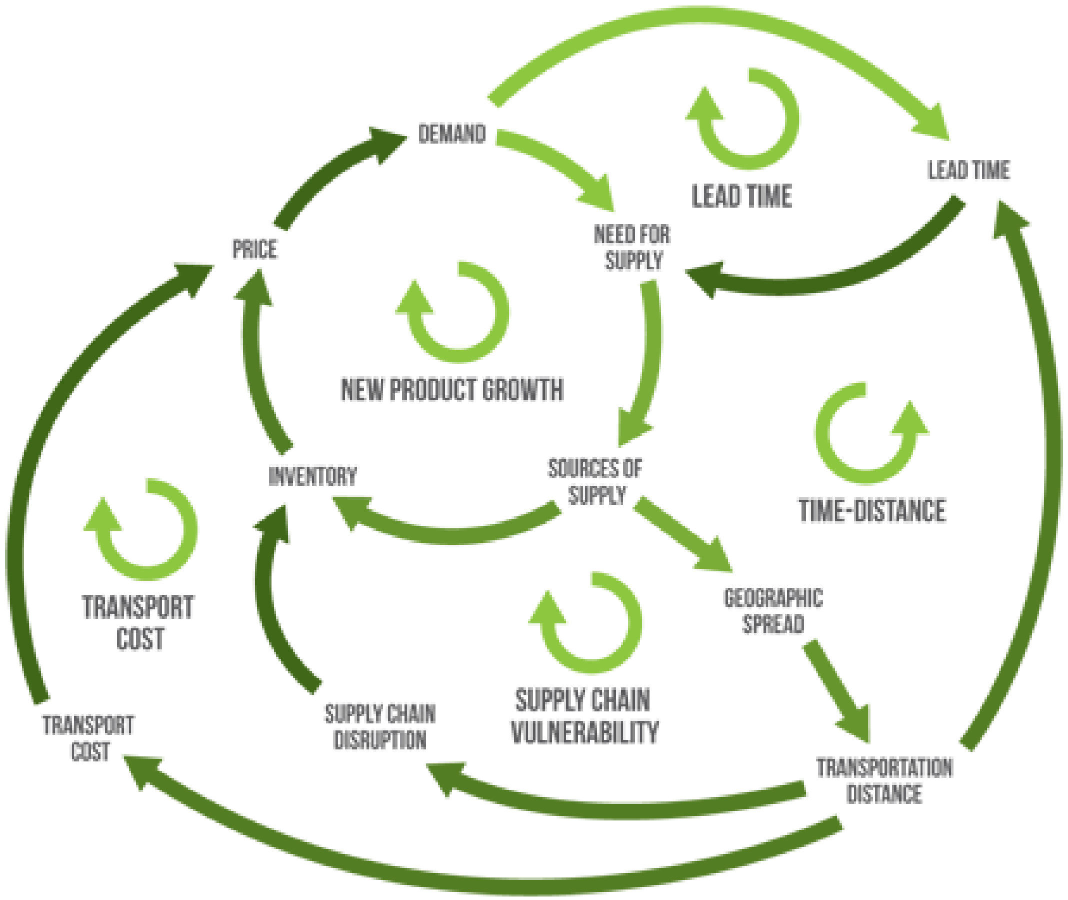
- Inherently uncertain and unpredictable, and we cannot fully understand its structure or behavior
- Cannot be adequately reduced into parts, recursively designed and re-assembled to form the whole solution
- Unintended consequences can overwhelm or negate the system's design
- Cannot be described at a single level; multi-scale descriptions are needed to understand complex systems
- Emergent behavior, derived from the relationships among their elements and from multiple internal feedback loops, gives rise to observed patterns that may not be understood or predicted



Supply Chains Risks: A Systems Thinking Perspective, Abhijeet Ghadge, S. Dani

Adapted from A Complexity Primer for Systems Engineers, INCOSE, unpublished draft

The Supply Chain is a Causal System… …with Many Emergent Properties



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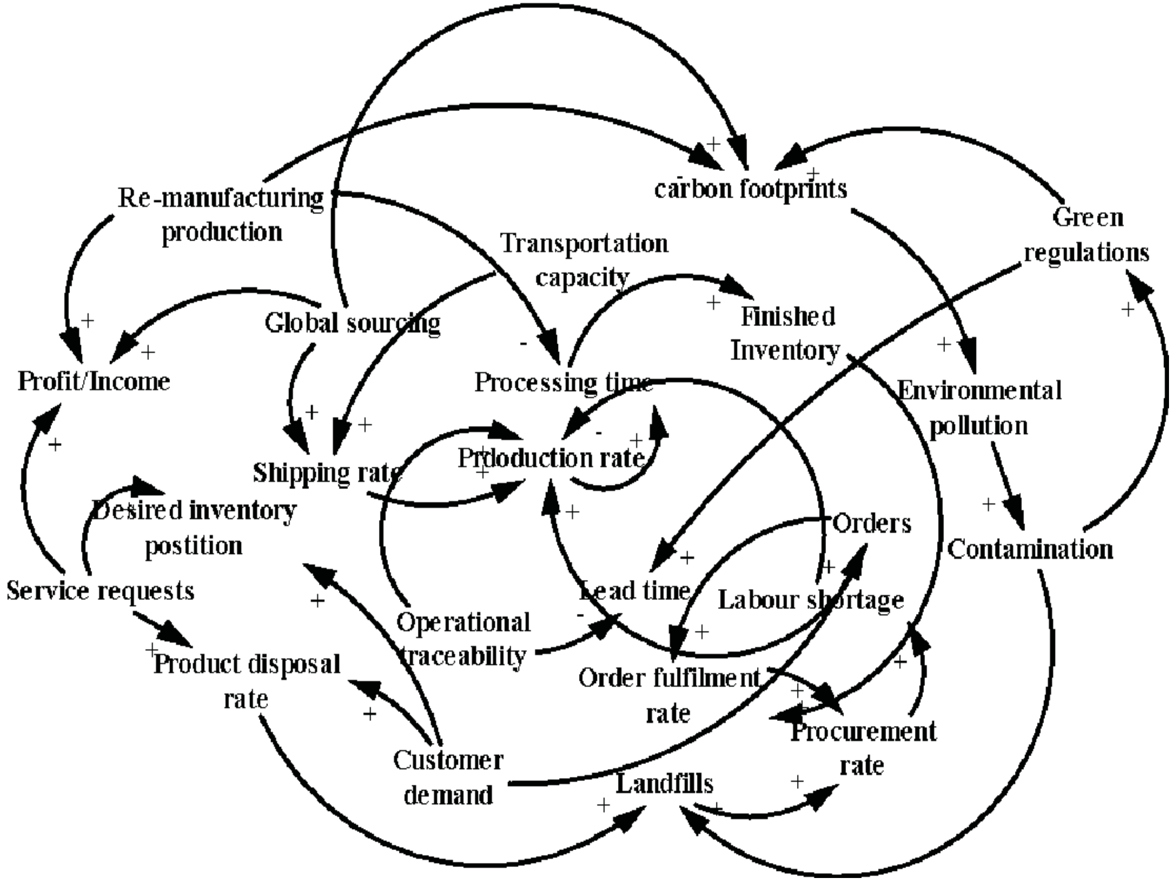


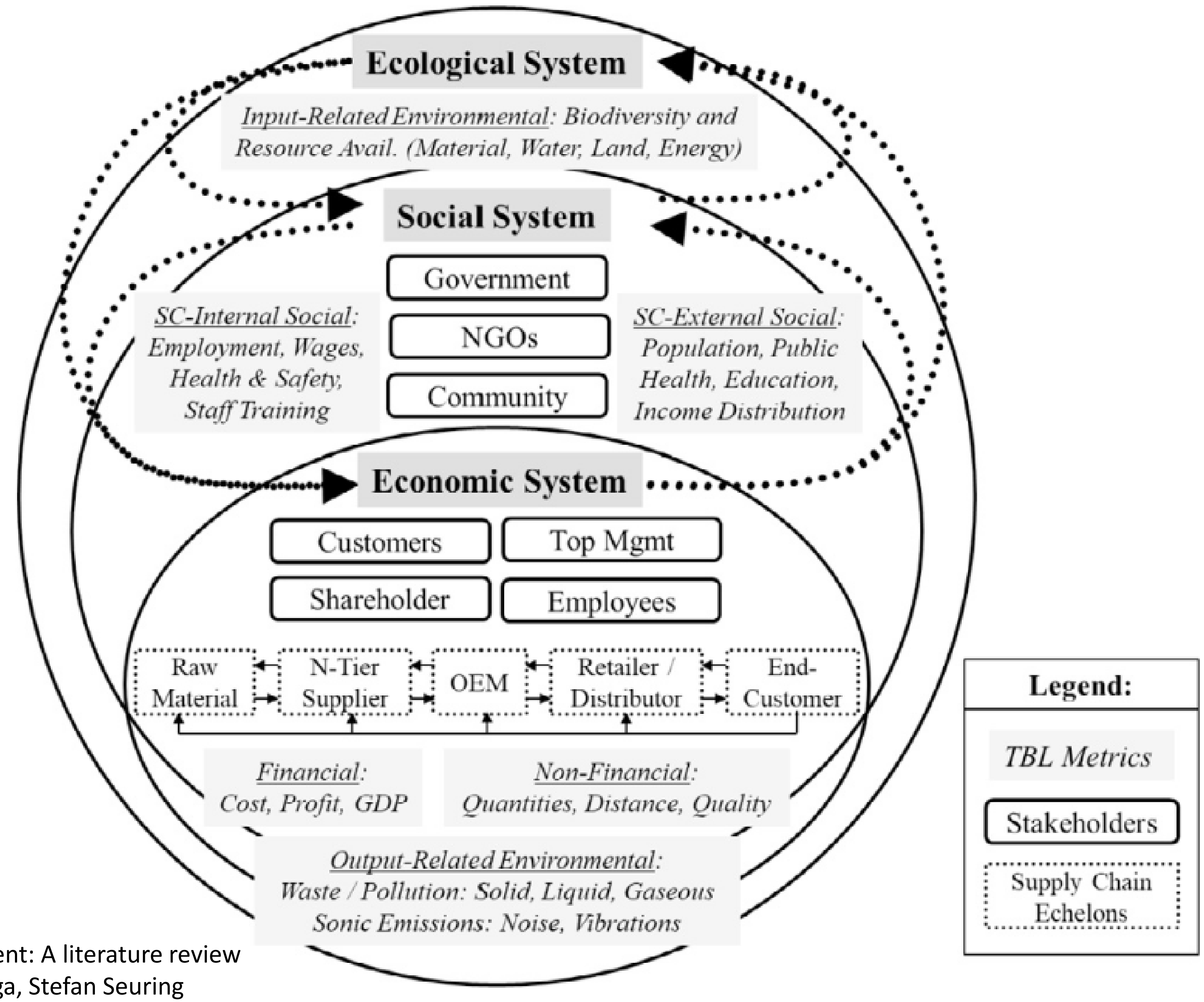
Supply Chains Risks: A Systems Thinking Perspective, Abhijeet Ghadge, S. Dani

State of the Practice in SCM Modeling

Descriptive and bibliometric analysis	• Most models published within the last five years • Four focus journals: JCLEPRO, JENVMAN, RESCONREC, SDR • Two central papers identified: Vlachos et al. (2007), Georgiadis and Besiou (2008)
Model complexity	• Small, medium, and large models in balance • Comprehensive hybrid approaches underrepresented
Scientific rigor	• Model validation often neglected • Model equations often undisclosed
Focus of analysis	• Most models take an industry or macro-economic focus • Functional focus on planning and production • Utilities sector most often focused (1/4 of all papers)

System dynamics modeling for sustainable supply chain management: A literature review and systems thinking approach, Tobias Rebsa, Marcus Brandenburga, Stefan Seuring

A Framework for Applying Systems Thinking to SCM



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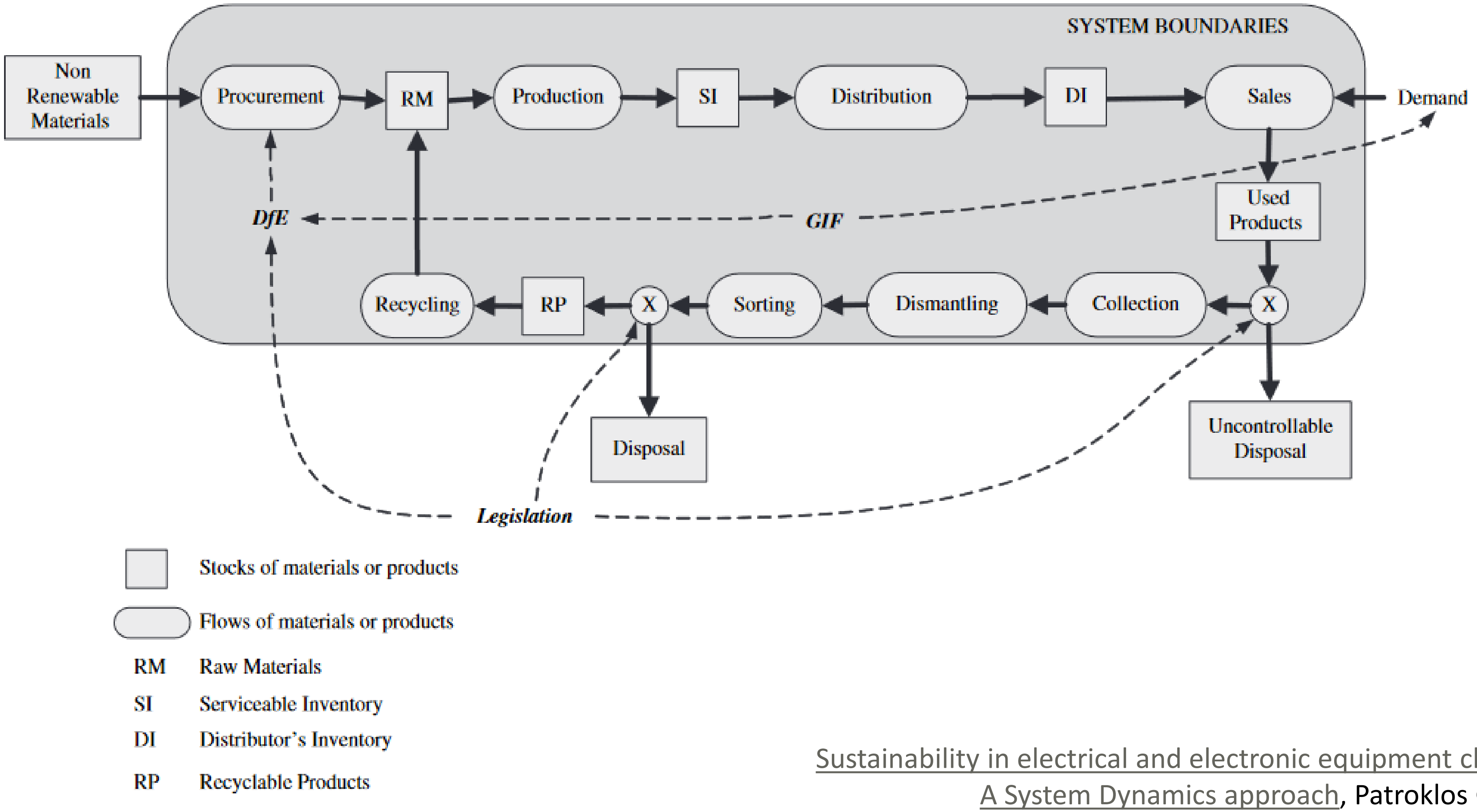
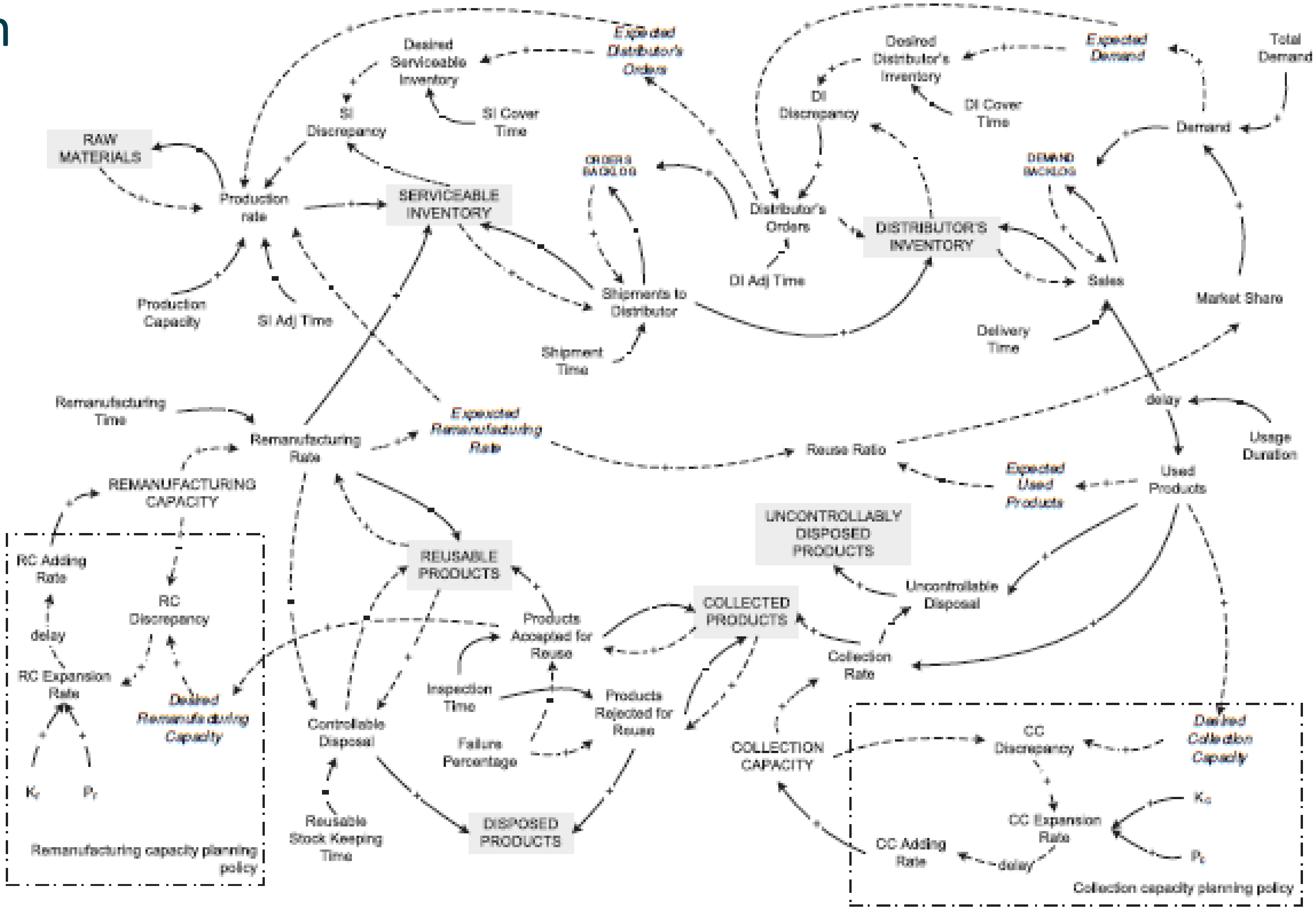
Systems Thinking Models – Flow Diagram



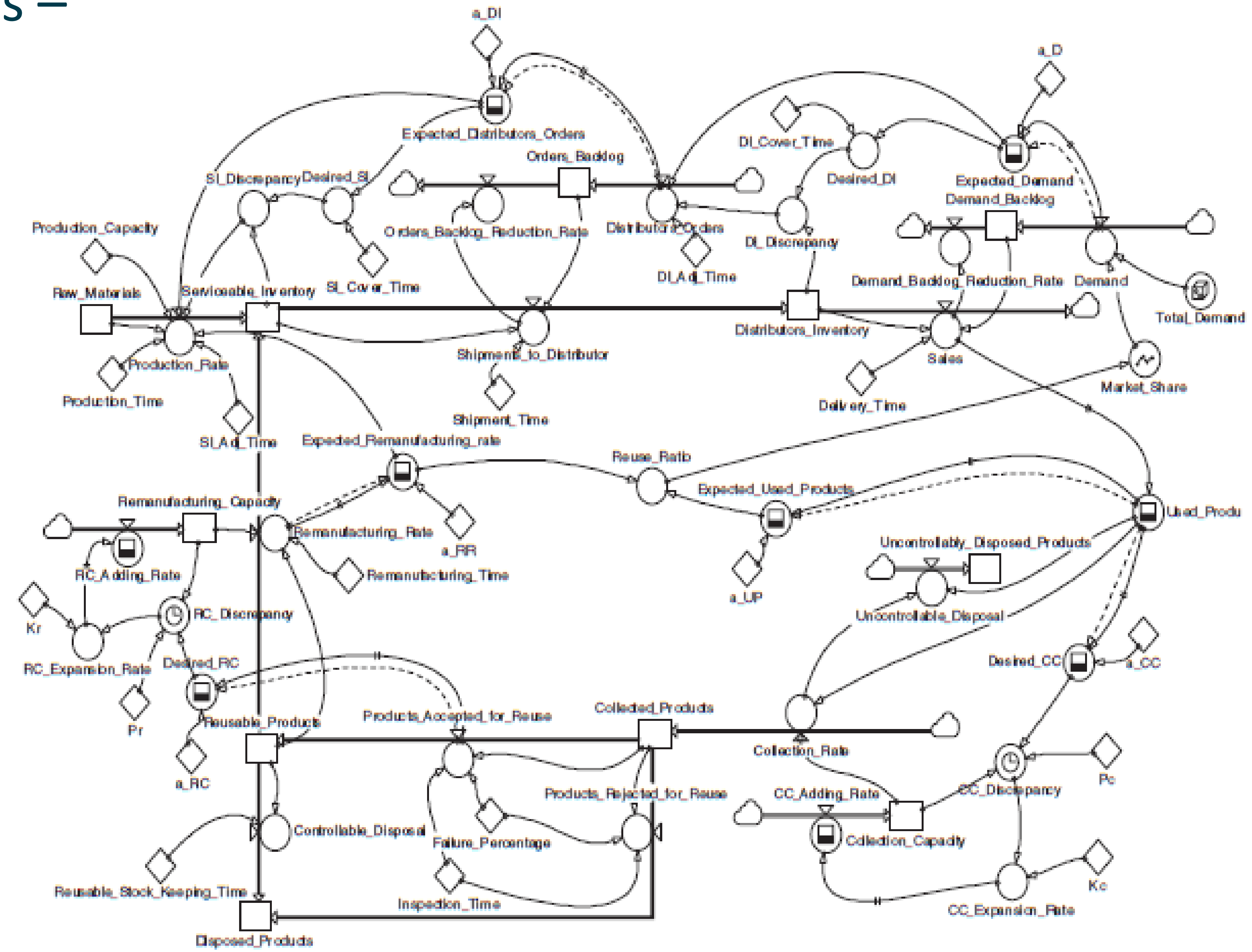
Sustainability in electrical and electronic equipment closed-loop supply chains: A System Dynamics approach, Patroklos Georgiadis, Maria Besiou

Systems Thinking Models – Causal Loop Diagram



A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains, Dimitrios Vlachos, Patroklos Georgiadis, Eleftherios Iakovou

Systems Thinking Models – Stock-Flow Diagram



A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains, Dimitrios Vlachos, Patroklos Georgiadis, Eleftherios Iakovou

Systems Thinking Resources

- What is Systems Thinking?, INCOSE SEBOK
- What are the General Principles Applicable to Systems?, D. Hitchins
- Supply Chains Risks: a Systems Thinking Perspective, Ghadge, Abhijeet and Dani, Samir, Proceedings of the 10th International Research Seminar on Supply Chain Risk Management, 2010
- System dynamics modeling for sustainable supply chain management: A literature review and systems thinking approach, Tobias Rebsa, Marcus Brandenburga, Stefan Seuring
- A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains, Dimitrios Vlachos, Patroklos Georgiadis, Eleftherios Iakovou
- Sustainability in electrical and electronic equipment closed-loop supply chains: A System Dynamics approach, Patroklos Georgiadis, Maria Besiou
- Caltech courses on systems thinking: https://ctme.caltech.edu