

## Chapter 2

# Modeling the Sustainable Development Nexus as a Complex–Coupled System: System Dynamics Modeling

**David Zelinka**

 <https://orcid.org/0000-0003-2457-5813>

*Civitas Systems, USA*

**Bassel Daher**

*Energy Institute and the Institute for Science, Technology, and Public Policy, Texas A&M University, USA*

### **ABSTRACT**

*This chapter begins with defining complex systems, presents an overview of the applied science of dynamical systems by focusing on the main components of complexity and chaos, and introduces the concept of dimensionality of systems. Systems have structural and temporal (dynamic) components – they exist in space and time. This chapter focuses on the time dimension, called temporality. The authors classify a third dimension, chaos (randomness), and illustrate that all systems can be defined according to their structure, dynamics, and chaos. These three dimensions constitute the dimensionality of systems, which can be used to define and categorize all types of systems. A system dynamics model to quantify the progress and interactions among the United Nation’s Sustainable Development Goals (SDG) is introduced. The benefits and limitations of a system dynamics modeling approach in this context are then discussed.*

### **INTRODUCTION**

There are many types of systems (e.g., simple, complicated, complex, and so on), but they all have a structural and temporal (dynamic) dimension – they exist in space and time (Krakauer, 2019). It is recommended – but not necessary – that the reader looks at the first chapter for a detailed discussion of

DOI: 10.4018/978-1-7998-5788-4.ch002

the spatial (structure) component. This chapter will cover the dimension of time (temporality) using the overarching concept of complexity, as well as system dynamics (SD) modeling.

The analysis herein is based on the rationale that sustainable development issues form an anthropocentric network and coupled system consisting of many structural and spatial interactions among its subsystems (i.e., sectors). This holds true for the dynamic aspect of systems through time, so the Sustainable Development Goals (SDGs) will function as a case study in the second part of this chapter.

Although many authors have acknowledged the interactions among the SDGs in the sustainable development literature little has been done to model how the SDGs influence or depend on one another through time, and their long-term system dynamics have been relatively unexplored (see Allen et al., 2017; Coopman et al., 2016; Le Blanc, 2015; Nilsson et al., 2016; Nilsson, 2017; Nilsson et al., 2017; Nilsson et al., 2013; UN Water, 2016; United Nations Economic and Social Council, 2015; United Nations General Assembly, 2015; Vladimirova & Le Blanc, 2016; Weitz et al., 2014; Daher et al., 2018; Stephan et al., 2018). Some notable works do exist including the SDGs and their targets as a network (Allen, Metternicht, & Wiedmann, 2019; Zhou & Moinuddin, 2017); the SDGs as various interacting sectors (Collste, Pedercini, & Cornell, 2017); and the SDGs as a dynamic system (Collste, Pedercini, & Cornell, 2017; Millennium Institute, n.d.; Zelinka & Amadei, 2019a). It is the goal of this chapter to show that the dynamics of the SDGs can be modeled in a way that is not too complex to understand while still producing informative results. Following this introduction section, the rest of the chapter is organized as follows:

**Section 2** defines a complex system and presents an overview of the applied science of dynamical systems by focusing on the main components of complexity and chaos and introducing the concept of dimensionality of a system

**Section 3** describes the limitations of more static approaches (see the previous chapter) to modeling systems and how system dynamics can be used to complement them, and it provides a brief overview of the components of causal-loop diagrams, stock-and-flow diagrams, and system dynamics modeling

**Section 4** introduces the lower-level of the system dynamics model from the context of system archetypes based on the logistic diffusion model for the SDGs

**Section 5** finishes building the system dynamics model by connecting the many structures in the lower-level together using a nested cross-impact matrix based on the nexus approach

**Section 6** discusses the benefits and limitations of system dynamics modeling

**Section 7** provides a brief overview of potential future work and then concludes

## **SYSTEMS SCIENCE: DYNAMICAL SYSTEMS**

Interconnectivity and hierarchy describe a system's spatial and structural dimension, but systems and particularly complex ones, also have a time dimension called **temporality**. Systems for which time has an impact on their state and function are called dynamical systems as their temporality is strong. More accurately, though, the change in time is mathematically governed by a well-specified rule or set of rules, like an equation or algorithm (Feldman, 2019). This well-defined rule also makes the system deterministic by definition.

The effect of time is characterized by **iterative** cycles (recurring sequences) and **oscillations** (periodic movement between two bounded thresholds) and is inferred through the concept of feedback and causal

27 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

[www.igi-global.com/chapter/modeling-the-sustainable-development-nexus-as-a-complex-coupled-system/271033](http://www.igi-global.com/chapter/modeling-the-sustainable-development-nexus-as-a-complex-coupled-system/271033)

## Related Content

---

### A Web-Enabled, Mobile Intelligent Information Technology Architecture for On-Demand and Mass Customized Markets

M. Ghiassian and C. Spera (2011). *Interdisciplinary Advances in Adaptive and Intelligent Assistant Systems: Concepts, Techniques, Applications, and Use* (pp. 83-123).

[www.irma-international.org/chapter/web-enabled-mobile-intelligent-information/46286](http://www.irma-international.org/chapter/web-enabled-mobile-intelligent-information/46286)

### A Cross-Layer QoE-Based Approach for Event-Based Multi-Tier Wireless Multimedia Sensor Networks

Denis Rosário, Zhongliang Zhao, Torsten Braun and Eduardo Cerqueira (2014). *International Journal of Adaptive, Resilient and Autonomic Systems* (pp. 1-18).

[www.irma-international.org/article/a-cross-layer-qoe-based-approach-for-event-based-multi-tier-wireless-multimedia-sensor-networks/111530](http://www.irma-international.org/article/a-cross-layer-qoe-based-approach-for-event-based-multi-tier-wireless-multimedia-sensor-networks/111530)

### Automatic Personalization in E-Learning Based on Recommendation Systems: An Overview

Mohamed Koutheaïr Khribi, Mohamed Jemni and Olfa Nasraoui (2012). *Intelligent and Adaptive Learning Systems: Technology Enhanced Support for Learners and Teachers* (pp. 19-33).

[www.irma-international.org/chapter/automatic-personalization-learning-based-recommendation/56070](http://www.irma-international.org/chapter/automatic-personalization-learning-based-recommendation/56070)

### A Recovery-Oriented Approach for Software Fault Diagnosis in Complex Critical Systems

Gabriella Carrozza and Roberto Natella (2011). *International Journal of Adaptive, Resilient and Autonomic Systems* (pp. 77-104).

[www.irma-international.org/article/recovery-oriented-approach-software-fault/51550](http://www.irma-international.org/article/recovery-oriented-approach-software-fault/51550)

### Modelling the Growing Process of Integrated Healthcare Supply Networks

Daria Battini, Maurizio Faccio, Alessandro Persona and Fabio Sgarbossa (2013). *International Journal of System Dynamics Applications* (pp. 1-13).

[www.irma-international.org/article/modelling-growing-process-integrated-healthcare/76346](http://www.irma-international.org/article/modelling-growing-process-integrated-healthcare/76346)