Complex Systems and Dynamics

Code	Credit Hours
SYSE-806	2-1

Course Description:

The course aims to provide an insight into complex systems, their characteristics and system dynamics to address complexity issues. Complexity science is a new approach to scientific thought and process, which studies how relationships between parts give rise to the collective behaviors of a system, and how the system interacts and forms relationships with its environment. The interplays between order and disorder, predictability and unpredictability, regularity and chaos, are characteristics of complex systems. Complex systems abound in the real world, and they reflect the world's inherent irregularity and fragility. System dynamics is a method to enhance learning in complex systems. It could address complexity involving interactive modelling, tools for representation of feedback structure, and simulation software making it possible for anyone to engage in the modelling process. This course will enable the students to learn about complex systems, system dynamics approach including systems thinking, and necessary tools and techniques for modelling and simulation to address complexity issues in the construction sector, and in general.

Reference Books:

1. Sterman, J.D. (2000). Business dynamics: systems thinking and modeling for a complex world. Irwin/McGraw-Hill Boston.
2. Strogatz, S.H. (2014). Nonlinear dynamics and chaos: with applications to physics, biology, chemistry and engineering. Westview press.
3. Feldman, D. P. (2012). Chaos and fractals: an elementary introduction. Oxford University Press.
4. Morecroft, J. (2007). Strategic Modelling and Business Dynamics: A Feedback Systems Approach. Chichester: John Wiley & Sons. 37
5. Maani, K. E., and R. Y. Cavana. (2007). (first edition published in 2000) Systems Thinking, System Dynamics: Managing Change and Complexity, Second Edition. Auckland: Pearson Education New Zealand.
6. Senge, P. M. (1990). The fifth discipline: The art and practice of the learning organization. Lincoln: Century Books.
7. Gleick, J. (1987). Chaos: Making a new science. New York: Viking, 23.

Prerequisites:

Nill

ASSESSMENT SYSTEM FOR THEORY

Quizzes	10%
Assignments	10%
Mid Terms	25%

Term Project	10%
ESE	45%

ASSESSMENT SYSTEM FOR LAB

Quizzes	10%-15%
Assignments	5% - 10%
Lab Work and Report	70-80%
Lab ESE/Viva	20-30%

Teaching Plan

Week No.	Topics	Learning Outcome
1	Introduction to Chaos Theory	Students will understand the fundamentals of chaos theory, including the butterfly effect and the nature of fractals. They will explore how small changes can lead to significant impacts in complex systems, gaining insight into the inherent unpredictability and patterns of chaos.
2-6	Understanding and Applying Complexity Science, Systems Thinking, and System Dynamics in Real-World Problem Solving	Students will learn about complexity science and its principles, focusing on the behavior and interaction of complex systems. They will grasp how emergent properties arise from simple rules and interactions within these systems. Students will comprehend the principles of systems thinking, including its definition and key concepts. They will explore practical applications of systems thinking in analyzing and solving complex problems in various domains. Students will be introduced to complex systems and the basics of system dynamics. They will learn about feedback processes in learning and identify common barriers to learning within dynamic systems. Students will understand the purpose and steps involved in the modelling process. They will learn that modelling is an iterative process and will study applications and case studies to see how modelling is implemented in real-world scenarios.
7-8	Systems Thinking Tools: Causal Diagrams and Their Applications in Real-World Scenarios	Students will become proficient in using systems thinking tools such as causal diagrams. They will learn notation guidelines, how to conceptualize case studies like managing workloads, and explain phenomena such as policy resistance in traffic congestion.

9	**MID-TERM EXAM**	
10-12	Analyzing and Visualizing Stock and Flow Structures in Dynamic Systems	Students will learn to identify and map stock and flow structures within systems. They will understand the concept of accumulation and how to represent stocks and flows visually. Students will explore the relationship between stocks and flows, understanding how these elements interact dynamically over time. They will learn to analyze the impact of changes in stocks and flows on system behavior.
13-17	Exploring Dynamics of Simple Systems: Feedback Loops, Growth Patterns, and Epidemic Modeling	Students will gain insights into the dynamics of simple systems, including first-order systems. They will study positive and negative feedback loops, exponential growth and decay, and the behavior of multiple-loop and non-linear first-order systems. Students will learn to model S-shaped growth and the dynamics of disease spread through epidemic modeling. They will explore how growth dynamics can be represented and analyzed within different contexts and systems.

Practical:

Experiment No	Description
1	Introduction to Modelling Environment.
2	Development and Functioning of Causal Loop Diagram.
3	Development and Functioning of Stocks and Flows.
4	Simulations and Interpretations.