22nd On-Line HSSS National & International Conference

in collaboration with

University of Ioannina , Department of Accounting and Finance,

Preveza, Greece

07 - 10, October 2026. Preveza, Greece

Applied Systemic Management in AI Era

Using Fuzzy Cognitive Maps in Applied Systemic Management

KEYNOTE PAPER
September 10th, 2026

Prof. Peter P. Groumpos
Emeritus Professor
University of Patras.

Using Fuzzy Cognitive Maps in Applied Systemic Management
From Systemic Thinking to Computational Scenario Analysis

Visual: A simple network of interconnected concepts surrounding the words:

SYSTEM → MANAGEMENT → FCM → DECISION SUPPORT

Why This Topic?

Contemporary management problems are systemic

Organizations face:

1. Multiple interacting factors
2. Uncertainty and incomplete information
3. Feedback relationships
4. Conflicting stakeholder perspectives
5. Delayed and indirect effects
6. Unintended consequences

The central problem

Traditional linear reasoning often assumes:

Decision → Action → Result

- Complex organizations frequently behave more like:
- Decision → Multiple Effects → Feedback → New Conditions → Further Decisions
- **Key question:**
- **How can managers represent and explore such interconnected causal structures, meeting organizations' goals?**

Applied Systemic Management (ASM)

Applied Systemic Management (ASM) is a practical management framework that views an organization not as a collection of isolated departments, but as an interconnected ecosystem (an open system) of moving parts working toward a shared goal.

Moving beyond theoretical systems theory, the "applied" aspect focuses on using **concrete tools, multi-method techniques, and data analytics** to optimize how a company adapts to its changing external environment in real time.

Applied Systemic Management (Cont.)

Instead of trying to fix a business problem by looking at **one department in a silo**.

Applied Systemic Management (ASM) requires leaders to analyze how a change in one area ripples out to impact the entire organization.

CORE ELEMENTS OF APPLIED Fmework

The framework operates like a continuous biological or **cybernetic feedback loop**, broken down into five distinct operational stages:

1) Inputs: The resources the system extracts from the environment, including capital, raw materials, and human labor……

2) **Transformation Process:** The daily workflows, strategic management actions, production pipelines that take those inputs and turn them into something valuable.

3) Outputs: The final goods, services, or results generated by the organization and released into the market.

4) Feedback Loops: Continuous data streaming back into the system (e.g., customer complaints, financial deficits) that forces the organization to adapt its internal behaviors.

5) Environment: The external ecosystem—including inflation, shifting regulations, and competing companies—that constantly applies pressure to the business.

Why It Matters in Modern Business

In today's hyper-connected landscape, businesses face extreme complexity. Applied Systemic Management gives managers the structural tools to prevent **unintended consequences**—such as a cost-cutting measure in manufacturing accidentally sabotaging product quality and overwhelming the customer support team.

Companies like McDonald's and Walmart lean heavily on standardized systemic processes **to scale global operations while dynamically adjusting to regional supply chains.**

History of Applied Systemic Management

For decades, management was viewed through a strictly mechanical lens without any concept of "systems" or "systemic" interactions.The shift from classical management to **systems and systemic theory** occurred in waves during the **mid-20th century (specifically between the late 1940s and the 1960s)**.

The transition from "just management" to "systemic management" happened across a distinct historical timeline

The Pre-Systemic Era (Late 1800s – 1940s): The Machine Metaphor

Before systemic theories, management was dominated by **Classical Management Theory**, which viewed organizations as **closed machines**.

- **Scientific Management (Taylorism, 1880s–1910s):** Pioneered by Frederick Winslow Taylor, this era focused entirely on micro-efficiency. Workers were viewed as literal cogs in a machine; If you optimized one task (like shoveling coal), the whole factory would magically work better.
- **Administrative Management (Fayolism, 1910s–1940s):** Henri Fayol introduced the structural functions of management (planning, organizing, controlling).
- However, it still treated departments as isolated, top-down columns rather than an interconnected ecosystem.

The Spark (1940s – early 1950s): Interdisciplinary Science

The foundation for the term "systemic" did not actually start in a business school—it migrated from biology and engineering:

- **General Systems Theory (GST):** Formulated by biologist Ludwig vonBertalanffy in the late 1940s and early 1950s. He argued that scientists should study the *relationships between parts* rather than reducing everything to isolated pieces.
- **Cybernetics (1948):** Mathematician Norbert Wiener introduced the ideas of feedback loops and self-regulation. [1, 2, 3]

The Official Transition into Management (1950s – 1960s)

- Management scholars realized that factories and offices behaved exactly like the biological "open systems" Bertalanffy talked about.

1) The Tavistock Institute (1950s): Researchers in the UK began examining **Socio-Technical Systems**. They proved that you could not change a company's technology without systemically altering the human social structure. [1]

- **2)The Breakthrough Paper (1964):** Scholars Richard A. Johnson, Fremont E. Kast, and James E. Rosenzweig published a seminal paper explicitly titled **"Systems Theory and Management"** in the journal*Management Science*. This marked the formal recognition of the systems framework in major corporate academic research. [1]

The Definitive Text (1966): Daniel Katz and Robert L. Kahn published *The Social Psychology of Organizations*. They officially framed corporations as **"open systems"** that constantly ingest inputs from the environment, transform them, and push outputs back out

When did "Systemic" become a standard term?

While "systems theory" was used in the 50s and 60s, the adjective **"systemic"** (meaning *affecting the whole system rather than just a single part*) gained heavy traction in business literature during the **1970s and 1980s**.

This was accelerated by **Management Cybernetics** (Stafford Beer's Viable System Model) and **System Dynamics** (Jay Forrester at MIT), which gave managers the computer modeling tools to look at corporate problems *systemically*. Later, in 1990, Peter Senge's famous book *The Fifth Discipline* fully popularized "systems thinking" for mainstream corporate managers. [1, 2]

Would you like to look closer at the differences between **Scientific Management (Taylorism)** and **Systems Theory**, or are you curious about **why it took so long** for business schools to adopt biological concepts?

From Systems Thinking to FCMs

Systems thinking emphasizes:

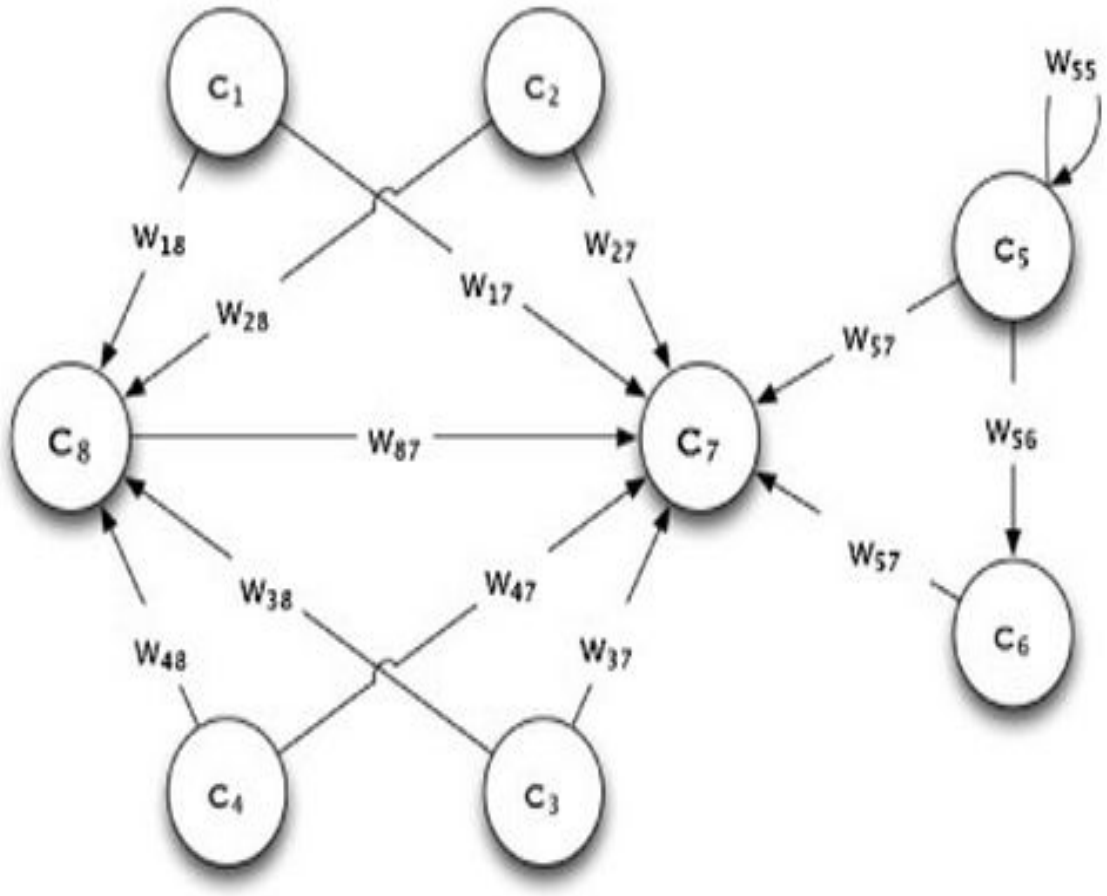
- Relationships rather than isolated variables
- Feedback rather than simple linear causality
- Whole-system behavior
- Multiple perspectives
- Emergence and unintended consequences

Fuzzy Cognitive Maps provide:

- Concepts
- Directed causal relationships
- Positive/negative influences
- Weighted causal links
- Dynamic propagation
- Scenario simulation

Fuzzy Cognitive Maps (1/3)

- (C) Nodes: Represent the system's concepts or variables
- Arrows: Interconnection between nodes. Show the cause-effect relationship between them.
- W: Interrelationships between two nodes:
  - W>0 positive causality
  - W<0 negative causality
  - W=0 no relationship



Fuzzy Cognitive Maps (2/3)

The value of each concept at every simulation step is calculated, computing the influence of the interconnected concepts to the specific concept by applying the following calculation rule:

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j \neq i}}^{N} A_j^{t-1} \cdot W_{ji} + A_i^{t-1}\right)$$

Fuzzy Cognitive Maps (3/3)

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j \neq i}}^{N} A_j^{t-1} \cdot W_{ji} + A_i^{t-1}\right)$$

- A_i^{t-1} the value of the concept Ci at the iteration step t-1
- A_i^t the value of the concept Cj at the iteration step t

- Wji : the weight of interconnection from concept Cj to concept Ci
- f: Sigmoid function $f = \frac{1}{1 + e^{-\lambda x}}$

HISTORY OF FCM .

Important historical clarification

Kosko (1986) established the FCM framework and causal propagation mechanism.

Later researchers developed alternative state-transition formulations, activation functions, learning algorithms, and adaptive methods.

Therefore, the equation should not simply be described as a verbatim “Kosko equation.”

The Management Example

Illustrative service organization with FCM

- Problem:
- Declining customer satisfaction despite increased operational investment.

- Training Investment
- Employee Capability
- Employee Workload
- Employee Engagement
- Service Quality
- Customer Satisfaction
- Organizational Reputation
- Financial Performance

Eight concepts

- C1 to C8

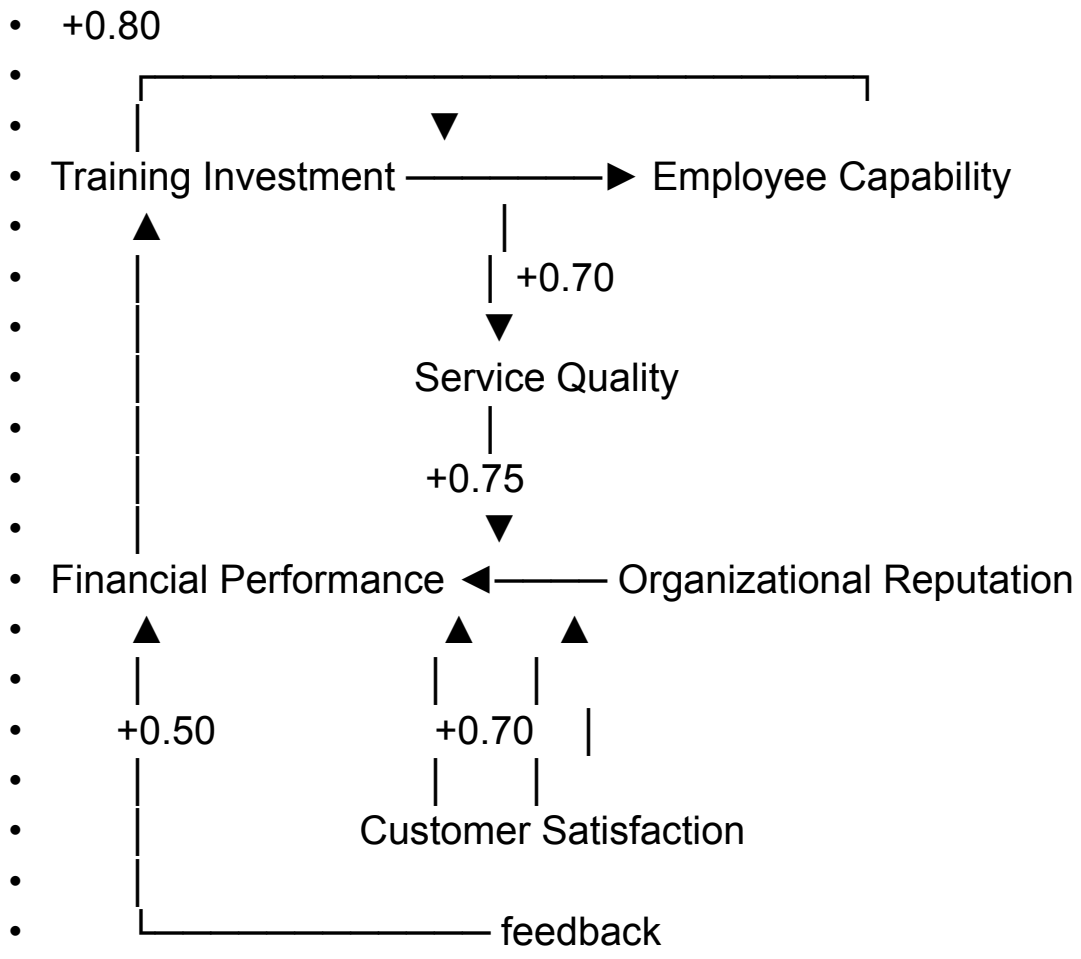
CONTINUE

- The purpose is not to predict an organization's actual performance.

- The purpose is to examine:

How might an intervention propagate through an interconnected management system?

The FCM Conceptual Map



- Employee Workload —−0.60—▶ Employee Engagement
- Employee Workload —−0.55—▶ Service Quality
- Employee Engagement —+0.65—▶ Service Quality
- Service Quality —+0.75—▶ Customer Satisfaction
- Customer Satisfaction —+0.70—▶ Organizational Reputation
- Organizational Reputation —+0.65—▶ Financial Performance

Central feedback loop

This is the key systemic feature of the model analyzing ASM with FCM theories.

THE FCM Weight Matrix

From / To	Training	Capability	Workload	Engagement	Service Quality	Satisfaction	Reputation	Financial
Training	0	+0.80	0	0	0	0	0	0
Capability	0	0	0	0	+0.70	0	0	0
Workload	0	0	0	−0.60	−0.55	0	0	0
Engagement	0	0	0	0	+0.65	0	0	0
Service Quality	0	0	0	0	0	+0.75	0	0
Satisfaction	0	0	0	0	0	0	+0.70	0
Reputation	0	0	0	0	0	0	0	+0.65
Financial	+0.50	0	0	0	0	0	0	0

Important: These values are illustrative expert judgments, not

Three Management Scenarios

Scenario A — Baseline

No intervention.

The system evolves from

the initial organizational state.

Scenario B — Training intervention

Increase:

Expected modeled pathway:

Scenario C — Combined intervention

Increase training while reducing workload:

This simultaneously affects:

1. Capability
2. Engagement
3. Service Quality
4. Customer Satisfaction

Purpose

Compare **system responses**, not simply individual indicators.

Example of Iterative Simulation

Concept activation

Suppose:

The model is repeatedly updated:

Iteration	Capability	Engagement	Service Quality	Satisfaction	Reputation
0	0.50	0.50	0.50	0.50	0.50
1	0.70	0.50	0.69	0.50	0.50
2	0.78	0.50	0.83	0.72	0.50
3	0.82	0.50	0.87	0.85	0.65
4	0.84	0.50	0.89	0.88	0.83

Note: The numerical values shown here are illustrative and should be recalculated consistently with the selected activation function and initial vector before taking a decision

Main message

A local intervention can propagate through the entire system.

Why FCM Rather Than a Simple Causal Diagram?

Conventional causal diagram

Shows:

A → B → C

but generally does not calculate system evolution.

FCM

Adds:

1. Strength of relationships
2. Activation levels
3. Feedback
4. Iterative updating
5. Scenario experimentation

Therefore

Causal diagram

→ represents relationships only

FCM

→ **represents relationships and permits computational exploration and feedback through equations**

FCMs and Systemic Management

Proposed management cycle

- SYSTEMIC DIAGNOSIS
- ↓
- STAKEHOLDER MAPPING
- ↓
- FCM CONSTRUCTION
- ↓
- MODEL INTEGRATION
- ↓
- SIMULATION
- ↓
- SCENARIO ANALYSIS
- ↓
- VALIDATION
- ↓
- MANAGEMENT LEARNING
- ↺

The important point

The FCM is not the end of the process.

It is part of an iterative **learning cycle**.

Advantages FCM-based systemic management offers:

Qualitative knowledge representation

Managers can contribute knowledge even when precise data are unavailable.

2. Multiple perspectives

Different stakeholder maps can be compared.

3. Feedback representation

Circular relationships become explicit.

4. Scenario analysis

Potential interventions can be explored before implementation.

5. Transparency

Concepts and causal weights remain visible.

6. Data integration

Learning algorithms can adapt expert-defined models using empirical data.

•

Important methodological limitations

Subjectivity

Causal weights may depend on expert judgments.

Model boundaries

Excluded variables cannot influence the simulation.

Causality

An FCM relationship represents modeled causality, not necessarily empirically established causality.

Convergence

Different structures and activation functions can produce different dynamic behavior.

False precision

A numerical weight such as 0.75 should not automatically be interpreted as an empirical coefficient.

Therefore

FCM results should be interpreted as:

conditional consequences of an explicit model

rather than deterministic predictions.

From Expert Knowledge to Hybrid FCMs

- Classical approach

  Expert" " Knowledge→FCM→Simulation

- Learning approach

  Expert" " Knowledge+Organizational" " Data

↓

- Learning" " Algorithm

  Adapted" " FCM

Main Contribution

Proposed contribution of the paper

FCMs can serve as a **bridge between systemic thinking and computational management analysis**.

The central proposition

- The principal value of an FCM in management is not necessarily to predict the future with precision.

It is to make assumptions about the system:

- visible,
- explicit,
- discussable,
- testable,
- and computationally explorable.

Conclusions

MAIN CONCLUSION: Organizational management problems frequently contain complex causal interactions.

- Systems thinking provides an appropriate conceptual foundation for such problems.
- FCMs provide a computational representation of qualitative causal knowledge.
- Kosko established the foundational FCM framework in 1986.
- Later researchers substantially extended FCM state updating and learning.
- FCMs can support stakeholder participation and scenario analysis.
- Their outputs should be interpreted conditionally rather than as deterministic forecasts.
- Validation and sensitivity analysis are essential.
- FCMs are particularly promising as a bridge between qualitative systemic inquiry and quantitative/computational analysis.
- **Final message**
- **Understand the system → Map the system with an FCM model→ Simulate the system → Learn about the system+Decisions**

Selected References

Foundations

1. Axelrod, R. (1976). *Structure of Decision: The Cognitive Maps of Political Elites*.
2. Kosko, B. (1986). "Fuzzy cognitive maps." *International Journal of Man-Machine Studies*, 24(1), 65–75.

- Systems thinking
- Checkland, P. (1981). Systems Thinking, Systems Practice.
- Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World.
- Mingers, J., & White, L. (2010). "A review of the recent contribution of systems thinking to operational research and management science."

FCM methodology

1. Glykas, M. (Ed.). (2010). *Fuzzy Cognitive Maps*.
2. Groumpos, P. P. (2015). “Modelling business and management systems using fuzzy cognitive maps.”
3. Papageorgiou, E. I. (2012). “Learning algorithms for fuzzy cognitive maps—A review study.”

1. Papageorgiou, E. I., & Salmeron, J. L. (2013). “A review of fuzzy cognitive maps res

Learning

1. Papageorgiou, Stylios & Groumpos (2004).
2. Papageorgiou & Groumpos (2005).
3. Stach, Kurgan & Pedrycz (2010).