Towards Closed-Loop Management

Rudolf Kulhavý
Agenda

1. The Challenge of Management
2. Addressing Complexity
   a. System Dynamics
   b. Variety Engineering
   c. Viable System Model
   d. Pattern Theory
3. Practical Issues
Management?!
Management

judicious use of **means** to accomplish an **end**

Manage

may imply handling or maneuvering, or guiding along a desired course or to a desired result; it often indicates a general overseeing, with authority to handle details, cope with problems, and make routine decisions
Management Versus Control

What do James Watt’s steam governor and organizational performance management have in common?
Steam Engine Speed Control

Desired Speed → Deviation → Controller → Feedback Loop

Fly-Ball Governor

Actual Speed → Sensor

Steam Engine

Steam Supply → Actuator

Machine Operator

Machine Use

Negative (Balancing) Feedback
Organizational Performance Management

- Higher-Level Management
  - Performance Targets
  - Performance Indicators/Metrics
  - Deviation Analysis
- Management
  - Actual Performance
- Feedback Loop
  - Decisions & Actions
  - Allocated Resources
  - Performance Incentives
- Broader Information
  - Negative (Balancing) Feedback
Feedback loop control has been a recurrent topic in management of organizations

- **Scientific Management** “Measure-Analyze-Standardize-Reward”
  - Frederick Winslow Taylor, 1910s
- **Statistical Process Control** “Plan-Do-Check-Act”
  - Walter A. Shewhart, Bell Labs, 1930s
  - W. Edwards Deming, Japan, 1950s
- **Total Quality Management** “Continuous Improvement”
  - U.S. Department of the Navy, 1985
- **Six Sigma Framework** “Define-Measure-Analyze-Improve-Control”
  - Bob Galvin and Bill Smith, Motorola, mid-1980s
- **Sense & Respond Organization** “Adaptive Enterprise”
  - Stephan Haeckel, IBM, 1990s
Human organizations are considerably more difficult to cope with than manufacturing processes.

Human organizations (as socio-technical systems)
- Are inherently insensitive to most policy changes
- Have few leverage points through which behavior can be changed (often not where you might expect them)
- Exhibit a conflict between short-term and long-term consequences of a policy change
Human organizations exhibit much higher level of complexity than technical systems.

The concept of organization goes beyond the formal hierarchy of functionally based reporting relations among people.

A closed network of recurrent interactions

Relations

- Stable forms of communication
- Organizational structure

- Social relationships
- Organizational identity

Raul Espejo, “The viable system model: a briefing about organisational structure,” 2003
Each organization operates around two principal feedback loops:

**Org. Performance Management**

- **Performance Measures**
- **Environment**
- **Management**
- **Operations**
- **Resources and Incentives**
- **Products or Services Provided**

**Supply/Demand Management**

- Make & Sell → Sense & Respond
Modeling organizational performance requires understanding both management and environment behaviors, i.e., taking a closed loop perspective.
Modeling Performance Dynamics

If we design an organization in a certain way, how will it affect the organizational performance over time?

Organizational design

Org. structure
Decision policies

Extended Organization

Performance measures

Externally determined parameters

Closed-loop system’s behavior
The complexity of an extended organization makes its modeling an extremely challenging task

- **Variety**
  - Much higher than typical for technical systems
  - No obvious/natural mapping of variety

- **Dynamics**
  - Inherently nonlinear
  - Typically of high order

- **Uncertainty**
  - Both stochastic behavior and model uncertainty
  - Both performance evolution and structural jumps
System Dynamics
Jay W. Forrester (*1918)

- An electrical engineer, graduate of MIT, inventor of random-access magnetic-core memory
- Since 1956, with MIT's Sloan School of Management
- The founder of **System Dynamics**
  - 1961 – Industrial Dynamics
  - 1968 – Principles of Systems, 2/e
  - 1969 – Urban Dynamics
  - 1973 – World Dynamics
The Endogenous Perspective (Richardson, 1991)

- System Dynamics views the structure of a system as the primary cause of the problem behaviors it is experiencing, as opposed to seeing these behaviors as being “foisted upon” the system by outside agents.

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Organizational design

Externally determined parameters  Causally Closed Model  Performance measures
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System Dynamics views the structure of a system as the primary cause of the problem behaviors it is experiencing, as opposed to seeing these behaviors as being “foisted upon” the system by outside agents.
More often than we realize, systems cause their own crises, not external forces or individuals' mistakes.

Peter Senge
The Fifth Discipline, 1994
System Dynamics

- Represents the real-world processes in terms of
  - stocks (e.g. of material, knowledge, people, money),
  - flows between these stocks, and
  - information that determines the values of the flows.

- These stocks, flows, and feedback relationships map out the actual structure of a system – including any physical flows, non-measured or non-measurable variables that are important to the problem being addressed, and actual (as opposed to idealized) human decision making structures.

- Abstracts from single events and entities and takes an aggregate view concentrating on policies.
Bathtub Dynamics

Level\( (t_2) - Level\( (t_1) \)

\[= \int_{t_1}^{t_2} \text{Inflow}(t) \, dt - \int_{t_1}^{t_2} \text{Outflow}(t) \, dt\]
Compare notation

- **System Dynamics**: stock-and-flow notation

  ![System Dynamics Diagram]

- **Simulink**: block diagram notation

  ![Simulink Diagram]
System Dynamics: An old thing?

- System dynamics modeling is problem-oriented: problems are modeled, not systems.
- Any information that is thought to be relevant to the modeling problem at hand (process, business, equipment, human factors) can be formally incorporated into a system dynamics model.
- This holistic, “big picture” perspective of system is what distinguishes system dynamics from control theory, which has, in its majority, followed rather a reductionist and quantitative route (applying “hard” thinking as opposed to “soft” one).
System dynamics modeling has been a favorite tool of strategy consulting.

Example 1


**Bass Diffusion Model** (Frank M. Bass, 1969)

Andrei Borshchev & Alexei Filippov, "From system dynamics and discrete event to practical agent based modeling: reasons, techniques, tools," *The 22nd International Conference of the System Dynamics Society*, 2004
Example 2

Example 3

Asset-Driven Model of Performance

- Organizational performance depends on resources and capabilities that the organization owns or has access to

  \[ \text{Assets} = \text{Resources} + \text{Capabilities} \]

- An **asset** is a resource controlled by the enterprise as a result of past events and from which future economic benefits are expected to flow to the enterprise

  *International Accounting Standards Board (IASB)*
Performance = function(Assets)

Future Assets = function(Present Assets)

To predict the future performance, one needs to understand how the resources and capabilities affecting the organizational performance change from today’s level to tomorrow’s

Generalization of System Dynamics

Continuous time, deterministic behavior

\[ \dot{x}_t = f(x_t) \]
\[ y_t = g(x_t) \]

Discrete time, deterministic behavior

\[ x_{k+1} - x_k = f'(x_k) \]
\[ y_k = g'(x_k) \]

Discrete time, stochastic behavior

\[ p(x_{k+1} | x_k) \]
\[ q(y_k | x_k) \]

Bayesian inference

Particle filter approximation
Hidden Markov Model

Put in a graph form, the model has the following structure
Bayesian Solution

\[ p(\theta, x_{N-m}^N | u_0^{n-1}, y_1^n, x_{N-m-1}^N, u_{N-m-1}^{N-1}) \]

Proportionality (equality up to a normalizing constant)

Joint probability of parameters and states (within the simulation horizon) conditional on the historical data and simulation conditions

Posterior probability of unknown parameters

Joint probability of states conditional on input sequence and parameters
Variety Engineering
How should one define the performance measures and underlying assets (resources and capabilities)?
W. Ross Ashby (1903–1972)

- An English psychiatrist and a pioneer in the study of complex systems
- 1956, Law of Requisite Variety
  - Only variety can absorb variety
- 1970, Conant-Ashby Theorem
  - Every good regulator of a system must be a model of that system
Variety (Ashby, 1956)

a measure of complexity, determined by the number of states that the system (environment, operations, or management) can take on
Meanings of Variety

- Logarithmic function of the number of states
  \[ \text{Variety} = \log |\mathcal{X}| = \log N \]

- Coincides with entropy for equally probable states
  \[ \text{Entropy} = - \sum_{x \in \mathcal{X}} \frac{1}{N} \log \frac{1}{N} = \log N \]

- Proportional to the dimension of a (uniformly partitioned) state space
  \[ \log N = \log m^n = n \log m \]
Variety needs to be managed actively along all communication channels

The challenge is to balance the varieties of operations & environment and management & operations via appropriate attenuators and amplifiers.
To attenuate variety:
- Standardize communication
- Standardize processes
- Ignore unimportant information
- Filter unnecessary details
- Deal with exceptions only
- Aggregate similar cases
- Model the environment behavior
- Model the organization behavior

To amplify variety:
- Empower subordinates
- Hire more employees
- Train existing employees
- Hire more experienced employees
- Cooperate with external agents
- Customize product/service offerings
- Multiply product/service options
- Combine multiple products/services
Viable System Model
What should the structure of a viable organization look like?

\textit{viable} = \textit{capable of maintaining separate existence in a dynamic and uncertain environment}
Stafford Beer (1926-2002)

- A British theorist in operational research and management cybernetics
- Worked as a top manager, scientist, consultant and as a teacher of management
- Formulated conditions for system viability in *Viable System Model*
  - 1972 – *Brain of the Firm*
  - 1979 – *The Heart of Enterprise*
  - 1985 – *Diagnosing the System for Organizations*
The Viable System Model

System 1
Operation
Regulatory capacity of the basic units, autonomous adaptation to their environment, optimization of ongoing business
The Viable System Model

Environment

Present

Op Unit 1

Op Unit 2

Op Unit 3

Coordination

System 2

Coordination

Amplification of self-regulatory capacity and attenuation to damp oscillations and coordinate activities via information and communication
Establishment of an overall optimum among basic units, providing for synergies as well as resource allocation.
The Viable System Model

System 4
Intelligence
Dealing with the future, especially the long term and with the overall outside environment, diagnosis and modeling of the organization in its environment.
Balancing present and future as well as internal and external perspectives; moderation of the interaction between Systems 3 and 4; ascertaining the identity of the organization and its role in its environment; embodiment of supreme values, rules and norms - the ethos of the system.
The organizational behavior is produced by its structure, which is determined by the relationships between
- an **Operation**,  
- its **Management**,  
- their **Environment**.
VSM works recursively:
- Each of the operational units is a viable system in its own right.
- The organization is itself a part of a larger viable system.
The Viable System Model has received significant attention. 100+ books.
Pattern Theory
Lower transaction costs facilitate internal and external specialization

**The Nature of the Firm (1937)**

- A firm tends to expand until the costs of organizing an extra transaction within the company become equal to the costs of carrying out the same transaction on the open market.
- If interaction costs go down, the need to keep all business activities in-house diminishes.
- As transactions costs decline, in large part because of developments in IT, corporations come to function at lower levels of aggregation.

**Ronald Coase**

Nobel Prize for Economics in 1991
Individual business capabilities are easier to develop, maintain and optimize.

No Free Lunch Theorem
Yu-Chi Ho, Harvard Univ.

Efficiency \times Robustness = \text{constant}

Globally optimized performance is difficult to sustain if the organization’s environment changes frequently.

Autonomous business components give an organization increased robustness with respect to varying environment.
Specific capabilities can be combined on demand as the environment changes

- The traditional factory is like a battleship that is a large, inflexible structure designed for one task.
- The “postmodern” factory is more like a flotilla, consisting of modules centered either on a stage in the production process or around a number of closely related operations.
- The flotilla model allows for changes in the production process in order to respond to surges in market demand.

Peter Drucker, 1990
The emerging theory of manufacturing
Harvard Business Review, 94-102
Whatever the perspective, value networks continue to replace the virtually integrated organizations

- Natural Gas Distributors → Electricity Generators
- Electricity Generators → Manufacturers
- Parts Suppliers → Car Manufacturers
- Mortgage Originators → Mortgage Servicers
- Insurance Underwriters → Claims Processors
- Food & Beverage Suppliers → Hypermarkets
- Pesticide & Fertilizers Manufacturers → Farmers

*Also known as supply chains, value chains, value webs, collaborative networks, etc.*
Organizational nodes get connected into high-performing value network configurations.
Multiple stakeholders may need to be considered

- Investor
  - ROC Offered/Requested
- Bank
  - Compliance Granted/Requested
  - Regulatory Capital Allocated/Required
  - Price Offered/Requested
- Client
  - Loan Offered/Requested
  - Capital Invested/Required
Pattern Theory provides a convenient mathematical framework for modeling value networks.

- **Supplier**
- **Product/Service Offered**
- **Price Requested**
- **Price Offered**
- **Purchaser**
- **Product/Service Requested**
- **Generator**

**Generator Attributes**

**Bonds**
- **Price Offered**
- **Product/Service Offered**
- **Product/Service Requested**

**Bond Values**

**Configuration**
A regular (bond-matching) combination of generators

**Image**
A class of equivalent (undistinguishable) configurations

**Deformed Image**
A noisy or uncertain image
Ulf Grenander (*1923)

- A Swedish mathematician, since 1966 with Division of Applied Mathematics at Brown University
- Highly influential research in time series analysis, probability on algebraic structures, pattern recognition, and image analysis.
- The founder of Pattern Theory
  1993 – General Pattern Theory
  2007 – Pattern Theory: From Representation to Inference
Value networks get modeled as Markov random fields with nodes whose dynamic performance is determined by both endogenous factors and external (bond-enabled) inputs.

Bonding does not come for free – the transactional costs add up to the price of product or service purchased!

Discrete-time analog of a jump-diffusion Markov process.
Problems of Interest

- Optimum configuration of a value network (from the process orchestrator’s viewpoint)
- Optimum selection of suppliers and purchasers (from the node-level organization’s viewpoint)
- Optimum design of organizational structure (which organizational competencies should be maintained and which should be outsourced)
- Optimum positioning within existing value networks (which organizational competencies would deserve to be insourced)
- Optimum organizational performance development (how to increase the bonding potential of the organization within existing or future value networks)
Practical Issues
Two Primary Challenges

- The tedious modeling phase
  - The approach outlined models specific problems rather than underlying systems
  - There are many problems of potential interest …
  - How can one proceed effectively, without starting anew in each problem

- Way to market
  - There are established ways how advanced process control can reach the market
  - The situation with organizational management is different
Way to Market

- The chasm of *Two Cultures* (C.P. Snow)
  - The application of mathematical models in management is still viewed with distrust, as an academic and impractical endeavor

- The preference for *one-size-fits-all* predictive models
  - An opportunity for rich, elegant and widely applicable theory
  - A sufficient demand to justify the software development costs

- The difficulty of turning dynamic simulation modeling into a practical tool
  - Educating managers in dynamic modeling?
  - Developing reusable model archetypes?
  - Facilitating the modeling process with software?
Many Related Disciplines

- Cybernetics, Organizational Cybernetics
- Systems Theory, Control Theory
- Nonlinear Dynamics, Chaos Theory
- Operations Research, Systems Analysis
- Decision Theory, Decision Analysis, Decision Support
- Statistics, Econometrics
- Macroeconomics, Microeconomics
- Organizational Behavior, Management Science
- Business Intelligence, Business Performance Management

Yet, no established name for control of human organizations!
[Feynman’s] driving curiosity was apparent when, in his last media interview, he told The Boston Globe last year that his work on the Shuttle commission had so aroused his interest in the complexities of managing a large organization like NASA that if he were starting his life over, he might be tempted to study management rather than physics.

From the obituary of Richard P. Feynman in the Boston Globe, 16 February 1988
Questions?