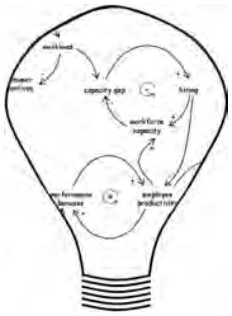
This course book preview is provided as an opportunity to see the quality of the course material and to help you determine if the course matches your needs. The preview is provided in a PDF form that cannot be printed.

It is my goal to provide a course book that is content-rich and that is useful as a reference document after the class has ended.

This preview shows selected pages that are representative of the entire course book. The pages shown are not consecutive. The page numbers as they appear in the actual course material are shown at the bottom of each page. All table-of-contents pages are included to illustrate all of the topics covered by the course.

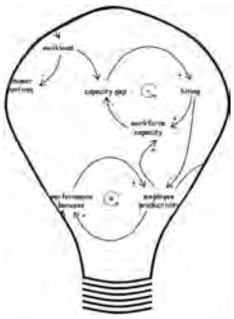
Dave Wells - dwells@infocentric.org



Understanding Cause and Effect

An Introduction to Systems Thinking

TABLE OF CONTENTS

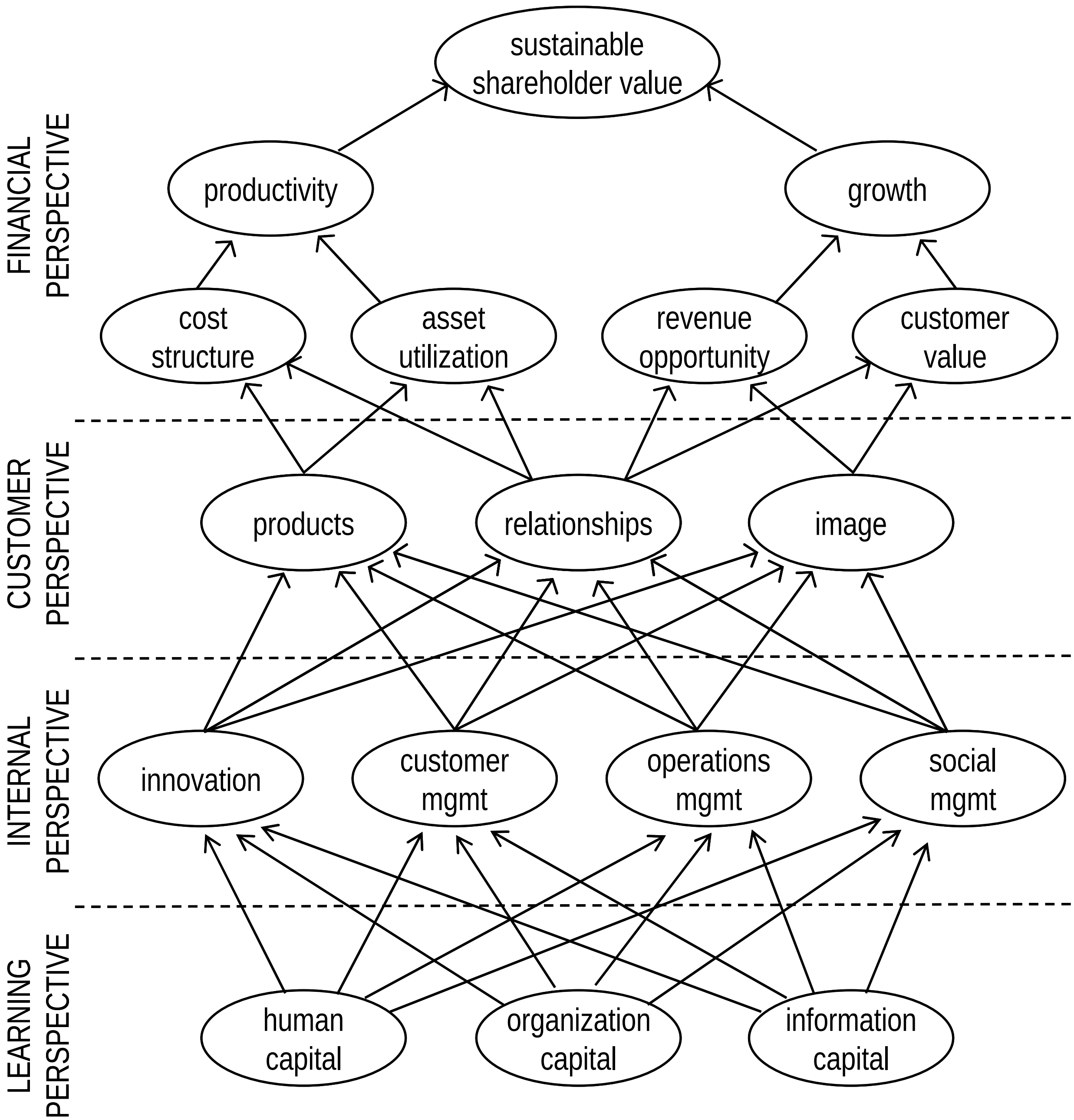


Module 1

The Nature of Cause and Effect

Cause-Effect Models

Strategy Maps



Cause-Effect Models

Strategy Maps

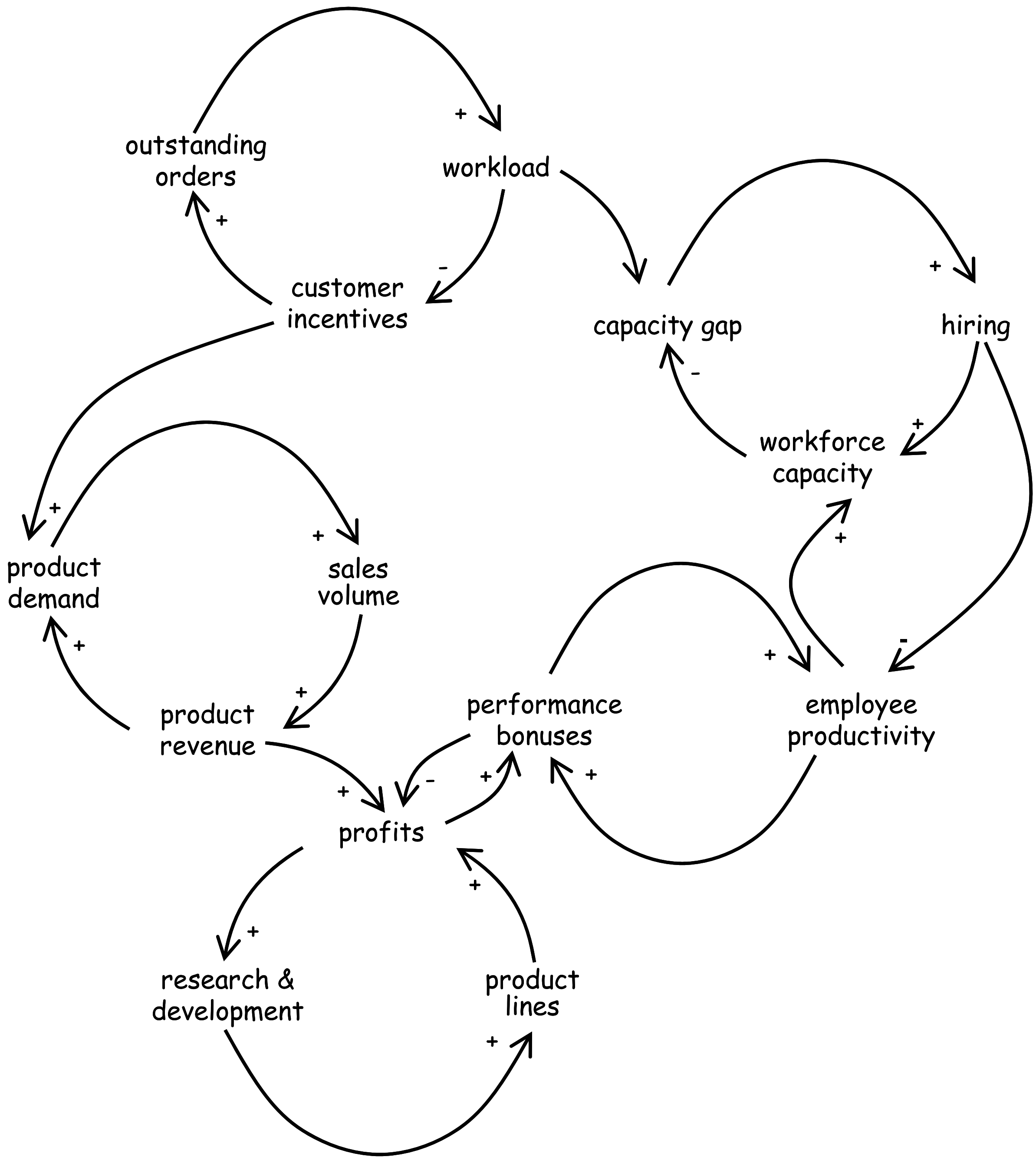
TOP-DOWN AND GOAL SEEKING

Strategy mapping is a specific variation of causal hierarchy that is aligned with the Balanced Scorecard approach to business management. Strategy mapping is a top-down approach but is not strictly hierarchical because it allows many-to-many relationships between elements of the model.

Strategy mapping is particularly useful for organizations that practice the Balanced Scorecard approach to management. As with fishbone diagrams and causal hierarchies, strategy maps fail to recognize and support feedback in cause-effect relationships.

Cause-Effect Models

Causal Loop Models



Cause-Effect Models

Causal Loop Models

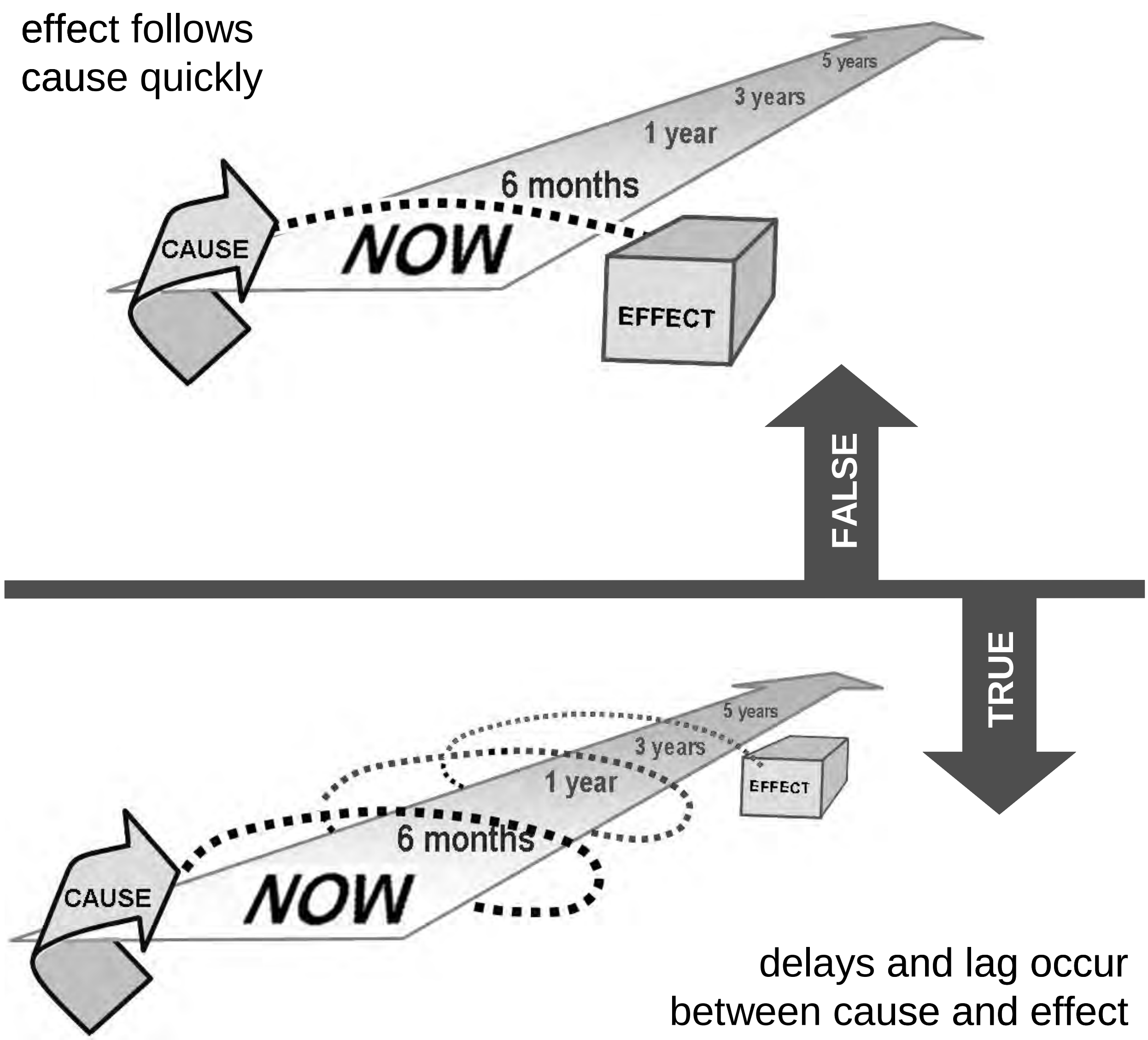
INFLUENCE AND FEEDBACK

Causal loop diagramming is a form of cause-and-effect modeling. The diagrams represent systems and their behaviors as a collection of nodes and links. Nodes represent the things in a system and links illustrate interactions and influences.

This modeling technique is well aligned with the principles of systems thinking. While more complex than fishbone diagrams, they remain relatively easy to understand and to create. Among the strengths of causal loop models is the ability to represent feedback. Feedback loops are, in fact, a basic construct of the models. Causal loop diagrams are effective to represent a system as a collection of interacting things. They illustrate *what* influences exist but do not show *how much* influence is exerted.

Cause and Effect Misconceptions

Immediate vs. Delayed



Cause and Effect Misconceptions

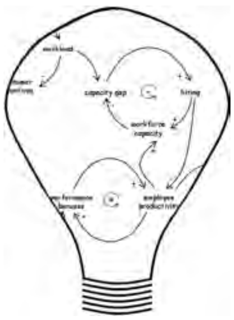
Immediate vs. Delayed

TEMPORALLY SEPARATED

Just as cause and effect may be separated in space, they are also likely to be separated in time. The effects of a causal event are rarely immediate, and are frequently subject to long delays. Time and delay are, in fact, among the most important principles of systems thinking. Temporal separation makes cause-effect patterns difficult to detect, compounds relatively minor effects, and makes problem-to-solution processes a challenge.

Consider these real life examples:

- It is much easier and takes less time to get into debt than to get out of debt.
- It is faster and easier to gain weight than to lose weight.



Module 2

The Nature of Systems

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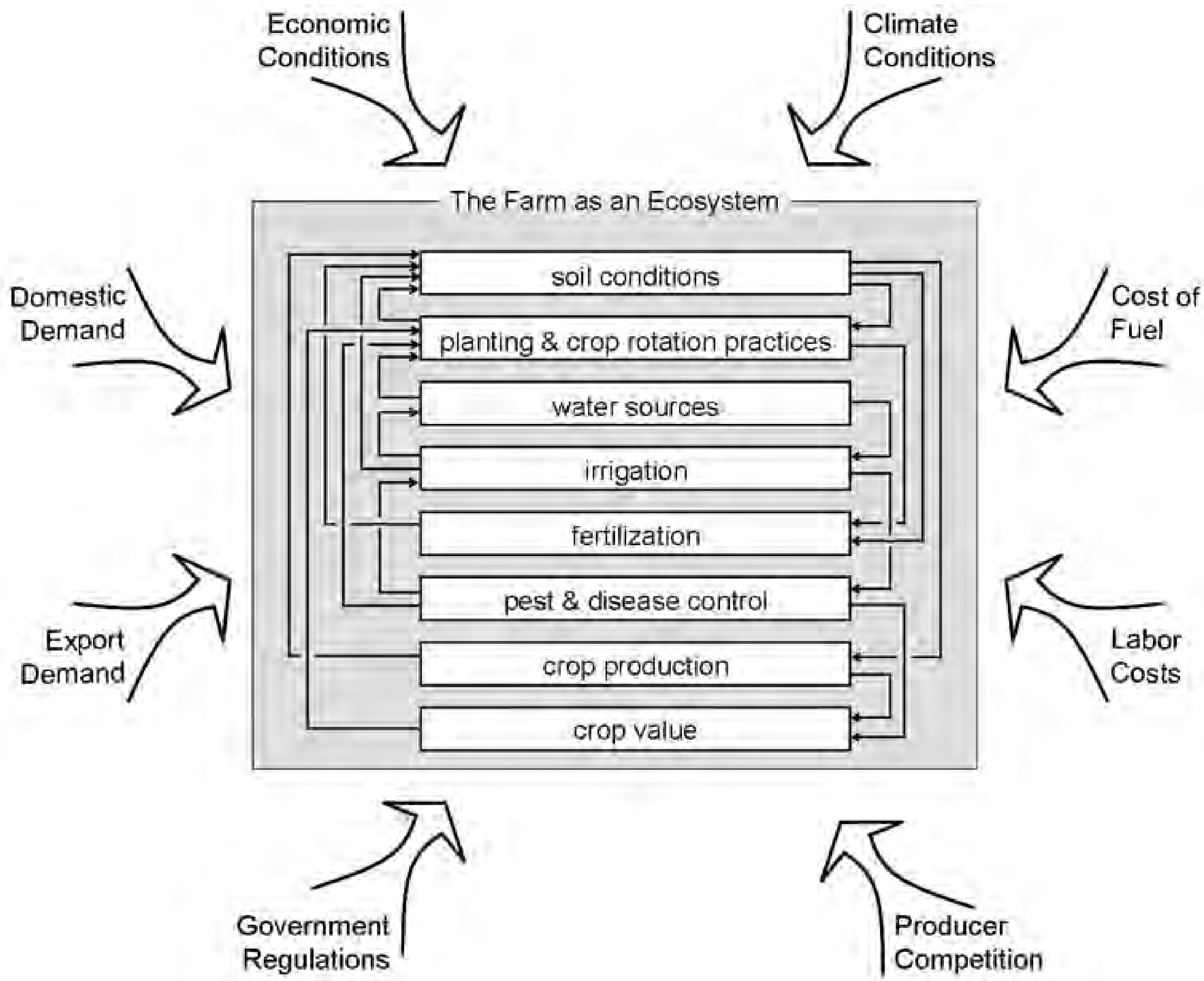
System Boundaries

Purpose and the Scope of a System



System Boundaries

Purpose and the Scope of a System

WHERE ARE THE BORDERS?

Recall the earlier statement from wikipedia:

We determine a system by choosing the relevant interactions we want to consider, plus choosing the system boundary.

Every system is part of some larger system. Boundaries identify what lies within the scope of the system and what lies immediately outside of the borders. Boundaries help to understand the purpose of a system, and purpose helps to identify the boundaries.

INSIDE-OUTSIDE

Although a system is defined as a collection of interacting parts, the interactions of a system are not restricted to interactions among parts within the boundaries. Most systems (we'll discuss closed systems later) interact with, influence, and are influenced by things outside of the border.

THE EXAMPLE

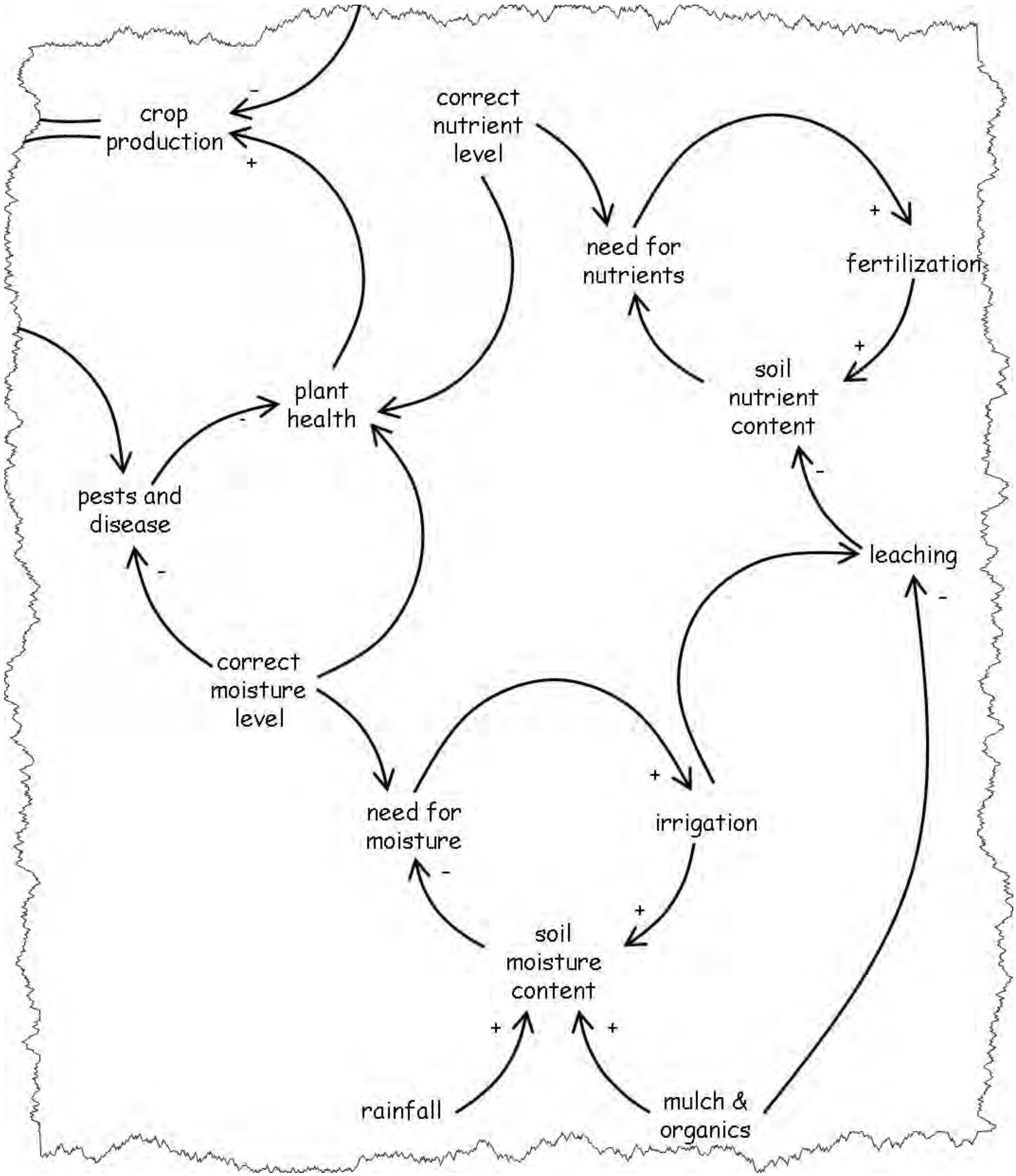
The facing page illustrates an example of a crop farm as a system. The parts within the boundary – soil, nutrients, water, plants, disease, etc. – interact to produce crops. The purpose of this system is sustainable crop production. Many things exist external to the system that exert influence and affect the ability of the system to fulfill its purpose.

The farmer must be aware of all of these forces from climate conditions to government regulations. Yet to include them in the scope of analysis would fundamentally change the nature and purpose of the system under analysis.

Define the boundaries based upon the purpose of analysis. If the farmer seeks to understand the causes of high-yield crop production then this is the right scope. Everything within the boundary can be influenced by the farmer. What is outside the boundary simply exists and must be accepted as influences upon the crop producing system.

System Behaviors

Interactions and Outcomes



System Behaviors

Interactions and Outcomes

FINDING PARTS BY LOOKING AT INFLUENCE

Studying a system from the perspective of interaction and influence leads to discovery of parts in a different way than decomposing a system functionally or structurally. The earlier (reductive) model of the farm identified the parts as soil conditions, planting and crop rotation practices, water sources, irrigation, fertilization, pest and disease control, crop production, and crop value.

The problem with this list of parts is that I can't go deeper; I can't describe in a simple relationship *how* soil conditions influence crop production or *why* crop rotation practices influence soil conditions. When I begin to explore these kinds of questions about influence the list of parts changes significantly. It becomes more granular and specific. Soil condition is represented as soil nutrient content and soil moisture content which interact with need for nutrients and need for moisture respectively. These parts, in turn, interact with other objects such as irrigation, leaching, fertilization, etc.

Now I begin to understand the behaviors inherent in this system. The answers are different because the questions are different. Instead of asking *"what are the parts?"* ask *"what are the influences?"* With this question you'll find a more interesting and more useful list of parts.

BEHAVIOR, INFLUENCE, PURPOSE, AND PARTS

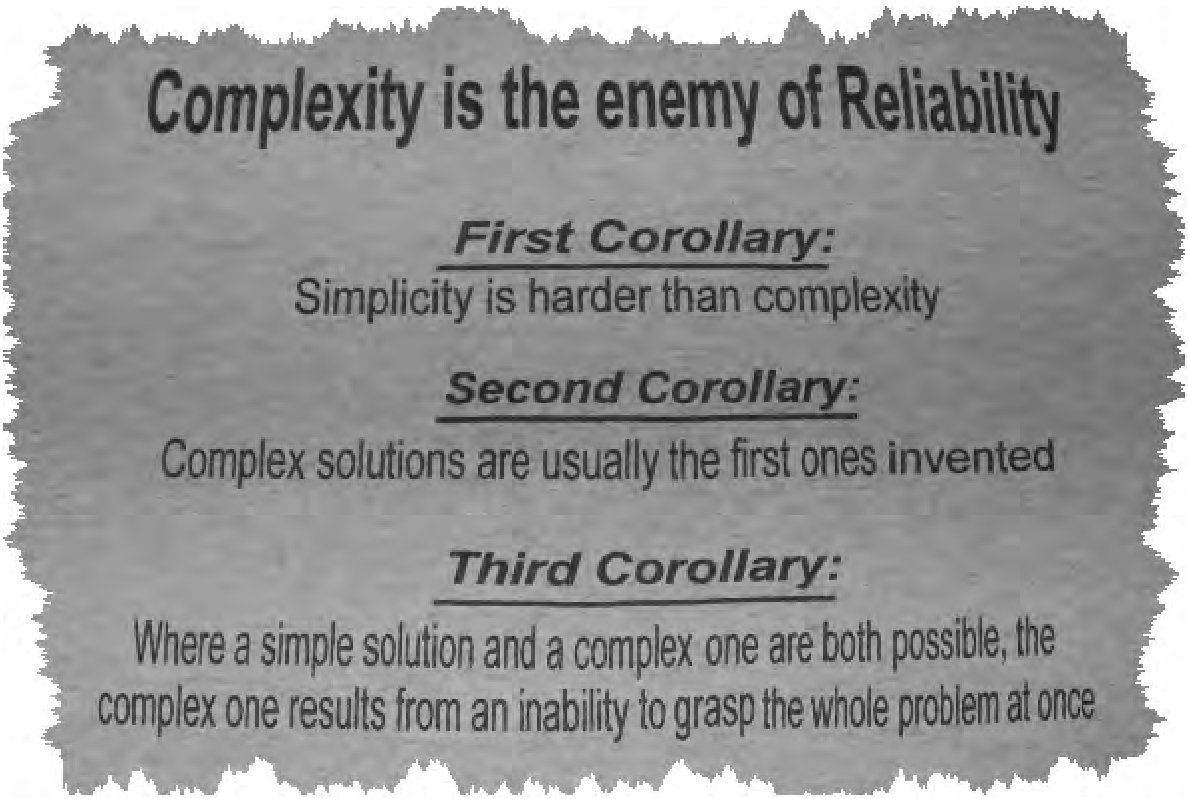
Every systems analysis effort is undertaken with an objective – typically to optimize or improve the system. The goal, then, is to understand the behavior of the system sufficiently to affect that behavior. When seeking to affect behavior, the parts are the least interesting things in a system. Consider these truths about the nature of systems:

- Changing the parts of a system has little or no impact.
- Changing the interactions in a system has greater effect than changing the parts.
- Changing the purpose of a system has huge and potentially disruptive impact.

The Reality of Systems

Quotes, Clichés, and Realities

Salnick's Law (Bob Salnick)


Complexity is the enemy of Reliability

First Corollary:
Simplicity is harder than complexity

Second Corollary:
Complex solutions are usually the first ones invented

Third Corollary:
Where a simple solution and a complex one are both possible, the complex one results from an inability to grasp the whole problem at once

If A causes B, is it possible that B also causes A?

Donella "Dana" Meadows

The Reality of Systems

Quotes, Clichés, and Realities

SYSTEMS THINKING AND COMMON SENSE

Much of systems theory and systems thinking is represented in common quotes and sayings. Some examples from Donella "Dana" Meadows, a leader in the field of systems thinking:

"A quantity growing exponentially toward a constraint or limit reaches that limit in a surprisingly short time." – D. Meadows

Nothing succeeds like success …

"The least obvious part of the system, its function or purpose, is often the most crucial determinant of the system's behavior." – D. Meadows

Can't see the forest for the trees …

"Because of feedback delays within complex systems, by the time a problem becomes apparent it may be unnecessarily difficult to solve." – D. Meadows

A stitch in time saves nine …

"If a reinforcing feedback loop rewards the winner of a competition with the means to win further competitions, the result will be the elimination of all but a few competitors." – D. Meadows

The rich get richer, and the poor get poorer …

"A diverse system with multiple pathways and redundancies is more stable and less vulnerable to external shock than an uniform system with little diversity." D. Meadows

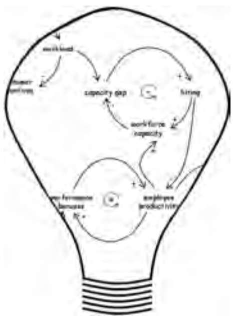
Don't put all of your eggs in one basket …

. Poul Anderson

MORE QUOTES

Poul Anderson, the science fiction author, once said "I have yet to see any problem, however complicated, which, when looked at in the right way did not become still more complicated." Systems thinking seeks to achieve the opposite – to uncomplicated.

Salnick's Law (by Bob Salnick, a little-known systems engineer) expresses similar sentiments.

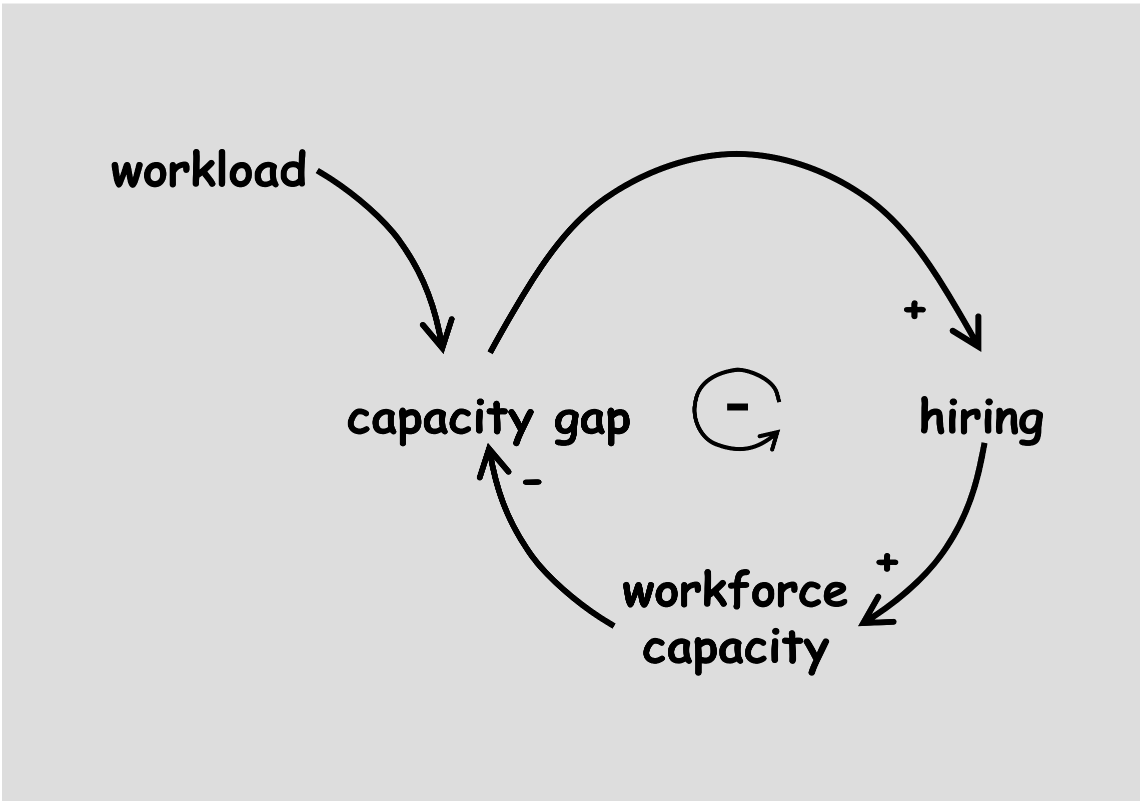


Module 3

Systems Thinking Concepts

Systems Thinking Loops

Balancing Loops



Systems Thinking Loops

Balancing Loops

NEGATIVE LOOPS

Negative polarity loops are known as balancing loops. These loops attempt to bring two things into agreement. They are sometimes referred to as goal-seeking loops.

The things in a balancing loop will assume specific roles. A desired state is established by an external link – the "goal" of goal-seeking. Participating in the loop are things that represent the current state, the gap between desired and current states, and the action which seeks to close the gap.

In the example the balancing loop roles are

- Workforce Capacity describes the current state.
- Workload establishes the desired state.
- Capacity Gap is the difference between current and desired states.
- Hiring seeks to balance workforce capacity with workload.

Systems Thinking Archetypes

Recurring Patterns of Behavior

Systems Archetypes are generic causal loop models that represent recurrent patterns of behavior in systems. Balancing and reinforcing loops are the two most basic archetypes upon which more complex archetypes are constructed.

Accidental Adversaries

Drifting Goals

Escalation

Fixes that Fail

Growth & Underinvestment

Limits to Success

Shifting the Burden

Success to the Successful

Tragedy of the Commons

Systems Thinking Archetypes

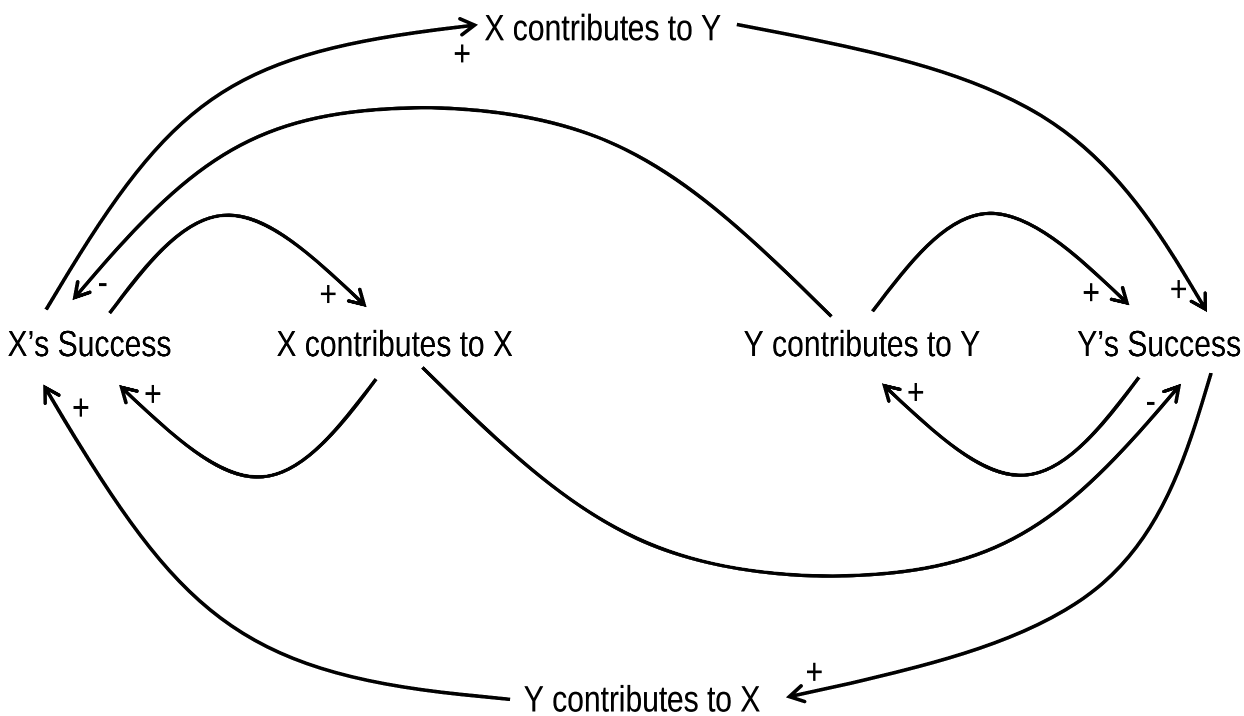
Recurring Patterns of Behavior

GENERIC SYSTEM STRUCTURES

Generic structures in systems that can be generalized across many different settings because the underlying relationships are fundamentally the same are known as archetypes. In addition to reinforcing loops and balancing loops, nine system archetypes are widely recognized as illustrated on the facing page.

Systems Thinking Archetypes

Accidental Adversaries



Systems Thinking Archetypes

Accidental Adversaries

BEHAVIOR

Localization with system-wide sub-optimization is characteristic of Accidental Adversaries.

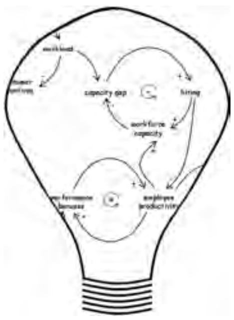
CHARACTERISTICS

- Two distinct local reinforcing loops exist, represented by X and Y.
- X behaves locally to contribute to X's own success.
- Y behaves locally to contribute to Y's own success.
- X behaves cooperatively to contribute to Y's success.
- Y behaves cooperatively to contribute to X's success.
- The two cooperative links create a system global reinforcing loop.
- X's local actions to contribute to X's success have unintended consequences that inhibit Y's success.
- Y's local actions to contribute to X's success have unintended consequences that inhibit X's success.
- Overall system potential is limited by the effects of unintended consequences of local optimization without global system awareness. The value of the global reinforcing loop is diminished.

EXAMPLES

Socio-Cultural Example: National security vs. workforce economics as they are related to US immigration policies.

Consider an example where you and I are managing separate but related software development projects. Cooperatively we have agreed to develop shared and reusable software components where practical. Yet each of us, when faced with schedule pressures or conflicting needs, chooses to build local custom components



Module 4

Causal Loop Modeling

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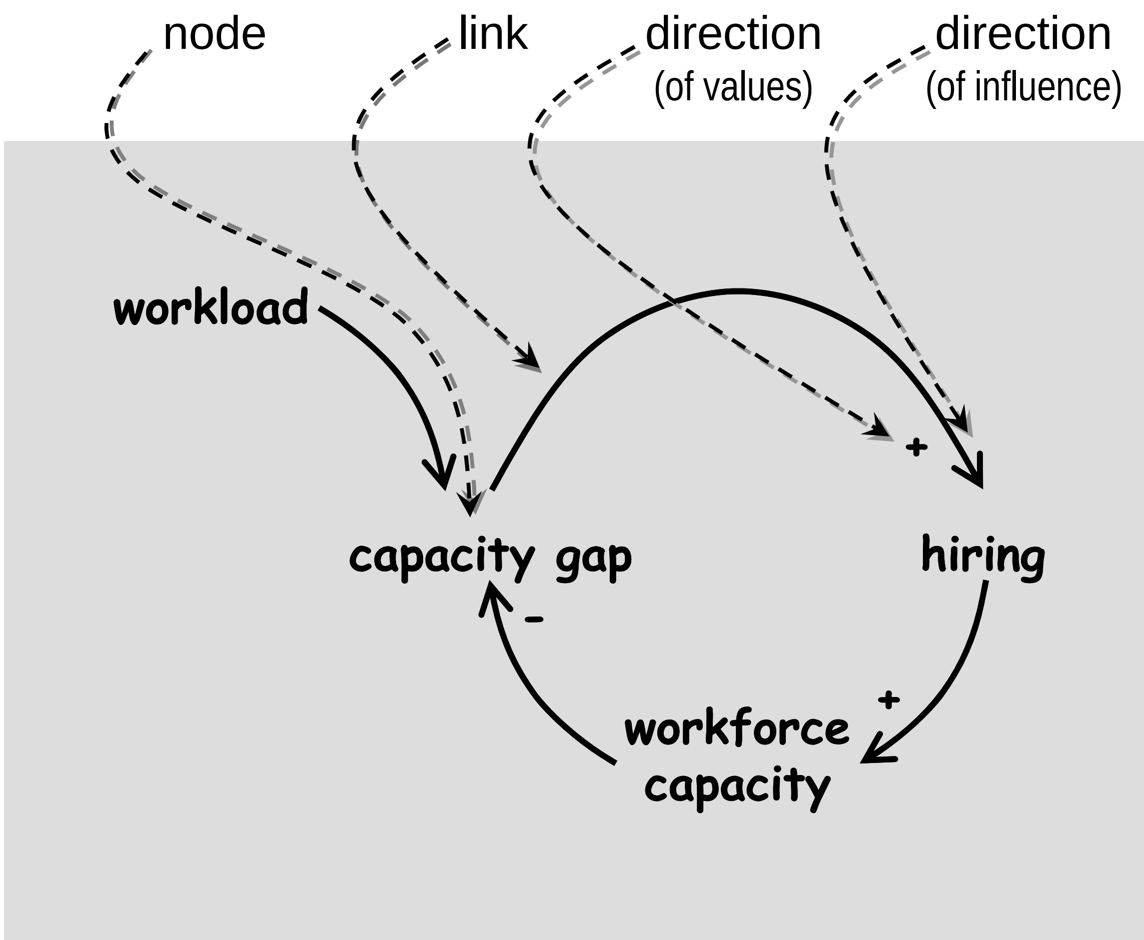
Modeling Basics

Nodes and Links



Modeling Basics

Nodes and Links

CLDs

Visually Representing System Behavior is widely practiced in systems thinking with a Causal Loop Diagram (CLD). Causal loop diagramming is a form of Cause and Effect modeling. The diagrams represent a systems and behaviors as a collection of nodes, links, and loops.

NODES

Nodes illustrate the things in a system. A node is simply a text label to which links are connected.

LINKS

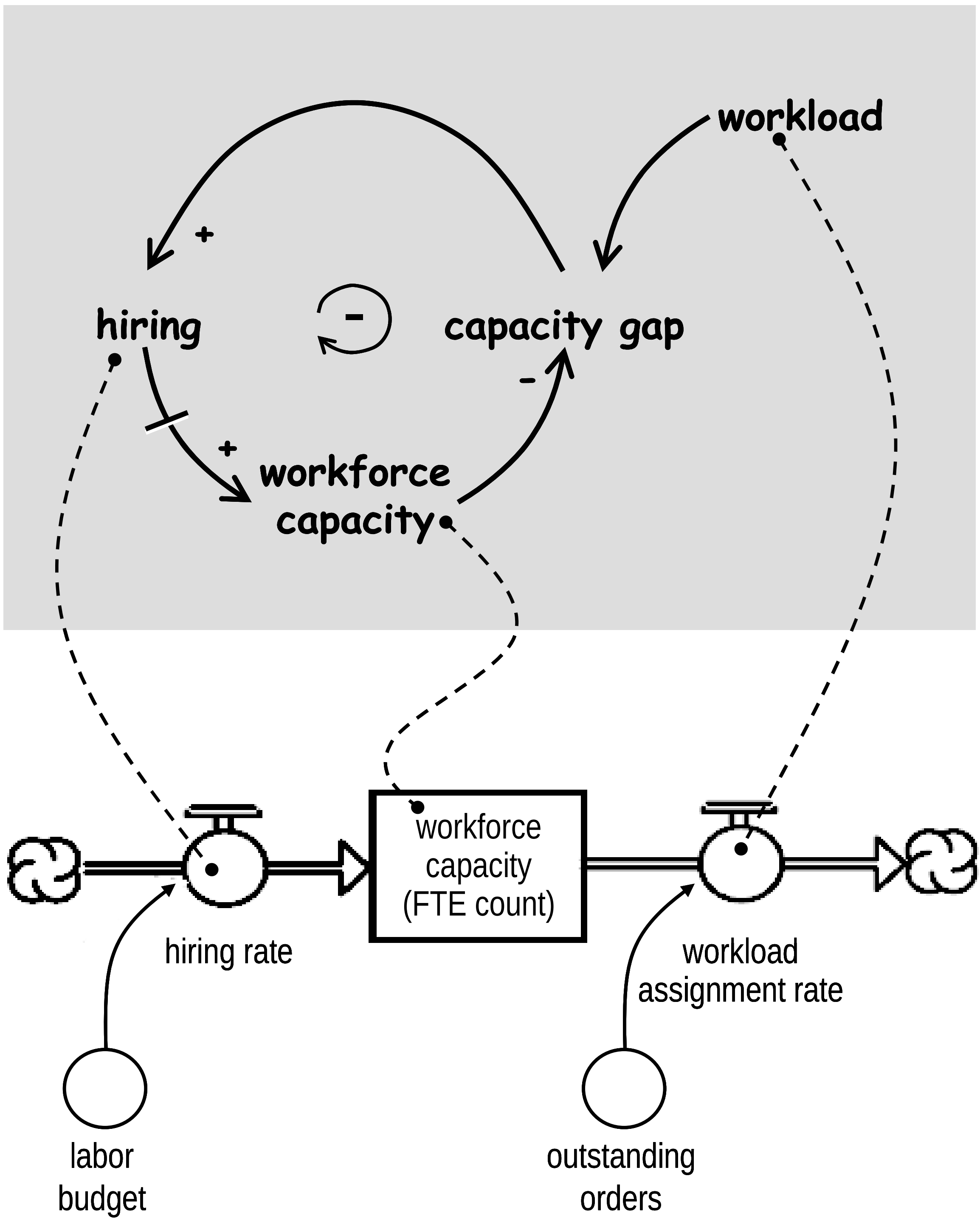
Links illustrate the interactions and influences among nodes.

Direction of values is a property of a link indicating whether influence causes values to move up and down in the same direction or in opposite directions.

Direction of influence is a property of a link drawn as an arrowhead to show which node exerts influence and which node demonstrates effects of influence.

Causal Modeling and Quantification

From Causal Loop to Stock-and-Flow



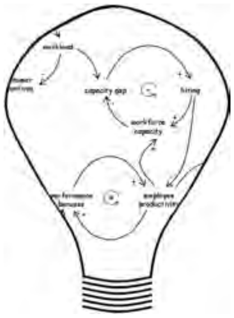
Causal Modeling and Quantification

From Causal Loop to Stock-and-Flow

MORE INSIGHT INTO SYSTEM BEHAVIORS

A systematic process of working from a CLD to create stock and flow diagrams uses a sequence of:

- Identify critical behaviors of the system – those that are problematic, under study of analysis, or central to the goals and strategies of the organization.
- Identify the stocks that participate in critical behaviors of the system – those things that are accumulated in the system upon which critical behaviors are dependent.
- Name each stock with a term that is quantitative but not comparative. (The example on the facing page adds “(FTE count)” to the name “workforce capacity” to make it quantitative. But it does not say “more workforce capacity” which is comparative language.)
- Examine every link to each stock to determine if it becomes a flow. If the influence is one that changes the accumulated quantity of the stock, then it is a flow.
- Add each flow to the diagram expressing the influence as units-over-time or rate of flow. (The example on the facing page translates “hiring” from the CLD to “hiring rate” in the stock and flow diagram, and “workload” to “workload assignment rate.”)
- Examine each flow in context of the system-wide CLD to identify links that are converters – influences that regulate or otherwise affect the rate of flow. Labor budget and outstanding orders are converters in the example on the facing page.
- Mark the boundaries – start and end – of the model.



Module 5

Applied Systems Thinking

Topic	Page
Systems Thinking for Analytics	5-2
Systems Thinking and Business Strategy	5-4
Systems Thinking and Organizations	5-6
Systems Thinking and Quality Management	5-8

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Systems Thinking and Quality Management

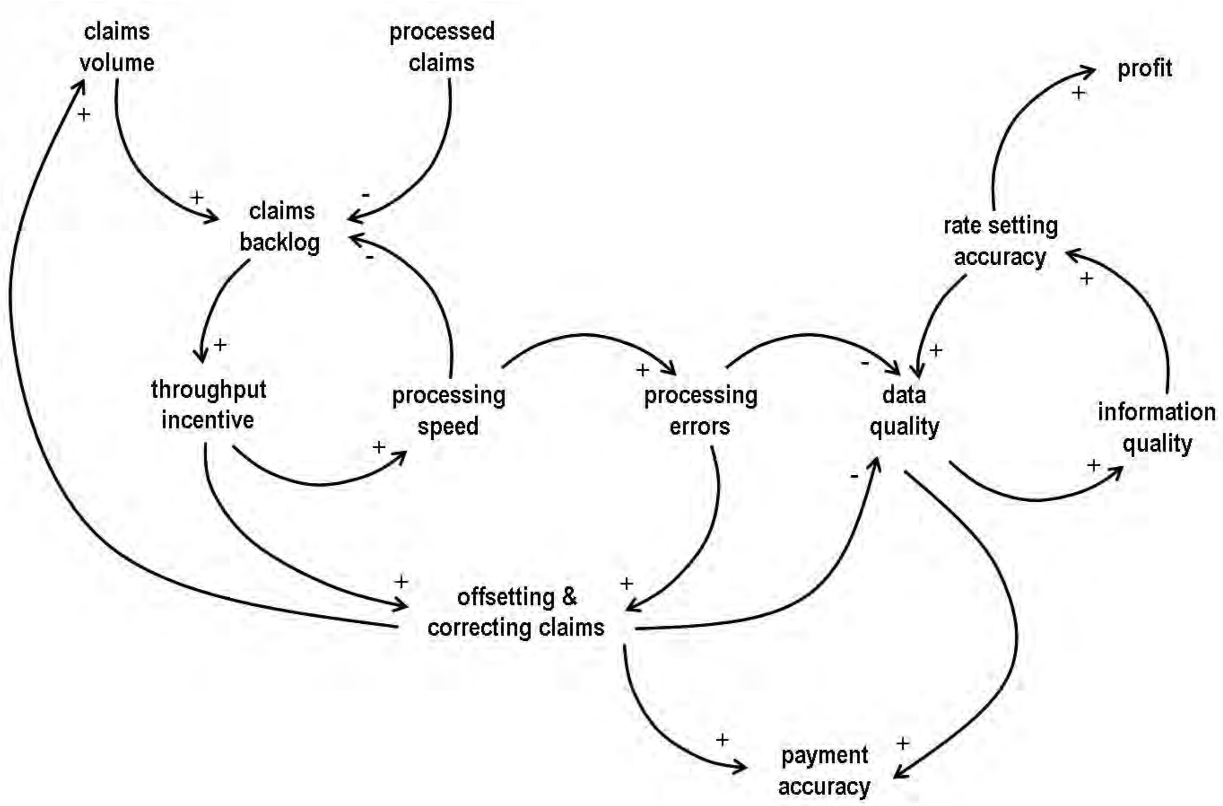
Quality Improvement Applications

Information systems are complex.

Data quality has many influences.

Root cause analysis is especially difficult in data quality.

Many DQ efforts fail because they fix only the symptoms.



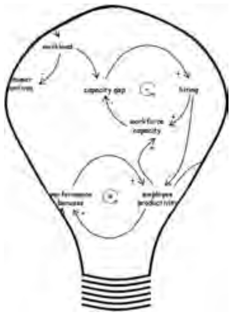
Systems Thinking and Quality Management

Quality Improvement Applications

SEEKING ROOT CAUSES

Understanding root causes is fundamental to quality improvement efforts. Too frequently quality initiatives spend their time and resources addressing symptoms. Systems-thinking provides a disciplined way to find the real causes and make significant steps in quality improvement.

At the time of this writing I am not aware of any books or courses that address this application area. I do have plans to develop a course that specifically addresses systems-thinking for data and information quality processes.



Appendix A

Glossary of Terms

Glossary

Page 1 of 7

Abstraction	Abstraction is the act of removing details and specifics from something. Abstraction makes us able to see the general concepts, ideas, or impacts of a thing or a class of similar things.
Accidental Adversaries	Accidental Adversaries is a system archetype in which two reinforcing loops each inhibit the success of the other as a side-effect of localized optimization and system-wide sub-optimization.
Action	In a causal loop diagram action is a node of a balancing loop that seeks to close the gap between current state and desired state. Note that the word action also has a less specific meaning in the context of systems thinking.
Actionable Information	Information is actionable when it supports the entire process of action-taking including discovery and insight, determination and resolve, decision-making, innovation and creativity, and the implementation of decisions. Actionable information is aligned with the knowledge of the person taking action, and integrates with the processes where actions are to be implemented.
Analytic Systems	Analytic Systems are those systems that aggregate measures into metrics, present them in graphical, tabular, or other formats, and provide end-user capabilities for access and analysis.
Archetype	A system archetype is a generic structures in Systems that can be generalized across many different settings because the underlying relationships and behaviors are fundamentally the same.
Balancing Loop	A balancing loop is a negative polarity loop in a causal loop diagram – one which seeks to bring two things into agreement. Balancing loops are also known as goal-seeking loops.
Behavior over Time Graph	A Behavior over Time Graph (BOTG) is a simple and widely used tool to understand patterns of behavior over a period of time. It removes attention from isolated events which leads to deeper understanding of systemic behaviors.
BOTG	See Behavior over Time Graph.
Business Intelligence	Business Intelligence is the ability of an organization or business to reason, plan, predict, solve problems, think abstractly, comprehend, innovate, and learn in ways that increase organizational knowledge, inform decision processes, enable effective actions, and help to establish and achieve business goals.