Maritime College
State University of New York

Department of Global Business and Transportation

System Design and Control within the Context of Supply Chain Management Certificate

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Introduction

Central to the Certificate in Supply Chain Management, a supplement to the Masters of Science in International Transportation Management granted by SUNY Maritime College, is a course sequence comprising Supply Chain I, Supply Chain II, and System Design and Control.

Supply Chain I asks the student to examine a supply chain to uncover the opportunities for improving performance (i.e., the existing or as-is situation). Supply Chain II asks the student to recommend actions for realizing the opportunities uncovered in Supply Chain I (i.e., the future or to-be situation). System Design and Control asks the student to consider how the as-is may be transformed into the to-be and, subsequently, how the to-be will be controlled.

Figure 1 The Three Courses

This sequence is taken over a two-term sequence with Supply Chain I in the first term, and the remaining two courses concurrently in the second term. This notion of concurrency is critical. The to-be constitutes a set of objectives that must be achievable within reasonable investments of talent, time, and money. An objective (e.g., a perpetual motion machine) that is not reasonably achievable ought not be declared nor should the mechanism be designed to achieve that objective.

There is constant tension between dreaming and practicality. System design and control aims to manage that tension.

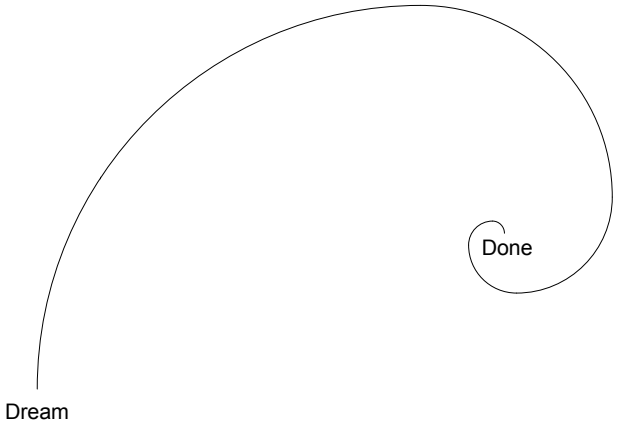

Figure 2 From Dream to Done

Figure 2 is representative of this idea of trade-offs and iteration. Consider also that the destination may not be what was originally planned. For example, Columbus was not intending to discover the Americas when he sailed west from Palos de la Frontera in 1492.

This note, a composition of four additional notes or papers, is intended to be introduced in Supply Chain I as guidance to the student during this course an its postrequisite, Supply Chain II.

Part I: An Introduction to System Design and Control (James Drogan, 2008, pp. 1-13) and A Note on Control (J. Drogan, 2008).

The fundamentals of systems and design are introduced in the first note. The second note takes up the matter of control.

Part II: An Introduction to System Dynamics ("Chapter 1: System Behavior and Causal Loop Diagrams," n.d.; "Chapter 2: A Modeling Approach," n.d.)

One would not need control mechanisms if systems did not exhibit dynamic behavior. Part II introduces systems (or business) dynamics as an approach to understanding the critical dynamics of systems.

Part III: An Introduction to the Supply Chain Operations Reference Model (*Supply Chain Operations Reference (SCOR) Model: Overview, Version 10.0*, n.d., pp. 1-8)

Supply chains are not new. Much has been discovered, designed, developed, and implemented. While there may be reason to invent, there seems to be little reason to reinvent. SCOR is a synthesis of a considerable amount of thought and experience on how to improve supply chain performance. It provides reusable objects, tools, and techniques which can help in the design, development, and implementation of a supply chain.

Part IV: Other Things Not Yet Mentioned. Organizational and Personal Change Management, Process, Plans, Change Management and Business Development Tips (Chapman, 2010) and (James Drogan, 2009)

Other factors are important to effective and efficient system design and control. Managing the change from the as-is to the to-be and the management of data are two of these factors.

Note the page numbers in the citations in the above list. These pages are the most relevant to the purposes of this note. If no pages are given then you should read the entire note.

References

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An Introduction to System Design and Control

Introduction

We are surrounding by systems – banking, transportation, medical, education for example – that we often take for granted simply because they are such a regular part of our lives. We often don't give much thought to what constitutes these systems, why they exhibit certain aspects of behavior, why they fail, what distinguishes a good system from a poor system.[1]

And, in fact, if systems are not our principal responsibility and if they provide the outcome that satisfies us, then we likely don't wish to know any more. This is a natural human reaction, but I find it somewhat unsatisfying not to know how and why systems act the way they do.

My experience with system design and control began in my youth when I worked for my father, a carpenter. This experience received a more formal emphasis when I began working for IBM in 1965 and subsequent to that time I have participated in a considerable amount of system design and control activity – some a success, some not.

I bring this experience into the picture to suggest that this note is not only about some of the theoretical aspects of system design and control, but also about actually trying to get things accomplished. Hence, along the way, I will discuss a few bumps and bruises, how I think they happened and, therefore, what you may be able to do to avoid similar bumps and bruises.[2]

I don't propose that what is here is the only way to think about system design and control. The power that one must develop to be effective in the discipline of system design and control results from an internalization of the thinking of others as well as your own. Let me be clear. Your ability to be competent at system design and control results from your belief in your understanding of and ability to apply the principles and practices of the discipline. Reading this note and books, listening to practitioners in the field is not sufficient. You need to make the discipline yours.

System

Wikipedia, as good a source as any, defines a system as "…a set of interacting or interdependent entities, real or abstract, forming an integrated whole."[3]

So let's start our introduction to systems from this point. And for a system to explore, let's assume the US commercial banking system, a system with which I have some familiarity.

The words "with which I have some familiarity" in the last paragraph are particularly important. That is, this note is written from my point of view. I do not suggest that there is anything in this note other than my point of view and my interpretation of the points of view of others. Weinberg[4] discusses the

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[1] This note is prompted by my acceptance of an opportunity to teach a new graduate course at SUNY Maritime College, TMGT 8510 System Design and Control.

[2] If you have no bumps and bruises, if you have no failure, if you are batting 1,000, if there is that warm, comfortable feeling about what it is you are doing, then you are not pushing the boundaries enough to make a difference.

[3] Wikipedia, http://en.wikipedia.org/wiki/System [April 3, 2008]. Why "as any" you night ask. In general, there as many definitions of just about anything as there are stars in the sky. Now there are certain laws (e.g., the First Law of Thermodynamics) that are universally accepted, but, in many cases, even the experts have different views. So, we need to do two things. First of all is to understand what someone means and second, not to get to too distracted by semantic arguments. We need to get on down the road.

[4] Gerald M. Weinberg, An Introduction to General Systems Thinking, Silver anniversary ed. (New York: Dorset House, 2001) 0932633498 (pbk.). My view is that if you are serious about system design and control, this book ought to be in your library.

importance of understanding points of view at some length in chapters three and four of *An Introduction to General Systems Thinking*.

> **The first point of system design and control is to understand the point of view from which the system is being examined.**

Now back to the US commercial banking system.

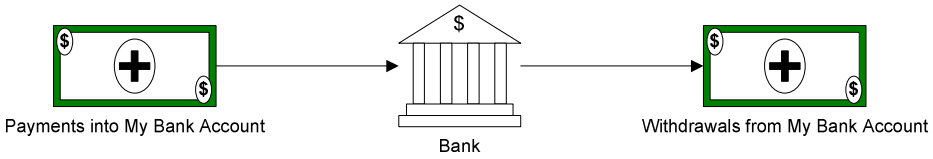

Figure 1 The US Commercial Banking System at Its Most Abstract

No great revelation here. In a sense, there is nothing at this level that necessarily distinguishes my banking system from, say, putting cash in coffee can and hiding it in the closet. Why then, start here?

Well, it reflects an approach to systems thinking – beginning at the highest level of abstraction, then decomposing and becoming more concrete as one removes the abstraction and gets to the level of detail where essential similarities and differences are seen, where true analysis can be made, and the level at which the system can be meaningfully changed. The power of this top down approach is that when one is stuck at a lower level due to misunderstanding, one can always go up a level to where understanding existed and hence explore why the decomposition resulted in misunderstanding.[5]

The second point of system design and control is to understand the method of examination.

Well, inasmuch as we have agreement at the level of Figure 1 we can go to next and more interesting level.

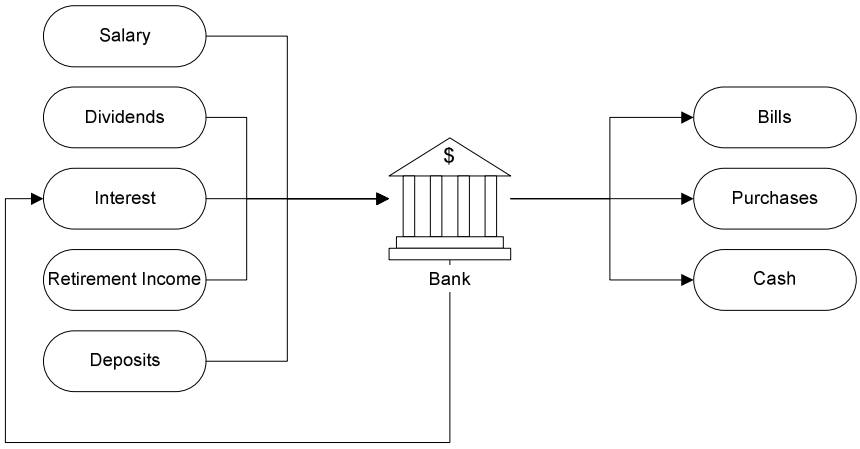

Figure 2 Inputs to and Outputs from My Bank Account

Figure 2 indicates what goes into and out of my banking account in more detail. There is some implication of where the money comes from and where it goes, its form, the manner in which it may enter and leave the account, but nothing about the frequency and size of these transactions.[6]

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[5] I am applying deductive reasoning. This approach is also at the basis for fact-based hypothesis-driven thinking that has always, it seems, underlain my analysis ever since I disassembled my first clock as a child. By the way, I don't think I every reassembled a clock.

[6] Frequency and size of my banking transactions, and the sources and uses of funds are not going to be detailed beyond this point. Understandable, of course, but if my account and its activity was being examined by an authorized regulatory agency this information would surely come to light and a much clearer understanding of this system would develop.

While we now have some better understanding of this system, we obviously have deeper analysis to do before we come to a level of understanding that allows us to draw conclusion regarding the performance of the system and recommend ways in which the system can be changed to improve performance.

Many years ago I heard of Rudyard Kipling's Six Best Friends – who, what, when, where, why, and how. These have always stood out to me as fundamental questions to be asked when trying to understand systems. As you can see from the two levels of abstraction we have explored, we are beginning to get at these questions.

The Wikipedia entry referred to above goes on to say, "There are natural and man-made (designed) systems. Man-made systems normally have a certain purpose, set of objectives. They are designed to work as a coherent entity. Natural systems may not have an apparent objective but they are sustainable, efficient and resilient."[7]

We are only going to be concerned about man-made systems in this note. However, we will also come to the point that man-made systems exist within the context of natural systems that influence the design and hence performance of these man-made systems. And, of course, man-made systems influence natural systems.

Design

"Man-made systems normally have a certain purpose, set of objectives."[8]

Inasmuch as the course that has prompted this note is within the SUNY Maritime College graduate program leading to a Masters of Science in International Transportation Management with a Supply Chain Certificate, the systems under discussion are those oriented with international transportation. More specifically,

> "This course examines the consequences of global markets, meaning that successful competition in an uneven cultural, economic, political, and social playing field requires deriving cost efficiencies from constantly re-engineered, extended supply chains. The best of the re-engineering takes a total cost analysis approach, viewing all parts of the supply chain as an integrated whole and leaving nothing in isolation. Students are introduced to the design and control techniques that derive from a systems approach."[9]

Hence, a question to be asked here is, "What are the set of objectives that should drive the design in this context?"

In a long career of looking at systems I evolved a way of looking at business and the systems of which it is comprised that helped me understand how business worked.[10]

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[7] Wikipedia, http://en.wikipedia.org/wiki/System

[8] Wikipedia, http://en.wikipedia.org/wiki/System

[9] Larry Howard, Catalog Description Form, "TMGT 7060 System Design and Control," February 14, 2007. The course number was subsequently changes to 8510.

[10] See James Drogan, A Note on Business Drivers, Business Configuration, and Information Technology Strategy, 2005, http://jmsdrgn.squarespace.com/storage/A%20Note%20on%20Business%20Drivers%20Business%20Configuration%20and%20Information%20Technology%20Strategy.pdf, [June 6, 2007]] and James Drogan, Thinking About the Business Configuration, 2007, http://jmsdrgn.squarespace.com/storage/Thinking%20About%20the%20Business%20Configuration.pdf, [February 28, 2007]] for additional discussion of the business configuration.

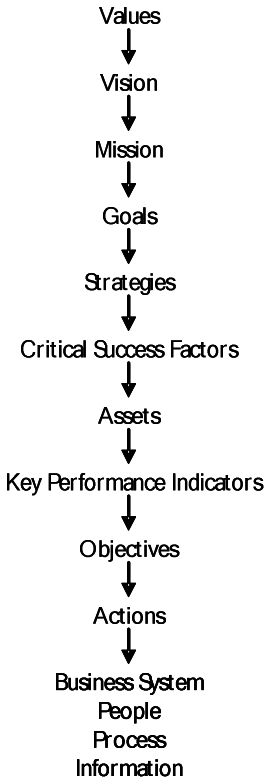

Figure 3 Business Configuration

The system of which we are speaking in this note is depicted in Figure 3. Its objectives are derived from the values statement of the organization. Oft times we are not asked to design a corporate system in the sense implied here, but rather we look at a more narrow perspective of the business system and of subsystems (e.g., payroll) within the business system.

In any case, the system or subsystem we are designing (or analyzing) has (or ought to have[11]) a set of objectives. The means whereby performance can be designed or improved in a system[12] rests on a clear understanding of the objectives.

Implicit in Figure 3 is the existence of a number of systems. Consider the augmented balanced scorecard.[13]

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[11] This is not as strange a parenthetical as you might think. I have encountered numerous systems over the years that have evolved without seemingly any conscious thought. Clues to this sort of evolution are found in answers such as "We've always done it this way."

[12] I shall freely interchange the use of system and subsystem inasmuch as there is rarely a system to be found that is not a component of another system. There may be a grand unifying theory of business that implies a grand system, but I've yet to discover it.

[13] Robert S. Kaplan and David P. Norton, "The Balanced Scorecard - Measures That Drive Performance," Harvard Business Review. January-February 1992 (1992). The augmentation comes from the addition of the measurement labeled Behavior. By that I mean to answer the question, "What must we do to assure we are good stewards of the world's resources?" Credit for this addition is to be shared with my 2002 and 2003 classes in International Logistics at Baruch College.

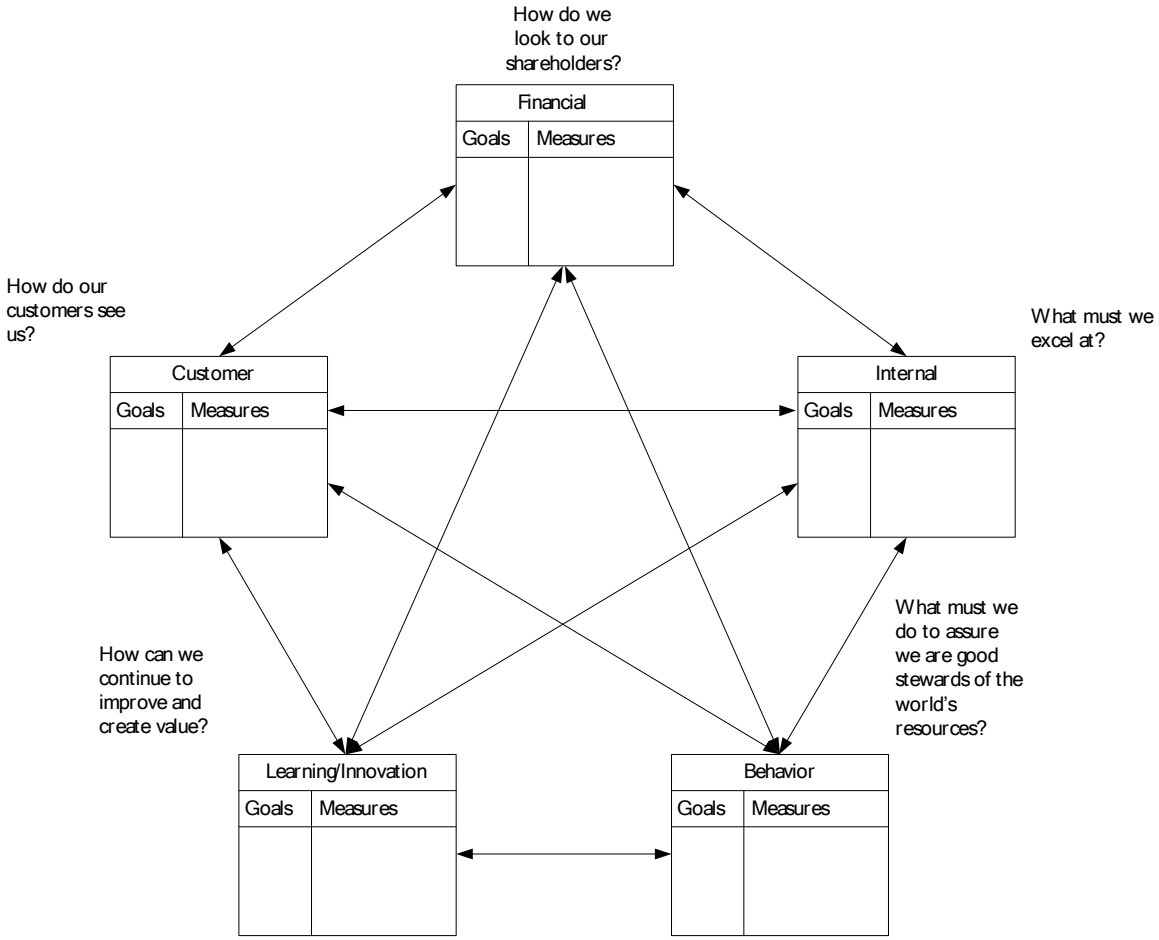

Figure 4 Augmented Balanced Scorecard

This suggests that the system represented in Figure 3 contains, at some level of abstraction, five subsystems.

Another way of teasing out the subsystems in a business is by examining its associated value chain.[14]

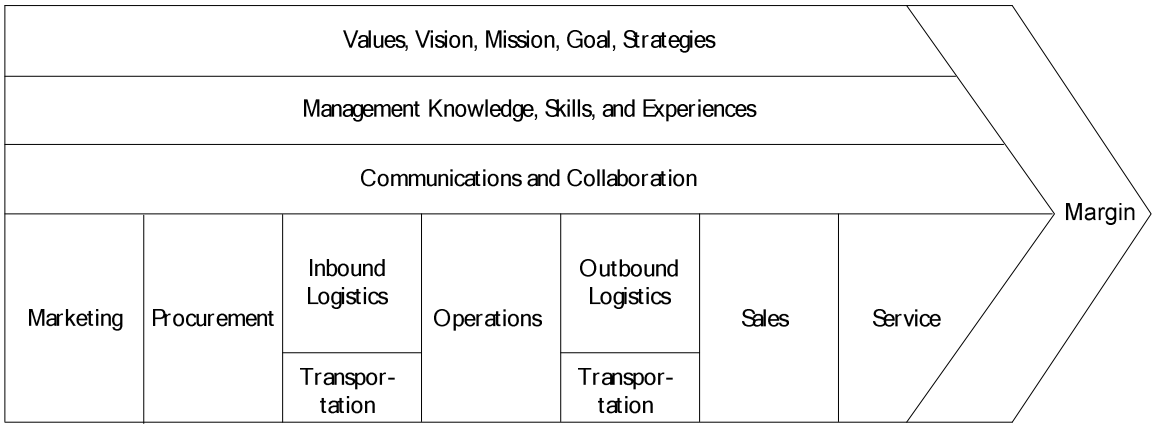

Figure 5 Value Chain

[14] Michel E. Porter, Competitive Advantage: Creating and Sustaining Superior Performance (The Free Press, 1985) 0-02-925090-0. Porter's original view has been modified by me over the years.

Inspection of Figure 5 suggests the possibility of a dozen subsystems. Work I did in the freight railroad industry beginning in 1975 identified nine major subsystems.

Now design results in systems and subsystems. Design is subject to a number of forces and, most importantly, the interaction between forces. These interactions lead to causal loop diagrams, a powerful tool for system design.[15]

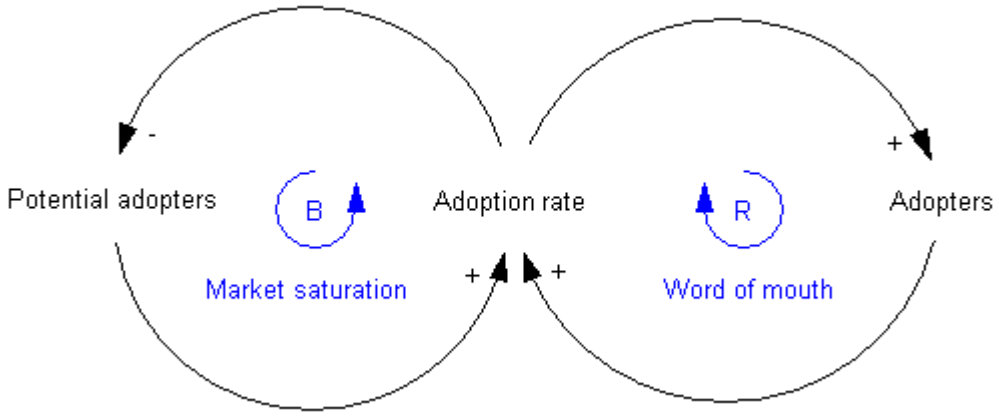

Figure 6 Causal Loops[16]

Good system design is about attention to and the management of the interaction of forces. A note of caution here: Despite one's best efforts it is not always possible to identify all forces and all interactions, particularly when the human system does not wish these forces and interactions revealed.[17]

Control

A system will succeed or fail on the basis of the quality of its design.

Another source of success or failure is the quality of the control in the system. Just as quality cannot be tacked on to a product, but rather must be designed in, control cannot be tacked on a system, but must be designed in.

Control may be defined in a number of ways.

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[15] John Sterman, Business Dynamics : Systems Thinking and Modeling for a Complex World, Irwin/McGraw-Hill, Boston, 2000. This is the text for the system design and control course mentioned in an earlier footnote. It deals extensively with causal loops. Another excellent text in this area is Peter M. Senge, Richard Ross, Bryan Smith, Charlotte Roberts and Art Kleiner, The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization (New York: Doubleday, 1994) 0-385-47256-0. My view is that if you are serious about system design and control, these books ought to be in your library.

[16] http://upload.wikimedia.org/wikipedia/en/8/8a/Adoption_CLD.gif [May 13, 2008].

[17] "If stated reasons don't sit well with your conscience or stand the test of logic, look for deeper motivations." Docent Glax Othn in Brian Herbert and Kevin J. Anderson, Dune: The Butlerian Jihad, 1st Edition ed. (Tor Books, 2002) 0-765-30157-1.

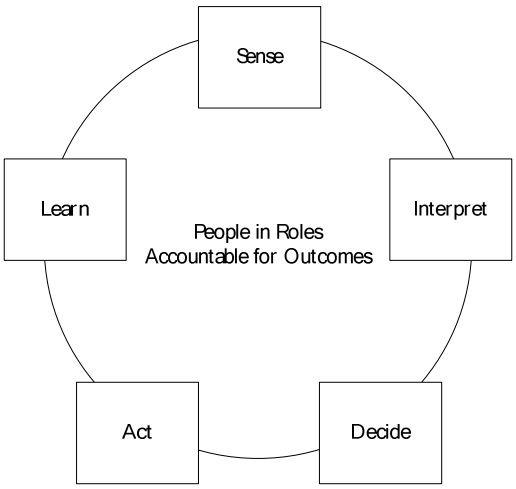

Figure 7 SIDAL Loop[18]

Think of control in the context of something familiar, say driving on wet roads.

One senses the onset of a dangerous condition (e.g., wheel slip or the beginning of a skid), interprets the meaning of the change (e.g., growing danger), decides amongst alternatives (e.g., slow, steer in the direction of the skid), acts (e.g., implements an alternative), and, hopefully, learns (e.g., slow down, don't drive on rainy days).

The control mechanism comprises a number of subsystems; the human body and its capability and capacity for SIDAL, the automobile and its capability and capacity for responding to the decisions of the human. One might also argue that the highway is part of the control mechanism. For example, highways designed with gentle curves, superelevation, surfaces sloped such that water drains, wide lanes, etc. are part of the system and, indeed, can be considered adaptive albeit it a much slower pace than that associated with the driver and the automobile.

In these three subsystems – driver, automobile, and highway – the control mechanism was "designed in."[19]

We need to examine the components of the SIDAL loop in a bit more detail.

Albert Einstein is said to have remarked, "Not everything that counts can be counted, and not everything that can be counted counts." We need, therefore, to figure out what it is we need to count, or sense.

The answer to that question depends on the answers to three other questions.

1. What decisions must be made and why?
2. How will these decisions be made and why?
3. What data is required and what will be its source?

Now this sequence of determining what to sense seems rather straightforward to me, but I am somewhat stunned by amount of data collected that is not in response to this sequence.

> "There is nothing more inefficient than doing efficiently that which should not be done at all." Peter Drucker.[20]

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[18] Based on Stephan H. Haeckel and Adrian J. Slywotzky, Adaptive Enterprise: Creating and Leading Sense-and-Respond Organizations (Harvard Business School Press, 1999) 0-875-84874-5.

[19] This note will not take up the popular debate between intelligent design and evolution. The note cannot, however, avoid the use of these words. That is, there are ways to intelligently design systems that produce the expected outcomes. There are ways in which systems evolve and produce unexpected outcomes.

[20] There is an area of knowledge management called data mining which, to my way of thinking, is about extracting value from a mass of seemingly valueless data. This can be a key capability for an organization, but one cannot, *a priori*, determine the value. One

Hence, the intelligent approach to sensing first has in mind the desired outcome (i.e., the answer to question 1).

The second question deals with the interpreting and deciding.

Wayne Gretzky, the retired ice hockey player, was said to have a great understanding where the puck would be and to skate to that spot before anyone else. His interpretation and decision skills were considered to be far above average. Other players may have been sensing the same thing as Gretzky, but lacked the interpretive and decision making skills to turn that sensing into value.

We shouldn't sense (or measure, or count) that which we cannot turn into action. If you lack the means and the motivation to sense something, don't sense it, even though it may be of potential value.

This then takes us to action. To stop the skid we must turn in the direction of the skid – we must act. The inability to act is demonstrated to us almost every day. The baseball player at the plate who is "frozen by the pitch." The business person who sees that decline in customer satisfaction, but is unable to act. The teacher who senses and proves plagiarism, but chooses not act upon the knowledge. The person who sees the "Do Not Walk" sign, but walks anyway, putting themselves and others in harms way.

Sense, interpret, and decide are wasted in the face of inaction. Here is a graphic I frequently use in my courses that seeks to make this point.

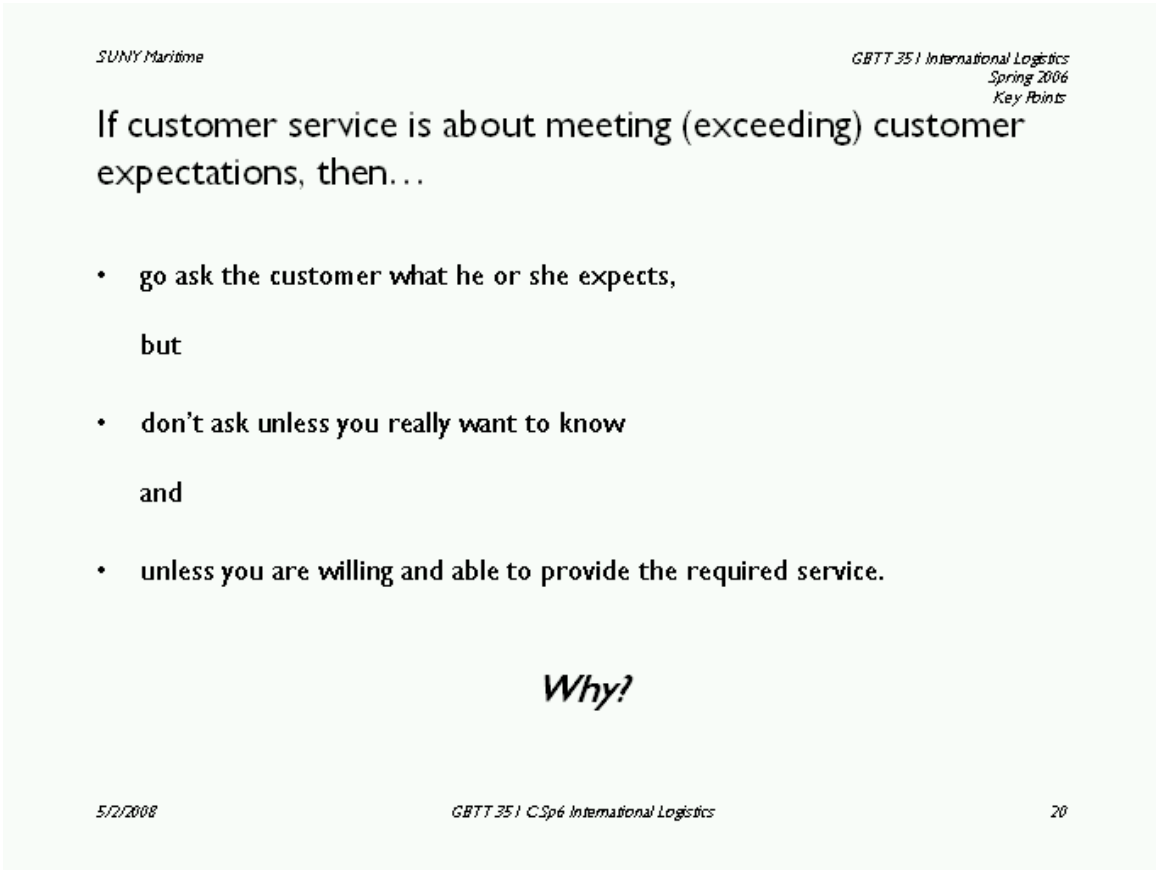

Figure 8 Setting Expectations

Asking the customer what s/he wants sets expectations the customer is anticipating you will, at least in part, meet. Failure to do that compromises the business relationship.

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can create data mining systems, but these are not considered in this note. Data mining goes at the three questions on page 7 associated with sense from the bottom up. In other words, value evolves from the analysis of the data.

Learning was not in Haeckel and Slywotzky's original work. I had always known about the importance of learning, but I didn't add it to Haeckel and Slywotzky until early in 2005.

We tend to learn by experience and often this occurs without conscious thought. This *ad hoc* learning as a byproduct of doing is insufficient for developing learning in the organization. Why, to take a trivial example, must everyone learn the stove is hot by burning their fingers? Why doesn't one person learn and make the knowledge available to all? That is, why not formalize the learning process.

The armed forces undergo After Action Reports and hotwashes in order to immediately learn from the experience and formalize, store, and share the learning.

Checkpoint

The system needs to deliver the desired outcome – a combination of price and performance – appealing to the customer. This delivery is the result of attention to design and control. Figure 3 Business Configuration on page 4 asserts that the business system, a superset of information systems, comprises people, processes, and information is shaped by its predicates. Hence, only by understanding these components can one rationally derive the resulting system.

I will also argue that system design and control is an iterative process. One doesn't make a single pass, starting with values and ending up with a business system. Trade-offs abound throughout the structure. One may find that the necessary assets are not available and therefore the goals and objectives may need to be modified. Consider the relationship between Critical Success Factors and Assets.

Figure 9 Component Relationships

Critical Success Factors define the Assets required by the business; Assets enable the Critical Success Factors to be achieved. If one cannot provide the Assets required, then perhaps the Critical Success Factors need to be redefined. If that is true, then perhaps all the components above the Critical Success Factors also need to be redefined.

That is, once we work our way down the configuration we check our analysis and design by working our way back assuring that the lower levels will enable the higher levels.

But all this is, most of the time, nirvana.

Systems That Evolve

Most of the time we are confronted by existing systems that have evolved on a piecemeal basis in response to pressures of the time and place, or the well-intentioned, but naïve whims of management, or for reasons lost in the dim distant past of organizational memory.

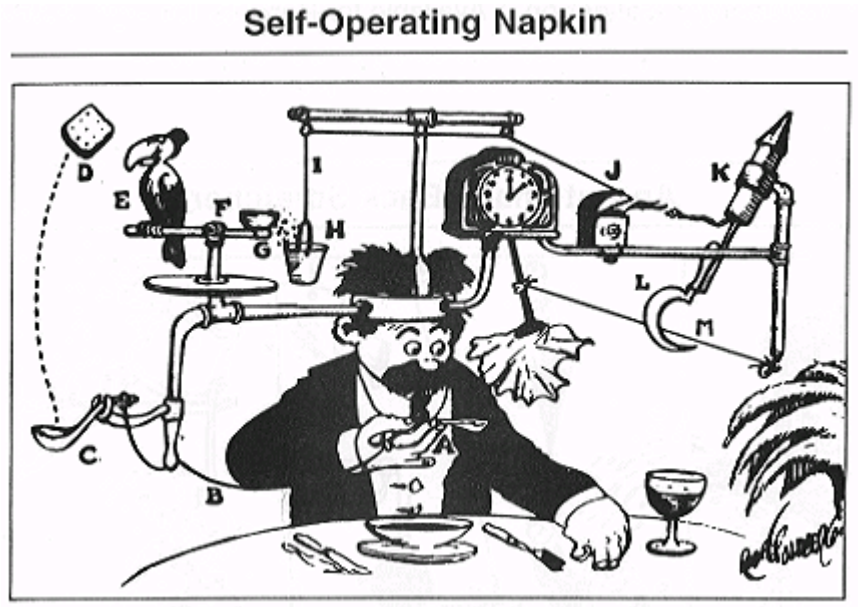

Figure 10 Rube Goldberg System

A Rube Goldberg device is distinguished by performing a very simple, easy task in an indirect and convoluted way.[21] Systems we encounter often have the appearance of being designed by Golderg. That notwithstanding, the systems are what they are and our task is to improve their performance.

This leads us to the phrase "systems analysis," which, for our purposes, I will define as the decomposition of an existing system to a sufficient level of detail such that we can understand how it does what it does and what may be done to improve its performance.

Consider an institution of higher education.

[21] Rube Goldberg, http://en.wikipedia.org/wiki/Rube_Goldberg [May 6, 2008]

Figure 11 Abstraction of a College[22]

Clearly there is insufficient information at this level that allows us to understand how this system, the college, works. We need to decompose this abstraction to the point where we understand the system. At a first level of decomposition we could come up with something like this.

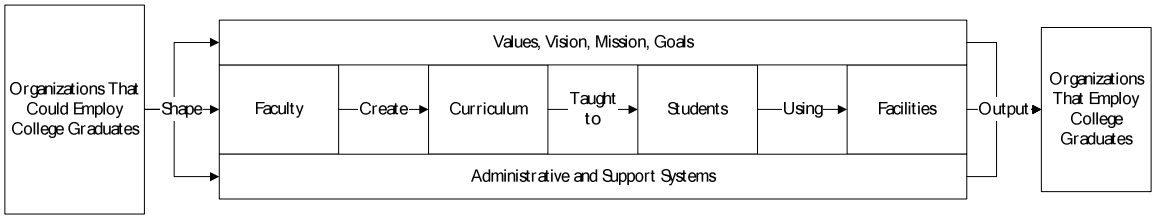

Figure 12 First Level of Decomposition

In Figure 12 we begin to develop a bit more comfort that the workings of the college system are beginning to become evident. This is still too abstract, but we are on the correct path.

How far do we go? The answer to this lies in answering the question of identifying what can one change to improve the performance of a system.

My experience suggests that one can change the following four things.

1. The rules for making decisions.
2. The data that is used when applying these rules.
3. The manner in which the rules are linked together.
4. The people who make and apply the rules.

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[22] http://humanities.osu.edu/departments/images/u_hall_autumn.jpg [May 6, 2008]

Suppose one is buying a car. The rules to be applied are, in order, 1.) select the automobile that goes from 0-60 miles per hour in seven seconds or less (acceleration to a ≤ b seconds), then 2.) select the automobile that gets 30 miles per gallon or better on the highway (mileage ≥ c mpg).

There are the rules, the data used, and the manner in which the rules are linked. It seems obvious, although I haven't tested this, that changing the data and the sequence in which the rules are applied will give you different results. As will changing the values substituted for a, b, and c.

My experience has been that the most significant factor critical to successfully understanding and changing systems are the people.

> "There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new."[23]

and

> 'Mystified supply chain and logistics professionals initiate change only to find their best efforts thwarted by a seemingly invisible force – an unreasonable human resistance to change. Despite attempts to communicate, train and explain the logic of the proposed change, resistance remains immutable. Some professionals accept resistance as part of the change game, while other seek to find the "missing link" between business change and behavior change. Toward this end, Part One of the *The Shadow Organizations in Logistics* identifies organizational culture as the missing link. Operating as a "shadow organization," the culture establishes an unwritten organizational "code of behavior" that tells everyone from the shopfloor worker to the chief executive officer what behavior is expected and demanded if an individual wishes to fit in and be accepted as a member of the organization.
>
> Organizational culture forms spontaneously, is transmitted instantaneously and is tenacious in iys drive to preserve itself. Therefore, any attempt to change the business must be accompanied by an equal or greater effort to change the culture. This insight gives rise to new principles of change grounded in a deeper understanding of the inexorable interdependency between business and culture.'[24]

In my long career in IBM, the final barrier, the final frontier to be crossed on the way to success, and the most difficult hurdle, was that of organizational change. With few exceptions, I continue to encounter this type of resistance to change in every organization with which I work. I don't expect to spend a considerable amount of time on this matter in this paper. You are referred to Gabel and Pilnic's book and the knowledge base available to you[25] contains extensive information on this subject.

So, after this little aside, let me suggest that the level of detail in systems understanding one needs to achieve is where there is a clear specification of rules, data, linkage of rules, and people.

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[23] Niccolo Machiavelli, The Prince, trans. David Wootton (Indianapolis/Cambridge: Hackett Publishing Company, Inc., 1995) 0-87220-316-6

[24] Jo Ellen Gabel and Saul Pilnick, The Shadow Organization in Logistics: The Real World of Culture Change and Supply Chain Efficiency (Oak Brook: Council of Logistics Management, 2002) 0-965-86536-3

[25] By "the knowledge base available to you" I mean libraries, personal contacts, and the Internet.

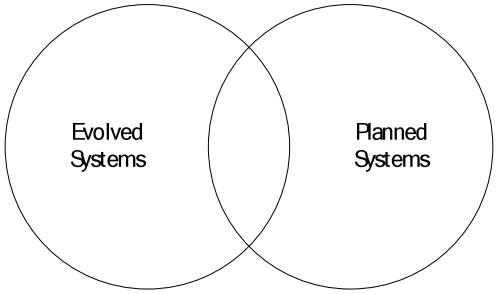


Figure 13 Shared Concepts, Tools, and Methods

It should be evident that there is a set of concepts, tools, and methods that can be shared whether one is interested in evolved or planned systems.

Coda

The thinking that underlies systems design and control (inclusive of analysis) may be new to you. If so, you will encounter concepts, skills, and tools that may be, at first, difficult to grasp. Don't shy away. Grab on. Those that best understand systems, can make recommendations for improving system performance, and can implement the changes are the ones that will thrive and make a difference in the current and emerging business world.

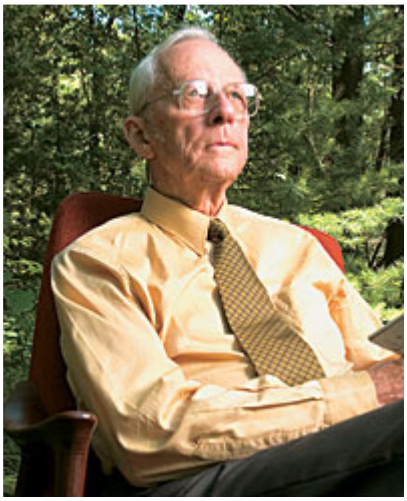
> "Who the deuce ever did anything worth naming without sacrifice?"
>
> John Herschel 1830

James Drogan
May 13, 2008

Appendix

The Prophet of Unintended Consequences[26]

by Lawrence M. Fisher



Photographs by Steve Edson

Jay Forrester's computer models show the nonlinear roots of calamity and reveal the leverage that can help us avoid it.

A visitor traveling from Boston to Jay Forrester's home in the Concord woods must drive by Walden Pond, where the most influential iconoclast of American literature spent an insightful couple of years. Jay Forrester, the Germeshausen Professor Emeritus of Management at the Massachusetts Institute of Technology's Sloan School of Management, also has a reputation as an influential and controversial iconoclast, at least in management and public policy circles. But whereas Henry David Thoreau famously urged humankind to live a life of simplicity, Jay Forrester has spent the past 40 years trying to help people live more effectively amid complexity.

Professor Forrester, who turned 87 this year, is the father of a field of research and analysis called system dynamics — a methodology that uses computer-based models to simulate and study the interplay of growth and equilibrium over time. Absorbing the implications of these models in ways that Professor Forrester prescribes can allow mere mortals to comprehend the obscure nature of (and counterintuitive solutions to) such knotty problems as environmental damage, the boom-and-bust pattern of economic cycles, supply chain malfunctions, and the pernicious side effects of well-intended policies everywhere.

These problems, says Professor Forrester, are all manifestations of the underlying nature of complex systems, from living cells to organisms to organizations and corporations to nations to the world at large. For example, there is generally a principle at work called compensating feedback: When someone tries to change one part of a system, it pushes back in uncanny ways, first subtly and then ferociously, to maintain its own implicit goals. Dieters know this well; a person's body will seek to maintain its current weight, producing cravings for fattening food. Similarly, a corporate reorganization, however well designed, tends to provoke resistance as employees circumvent the new hierarchy to hang on to their old ways. To Professor Forrester, these kinds of discomfiting phenomena are innate qualities of systems, and they routinely occur when people try to instill beneficial change. If you're attempting to shift a complex system, such as a company, and you haven't become aware of resistance or other unintended consequences, then the problems are probably building under the surface and simply haven't burst forth yet.

Professor Forrester's understanding of complex systems derives in part from years designing servomechanisms — the automatic control devices that inspired the field of cybernetics in the mid-20th century — for the U.S. Navy. In his pioneering computer simulations, Professor Forrester modeled the slow-to-emerge "tipping points" (as writer Malcolm Gladwell would later call them) that make systems difficult to manage, yet can also provide hidden leverage points for effective intervention. Modeling this kind of growth and resistance requires nonlinear calculus — a form of math so intricate that even the most gifted and highly trained mathematicians are incapable of solving nonlinear equations in their heads.

Thus one of the most controversial aspects of Professor Forrester's work is also his core premise. He argues that most social organizations, from corporations to cities, represent a far higher level of complexity and abstraction than most people can grasp on their own. And yet corporate and government leaders of all sorts persist in making decisions based on their own "mental models" — Professor Forrester's term for the instinctive theories that most people have about the way the world works. These decisions, no matter how well intentioned or intuitively comforting, are decidedly inferior, he says, to policies and strategies based on

[26] Thanks to David Livingston for bringing my attention to this article.

computer models of “system dynamics” — the interplay of complex, interrelated forces over time. As a result, Professor Forrester argues, most of the pressing problems facing humanity today will elude solution until a new generation, familiar with computer models, enters leadership roles.

“The older the person is, the more the tendency to inquire has been driven out,” Professor Forrester says. “It is much easier to bring system dynamics in at the grade-school level than it is at the graduate school, because there is much less to unlearn.”

Professor Forrester suffers repeatedly from one unintended consequence of his own work: its habit of provoking infuriated responses from liberals (for his criticisms of urban planning in the 1960s) and conservatives (for his predictions of global environmental crisis and collapse). If he was at first surprised by the clamor his works incited, over time this otherwise extremely shy, private person came to enjoy playing the provocateur. Meanwhile, Professor Forrester’s influence, particularly in business circles, is broader than his modest name recognition might suggest. Several of his former students have written bestsellers based on his work — including Peter Senge, author of *The Fifth Discipline* (Doubleday, 1990), which posited a new kind of “learning” organization, and Dennis and Donella Meadows, Jørgen Randers, and William Behrens III, who wrote *The Limits to Growth* (Potomac Associates, 1972), which became the *ur*text of the global sustainability movement. Former Royal Dutch/Shell group planning coordinator Arie de Geus, market wizard Ed Seykota (inventor of the first commercialized computer trading system), and Will Wright, inventor of the computer game “Sim City,” have all named Professor Forrester as a key influence. Peter Drucker tagged him long ago, in the 1975 book *Innovation and Entrepreneurship*, as the most “serious and knowledgeable prophet” of long-wave trends. The principles of system dynamics have been incorporated into scenario planning, wargaming, “lean production,” and supply chain management. More than a dozen universities, most prominently MIT, have business school departments devoted to the field. Project-based learning, now a popular method in elementary school education, derives directly from extensive efforts over the past 15 years by Professor Forrester and others to extend system dynamics concepts to the K–12 classroom.

“System dynamics is not biased toward any political ideology,” says John D. Sterman, a former Forrester student and professor of management at MIT’s Sloan School. “Some people apply it to help companies grow faster; others use it to promote a sustainable world in which corporations would have a lesser role.” Meanwhile, adds Professor Sterman, “it’s clear that we need a sustainable society where we don’t work ourselves to death and consume ever more junk. Jay was one of the first to reach that conclusion through systems analysis rather than an epiphany in the woods.”

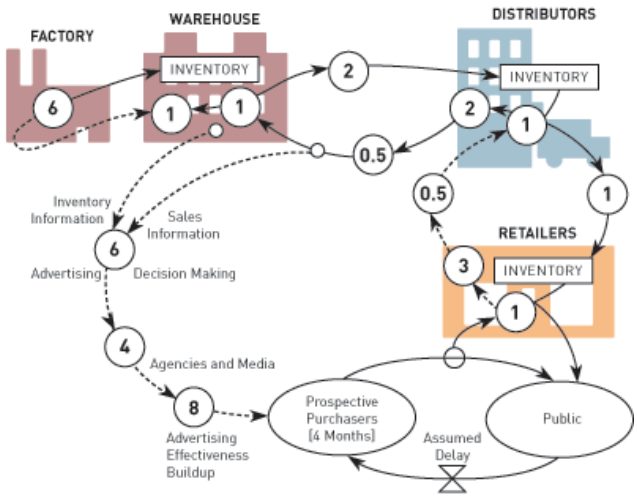
Natural Complexity

People who work on farms become naturally attuned to systems, if only because their livelihood depends on the interrelationships among weather, soil, and plant and animal growth. Jay Forrester’s interest in complexity began on the cattle ranch in rural Nebraska where he grew up. (Slim and bespectacled, he resembles the male figure in the Grant Wood painting *American Gothic*.) “A ranch is a cross-roads of economic forces,” he later recalled, in a 1992 autobiography. “Supply and demand, changing prices and costs, and economic pressures of agriculture become a very personal, powerful, and dominating part of life.” He was a natural systems engineer; as a senior in high school, he built a 12-volt wind-driven generator, using cast-off automobile parts, that provided the first electricity on his family’s ranch. At the University of Nebraska, he earned a B.S. in electrical engineering, which was then the only academic field with a solid core in theoretical dynamics. From there he went to MIT, lured in part by the offer of a $100 per month research assistantship.

At MIT, Jay Forrester met Gordon S. Brown, who would become his mentor and closest friend. Professor Brown had founded MIT’s Servomechanisms Laboratory. During World War II, when Jay Forrester was there, the lab pioneered the use of feedback control systems. These systems used signals (“feedback”) that tracked the positions of rotating radar antennas and gun mounts to help moderate their movements and thus gain precision. At one point, Jay Forrester was dispatched to Pearl Harbor to repair a radar antenna control system that he had designed for the aircraft carrier *Lexington*. The ship left harbor with him on board, still at work, and soon encountered heavy fire from Japanese aircraft. When a direct hit severed a propeller shaft and threw the ship into a hard turn, Professor Forrester recalled, “The experience gave me a very concentrated immersion in how research and theory are related to practical end uses.”

After the war, Professor Forrester led the team that designed the Whirlwind 1, the first general-purpose digital computer at MIT. Robert Everett, who worked with Professor Forrester during those years, recalls him as an exceptionally versatile and resourceful innovator. When vacuum tubes proved too short-lived for

Exhibit 1: **Modeling System Dynamics**



Source: Adapted from "Industrial Dynamics: A Major Breakthrough for Decision Makers," *Harvard Business Review*, July–August 1958

This diagram shows the interrelationships in Jay Forrester's early model of General Electric's supply chain problems. The "buildings" (factory, warehouse, distributors, retailers) represent stocks — in this case, inventory levels. Dotted lines represent flows of information (such as orders or sales figures); solid lines, flows of products or causal influence. Numbers in circles show the number of weeks required for each step.

reliable high-speed data storage, Professor Forrester invented random-access magnetic computer memory, a forerunner of today's DRAM chips. Already, he had a reputation as a perfectionist, prone to accomplishing the impossible, with little patience for those who didn't measure up to his standards. When a new receptionist was having difficulty typing labels on file folders, Professor Forrester typed them out for her during her lunch break.

"I think there was nothing anybody in the lab could do that he couldn't do as well or better," says Mr. Everett. "That tended to be tough on the people who worked for him, but they knew there was nothing personal about it. He was almost always right."

Professor Forrester's early inventions and patents earned him a place in computer history, and he could have gone on to a long and lucrative career in the new industry. Indeed, the founders of Digital Equipment Corporation, the minicomputer company credited with sparking the technology boom along Boston's Route 128, were all his graduate students from MIT. But by 1956, he felt that the pioneering days in digital computers were over, and he craved a fresh challenge.

He found it in a faculty position in the newly formed MIT School of Industrial Management, later renamed the Sloan School of Management. A group of executives from General Electric had come to MIT for help; their household appliance plants in Kentucky oscillated between periods of peak demand, when everyone had to work overtime, and slumps that lasted long enough to force layoffs. So Professor Forrester interviewed GE's manufacturing people and charted the impact of their hiring and inventory decisions on orders and sales. The resulting pattern looked surprisingly like the technical patterns he had seen with servo-driven cannons in the military; the first shot would overshoot its mark, the next shot would overcompensate, missing the mark in the other direction, and the whole system would miss and correct itself several times before finally connecting with the target. GE's pattern of overcorrection was exaggerated further by delays in the ordering process and poor communication between manufacturing and distribution. (See Exhibit 1.)

Stocks and Flows

In what would be Jay Forrester's modus operandi for years to come, he tapped one of his graduate students to write a program, later named DYNAMO, that could translate his pencil-written calculus into the ones and zeros of a computer's machine language. In naming this new field, he used the engineering term *dynamics* — which commonly referred to the interplay of physical or electrical forces over time — to indicate that his models didn't simply represent a snapshot of a situation at any given moment, but an opportunity to see situations grow and evolve. Today, system dynamics students use sophisticated modeling programs, "playing out" the impact of possible policies or strategies by entering them into the model and running it like a computer game. In the 1950s, Professor Forrester wrote all of the code himself, using the primitive programming tools of the time.

The conceptual basis of his models was the critical relationship he had originally observed in servomechanics: the way that stocks and flows governed each other. Consider, for example, the flow of water into a bathtub. A person turns the tap to fill the tub, and when the level of water in the tub (a stock) is nearly full, the person turns off the water (a flow). The chain of cause and effect is actually a feedback loop; the person and the level of water influence each other. Similarly, a company's reserve of cash is a stock; its profits and losses are flows that affect the level of that cash reserve. But when the cash reserve gets too low, the company's managers do whatever is needed to increase cash flow. No single factor dominates;

they all influence and regulate one another. In Professor Forrester's world, what goes around does inevitably come around.

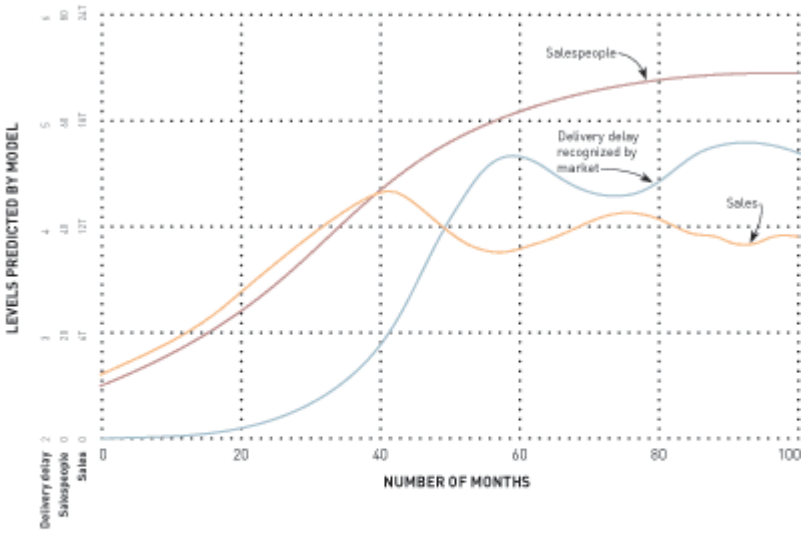
Most people can grasp very simple systems — say, a system with one stock, one flow, and one feedback loop. Cash flows in and out of an individual's checking account (a stock) as that person makes deposits and writes checks. When the balance gets low, he or she must stop spending or start earning. But even the simplest organizations have multiple stocks and flows that operate in interconnected networks. Professor Forrester postulated that most industrial activity could be represented by five networks — materials, orders, money, capital equipment, and personnel — with a sixth, the information network, functioning as the connecting tissue between the other five. The complex interactions among the different networks, each of which has its own set of stocks and flows, and the feedback delays inherent in the information network make true cause and effect difficult to gauge.

For his first book, *Industrial Dynamics* (1961), Professor Forrester drew on the experience of his MIT students. They were typically managers, age 30 to 40, who were eager to bring their problems to Professor Forrester in the hope that his computer simulations could help them.

One of the consistent findings was particularly disturbing at first glance: The problems of most companies were not brought on by competitors or market trends, but were the direct result of their own policies. "People discover that their own policies inevitably generate their troubles," says Professor Forrester. "That's a very treacherous situation because if you believe these policies solve the problem, and you do not see that they are causing the problem, you keep repeating more of the very policies that create the problem in the first place. This can produce a downward spiral toward failure."

On the other hand, once the links were revealed, companies could often fix the problem by changing some small but consequential practice that happened to influence all the other factors of the system. (Professor Forrester calls these "high-leverage" solutions.) For example, an electronics-component manufacturer suffered from inexplicable losses of market share. Professor Forrester's model showed the culprit to be the company's policy of buffering itself against downturns by waiting to hire more factory workers until there was a large backlog of orders. This had given the company a reputation for slow deliveries, which caused customers to lose interest, which led to falling orders — which, in turn, made the manufacturer even more cautious about hiring, and thus even more prone to backlogs. The solution was simple: Maintain a steady work force even during occasional downturns, while building up enough inventory to improve delivery times. (See Exhibit 2.)

Exhibit 2: **Anatomy of a System Dynamics Story**



Source: Adapted from "Market Growth as Influenced by Capital Investment," *Sloan Management Review*, Winter 1968

This typical example of Jay Forrester's system dynamics shows the evolution of an electronics manufacturer's unexpected stagnation. Over the first 40 months, sales rose, fueled by the increasing number of salespeople. Then sales suddenly leveled off. Why? Because those sales had not been backed up with added production capacity; this produced delivery delays, starting around month 20, and began to affect sales a few months after that.

Click image to zoom.

Contemporary reviewers compared *Industrial Dynamics* to the works of Galileo, Malthus, Rousseau, and John Stuart Mill, and it is still required reading in many MBA programs around the world — a remarkable feat for a 40-year-old book packed with dense text and intricate diagrams. Its success brought Professor Forrester consulting engagements at major companies. But the assignments often frustrated him. Executives would listen politely to his presentation, and go on with the same problematic practices. Even at Digital Equipment, managed by his former students, he found system dynamics a tough sell.

"I was never successful in getting the board to believe the models would work," he says. "The last time I tried, one of them said, 'We agree that we've been successful following your advice, but it's not because of your modeling. It's just because you're a better manager than we are.' That excused them from having to pay attention to the source of my insights."

Part of the problem was the computers of the day. Jay Forrester would run his models at the MIT computer lab and return to the company with a paper printout. Clients "could see the logic of the result, but they had not internalized the process of getting there," he says. And managers did not enjoy hearing that they had caused their own troubles; they just wanted a solution. But another part of the problem was Professor Forrester's own impatience: He chafed at the time it took to explain his solutions.

Some of Professor Forrester's protégés were more enthusiastic ambassadors to the corporate world. Two of his graduate students, Jack Pugh and Ed Roberts, started a consulting business (Pugh-Roberts) in 1963; they applied system dynamics to nuclear power plant design, missile system development, and planning the tunnel under the English Channel. One simulation prompted MasterCard's decision to introduce the first third-party affinity cards. The model accurately predicted the amount of market share MasterCard would gain as well as the fact that Visa would match the offering within a year, and that American Express and Discover would not or could not follow in the cobranding. Pugh-Roberts never trumpeted its connection to Professor Forrester or his ideas. "We used the methodology, but we didn't sell ourselves as system dynamics consultants," says James M. Lyneis, who worked with the firm from 1978 to 2002.

Businesspeople, it turned out, needed more than a solution. They needed to internalize that solution. It would take until the early 1980s for other Professor Forrester students to create experiences that might

change the thinking of decision makers more directly. Professor Forrester himself, meanwhile, had reached the conclusion that the slow uptake on the part of corporations was a symptom of their stultifying management structures. The conventional command-and-control hierarchy, in his view, amounted to a kind of corporate socialism, no more likely to thrive in the long run than the planned economies of the Communist world. In a 1965 paper titled "A New Corporate Design," he predicted that less self-defeating management forms, based on individual responsibility and the free exchange of information, would ultimately prevail. These ideas anticipated the thinking of later organizational theorists, including Charles Handy and Shoshana Zuboff. In the meantime, Professor Forrester was on to bigger projects.

When John F. Collins, a former mayor of Boston, took a temporary appointment at MIT as a visiting professor, he was assigned the office next to Professor Forrester's. It was 1968, riots had broken out in cities across America, and the two instructors naturally fell into conversations about solving the stagnation and unemployment that plagued many cities.

"Collins was very much a man of action," Professor Forrester recalls. "I suggested enlisting researchers — not urban studies students, but people who knew the real urban world — for a half a day a week, for as long as it would take, to extract a dynamic picture of the problem. Collins's immediate answer was: 'They'll be here Wednesday afternoon.'"

With Mr. Collins's clout, the two quickly assembled a team of high-level advisors from politics and business to research the dynamics of urban poverty. After four months, Professor Forrester had the basis for a new book, *Urban Dynamics*, with a startling assertion: The harder a policymaker tried to relieve poverty, the more that poverty would increase. Low-cost housing, intended to revive inner cities, actually crowded out industry that might have created jobs, while attracting underemployed people and concentrating them in decaying neighborhoods that made it harder for them to break out of the vicious cycle they were in. The model supported arguments for fostering industrial expansion *before* building low-cost housing, and thus giving cities room to expand their economies naturally.

Urban Dynamics offended many social activists, while free-market advocates claimed Professor Forrester as one of their own. In truth, he belonged to neither group; he was just relating the results of his models. Meanwhile, it took three to five hours to fully communicate the implications to an audience, and he rarely had an audience's attention that long. He made some converts, including one Harlem activist who started out decrying the report as racist, and ended up saying, "They don't just have *a* solution to the urban problem up there at MIT; they have the *only* solution." But as Professor Forrester lamented in his autobiography, "We have not solved the challenge of how to bring enough people across the barrier separating their usual, simple, static viewpoint from a more comprehensive understanding of dynamic complexity."

Overshoot versus Cornucopia

The notoriety generated by *Urban Dynamics* brought Professor Forrester many speaking engagements, including an appearance at the June 1970 meeting of the Club of Rome, in Bern, Switzerland. The Club of Rome was a private group, made up of about 75 corporate executives and nonprofit leaders drawn from many countries. Its members shared a concern about the interrelated predicaments they saw facing humankind: rising population, pollution, economic malaise, and social strife. They knew that all contributed to one another, but nobody was sure exactly how they were interrelated, or how to reverse the downward spiral.

The Club had been promised a $400,000 grant from the Volkswagen Foundation if they could come up with a relevant research project to solve the "problematique" (as they called it). Professor Forrester naturally proposed using computers to simulate it, but told the group they would have to visit MIT for 10 days of study, presentations, and discussion. To his surprise, they accepted and, although the grant was later cut in half, he was able to start work on a dynamic model of world interactions, such as population growth, capital flows, natural resources, pollution, and food production.

That model generated a new book, *World Dynamics*, which proved even more controversial than its predecessor. Most eye-opening were the unexpected consequences of exponential growth. Just as a river can accept a doubling of pollutants only so many times before its ability to flush them out to sea is exhausted, the model suggested that the world could accept only a limited number of doublings of the global human population and of industrial output before civilization would suffer. The book suggested that the planet was far closer to reaching those limits than most people then believed. The faster the level of

economic growth, the more dramatic the overshoot would be, and the more sudden and devastating would be the collapse of the natural environment and its support for human life and civilization.

Although Professor Forrester believed the book had "everything necessary to guarantee no public notice," including 40 pages of equations, its message immediately garnered worldwide attention. Reviews and press mentions ranged from the London *Observer* to the *Singapore Times*, and even a full-length article in *Playboy*. But this time Professor Forrester shied away from the public stage. And although he had scribbled out the initial model that attracted the Club of Rome, he left the actual assembly and fine-tuning to a team of students led by Dennis and Donella Meadows, who were in their mid-20s and just returning from a break.

"I literally came back to MIT the day Jay returned from Switzerland," Dennis Meadows recalls. "He announced that the Club of Rome was coming over in two weeks, and since I was the only one who didn't have five years of work to do, I became the director of the project."

The team produced a popular adaptation called *The Limits to Growth*, which sold several million copies and was translated into 30 languages. It painted a stark picture of the catastrophic outcomes that the model had predicted, but it also described an alternative future, in which humanity accepted less economic growth in return for a comfortable, and endlessly sustainable, future. The book became the rallying point of a global environmental movement that has continued to gain adherents. It also gained an increasingly outspoken group of critics, who argued that the model gave short shrift to the most significant economic forces, such as the self-regulating effects of markets and prices. It did not help Professor Forrester's standing with economists that he cited the *Encyclopedia Britannica* and the *World Almanac* as sources instead of econometric data, and that most of his references were to his own previously published papers. Moreover, Professor Forrester, in his usual blunt way, had spent 15 years dismissing most orthodox economic theory as trivial.

Typical was a negative review of *The Limits to Growth* in the *New York Times*, written by Peter Passell, a Columbia University economist, and two Harvard University economists named Marc Roberts and Leonard Ross. *The Limits to Growth*, they said, was "empty and misleading," based on an "intellectual Rube Goldberg device," full of "arbitrary conclusions that [had] the ring of science," but were really "less than pseudoscience." Dr. Passell, now editor of the *Milken Institute Review*, hasn't softened his opinion, though he allows there is a place in the world for modeling. "Simulation is always a problem," he says. "You've got to be very disciplined so you understand what the model is sensitive to. Professor Forrester and that crowd were oblivious to the reductiveness of their process."

At the heart of the debate over limits to growth is an unanswered question: Are planetary overshoot and collapse inevitable? Or can we rely on human ingenuity, economic forces, and technological advancement to mitigate the effects? Neither side has backed down. Bjorn Lomborg, for example, set up much of his book *The Skeptical Environmentalist* as an attack on the *Limits to Growth* mind-set, arguing, for example, that pollution levels and population growth rates have declined. But in a 30-year update to *The Limits to Growth* published in 2004 (three years after Donella Meadows passed away), the authors conclude that most statistics (including those for global climate change) are still playing out as the model predicted, that runaway growth has remained consistent with their model, and that growth restraints should remain an important element of global policy. Of his still-vocal critics, Professor Forrester says, "I don't really expect to convert them. The only option is to outlive them."

Dynamics versus Thinking

By the mid-1980s, a group of Professor Forrester's former students had recast his stock-and-flow notation into a set of "archetypes": common system patterns that showed up again and again in a variety of situations. *The Limits to Growth* was the basis of one of these archetypes; although it was famous as a warning to industrial society, it also applied to many innovative corporate initiatives, which tended to hit a wall and collapse just when it seemed that they were about to break through into success. Another common archetype, "Eroding Goals," charted the course of many companies that respond to competition by lowering

the quality of their offerings, until they can no longer match their original premium identity. Peter Senge, then an instructor at MIT, captured several of the archetypes and a simplified explanation of the system dynamics approach in *The Fifth Discipline*. That book, which has sold 2 million copies worldwide, is far easier to read than anything penned by Jay Forrester. But it also makes a distinction that Professor Forrester himself rejects: between "system dynamics," which requires constructing and testing electronic simulations, and "systems thinking," which draws people into conversation to consider the same types of systemic situations in depth.

Jay Forrester confesses to a certain ambivalence about Dr. Senge's book. He is glad of its success, but disappointed that the book doesn't adequately explore the assumptions that went into the models underlying the archetypes. "The trouble with systems thinking," he says, "is it allows you to misjudge a system. You have this high-order, nonlinear, dynamic system in front of you as a diagram on the page. You presume you can understand its behavior by looking at it, and there's simply nobody who can do that."

For his part, Dr. Senge says his mentor's concern is justified, but there is still a value in introducing systems thinking to people who may never go on to system dynamics. "Jay has always been focused on the high ground, training people who can develop advanced simulation models," Dr. Senge says. "I think that's great, but it takes years, and I grew impatient with this very long-term strategy. It is also useful to train people to do first aid, rather than to only develop physicians."

The Fifth Discipline, and the series of multiple-author "Fieldbooks" that followed, have probably exposed more people to Professor Forrester's thinking than any other source, including his own books. Professor Forrester's work has also gained exposure through the development of graphic software programs that allow people without Ph.D.-level math skills to create sophisticated models. Vensim, produced by Robert Eberlein of Ventana Systems Inc. of Harvard, Mass., is a powerful tool used today by systems modelers in business and graduate schools, including Professor Forrester himself. Stella, created by the late Barry Richmond of Isee Systems, of Lebanon, N.H., brings system dynamics modeling to the high school classroom. One system dynamics model, taught by Diana Fisher in a Portland, Ore., public high school, demonstrates how drugs work in the human body by showing an intravenous drip as a flow, and accumulated pharmaceuticals in the body as a stock.

"You don't need calculus, just first-year algebra," says Ms. Fisher. "I've taught this to freshmen, and I've seen it taught to 8th graders. Because the models are visual, they allow kids who are not very good with equations to analyze problems in pretty deep ways."

The Pessimist's Optimist

Jay Forrester and his wife, Susan, live in a simple, brown-shingled house in Concord that they purchased in 1952. Here, in the basement, Professor Forrester works on his most ambitious computer model: a general theory of economic behavior, which he began to develop 25 years ago. It incorporates the economic long-wave theory articulated by Russian economist Nikolai Kondratiev in 1926, discredited in the 1970s, and just

now making a comeback in economic circles. (Kondratiev himself was imprisoned by Josef Stalin in 1930, and executed in 1938, apparently because of his association with Leon Trotsky.) To Professor Forrester, the long wave is generated by the same sort of production shortages and gluts in capital goods that he observed in the early 1960s with toasters and refrigerators, but played out on a much longer time scale.

Professor Forrester's model suggests that the lifestyle afforded by historically low interest rates, the huge current account deficit, and the massive foreign purchases of U.S. assets, from treasury bonds to real estate, might come crashing to a halt when overseas investors lose confidence. Does that mean the world is overdue for a deep, 1930s-style depression? Professor Forrester believes this is probable, but he is undismayed.

"People hate depressions because of the huge human problems they create, but they are also the windows of opportunity to new technology, and they're the times when the stagnation and inefficiencies of the old corporate structure get liquidated," Professor Forrester says. "That clears the deck for a clean start and a more vibrant and efficient economy."

Though his name has been linked with corporate folly, urban decay, global decline, and now with likely economic depression, Professor Forrester says he remains positive in his outlook. "I consider myself an optimist, because I feel that with sufficient understanding and education, these issues can and will be dealt with." And even the most hardened pessimist would have to admit that the dire predictions Professor Forrester has made have often failed to come true. Some corporations (GE included) have managed to escape the worst effects of their supply chain problems. Most cities (in the industrialized world, at least) are better today than they were in the 1960s. The economy, while stumbling, has not yet fallen apart. And the global environment still supports human life. Perhaps we are indeed heading for overshoot-and-collapse scenarios in all these arenas; or perhaps Jay Forrester's models have served a subtler purpose, by warning society of the unintended consequences of its actions just in time for humans to make decisions that save themselves.

Professor Forrester himself would disagree with such complacency. Like Thoreau, he expresses little confidence in the capability of his fellow human beings. Pressed to think about what he would like to leave behind, the acerbically understated prophet of unintended consequences replies, "Well, when we begin to see people taking a new look at the way corporations are designed and the way countries are run — that would be satisfactory."

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A Note on Control

Introduction

> control (kən-trōl')
>
> n.
>
> 1. Authority or ability to manage or direct: lost control of the skidding car; the leaders in control of the country.[1]

Authority can accrue *de jure* by means of the policies and practices established by an organization.

Authority can also accrue *ad hoc* by means of superior knowledge, skill, and experience; by means of tradition as in the respect paid in some societies to elders or certain professions; by means of force or reward.

Without authority there can be no control.

There must be some means whereby this control can be exercised. This involves sensing performance that deviates from that which is desired and making such modifications to the business configuration that will change the performance.

In short, there needs to be a lever and someone's hand needs to be on the lever.

Metrics and Measurement

> "Not everything that counts can be counted and not everything that can be counted counts."
>
> Albert Einstein

We know when control needs to be exercised by understanding how actual performance compares to desired performance. Performance assessment requires metrics and some means of measurement.

There may well be numerous sources of metrics, but three present themselves within this course of study.[2]

1. Business dynamics[3] helps us to understand the significant variables that impact the performance of the firm. Our list of metrics should include those variables that emerge from this analysis.
2. Bolstorff and Rosenbaum[4] provide us with examples of metrics important to understanding the performance of supply chains. We can add these to our list of metrics.
3. The augmented balanced scorecard[5] is another source of metrics. While Bolstorff and Rosenbaum call our attention to The Balanced Scorecard,[6] the augmented balanced scorecard

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[1] Answers.com, http://www.answers.com/main/ntquery?sm1=Q29udHJvbCA=&fw=0&fc=3&ss=-1&es=-1&gwp=11&ver=2.1.0.502&method=1 [July 4, 2008]

[2] Maritime College, TMGT 8510 System Design and Control

[3] John Sterman, Business Dynamics : Systems Thinking and Modeling for a Complex World (Boston: Irwin/McGraw-Hill, 2000) 0-072-31135-5

[4] Peter Bolstorff and Robert Rosenbaum, Supply Chain Excellence : A Handbook for Dramatic Improvement Using the Scor Model, 2nd ed. (New York: AMACOM-American Management Association, 2007) 0814409261

[5] James Drogan, Managing the Business, 2007, Paper, SUNY Maritime College, http://jmsdrgn.squarespace.com/storage/Managing%20the%20Business.pdf, [February 19, 2008

[6] Robert S. Kaplan and David P. Norton, "The Balanced Scorecard - Measures That Drive Performance," Harvard Business Review. January-February 1992 (1992)

brings to bear stewardship of the world's resources used by the firm in the conduct of its business.

Of course our own investigation of the logistics channel and supply chain may suggest other metrics.

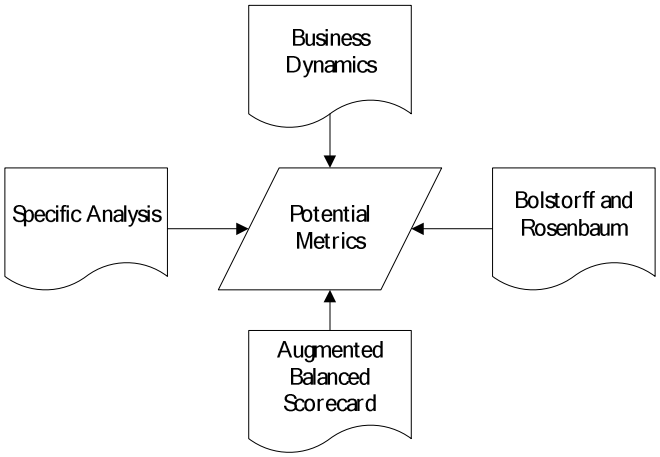

Figure 1 Building the Potential Metrics

I term this set of metrics as potential for, given the nature of the trade-offs required as we go forward in this discussion of control, it may not be the "final" set of metrics.

SIDAL

SIDAL is shorthand for sense, interpret, decide, act, and learn and has its origins in Haeckel and Slywotzky[7] and was introduced in "An Introduction to System Design and Control."[8]

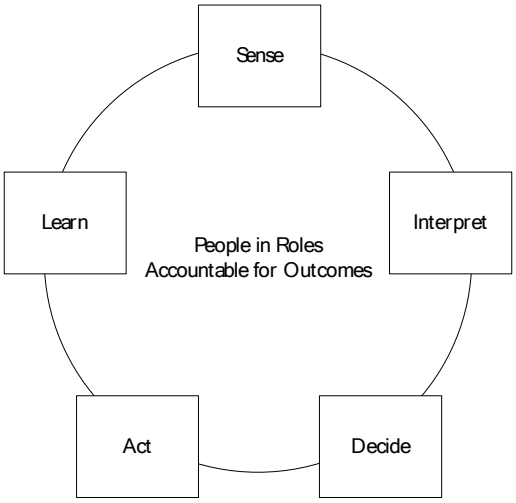

Figure 2 SIDAL

There needs to be a system that responds to the changes in the metrics. SIDAL is a good, not-too-abstract model representing what is required.

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[7] Stephan H. Haeckel and Adrian J. Slywotzky, Adaptive Enterprise: Creating and Leading Sense-and-Respond Organizations (Harvard Business School Press, 1999) 0-875-84874-5

[8] James Drogan, An Introduction to System Design and Control, 2008, Lecture Note, SUNY Maritime College, http://jmsdrgn.squarespace.com/storage/An%20Introduction%20to%20System%20Design%20and%20Control.pdf, [July 8, 2008

The six components of SIDAL are fairly straightforward and I will provide no further explanation here except to provide emphasis on Learning.

It's imperative in the current and emerging world that we continually become better at what we do. We need to learn and use that learning to improve performance in order to establish and retain sustainable competitive positions in the market. Learning in an *ad hoc* fashion will not sustain us. In "An Introduction to System Design and Control" I argued that the control must be designed in to the system. It can't be tacked on.

The same is true for learning.

SIDAL is what allows us to exercise control in systems. Several factors are critical if this is to happen.

The metrics must be measureable. This seems obvious, but we need to be cautious of the creation of a metric that is impossible or impractical to measure, or that does not support the essential decisions of the organization.

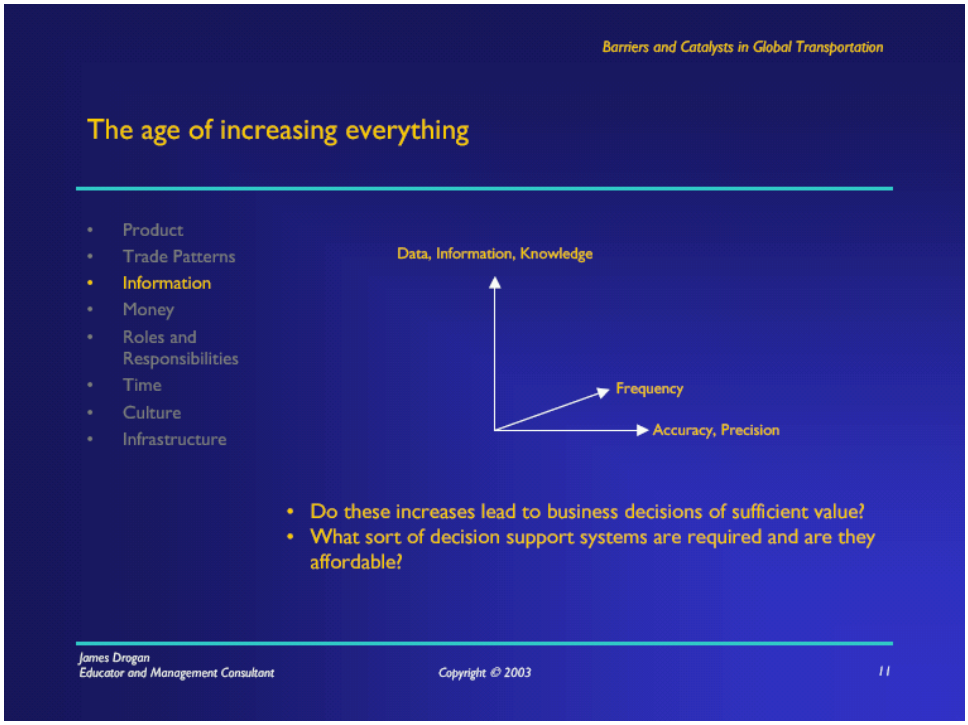

Figure 3 Issues Regarding Metrics[9]

Just because we can doesn't mean we should. Remember Einstein's comments regarding counting. Information needs should not be decided on an *ad hoc* basis. Three critical questions are involved.

a. What business decisions must be made and why?

b. How should these decisions be made and why?

c. What is the source of the data to support the decisions?

There is then a trade-off that balances the metrics against the needs, capability, and capacity of the SIDAL loop.

The above set of questions brings us to the notion of interpret. For example, handing me an EKG[10] would be a useless exercise.

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[9] James Drogan, Barriers and Catalysts in Global Transportation, 2003, http://jmsdrgn.squarespace.com/storage/Barriers%20and%20Catalysts%20in%20Global%20Transportation.pdf, [December 29, 2006

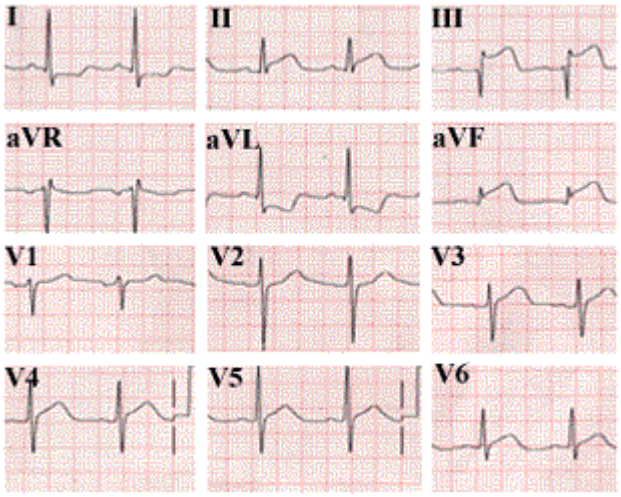

Figure 4 EKG[11]

I lack the knowledge, skills, and experience to make a proper interpretation.

Hence, the need to have a balance between sense and interpret may further constrain the useful set of metrics.

Said another way, can interpret effectively use the output of sense? That being the case one can continue clockwise around the SIDAL loop asking these questions and using the answers to make the trade-offs necessary to achieve an effective control mechanism.

Except for learn. It's not clear that there is necessity for trade-offs between learn and act, or sense and learn. Furthermore the learning process is intended to affect all other SIDAL components. What should we sense new or differently? What can we do to improve our ability to decide?

Another conclusion that one can draw here is that SIDAL needs to be adaptive. Since SIDAL is a system, its design and implementation must be such that this adaptiveness is not impaired.[12]

---

[10] Electrocardiogram

This means of studying the activity of the heart from electrical signals detectable from the body surface stemmed directly, early in the twentieth century, from the invention of the string galvanometer by the Dutch physiologist, Einthoven. Electrocardiography was demonstrated to the Royal Society in London in 1909.

Answers.com, http://www.answers.com/topic/electrocardiogram?cat=health [July 12, 2008]

[11] http://www.heartsite.com/assets/images/ekg2.gif [July 9, 2008]

[12] For more on this notion of adaptiveness see Drogan, Managing the Business,

Well, just how quickly must SIDAL adapt? This is a function of something I call the decision window.

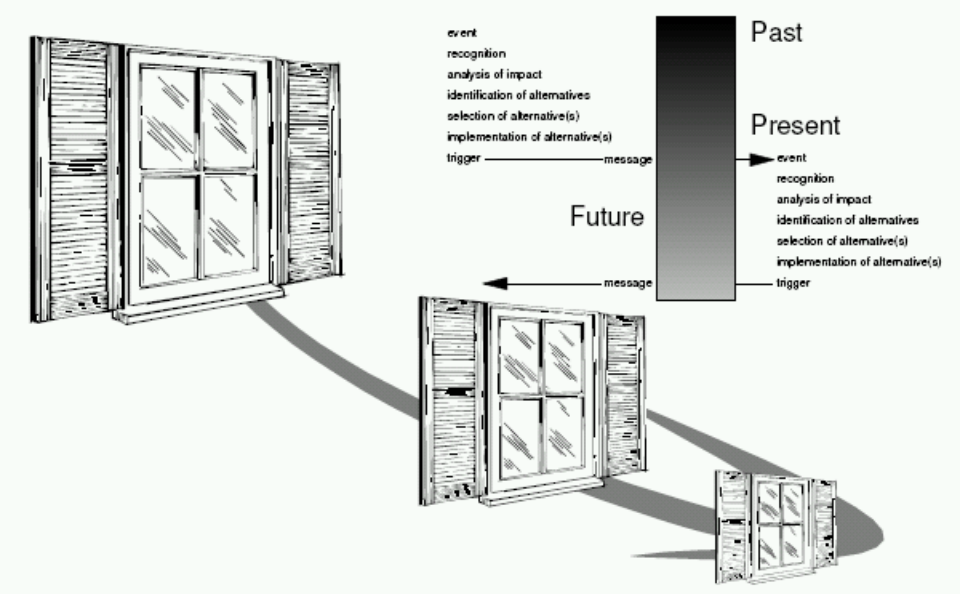

Figure 5 The Decision Window

The decision window[13] opens when an event occurs and closes when the outcome of that event can no longer be altered. Decision windows have become increasingly smaller over time, a trend that is expected to continue.[14] Examples of increasingly smaller decision windows are found in the technology and fashion industries.

SIDAL, or least the SIDA, needs to complete within the decision window.

This leaves the People in Roles Accountable for Outcomes requiring comment. I have for some time argued that the cadre of required knowledge, skills, and experience to ride the waves of the future needs to fundamentally change.[15]

This cadre will be distinguished by its systems thinking and analytical skills, and willingness to work in a collaborative fashion.

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[13] James Drogan, The Relevance of Data, Information, and Knowledge, 2007, http://jmsdrgn.squarespace.com/storage/Data%20Information%20and%20Knowledge%20-%20Relevance%20and%20Understanding.pdf, [September 28, 2007

[14] See "Homer, Great Books and Modern Life," http://jmsdrgn.squarespace.com/droganbloggin/2006/12/28/homer-great-books-and-modern-life.html [July 9, 2008] for further musings on this increasingly smaller decision window.

[15] Drogan, Managing the Business,. Also go to http://jmsdrgn.squarespace.com/ and search on "mind changes" for other comments.

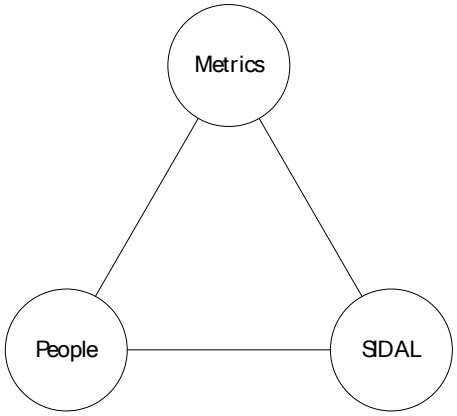

Figure 6 Trade-offs

There will be continuous trade-off between these three major elements of control as businesses look for the optimum point of operation in a constantly changing world.

The Business Configuration

The structure shown in Figure 6 exists within a context I refer to as the Business Configuration.[16]

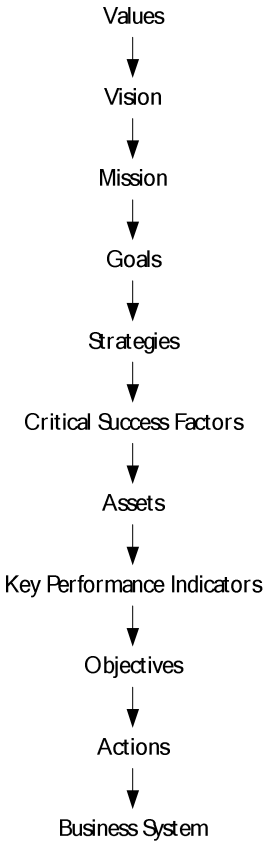

Figure 7 Business Configuration

This approach to describing an organization results from some 43 years of experience in helping organizations improve their performance. I don't claim it is better than any other approach, but it is one that has worked for me.

Metrics are most closely aligned with Key Performance Indicators, but it should be recognized that metrics of various importance may lie at various places in the configuration. For example, a metric of importance in the railroad industry is coupling speed. This is the maximum speed at which cars can be safely coupled together without damage to either the equipment or the lading. My recollection in that this is four (4) miles per hour. This is a critical metric for railway transportation, but would not be a Key Performance Indicator.

SIDAL is clearly part of the Business System.[17]

This suggests, therefore, that there is set of trade-offs regarding control of the system that need to take into consideration the entire Business Configuration.

There is one more context to consider.

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[16] James Drogan, A Note on Business Drivers, Business Configuration, and Information Technology Strategy, 2005, http://jmsdrgn.squarespace.com/storage/A%20Note%20on%20Business%20Drivers%20Business%20Configuration%20and%20Information%20Technology%20Strategy.pdf, [June 6, 2007 , James Drogan, Thinking About the Business Configuration, 2007, http://jmsdrgn.squarespace.com/storage/Thinking%20About%20the%20Business%20Configuration.pdf, [February 28, 2007

[17] The Business System comprises processes, people, and information.

The Context of Interest

In "An Introduction to System Design and Control" I inferred a strong equivalence between a business and the value chain. Let me repeat that diagram here.

Figure 8 Value Chain

SIDAL concerns itself with the lower half of this diagram.

However, the value chain is shaped by and responds to the context in which it exists.

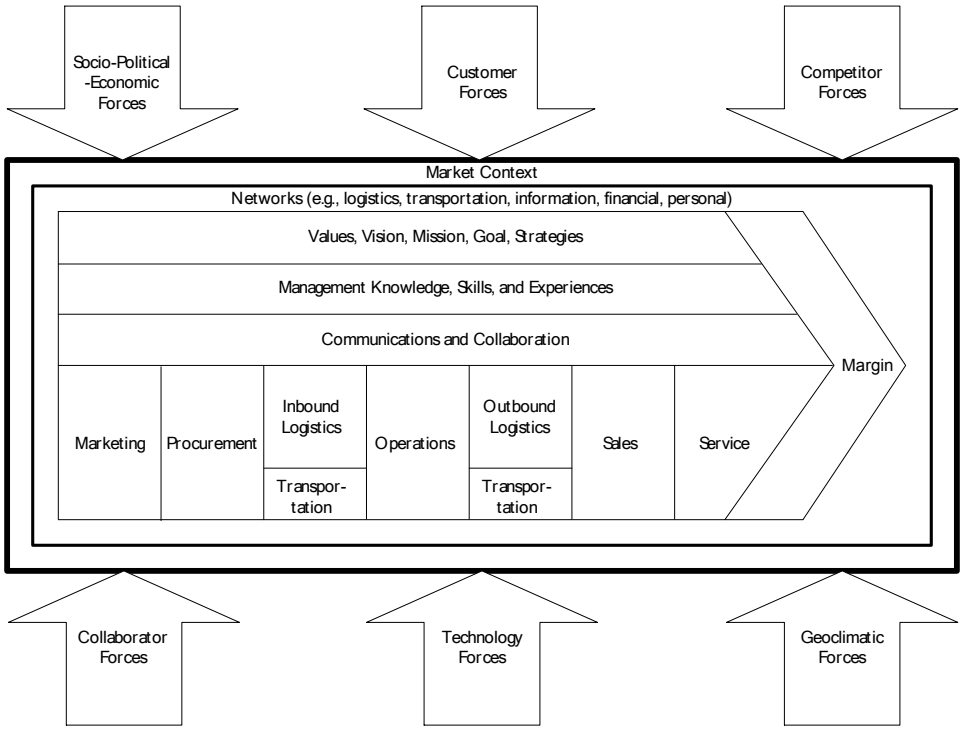

Figure 9 The Context of Interest

The context in which the Business Configuration (i.e., value chain) exists is influential on SIDAL, the mechanism whereby we impose control. We need to be considerate of how this.

Well, the obvious question arises. Must I go through all the levels of context before I know what to do?

The answer is no (recall the railway coupling speed example), but you do need to go far enough to understand the boundaries of influence. What I mean by that is that at some point of inclusiveness the forces of control become endogenous to the control system and one need not precede any further. One might liken this to a statistics sensitivity analysis.

Exercising Control

In "An Introduction to System Design and Control" I suggested that one can change the following four things.

1. The rules for making decisions.
2. The data that is used when applying these rules.
3. The manner in which the rules are linked together.
4. The people who make and apply the rules.

One might, of course, add other things to this list (e.g., assets, pricing) and should. The levers for change vary by organization and need to be relevant to what the firm is trying to do. These levers change over time.

This most directly affects the act in SIDAL.

The situation needs to look like this.

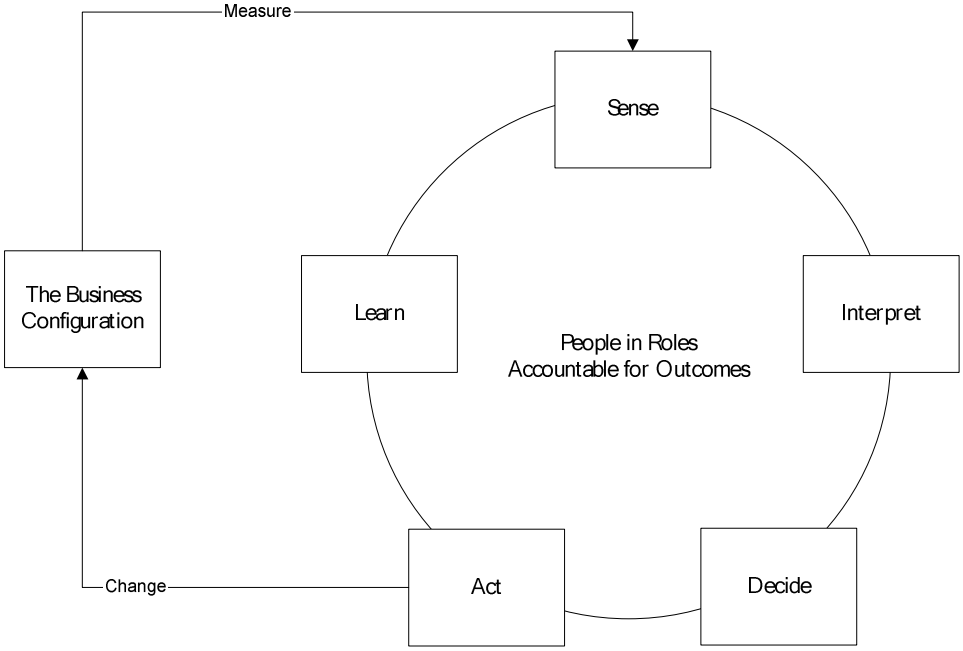

Figure 10 Connecting SIDAL and the Business Configuration

Sense depends upon measuring the performance of the organization. Act must change the way the organization operates in order to achieve the desired results.

Sight and Insight

There is a great deal of conversation regarding transparency and visibility in the supply chain. The point of view of this has generally been at an operational level and from where the customer sits.

I would argue that a similar, and perhaps prerequisite, transparency and visibility needs to exist into the business configuration and the relevant contexts. I say prerequisite because it's difficult to see how one can provide the required level of transparency and visibility externally without being to provide a similar capacity and capability internally.

I have previously called your attention to Haeckel and Slywotzky. I also want to call your attention to an earlier article by Haeckel and Nolan, "Managing by Wire."[18] Strongly related to these two works is the concept of the business dashboard.

Figure 11 The Bloomberg Terminal[19]

Figure 11 is an example of an interpretation of one of the most famous and ubiquitous of business dashboards, the Bloomberg Terminal. The dashboard is intended to present to you, much like an automobile dashboard does, relevant information that helps you run the business or drive the car. Note that there is a fair amount of graphical, as opposed to textual, information on the screens.

If exercising control is about having sight and insight then the manner in which relevant data is presented – the sight – is critical to interpretation and decision – the insight.

[18] Stephan H. Haeckel and Richard L. Nolan, "Managing by Wire," Harvard Business Review. September 01, 1993

[19] http://blogs.pcworld.co.nz/pcworld/ck-live/bloomberg.jpg [July 11, 2008]

The pace of the world is such that we can no longer afford the time to pour over computer printouts, trying to find the required information.

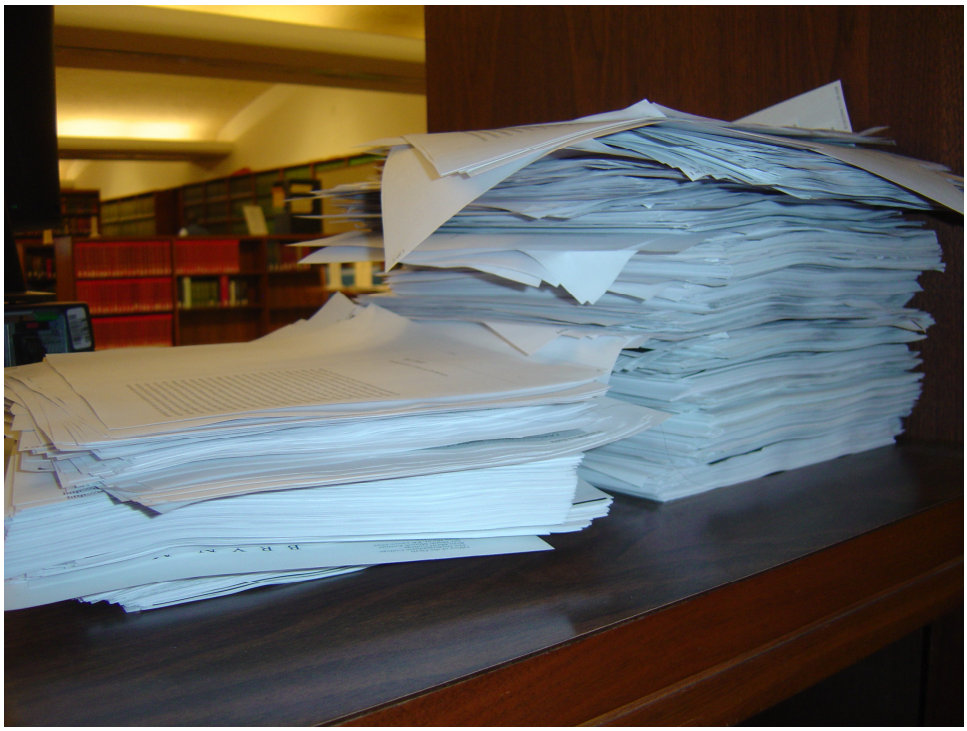

Figure 12 Computer Printouts[20]

We need the computer to pick from this pile what we need and arrange it in the way we need.

[20] http://people.brynmawr.edu/jlacovar/images/paper3.JPG [July 11, 2008]

Nor can we afford the time to look at data in the following fashion.

J2235R01 UNIVERSITY OF CONNECTICUT RUN DATE: 12/11/02 PAGE 0

COURSE NUMBER: NURS 217 SECTION: 01 ADULT HEALTH I INSTRUCTOR: MCNULTY JOHN ET AL EXAM DATE: 12/10/02

NUMBER OF EXAM VERSIONS: 1 NUMBER OF EXAM QUESTIONS: 90 BATCH: 001 RUN: . CMS OUTPUT: NONE

STUDENT NAME	ID NUMBER	EXAM VERSION	PART 1 SCORE	PART 2 SCORE	PART 3 SCORE	PART 4 SCORE	TOTAL SCORE	PERCENT SCORE	STANDARD SCORE	%TILE
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	000000000	1	42	37	0	0	79	88	01.58	96
	000000000	1	30	26	0	0	56	62	-2.02	04
	000000000	1	45	33	0	0	78	87	01.42	92
	000000000	1	41	31	0	0	72	80	00.48	70
	000000000	1	38	36	0	0	74	82	00.80	79
	000000000	1	45	34	0	0	79	88	01.58	96
	000000000	1	43	36	0	0	79	88	01.58	96
	000000000	1	29	21	0	0	50	56	-2.96	01
	000000000	1	37	32	0	0	69	77	00.01	49
	000000000	1	37	25	0	0	62	69	-1.08	12
	000000000	1	38	30	0	0	68	76	-0.14	44
	000000000	1	40	32	0	0	72	80	00.48	70
	000000000	1	42	34	0	0	76	84	01.11	84
	000000000	1	40	31	0	0	71	79	00.33	63
	000000000	1	36	34	0	0	70	78	00.17	57
	000000000	1	40	31	0	0	71	79	00.33	63
	000000000	1	39	30	0	0	69	77	00.01	49
	000000000	1	48	36	0	0	84	93	02.36	99
	000000000	1	37	30	0	0	67	74	-0.30	38
	000000000	1	28	26	0	0	54	60	-2.33	02
	000000000	1	38	36	0	0	74	82	00.80	79
	000000000	1	39	32	0	0	71	79	00.33	63
	000000000	1	39	33	0	0	72	80	00.48	70
	000000000	1	41	31	0	0	72	80	00.48	70

Figure 13 Computer Printout[21]

The notion of visualization as a means to increase our capacity for accepting and interpreting information plays a critical role in the notion of control.[22]

Yesterday, Today, and Tomorrow

Control presents us with three issues; learning from the past, understanding the present, and appreciating the alternative scenarios for the future.

The metrics we have established are, in general, strongly biased towards the present. That is to say that we might not be able to compare the past with the present using these metrics because the required historical data was simply not collected. For example, if I wanted to compare student grades for a course taught in the classroom and online from 2005 in order to try to gauge the impact of the mode of learning on student grades, I would be unable to do so. The reason is that our registration system does not unambiguously distinguish an online section from a classroom section.

And we should correspondingly realize that forward projections are based on metrics that may not be relevant in the future. For example, few talked about carbon footprints ten years ago.

There is a risk associated with the metrics that we must keep in mind. This risk can, to some extent, be hedged.[23]

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[21] http://ops.uconn.edu/sched/img/app5.gif [July 11, 2008]

[22] James Drogan, The Role of Visualization in Communication, 2007, http://jmsdrgn.squarespace.com/storage/The%20Role%20of%20Visualization%20in%20Communication.pdf, [February 10, 2007

[23] Drogan, The Relevance of Data, Information, and Knowledge,

Closing Comments

Within the system there need to be a SIDAL thread that allows the measurement of all critical metrics and the subsequent necessary changed to the system.

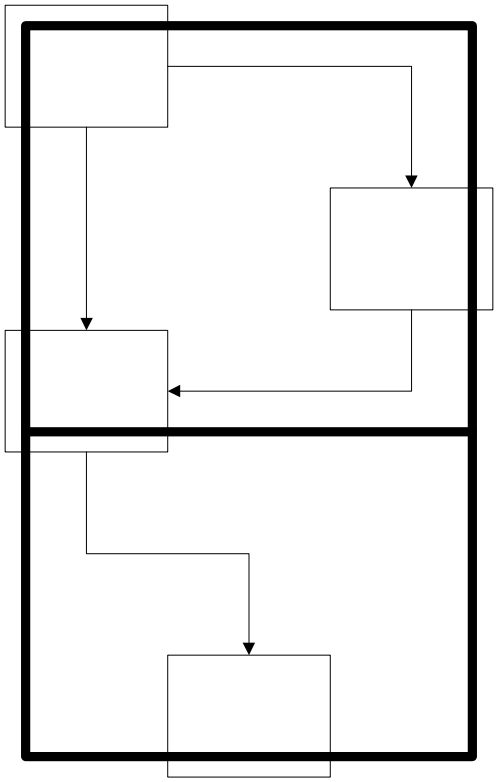

Figure 14 A System and the SIDAL Thread

Figure 14 is a system comprising four subsystems interconnected by the arrows. The broad line is to depict the SIDAL thread allowing the measuring and control of the subsystems and their interconnections. The system and its associated mechanisms for measurement and control must be designed and implemented together.

What's the point of a system that cannot be controlled?

Metrics and measurement, SIDAL, people, the business configuration, contexts, means of control, sight and insight, the past, present, and the future; all come together and must be considered together to arrive at the system that works. While one must start somewhere (i.e., metrics), and the end of the day all these matters are like so many simultaneous equations to be solved.

System design and control is not one pass and done. It's perhaps many passes and never done.

James Drogan
July 12, 2008

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CHAPTER 1

System Behavior and Causal Loop Diagrams

Human beings are quick problem solvers. From an evolutionary standpoint, this makes sense—if a sabertooth tiger is bounding toward you, you need to quickly decide on a course of action, or you won't be around for long. Thus, quick problem solvers were the ones who survived. We quickly determine a *cause* for any *event* that we think is a problem. Usually we conclude that the cause is another event. For example, if sales are poor (the event that is a problem), then we may conclude that this is because the sales force is insufficiently motivated (the event that is the cause of the problem).

This approach works well for simple problems, but it works less well as the problems get more complex, for example in addressing management problems which are cross-functional or strategic. General Motors illustrates the issue. For over half a century, GM dominated the automotive industry. GM's difficulties did not come from a lightning attack by Japanese auto manufacturers. GM had a couple of decades to adapt, but today it is still attempting to find a way to its former dominance, more than three decades after the start of Japanese automobile importation. During this period, many of GM's employees and managers have turned over, but the company still has difficulty adjusting. There seems to be something about the way that GM is put together that makes its behavior hard to change.

1.1 Systems Thinking

The methods of *systems thinking* provide us with tools for better understanding these dif ficult management problems. The methods have been used for over thirty years (Forrester 1961) and are now well established. However, these approaches require a shift in the way we think about the performance of an organization. In particular, they require that we move away from looking at isolated *events* and their *causes* (usually assumed to be some other events), and start to look at the organization as a *system* made up of interacting parts.

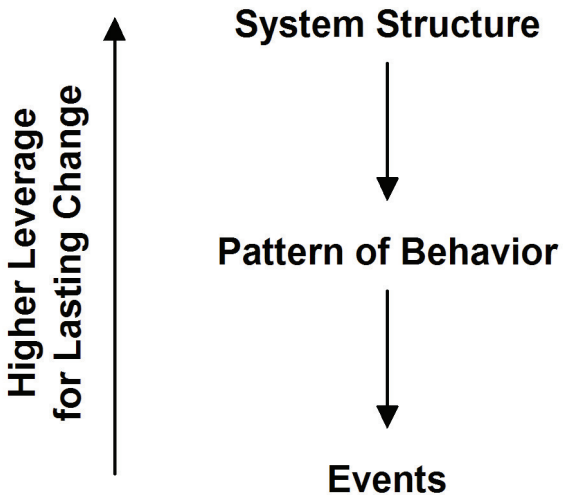


Figure 1.1 *Looking for high leverage*

We use the term *system* to mean an interdependent group of items forming a unified pattern. Since our interest here is in business processes, we will focus on systems of people and technology intended to design, market, produce, and distribute products or services. Almost everything that goes on in business is part of one or more systems. As noted above, when we face a management problem we tend to assume that some external event caused it. With a systems approach, we take an alternative viewpoint—namely that the internal structure of the system is often more important than external events in generating the problem.

This is illustrated by the diagram in Figure 1.1.[1] Many people try to explain business performance by showing how one set of events causes another or, when they study a problem in depth, by showing how a particular set of events is part of a longer term *pattern of behavior*. The difficulty with this "events causes events" orientation is that it doesn't lead to very powerful ways to alter the undesirable performance. This is because you can always find yet another event that caused the one that you thought was the cause. For example, if a new product is not selling (the event that is a problem), then you may conclude that this if because the sales force is not pushing it (the event that is the cause of the problem). However, you can then ask why the sales force is not pushing it (another problem!). You might then conclude that this is because they are overworked (the cause of your new problem). But you can then look for the cause of this condition. You can continue this process almost forever, and thus it is difficult to determine what to do to improve performance.

[1] Figure 1.1 and this discussion of it are based on class notes by John Sterman of the MIT Sloan School of Management.

If you shift from this event orientation to focusing on the internal *system structure*, you improve your possibility of improving business performance. This is because system structure is often the underlying source of the difficulty. Unless you correct system structure deficiencies, it is likely that the problem will resurface, or be replaced by an even more difficult problem.

1.2 Patterns of Behavior

To start to consider system structure, you first generalize from the specific events associated with your problem to considering *patterns of behavior* that characterize the situation. Usually this requires that you investigate how one or more variables of interest change over time. (In a business setting, variables of interest might be such things as cost, sales, revenue, profit, market share, and so forth.) That is, what *patterns of behavior* do these variables display. The systems approach gains much of its power as a problem solving method from the fact that similar patterns of behavior show up in a variety of different situations, and the underlying system structures that cause these characteristic patterns are known. Thus, once you have identified a pattern of behavior that is a problem, you can look for the system structure that is know to cause that pattern. By finding and modifying this system structure, you have the possibility of permanently eliminating the problem pattern of behavior.

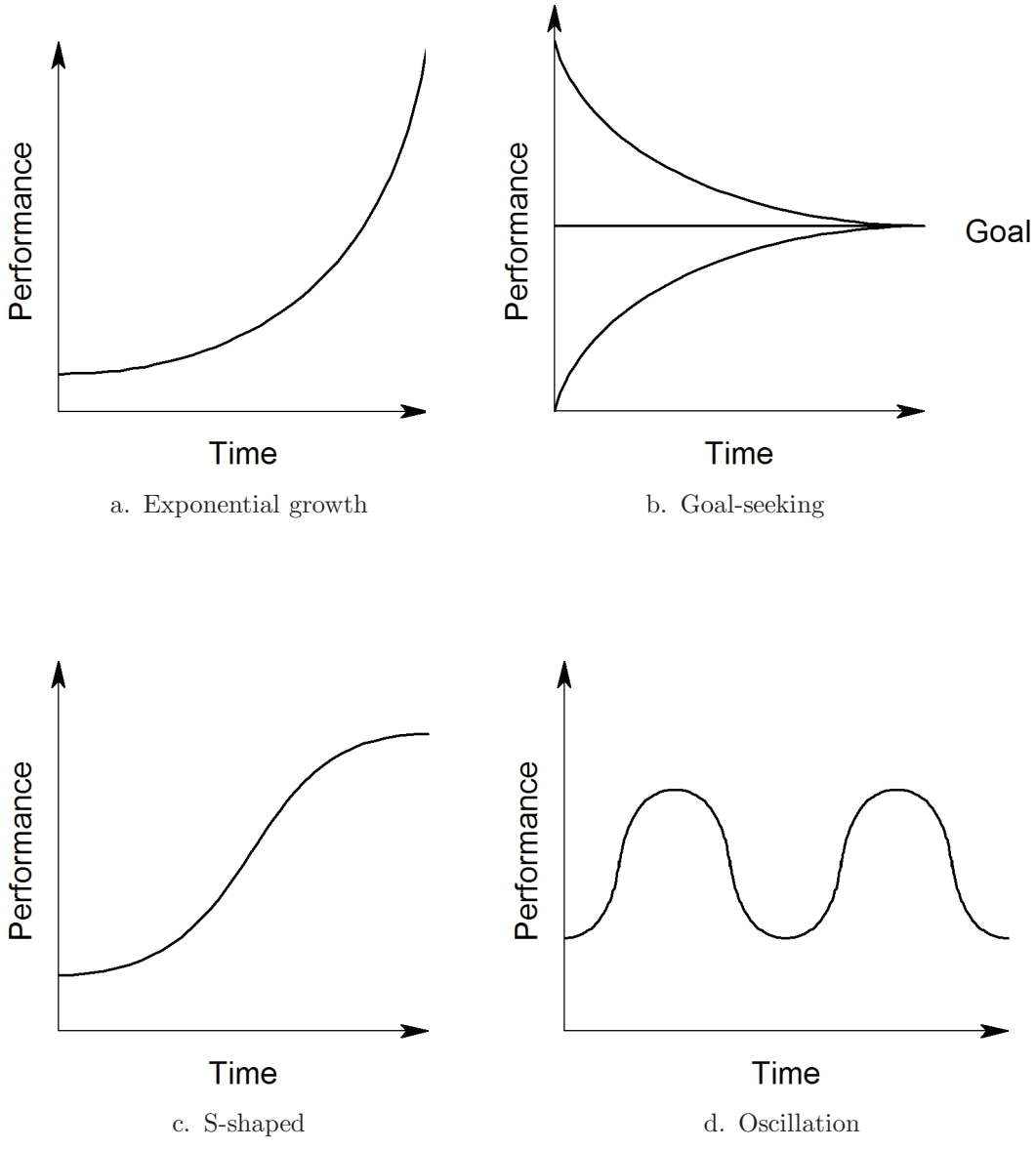
The four patterns of behavior shown in Figure 1.2 often show up, either individually or in combinations, in systems. In this figure, "Performance" refers to some variable of interest. This is often a measure of financial or operational effectiveness or efficiency. In this section, we summarize the characteristics of these patterns. In later sections, we examine the types of system structures which generate these patterns.[2]

With **exponential growth** (Figure 1.2a), an initial quantity of something starts to grow, and the rate of growth increases. The term "exponential growth" comes from a mathematical model for this increasing growth process where the growth follows a particular functional form called the exponential. In business processes, the growth may not follow this form exactly, but the basic idea of accelerating growth holds. This behavior is what we would like to see for sales of a new product, although more often sales follow the s-shaped curve discussed below.

With **goal-seeking** behavior (Figure 1.2b), the quantity of interest starts either above or below a goal level and over time moves toward the goal. Figure 1.2b shows two possible cases, one where the initial value of the quantity is above the goal, and one where the initial value is below the goal.

With **s-shaped growth** (Figure 1.2c), initial exponential growth is followed by goal-seeking behavior which results in the variable leveling off.

[2] The following discussion draws on Senge (1990), Senge et al (1994), and notes from David Kreutzer and John Sterman.



a. Exponential growth

b. Goal-seeking

c. S-shaped

d. Oscillation

Figure 1.2 *Characteristic patterns of system behavior*

With **oscillation** (Figure 1.2d), the quantity of interest fluctuates around some level. Note that oscillation initially appears to be exponential growth, and then it appears to be s-shaped growth before reversing direction.

Common combinations of these four patterns include

- Exponential growth combined with oscillation. With this pattern, the general trend is upward, but there can be declining portions, also. If the magnitude of the oscillations is relatively small, then growth may plateau, rather than actually decline, before it continues upward.
- Goal-seeking behavior combined with an oscillation whose amplitude gradually declines over time. With this behavior, the quantity of interest will overshoot the goal on first one side and then the other. The amplitude of these overshoots declines until the quantity finally stabilizes at the goal.
- S-shaped growth combined with an oscillation whose amplitude gradually declines over time.

1.3 Feedback and Causal Loop Diagrams

To better understand the system structures which cause the patterns of behavior discussed in the preceding section, we introduce a notation for representing system structures. The usefulness of a graphical notation for representing system structure is illustrated by the diagram in Figure 1.3 which is adapted from a figure in Richardson and Pugh (1981). This shows the relationships among the elements of a production sector within a company. In this diagram, the short descriptive phrases represent the elements which make up the sector, and the arrows represent the causal influences between these elements. For example, examining the left hand side of the diagram, we see that "Production" is directly influenced by "Workforce (production capacity)" and "Productivity." In turn, "Production" influences "Receipt into inventory."

This diagram presents relationships that are difficult to verbally describe because normal language presents interrelations in linear cause-and-effect chains, while the diagram shows that in the actual system there are circular chains of cause-and-effect. Consider, for example, the "Inventory" element in the upper left-hand corner of the diagram. We see from the diagram that "Inventory" influences "Availability of inventory," which in turn influences "Shipments." To this point in the analysis, there has been a linear chain of cause and effect, but continuing in the diagram, we see that "Shipments" influence "Inventory." That is, the chain of causes and effects forms a closed loop, with "Inventory" influencing itself indirectly through the other elements in the loop. The diagram shows this more easily than a verbal description.

When an element of a system indirectly influences itself in the way discussed for Inventory in the preceding paragraph, the portion of the system involved is called a *feedback loop* or a *causal loop*. [Feedback is defined as the transmission and return of information (Richardson and Pugh 1981).] More formally, a feedback loop is a *closed sequence of causes and effects, that is, a closed path of*

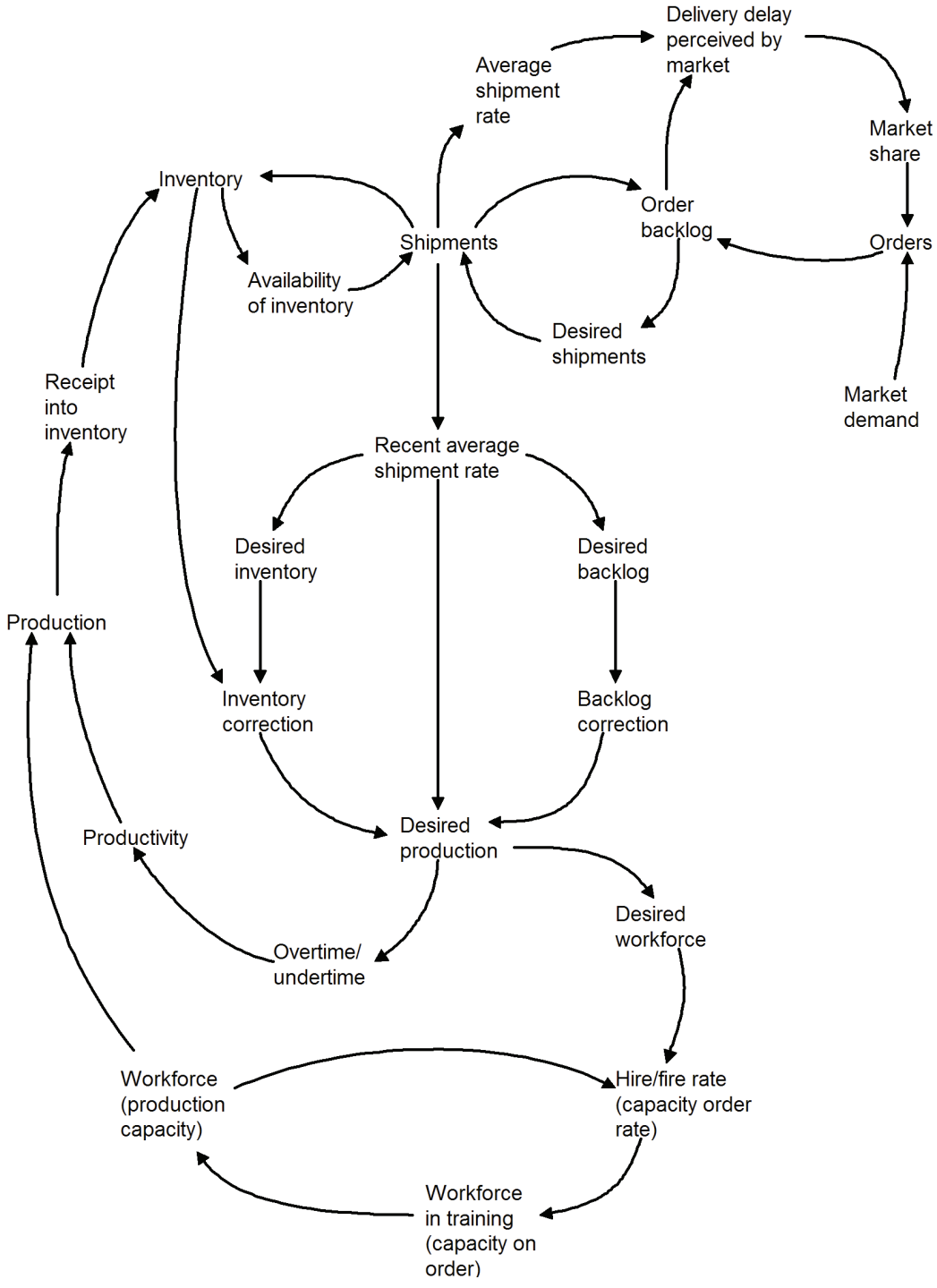


Figure 1.3 *Feedback structure of a basic production sector*

action and information (Richardson and Pugh 1981). The reason for emphasizing feedback is that it is often necessary to consider feedback within management systems to understand what is causing the patterns of behavior discussed in the preceding section and shown in Figure 1.2. That is, the causes of an observed pattern of behavior are often found within the feedback structures for a management system.

To complete our presentation of terminology for describing system structure, note that a linear chain of causes and effects which does not close back on itself is called an *open loop*. An analysis of causes and effects which does not take into account feedback loops is sometimes called *open loop thinking*, and this term usually has a pejorative connotation—it indicates thinking that is not taking the full range of impacts of a proposed action into account.

A map of the feedback structure of a management system, such as that shown in Figure 1.3, is a starting point for analyzing what is causing a particular pattern of behavior. However, additional information aids with a more complete analysis. Figure 1.4 defines notation for this additional information. This figure is an annotated *causal loop diagram* for a simple process, filling a glass of water. This diagram includes *elements* and arrows (which are called *causal links*) linking these elements together in the same manner as shown in Figure 1.3, but it also includes a sign (either + or −) on each link. These signs have the following meanings:

1. A causal link from one element A to another element B is *positive* (that is, +) if either (a) A adds to B or (b) a change in A produces a change in B in the *same* direction.
2. A causal link from one element A to another element B is *negative* (that is, −) if either (a) A subtracts from B or (b) a change in A produces a change in B in the *opposite* direction.

This notation is illustrated by the causal loop diagram in Figure 1.4. Start from the element "Faucet Position" at the top of the diagram. If the faucet position is increased (that is, the faucet is opened further) then the "Water Flow" increases. Therefore, the sign on the link from "Faucet Position" to "Water Flow" is positive. Similarly, if the "Water Flow" increases, then the "Water Level" in the glass will increase. Therefore, the sign on the link between these two elements is positive.

The next element along the chain of causal influences is the "Gap," which is the difference between the "Desired Water Level" and the (actual) "Water Level." (That is, Gap = Desired Water Level − Water Level.) From this definition, it follows that an increase in "Water Level" decreases "Gap," and therefore the sign on the link between these two elements is negative. Finally, to close the causal loop back to "Faucet Position," a greater value for "Gap" presumably leads to an increase in "Faucet Position" (as you attempt to fill the glass) and therefore the sign on the link between these two elements is positive. There is one additional link in this diagram, from "Desired Water Level" to "Gap." From

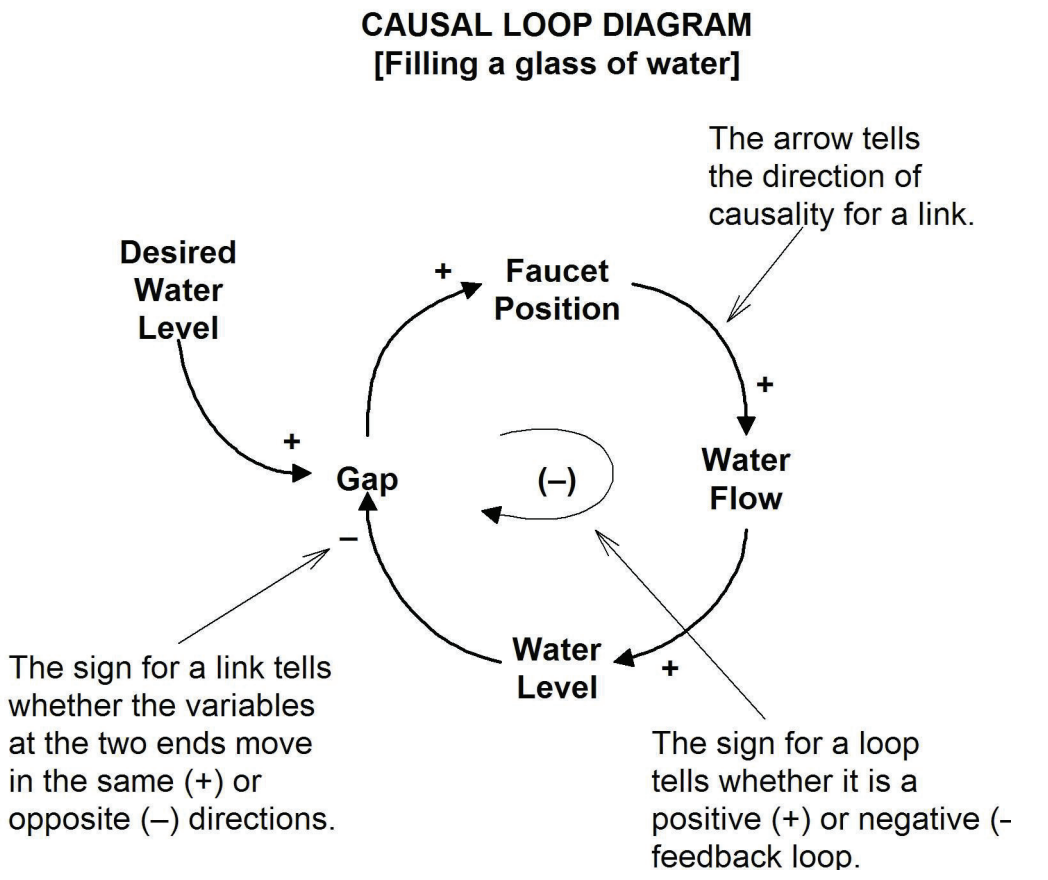


Figure 1.4 *Causal loop diagram notation*

the definition of "Gap" given above, the influence is in the same direction along this link, and therefore the sign on the link is positive.

In addition to the signs on each link, a complete loop also is given a sign. The sign for a particular loop is determined by counting the number of minus (−) signs on all the links that make up the loop. Specifically,

1. A feedback loop is called *positive*, indicated by a + sign in parentheses, if it contains an even number of negative causal links.
2. A feedback loop is called *negative*, indicated by a − sign in parentheses, if it contains an odd number of negative causal links.

Thus, the sign of a loop is the algebraic product of the signs of its links. Often a small looping arrow is drawn around the feedback loop sign to more clearly indicate that the sign refers to the loop, as is done in Figure 1.4. Note that in this diagram there is a single feedback (causal) loop, and that this loop has one negative sign on its links. Since one is an odd number, the entire loop is negative.

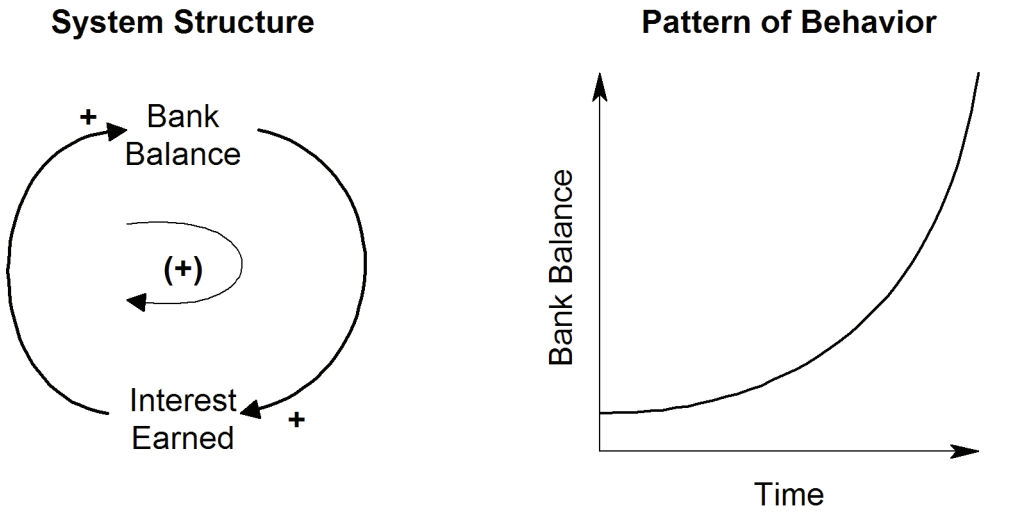


Figure 1.5 *Positive (reinforcing) feedback loop: Growth of bank balance*

An alternative notation is used in some presentations of causal loop diagrams. With this alternate notation, a lower case s is used instead of a + on a link, and a lower case o is used instead of a −. The s stands for "same," and the o stands for "opposite," indicating that the variables at the two ends of the link move in either the same direction (s) or opposite directions (o). For the loops, a capital R is used instead of (+), and a capital B is used instead of (−). The R stands of "reinforcing," and the B stands for "balancing." The reason for using these specific terms will become clearer as we discuss the patterns of behavior associated with different system structures in the next section.

1.4 System Structure and Patterns of Behavior

This section presents simple structures which lead to the typical patterns of behavior shown earlier in Figure 1.2. While the structures of most management systems are more complicated than those shown here, these structures are building blocks from which more complex models can be constructed.

Positive (Reinforcing) Feedback Loop

A positive, or reinforcing, feedback loop reinforces change with even more change. This can lead to rapid growth at an ever-increasing rate. This type of growth pattern is often referred to as *exponential growth*. Note that in the early stages of the growth, it seems to be slow, but then it speeds up. Thus, the nature of the growth in a management system that has a positive feedback loop can be deceptive. If you are in the early stages of an exponential growth process, something that is going to be a major problem can seem minor because it is

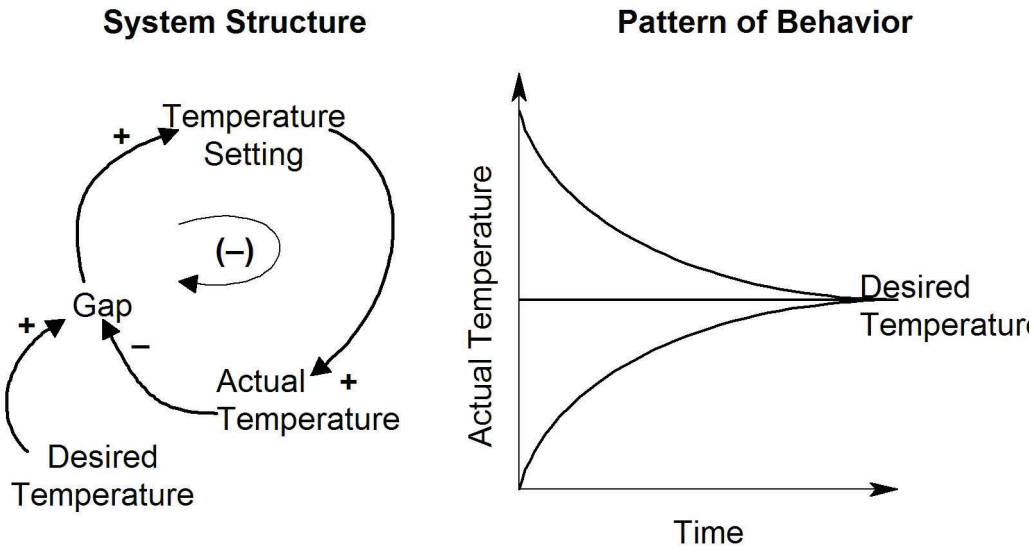


Figure 1.6 *Negative (balancing) feedback loop: Regulating an elective blanket*

growing slowly. By the time the growth speeds up, it may be too late to solve whatever problem this growth is creating. Examples that some people believe fit this category include pollution and population growth. Figure 1.5 shows a well know example of a positive feedback loop: Growth of a bank balance when interest is left to accumulate.

Sometimes positive feedback loops are called vicious or virtuous cycles, depending on the nature of the change that is occurring. Other terms used to describe this type of behavior include bandwagon effects or snowballing.

Negative (Balancing) Feedback Loop

A negative, or balancing, feedback loop seeks a goal. If the current level of the variable of interest is above the goal, then the loop structure pushes its value down, while if the current level is below the goal, the loop structure pushes its value up. Many management processes contain negative feedback loops which provide useful stability, but which can also resist needed changes. In the face of an external environment which dictates that an organization needs to change, it continues on with similar behavior. These types of feedback loops are so powerful in some organizations that the organizations will go out of business rather than change. Figure 1.6 shows a negative feedback loop diagram for the regulation of an electric blanket temperature.

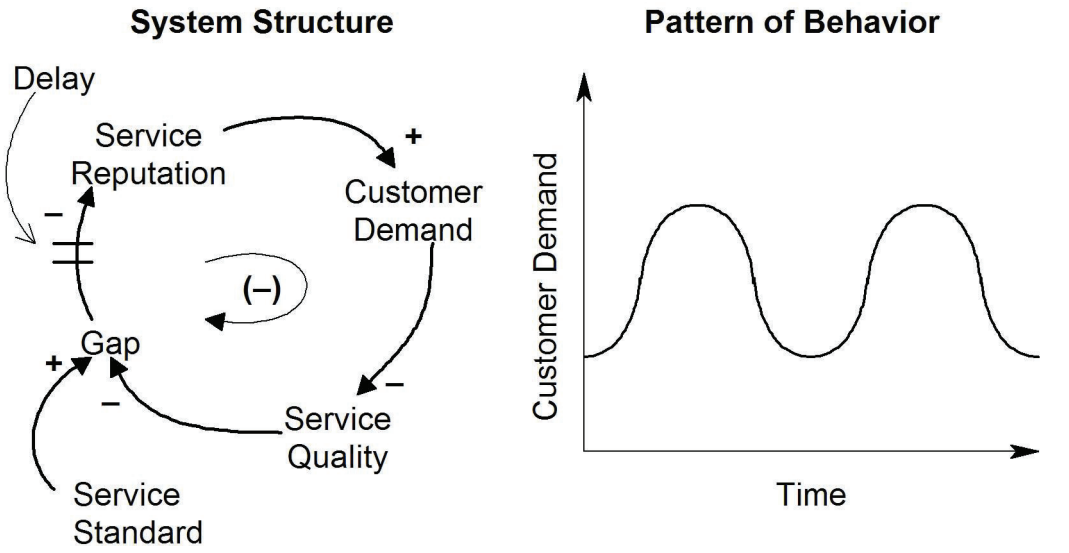


Figure 1.7 *Negative feedback loop with delay: Service quality*

Negative Feedback Loop with Delay

A negative feedback loop with a substantial delay can lead to oscillation. The specific behavior depends on the characteristics of the particular loop. In some cases, the value of a variable continues to oscillate indefinitely, as shown above. In other cases, the amplitude of the oscillations will gradually decrease, and the variable of interest will settle toward a goal. Figure 1.7 illustrates negative feedback with a delay in the context of service quality. (This example assumes that there are fixed resources assigned to service.)

Multi-level production and distribution systems can display this type of behavior because of delays in conveying information about the actual customer demand for a product to the manufacturing facility. Because of these delays, production continues long after enough product has been manufactured to meet demand. Then production is cut back far below what is needed to replace items that are sold while the excess inventory in the system is worked off. This cycle can continue indefinitely, which places significant strains on the management of the process. For example, there may be a pattern of periodic hiring and layoffs. There is some evidence that what are viewed as seasonal variations in customer demand in some industries are actually oscillations caused by delays in negative feedback loops within the production-distribution system.

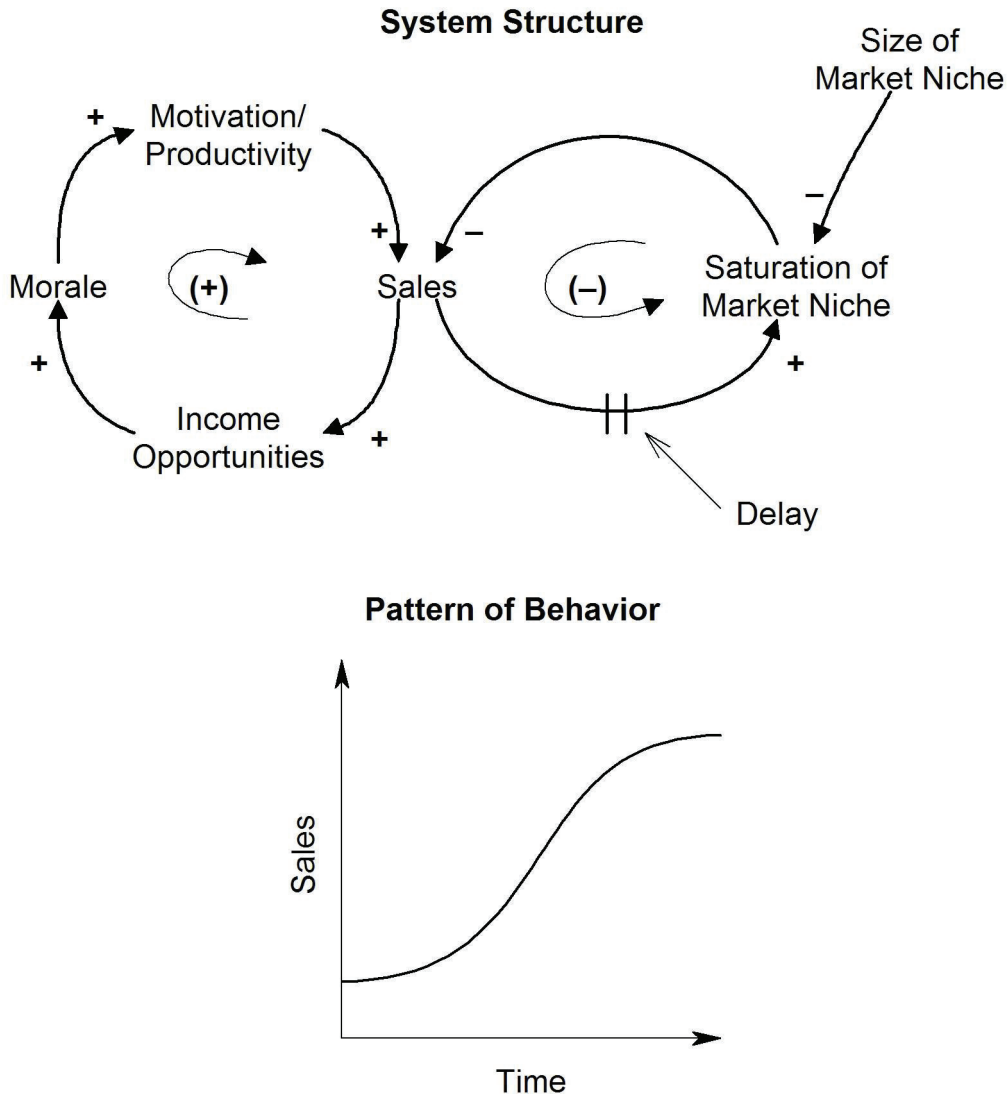


Figure 1.8 *Combination of positive and negative loops: Sales growth*

Combination of Positive and Negative Loops

When positive and negative loops are combined, a variety of patterns are possible. The example above shows a situation where a positive feedback loop leads to early exponential growth, but then, after a delay, a negative feedback loop comes to dominate the behavior of the system. This combination results in an s-shaped pattern because the positive feedback loop leads to initial exponential growth, and then when the negative feedback loop takes over it leads to goal seeking behavior. Figure 1.8 illustrates a combination of positive and negative loops in the context of sales for a new product.

Most growth processes have limits on their growth. At some point, some resource limit will stop the growth. As Figure 1.8 illustrates, growth of sales for a new product will ultimately be slowed by some factor. In this example, the limiting factor is the lack of additional customers who could use the product.

1.5 Creating Causal Loop Diagrams

To start drawing a causal loop diagram, decide which *events* are of interest in developing a better understanding of system structure. For example, perhaps sales of some key product were lower than expected last month. From these events, move to showing (perhaps only qualitatively) the *pattern of behavior* over time for the quantities of interest. For the sales example, what has been the pattern of sales over the time frame of interest? Have sales been growing? Oscillating? S-shaped? Finally, once the pattern of behavior is determined, use the concepts of positive and negative feedback loops, with their associated generic patterns of behavior, to begin constructing a causal loop diagram which will explain the observed pattern of behavior.

The following hints for drawing causal loop diagrams are based on guidelines by Richardson and Pugh (1981) and Kim (1992):

1 Think of the elements in a causal loop diagram as *variables* which can go up or down, but don't worry if you cannot readily think of existing measuring scales for these variables.

- Use nouns or noun phrases to represent the elements, rather than verbs. That is, the actions in a causal loop diagram are represented by the links (arrows), and not by the elements. For example, use "cost" and not "increasing cost" as an element.
- Be sure that the definition of an element makes it clear which direction is "up" for the variable. For example, use "tolerance for crime" rather than "attitude toward crime."
- Generally it is clearer if you use an element name for which the positive sense is preferable. For example, use "Growth" rather than "Contraction."
- Causal links should imply a direction of causation, and not simply a time sequence. That is, a positive link from element A to element B does not mean "first A occurs and then B occurs." Rather it means, "when A increases then B increases."

2 As you construct links in your diagram, think about possible unexpected side effects which might occur in addition to the influences you are drawing. As you identify these, decide whether links should be added to represent these side effects.

3 For negative feedback loops, there is a goal. It is usually clearer if this goal is explicitly shown along with the "gap" that is driving the loop toward the goal. This is illustrated by the examples in the preceding section on regulating electric blanket temperature and service quality.

4. A difference between actual and perceived states of a process can often be important in explaining patterns of behavior. Thus, it may be important to include causal loop elements for both the actual value of a variable and the perceived value. In many cases, there is a lag (delay) before the actual state is perceived. For example, when there is a change in actual product quality, it usually takes a while before customers perceive this change.
5. There are often differences between short term and long term consequences of actions, and these may need to be distinguished with different loops. For example, the short term result of taking a mood altering drug may be to feel better, but the long run result may be addiction and deterioration in health.
6. If a link between two elements needs a lot of explaining, you probably need to add intermediate elements between the two existing elements that will more clearly specify what is happening.
7. Keep the diagram as simple as possible, subject to the earlier points. The purpose of the diagram is not to describe every detail of the management process, but to show those aspects of the feedback structure which lead to the observed pattern of behavior.

1.6 References

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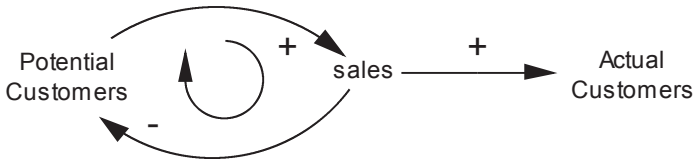
CHAPTER 2

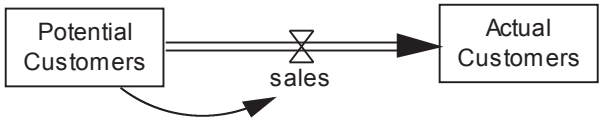
A Modeling Approach

The issues we will address to improve our understanding of how business processes work are illustrated by the causal loop diagram in Figure 2.1a. This models a simple advertising situation for a durable good. There is a pool of Potential Customers who are turned into Actual Customers by sales. Potential Customers and sales are connected in a negative feedback loop with the goal of driving Potential Customers to zero. If we visualize a typical mass advertising situation, we would expect that the greater the number of Potential Customers, the greater the sales, and this is shown in Figure 2.1a by the positive arrow between Potential Customers and sales. Similarly, greater sales lead to fewer Potential Customers (since the Potential Customers are converted into Actual Customers by sales), and hence there is a negative arrow from sales to Potential Customers. Since there are a odd number of negative links in the feedback loop between Potential Customers and sales, this is a negative feedback loop.

We obtain from this diagram the (not very profound) insight that eventually sales must go to zero when the number of Potential Customers reaches zero. However, this insight by itself is not particularly useful for business management purposes because there is no information about the *rate* at which Potential Customers will go to zero. It can make a big difference for managing the production and sales of this product if it will sell well for ten months or ten years before we run out of Potential Customers! For a simple situation like this, we could use a spreadsheet to develop a quantitative model to investigate the rate at which Potential Customers will go to zero, but as the complexity of the situation increases, this becomes more difficult. In the remainder of this chapter, we develop a systematic approach to investigating questions of this type which can be applied to both simple and complex business processes.



a. Causal loop diagram



b. Stock and flow diagram

Figure 2.1 *Advertising example*

2.1 Stock and Flow Diagrams

Figure 2.1b illustrates a graphical notation that provides some structure for thinking about the rate at which Potential Customers goes to zero. This notation consists of three different types of elements: stocks, flows, and information. As we will see below, it is a remarkable fact that the three elements in this diagram provide a general way of graphically representing *any* business process. Furthermore, this graphical notation can be used as a basis for developing a quantitative model which can be used to study the characteristics of the process.

This type of diagram is called a *stock and flow* diagram. As with a causal loop diagram, the stock and flow diagram shows relationships among *variables* which have the potential to change over time. In the Figure 2.1b stock and flow diagram, the variables are Potential Customers, sales, and Actual Customers. Unlike a causal loop diagram, a stock and flow diagram distinguishes between different types of variables. Figure 2.1b shows two different types of variables, which are distinguished by different graphical symbols. The variables Potential Customers and Actual Customers are shown inside rectangles, and this type of variable is called a *stock*, *level*, or *accumulation*. The variable "sales" is shown next to a "bow tie" or "butterfly valve" symbol, and this type of variable is called a *flow*, or *rate*.

To understand and construct stock and flow diagrams, it is necessary to understand the difference between stocks and flows. However, before considering this in more detail, it is useful to discuss what we are attempting to do with this approach to modeling business processes.

2.2 Generality of the Approach

I noted above that the stock and flow notation illustrated in Figure 2.1b provides a general way to graphically characterize any business process. This may seem ambitious: *any* process! In particular, if you have previously worked with computer simulation packages for, to take a specific example, manufacturing processes, you know that they generally contain many more elements than the two shown here. For example, a manufacturing simulation package might contain specific symbols and characterizations for a variety of different milling machines or other manufacturing equipment.

This type of detailed information is important for studying the specific detailed operation of a particular manufacturing process. We will not be providing such details here because they are specific to particular equipment (which will probably soon be obsolete). Instead, we are considering the characteristics that are generally shared by *all* business processes and the components which make up these processes. It is a remarkable fact that all such processes can be characterized in terms of variables of two types, stocks (levels, accumulations) and flows (rates).

The conclusion in the previous paragraph is supported by over a century of theoretical and practical work. Forrester (1961) first systematically applied these ideas to business process analysis almost forty years ago, and extensive practical applications have shown that this way of considering business processes provides significant insights based on solid theory. As the old saying goes, "there is nothing more practical than a good theory," and the theory presented here can be turned in practice, yielding competitive advantage.

2.3 Stocks and Flows

The graphical notation in Figure 2.1b hints at the differences between stocks and flows. The rectangular boxes around the variables Potential Customers and Actual Customers look like containers of some sort, or perhaps even bathtubs. The double-line arrow pointing from Potential Customers toward Actual Customers looks like a pipe, and the butterfly valve in the middle of this pipe looks like a valve controlling the flow through the pipe. Thus, the graphical notation hints at the idea that there is a flow from Potential Customers toward Actual Customers, with the rate of the flow controlled by the "sales" valve. And, in fact, this is the key idea behind the difference between a stock and a flow: A stock is an accumulation of something, and a flow is the movement or flow of the "something" from one stock to another.

A primary interest of business managers is changes in variables like Actual Customers over time. If nothing changes, then anybody can manage—just do what has always been done. Some of the greatest management challenges come from change. If sales start to decline, or even increase, you should investigate why this change has occurred and how to address it. One of the key differences

between managers who are successful and those who are not is their ability to address changes before it is too late.

We will focus on investigating these changes, and in particular learning how the elements and structure of a business process can bring about such changes. Because of this focus on the elements which make up a process (which are often referred to as the *components* of a *system*) and how the performance of the process changes over time, the ideas we are studying are often referred to as *system dynamics*.

Distinguishing between stocks and flows is sometimes difficult, and we will provide numerous examples below. As a starting point, you can think of stocks as representing physical entities which can accumulate and move around. However, in this age of computers, what used to be concrete physical entities have often become abstract. For example, money is often an important stock in many business processes. However, money is more often than not entries in a computer system, rather than physical dollar bills. In the pre-computer days, refunds in a department store might require the transfer of currency through a pneumatic tube; now they probably mean a computer credit to a MasterCard account. Nonetheless, the money is still a stock, and the transfer operation for the money is a flow.

Another way to distinguish stocks and flows is to ask what would happen if we could freeze time and observe the process. If we would still see a nonzero value for a quantity, then that quantity is a stock, but if the quantity could not be measured, then it is a flow. (That is, flows only occur over a period of time, and, at any particular instant, nothing moves.) For readers with an engineering systems analysis background, we use the term stock for what is called a *state variable* is engineering systems analysis.

Types of Stocks and Flows

Most business activities include one or more of the following five types of stocks: materials, personnel, capital equipment, orders, and money. The most visible signs of the operation of a process are often movements of these five types of stocks, and these are defined as follows:

Materials. This includes all stocks and flows of physical goods which are part of a production and distribution process, whether raw materials, in-process inventories, or finished products.

Personnel. This generally refers to actual people, as opposed, for example, to hours of labor.

Capital equipment. This includes such things as factory space, tools, and other equipment necessary for the production of goods and provision of services.

Orders. This includes such things as orders for goods, requisitions for new employees, and contracts for new space or capital equipment. Orders are typically the result of some management decision which has been made, but not yet converted into the desired result.

Money. This is used in the cash sense. That is, a flow of money is the actual transmittal of payments between different stocks of money.

The first three items above (materials, personnel, and capital equipment) are conceptually relatively straightforward because there is usually a physical entity corresponding to these. The last two items above (orders and money) are somewhat more subtle in this age of computers. Whether something is really money or just information about a monetary entry somewhere in a computer database may not be immediately obvious.

2.4 Information

The last element in the Figure 2.1b stock and flow diagram is the information link shown by the curved arrow from Potential Customers to sales. This arrow means that in some way information about the value of Potential Customers influences the value of sales. Furthermore, and equally important, the fact that there is no information arrow from Actual Customers to sales means that information about the value of Actual Customers does not influence the value of sales.

The creation, control, and distribution of information is a central activity of business management. The heart of the ongoing changes in business management is in changing the way that information is used. Perhaps nowhere is the impact of the computer on management potentially more significant. In a traditional hierarchical business organization, it can be argued that the primary role of much of middle management is to pass information up the hierarchy and orders down. This structure was required in pre-computer days by the magnitude of the communications problem in a large organization. With the current widespread availability of inexpensive computer-based analysis and communications systems, this large, expensive, and slow system for transmitting information is no longer adequate to retain competitive advantage. Business organizations are substantially changing the way they handle information, and thus the set of information links is a central component in most models of business processes oriented toward improving these processes.

The information links in a business process can be difficult to adequately model because of the abstract nature of these links. Materials, personnel, capital equipment, orders, and money usually have a physical representation. Furthermore, these quantities are conserved, and thus they can only flow to one place at a time. Information, on the other hand, can simultaneously flow to many places, and, particularly in computer-intensive environments, it can do this rapidly and with considerable distortion.

Practical experience is showing that modifying the information links in a business process can have profound impacts on the performance of the process. Furthermore, these impacts are often non-intuitive and can be dangerous. Some companies have discovered, for example, that computer-based information systems have not only not improved their performance, but in fact have degraded it. Doing large-scale experimentation by making *ad hoc* changes to a crucial aspect of an organization like the information links can be dangerous. The tools we discuss below provide a way to investigate the implications of such changes before they are implemented.

No one today would construct and fly an airplane without first carefully analyzing its potential performance with computer-based models. However, we routinely make major changes to our business organizations without such prior modeling. We seem to think that we can intuitively predict the performance of a changed organization, even though this organization is likely to be much more complex than an airplane. No one would take a ride on an airplane whose characteristics under all sorts of extreme conditions had not previously been analyzed carefully. Yet we routinely make significant changes to the structure of a business process and then "take a ride" in the resulting organization without this testing. The methods presented below aid in doing some testing before implementing changes to business processes.

2.5 Reference

J. W. Forrester, *Industrial Dynamics*, The MIT Press, Cambridge, Massachusetts, 1961.

Supply Chain Operations Reference (SCOR®) model

Overview - Version 10.0

SCC℠
supply chain council

About Supply Chain Council

Supply Chain Council (SCC, supply-chain.org) is a global nonprofit organization whose framework, improvement methodology, and benchmarking tools help member organizations make dramatic and rapid improvements in supply chain performance. SCC established and maintains the supply chain world's most widely accepted framework for evaluating and comparing supply chain activities and their performance: the Supply Chain Operations Reference (SCOR®) model. The SCOR framework makes it possible for organizations to quickly determine and compare the performance of supply chain and related operations within their organization and against other organizations. SCC and its member volunteers continually advance these tools and provide education on how to leverage them for achieving superior supply chain performance.

A consortium of 69 organizations founded SCC in 1996. Today, the SCOR model is used by thousands of organizations worldwide. SCC membership is open to all organizations interested in applying and advancing the state-of-the-art in supply chain management systems and practices. Our members represent a broad cross-section of industries including manufacturers, distributors, retailers, and service providers as well as technology solution providers, business consultants, academic institutions, and government organizations. SCC has chapters in Australia/New Zealand, Greater China, Europe, Japan, Latin America, Middle East, North America, Southern Africa, and South East Asia.

Supply Chain Council's website contains additional information on the SCOR model, SCC membership, and other resources.

www.supply-chain.org

Join Supply Chain Council

SCC's frameworks, network, benchmarking, research, and training help your management team analyze your supply chains faster, quickly recognize opportunities, implement changes, improve operational processes, track results, and sustain gains.

SCC is an active, peer-led research organization with a keen focus on continuous research and development. Membership participation on committees and working groups contributes to the development of new models, tools, and practices that are released to the membership.

Membership gives every supply chain professional within your organization access to the SCOR® model, the Customer Chain Operations Reference (CCOR℠) model for customer chain management, and the Design Chain Operations Reference (DCOR℠) model for design chain management.

We invite you to learn more and join us.

- supply-chain.org/join
- +1 202 962 0440

supply chain council

SCOR The Global Supply Chain Language

The Supply Chain Operations Reference (SCOR®) model provides a unique framework that links performance metrics, processes, best practices, and people into a unified structure. The framework supports communication between supply chain partners and enhances the effectiveness of supply chain management, technology, and related supply chain improvement activities.

Organizational benefits of adopting the SCOR model include:

- Rapid assessment of supply chain performance
- Clear identification of performance gaps
- Efficient supply chain network redesign and optimization
- Enhanced operational control from standard core processes
- Streamlined management reporting and organizational structure
- Alignment of supply chain team skills with strategic objectives
- A detailed game plan for launching new businesses and products
- Systematic supply chain mergers that capture projected savings

scor®
Supply Chain Operations Reference Model

SCOR is a consensus model. It was developed and continues to evolve with the direct input of industry leaders who manage global supply chains and use it daily to analyze and improve the performance of their organizations. It features an intentionally broad scope and definitions that can be adapted to the specific supply chain requirements of any industry or application.

Executive Overview

How SCOR Delivers Value

As a business leader you are accountable to your customers, shareholders, and stakeholders. Business value, whether real or perceived, is derived from the predictability and sustainability of business outcomes. It lives, healthy or sick, in those gaps between expected vs. perceived vs. actual performance. Value is articulated by measuring what is being managed.

The SCOR model helps refine strategy, define structure (including human capital), manage processes, and measure performance. An organization's annual strategic priorities are manifest in SCOR's vertical process integration (management-led programs for doing the right things, as defined by the customer) and its horizontal process integration (leadership-led programs for doing the right things well, as defined by capabilities).

Organizations that have applied SCOR to help with supply chain problem solving, process improvement, process redesign, or business process engineering, have demonstrated that SCOR is an effective enabler for aligning an organization's portfolio of improvement projects with strategic goals and objectives.

SCOR Helps Solve the Top 5 Supply Chain Challenges

Economic cycles, whether markets are growing or contracting, always force organizations to take an intense look at their supply chains, question their assumptions, root out inefficiencies, and plan for growth. Such analysis and restructuring are an ongoing requirement for effective supply chain management. Here is a brief summary of how SCOR aids this work and helps solve five of the never-ending supply chain management challenges.

1 Superior Customer Service

Effective supply chain management is all about delivering the right product in the right quantity and in the right condition with the right documentation to the right place at the right time at the right price. If only it were as simple as it sounds.

The SCOR model provides a framework for measuring and understanding current supply chain conditions and performance and creates a foundation for improvement. It can help supply chain managers evaluate cost/performance tradeoffs, develop strategies for meeting new customer expectations, and respond to domestic and global market growth.

2 Cost Control

Supply chain operating costs are under pressure from rising freight prices, global customers, technology upgrades, rising labor rates, expanding healthcare costs, new regulatory demands, and rising commodity prices. To control such costs there are thousands of potential metrics that supply chain organizations can and do measure. Managers need to zero in on the critical few that drive total supply chain costs within their organizations.

SCOR metrics provide the basis for an organization to measure how successful it is in achieving its desired objectives. SCOR metrics are designed to be used in conjunction with supply chain performance attributes, making it easier to compare different supply chains and different supply chain strategies.

3 Planning And Risk Management

Supply chains must periodically be assessed and redesigned in response to market changes, including new product launches, global sourcing, new acquisitions, credit availability, the need to protect intellectual property, and the ability to maintain asset and shipment security. In addition, supply chain risks must be identified and quantified.

Organizations in all sectors—commercial, military, and NGOs—have found that using SCOR as a planning and risk management foundation leads to faster implementation, more comprehensive identification of potential risks, and easier coordination with customers, suppliers, and other stakeholders. SCOR helps users establish rules and strategies, assign responsibilities, coordinate responses, and monitor current conditions.

4 Supplier/Partner Relationship Management

Different organizations, even different departments within the same organization, can have different methods for measuring and communicating performance expectations and results. Trust begins when managers let go of internal biases and make a conscious choice to follow mutually agreed upon standards in order to better understand current performance and opportunities for improvement.

SCOR provides a common language for supply chain classification and analysis. Using a common language and framework makes it easier for teams to communicate, speeds benchmarking efforts, and enhances the evaluation of best practices.

5 Talent

As experienced supply chain managers retire—and organizations scale up to meet growing demand in developing markets—talent acquisition, training, and development are becoming increasingly important. Supply chain leaders need a thorough understanding of the key competencies required for supply chain management roles, specific job qualifications, methods for developing future talent and leaders, and the ability to efficiently source specific skills.

Some SCC members have organized the capabilities of their global supply chain organizations around the SCOR framework. The SCOR skills management framework complements process reference, metrics reference, and practice reference components with baseline skills, experience, aptitudes, and training.

Achieving: Supply Chain Superiority

SCOR is about much more than individual improvement projects. The ultimate objective of any organization that deploys the SCOR model is to build a superior supply chain that is integrated with the overall organizational strategy. Aided by common supply chain definitions, metrics, and strategies, the integrated supply chain extends between and beyond the walls of the organization that owns the customer order.

You know that you can't manage what you can't measure. Well, it's also impossible to make effective decisions if every department in your organization measures performance differently. Organizations that are not integrated—where planning, sourcing, manufacturing, and logistics all have their own agendas and their own performance metrics that do not align with overall business goals—cannot respond effectively to market changes and opportunities. An integrated operating model does not happen spontaneously. The natural tendency is toward expediency and whatever set of metrics makes each department or functional area look best.

SCC research has found a high correlation between organizations that implement an integrated, end-to-end supply chain operating model enabled by the SCOR model and market outperformance in key financial measures. These include profit margins, inventory turns, asset turnover, and working capital. In addition, such organizations benefit from a much lower risk of supply chain disruption.

How SCOR Works: It's All About Relationships

The SCOR model provides a framework that links business processes, metrics, best practices, and technology into a unified structure. It is hierarchical in nature, interactive, and interlinked. The SCOR model supports supply chain improvement by aiding the capture of an "as-is" current state from which the desired "to-be" future state can be derived.

By speeding data collection, SCOR can make it much less time consuming for managers to find answers to basic questions about how a supply chain is performing, drill down to identify contributing factors, and quickly initiate corrective actions. SCOR facilitates supply chain integration by providing common process and metric definitions applicable across multiple organizations. For each process it includes parent and/or child processes, performance metrics, best practices, and the skills required for the employees performing the process.

For example, consider Perfect Order Fulfillment. This metric provides a good indication of how well every facet of a supply chain—planning, sourcing, manufacturing, and delivery—are tuned and coordinated to meet customer demand. Achieving Perfect Order Fulfillment of 100% is difficult, if not impossible, and may be prohibitively expensive because it has so many contributing factors. These include: on time to customer request, complete order shipment, undamaged, and the correct paperwork.

The SCOR model contains the Perfect Order Fulfillment metric definition, calculation methods, and discussion points. The SCOR model lists the processes that influence the performance of the level 1 metric and the associated level 2 metrics to analyze in order to identify the root causes of any issue. By examining level 2 metrics, managers can then determine the level 3 processes and metrics to investigate.

The SCOR Structure

The Boundaries of Any Model Must be Well Defined

SCOR processes extend from your supplier's supplier to your customer's customer. This includes all customer interactions from order entry through paid invoice; all product (physical material and service) transactions, including equipment, supplies, spare parts, software, etc.; and all market interactions, from understanding aggregate demand to the fulfillment of each order.

SCOR does not describe every business process or activity. It does not address sales and marketing, research and technology development, or product development. SCOR assumes but does not specifically address quality, information technology, or administration.

What is a Process Reference Model?

The purpose of a process reference model, or business process framework, is the ability to describe your process architecture in a way that makes sense to key business partners. It is especially useful for describing value chains that cut across multiple departments and organizations, providing a common language for managing such processes.

A process reference model can be a powerful management tool. Once a complex management process is captured in standard process reference model form, it can be measured, managed, and controlled. It can also be tuned and re-tuned to achieve a specific purpose or attain a competitive advantage.

The SCOR process reference model contains:

- **Performance Metrics:** Standard metrics to measure process performance
- **Processes:** Standard descriptions of management processes and a framework of process relationships
- **Practices:** Management practices that produce best-in-class performance
- **People:** Training and skills requirements aligned with processes, best practices, and metrics

SCOR Performance

The performance section of SCOR consists of two types of elements: Performance Attributes and Metrics. SCOR Level 1 metrics are strategic, high-level measures that cross multiple SCOR processes. Lower level metrics are associated with a narrower subset of processes. For example, delivery performance is calculated as the total number of products delivered on time and in full based on a commit date.

Performance Attributes

A performance attribute is a group of metrics used to express a strategy. An attribute itself cannot be measured; it is used to set strategic direction. For example, "The LX product needs to be best-in-class for reliability," and "The XY market requires us to be among the top five most agile manufacturers." Metrics measure the ability of a supply chain to achieve these strategic attributes.

SCOR identifies five core supply chain performance attributes: Reliability, Responsiveness, Agility, Costs, and Asset Management. Consideration of these attributes makes it possible to compare an organization that strategically chooses to be the low-cost provider against an organization that chooses to compete on reliability and performance.

Reliability	The Reliability attribute addresses the ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process. Typical metrics for the reliability attribute include: on-time, the right quantity, the right quality. The SCOR KPI (level 1 metric) is Perfect Order Fulfillment. Reliability is a customer-focused attribute.
Responsiveness	The Responsiveness attribute describes the speed at which tasks are performed. Examples include cycle-time metrics. The SCOR KPI is Order Fulfillment Cycle Time. Responsiveness is a customer-focused attribute.
Agility	The Agility attribute describes the ability to respond to external influences and the ability to change. External influences include: Non-forecasted increases or decreases in demand; suppliers or partners going out of business; natural disasters; acts of (cyber) terrorism; availability of financial tools (the economy); or labor issues. The SCOR KPIs include Flexibility and Adaptability. Agility is a customer-focused attribute.
Costs	The Cost attribute describes the cost of operating the process. It includes labor costs, material costs, and transportation costs. The SCOR KPIs include Cost of Goods Sold and Supply Chain Management Cost. These two indicators cover all supply chain spend. Cost is an internally-focused attribute.
Assets	The Asset Management Efficiency ("Assets") attribute describes the ability to efficiently utilize assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs. outsourcing. Metrics include: inventory days of supply and capacity utilization. The SCOR KPIs include: Cash-to-Cash Cycle Time and Return on Fixed Assets. Asset Management Efficiency is an internally-focused attribute.

Metrics

A metric is a standard for measurement of the performance of a process. SCOR metrics are diagnostic metrics. SCOR recognizes three levels of predefined metrics:

- **Level 1 metrics** are diagnostics for the overall health of the supply chain. These metrics are also known as strategic metrics and key performance indicators (KPIs). Benchmarking level 1 metrics helps establish realistic targets that support strategic objectives.
- **Level 2 metrics** serve as diagnostics for the level 1 metrics. The diagnostic relationship helps to identify the root cause or causes of a performance gap for a level 1 metric.
- **Level 3 metrics** serve as diagnostics for level 2 metrics.

The analysis of performance of metrics from level 1 through 3 is referred to as decomposition. Decomposition helps identify the processes that need to be studied further. (Processes are linked to level 1 and level 2 metrics.)

Many metrics in the SCOR model are hierarchical, just as the process elements are hierarchical. Level 1 metrics are created from lower level calculations. Level 2 metrics are generally associated with a narrower subset of processes. For example, Delivery Performance is calculated as the total number of products delivered on time and in full based on a commit date. Additionally, metrics (diagnostics) are used to diagnose variations in performance against plan. For example, an organization may wish to examine the correlation between the request date and commit date.

Supply Chain Council recommends that supply chain scorecards contain at least one metric for each performance attribute to ensure balanced decision making and governance.

Benchmarking: Get More Out of SCOR

SCORmark℠ benchmarking supports and integrates seamlessly into the analyze phase of applying the SCOR model. It provides a benchmark report that highlights where an organization stands against selected peer groups. Our members use SCORmark to set reasonable performance goals, calculate performance gaps against a global database, and develop organization-specific roadmaps for supply chain competitive success.

Visit supply-chain.org/scormark to learn more.

SCOR Metrics

Supply Chain Reliability

RL.1.1 - Perfect Order Fulfillment

RL.2.1 - % of Orders Delivered In Full

RL.3.33 - Delivery Item Accuracy

RL.3.35 - Delivery Quantity Accuracy

RL.2.2 - Delivery Performance to Customer Commit Date

RL.3.32 - Customer Commit Date Achievement Time Customer Receiving

RL.3.34 - Delivery Location Accuracy

RL.2.3 - Documentation Accuracy

RL.3.31 - Compliance Documentation Accuracy

RL.3.43 - Other Required Documentation Accuracy

RL.3.45 - Payment Documentation Accuracy

RL.3.50 - Shipping Documentation Accuracy

RL.2.4 - Perfect Condition

RL.3.12 - % Of Faultless Installations

RL.3.24 - % Orders/Lines Received Damage Free

RL.3.41 - Orders Delivered Damage Free Conformance

RL.3.42 - Orders Delivered Defect Free Conformance

RL.3.55 - Warranty and Returns

Supply Chain Responsiveness

RS.1.1 - Order Fulfillment Cycle Time

RS.2.1 - Source Cycle Time

RS.3.8 - Authorize Supplier Payment Cycle Time

RS.3.35 - Identify Sources of Supply Cycle Time

RS.3.107 - Receive Product Cycle Time

RS.3.122 - Schedule Product Deliveries Cycle Time

RS.3.125 - Select Supplier and Negotiate Cycle Time

RS.3.139 - Transfer Product Cycle Time

RS.3.140 - Verify Product Cycle Time

RS.2.2 - Make Cycle Time

RS.3.33 - Finalize Production Engineering Cycle Time

RS.3.49 - Issue Material Cycle Time

RS.3.101 - Produce and Test Cycle Time

RS.3.114 - Release Finished Product to Deliver Cycle Time

RS.3.123 - Schedule Production Activities Cycle Time

RS.3.128 - Stage Finished Product Cycle Time

RS.3.142 - Package Cycle Time

RS.2.3 - Deliver Cycle Time

RS.3.16 - Build Loads Cycle Time

RS.3.18 - Consolidate Orders Cycle Time

RS.3.46 - Install Product Cycle Time

RS.3.51 - Load Product & Generate Shipping Documentation Cycle Time

RS.3.95 - Pack Product Cycle Time

RS.3.96 - Pick Product Cycle Time

RS.3.102 - Receive & Verify Product by Customer Cycle Time

RS.3.110 - Receive Product from Source or Make Cycle Time

RS.3.111 - Receive, Configure, Enter, & Validate Order Cycle Time

RS.3.116 - Reserve Resources and Determine Delivery Date Cycle Time

RS.3.117 - Route Shipments Cycle Time

RS.3.120 - Schedule Installation Cycle Time

RS.3.124 - Select Carriers & Rate Shipments Cycle Time

RS.3.126 - Ship Product Cycle Time

RS.2.4 - Delivery Retail Cycle Time

RS.3.17 - Checkout Cycle Time

RS.3.32 - Fill Shopping Cart Cycle Time

RS.3.34 - Generate Stocking Schedule Cycle Time

RS.3.97 - Pick Product from Backroom Cycle Time

RS.3.109 - Receive Product at Store Cycle Time

RS.3.129 - Stock Shelf Cycle Time

Supply Chain Agility

AG.1.1 - Upside Supply Chain Flexibility

AG.2.1 - Upside Flexibility (Source)

AG.2.2 - Upside Flexibility (Make)

AG.2.3 - Upside Flexibility (Deliver)

AG.2.4 - Upside Return Flexibility (Source)

AG.2.5 - Upside Return Flexibility (Deliver)

AG.1.2 - Upside Supply Chain Adaptability

AG.2.6 - Upside Adaptability (Source)

AG.2.7 - Upside Adaptability (Make)

AG.2.8 - Upside Adaptability (Deliver)

AG.2.9 - Upside Return Adaptability (Source)

AG.2.10 - Upside Return Adaptability (Deliver)

AG.1.3 - Downside Supply Chain Adaptability

AG.2.11 - Downside Adaptability (Source)

AG.2.12 - Downside Adaptability (Make)

AG.2.13 - Downside Adaptability (Deliver)

AG.1.4 - Overall Value at Risk (VAR)

AG.2.14 - Supplier's/Customer's/ Product's Risk Rating

AG.2.15 - Value at Risk (Plan)

AG.2.16 - Value at Risk (Source)

AG.2.17 - Value at Risk (Make)

AG.2.18 - Value at Risk (Deliver)

AG.2.19 - Value at Risk (Return)

Supply Chain Costs

CO.1.1 - Supply Chain Management Cost

CO.2.1 - Cost to Plan

- CO.3.104 - Cost to Plan (Deliver)
- CO.3.105 - Cost to Plan (Make)
- CO.3.106 - Cost to Plan (Return)
- CO.3.107 - Cost to Plan (Source)
- CO.3.108 - Cost to Plan Supply Chain

CO.2.2 - Cost to Source

- CO.3.27 - Cost to Authorize Supplier Payment
- CO.3.115 - Cost to Receive Product
- CO.3.126 - Cost to Schedule Product Deliveries
- CO.3.137 - Cost to Transfer Product
- CO.3.138 - Cost to Verify Product

CO.2.3 - Cost to Make

CO.2.4 - Cost to Deliver

- CO.3.163 - Order Management Costs
- CO.3.200 - Order Delivery Costs

CO.2.5 - Cost to Return

- CO.3.131 - Cost to Source Return

CO.2.7 - Mitigation Cost ($)

- CO.3.178 - Risk Mitigation Costs (Deliver)
- CO.3.179 - Risk Mitigation Costs (Make)
- CO.3.180 - Risk Mitigation Costs (Plan)
- CO.3.181 - Risk Mitigation Costs (Return)
- CO.3.182 - Risk Mitigation Costs (Source)

CO.1.2 - Cost of Goods Sold

CO.3.140 - Direct Labor Cost

CO.3.141 - Direct Material Cost

CO.3.155 - Indirect Cost Related to Production

Supply Chain Asset Management

AM.1.1 - Cash-to-Cash Cycle Time

AM.2.1 - Days Sales Outstanding

AM.2.2 - Inventory Days of Supply

- AM.3.45 - Inventory Days of Supply (Finished Goods)
- AM.3.16 - Inventory Days of Supply (Raw Material)
- AM.3.17 - Inventory Days of Supply (WIP)
- AM.3.23 - Recycle Days of Supply
- AM.3.28 - Percentage Defective Inventory
- AM.3.37 - Percentage Excess Inventory
- AM.3.44 - Percentage Unserviceable MRO Inventory

AM.2.3 - Days Payable Outstanding

AM.1.2 - Return on Supply Chain Fixed Assets

AM.2.5 - Supply Chain Fixed Assets

- AM.3.11 - Fixed Asset Value (Deliver)
- AM.3.18 - Fixed Asset Value (Make)
- AM.3.20 - Fixed Asset Value (Plan)
- AM.3.24 - Fixed Asset Value (Return)
- AM.3.27 - Fixed Asset Value (Source)

AM.1.3 - Return on Working Capital

AM.2.6 - Accounts Payable (Payables Outstanding)

AM.2.7 - Accounts Receivable (Sales Outstanding)

AM.2.8 - Inventory

SCOR Processes

SCOR identifies the unique processes a supply chain requires to support the objective of fulfilling customer orders. By definition, a process is a unique activity performed to meet predefined outcomes.

Similar to nesting Russian matryoshka dolls, SCOR processes are organized by aggregation and decomposition relationships. From level 3 to 2 to 1 is aggregation; from 1 to 2 to 3 is decomposition. SCOR processes help standardize the description of the supply chain architecture (level 1 and level 2 processes) and the implementation of the architecture (level 3 processes). SCOR provides standards down to the level where process descriptions are applicable across a range of industries. Further detail is industry and organization specific (level 4 and below).

SCOR Contains Three Levels of Process Detail

	Level	Application	Examples
In Scope Applicable Across Industries	1	Level 1 processes are used to describe the scope and high level configuration of a supply chain. SCOR has five level 1 processes.	Plan, Source, Make, Deliver, and Return
	2	Level 2 processes differentiate the strategies of the level 1 processes. Both the level 2 processes themselves as well as their positioning in the supply chain determine the supply chain strategy. SCOR contains 26 level 2 processes.	Example Make level 2 processes: › Make-to-Stock › Make-to-Order › Engineer-to-Order
	3	Level 3 processes describe the steps performed to execute the level 2 processes. The sequence in which these processes are executed influences the performance of the level 2 processes and the overall supply chain. SCOR contains 185 level 3 processes.	Example Make-to-Order level 3 processes: › Schedule Production Activities › Issue Product › Produce and Test › Package › Stage › Dispose Waste › Release Product
Not in Scope Industry Specific	4	Level 4 processes describe the industry specific activities required to perform level 3 processes. Level 4 processes describe the detailed implementation of a process. SCOR does not detail level 4 processes. Organizations and industries develop their own level 4 processes.	Example Issue Product level 4 processes for the electronics industry: › Print Pick List › Pick Items (Bin) › Deliver Bin to Production Cell › Return Empty Bins to Pick Area › Close Pick Order

SCOR Is Based on Five Level 1 Management Processes

Plan (P)

The Plan processes describe the planning activities associated with operating a supply chain. This includes gathering customer requirements, collecting information on available resources, and balancing requirements and resources to determine planned capabilities and resource gaps. This is followed by identifying the actions required to correct any gaps.

Source (S)

The Source processes describe the ordering (or scheduling) and receipt of goods and services. The Source process includes issuing purchase orders, scheduling deliveries, receiving, shipment validation and storage, and accepting supplier invoices.

Make (M)

The Make processes describe the activities associated with the conversion of materials or creation of the content for services. It focuses on conversion of materials rather than production or manufacturing because Make represents all types of material conversions: assembly, chemical processing, maintenance, repair, overhaul, recycling, refurbishment, remanufacturing, and other material conversion processes. As a general guideline: these processes are recognized by the fact that one or more item numbers go in, and one or more different item numbers come out of this process.

Deliver (D)

The Deliver processes describe the activities associated with the creation, maintenance, and fulfillment of customer orders. It includes the receipt, validation, and creation of customer orders; scheduling order delivery; pick, pack, and shipment; and invoicing the customer.

Return (R)

The Return processes describe the activities associated with the reverse flow of goods back from the customer. The Return process includes the identification of the need for a return, the disposition decision making, the scheduling of the return, and the shipment and receipt of the returned goods. (Repair, recycling, refurbishment, and remanufacturing processes are not described using Return process elements. See Make.)

SCOR Processes

Each Level 2 Process Can Be Further Described by Type

Planning	A process that aligns expected resources to meet expected demand requirements.
	Planning processes: › Balance aggregated demand and supply › Generally occur at regular, periodic intervals › Consider consistent planning horizon › Can contribute to supply chain response time
Execution	A process triggered by planned or actual demand that changes the state of material goods.
	Execution processes: › Generally involve: 1. Scheduling/sequencing, 2. Transforming product, and/or 3. Moving product to the next process. › Can contribute to the order fulfillment cycle time
Enable	A process that prepares, maintains, or manages information or relationships on which planning and execution processes rely.

Each Execution process, for example, has three different possible capabilities of representing and responding to customer orders. Different supply chain strategy supports corresponding product or service types. These categories also affect Plan and Return processes.

Stocked Product (S1, M1, D1, D4)

- Inventory driven (Plan)
- Standard material orders
- High fill rate, short turnaround

Make-to-Order (S2, M2, D2)

- Customer order driven
- Configurable materials
- Longer turn-around times

Engineer-to-Order (S3, M3, D3)

- Customer requirements driven
- Sourcing new materials
- Longest long lead-times, low fill rates

SCOR Process Detailed Example

sD1.2 Receive, Enter, and Validate Order

Definition: Receive orders from the customer and enter them into a an organization's order processing system. Orders can be received through phone, fax, or electronic media. Technically examine orders to ensure an orderable configuration and provide accurate prices. Check the customer's credit. Optionally accept payment.

SCOR is available online in a searchable HTML format for all SCC member organizations. Visit supply-chain.org/online-access to access in HTML, download a PDF format, or order a print edition.

SCOR Online Access Screenshot

Metrics

ID	Name	Definition	Revision
RL.3.33	Delivery Item Accuracy	Percentage of orders in which all items ordered are the items...	10.0
RL.3.34	Delivery Location Accuracy	Percentage of orders which is delivered to the correct location...	10.0
RL.3.35	Delivery Quantity Accuracy	Percentage of orders in which all quantities received by the...	10.0
RS.3.94	Order Fulfillment Dwell Time	Any lead time during the order fulfillment process where no...	10.0
RS.3.112	Receive, Enter & Validate Order Cycle Time	The average time associated with receiving and verifying an...	10.0
CO.3.118	Cost to Receive, Enter & Validate Order	The sum of the costs associated with receiving, entering and...	10.0

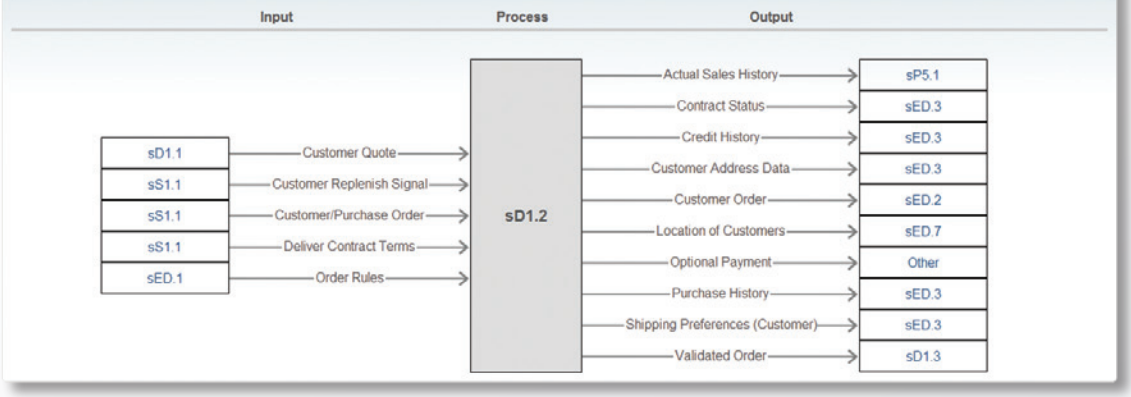
Practices

ID	Name	Definition	Revision
	Automatic Multi-level Credit Checking: Dollar Limits; Days Sales Outstanding; Margin Testing	Integrated Order/Financial Management	10.0
	Continuous Replenishment Programs; Vendor Managed Inventory, Telemetry to Automatically Communicate Replenishment of Chemicals	Integrated demand/deployment planning to customer location...	10.0
	Electronic Commerce (Customer Visibility of Stock Availability, Use of Hand-Held Terminals for Direct Order Entry, Confirmation, Credit Approval), On-Line Stock Check and Reservation of Inventory	EDI applications and integrated order management	10.0
	Enable Real-Time Visibility into Backlog, Order Status, Shipments, Scheduled Material Receipts, Customer Credit History, and Current Inventory Positions	None identified	10.0
	Remote (Sales, Customers) Order Entry Capability	None identified	10.0
	Value Pricing Based on 'Cost to Serve'; EDLP; Cost Plus Pricing	Activity Based Costing; Integrated Order Management by Customer...	10.0

People

ID	Name	Definition	Revision
HS.0026	Credit/Collection Management	Set of activities to assess and rate the credit risk of a...	10.0
HS.0028	Customer Order Management	The process or the work flow associated with the identification...	10.0
HS.0029	Customer Relationship Management (CRM)	The process for managing a company's relations and interactions...	10.0
HS.0064	Lead-time validation	The process of analyzing and validating feasibility of customer...	10.0
HS.0092	Pricing Management	The analysis and setting of prices (on a per unit or volume...	10.0
HS.0095	Product and Configuration Validation	The analysis of stated product and configuration specifications...	10.0

Workflow



SCOR Process Model

sP PLAN

sP1 Plan Supply Chain

sP1.1: Identify, Prioritize, and Aggregate Supply Chain Requirements

sP1.2: Identify, Prioritize, and Aggregate Supply Chain Resources

sP1.3: Balance Supply Chain Resources with Supply Chain Require-ments

sP1.4: Establish and Communicate Supply Chain Plans

sP2 Plan Source

sP2.1: Identify, Prioritize, and Aggregate Product Requirements

sP2.2: Identify, Assess, and Aggregate Product Resources

sP2.3: Balance Product Resources with Product Requirements

sP2.4: Establish Sourcing Plans

sP3 Plan Make

sP3.1: Identify, Prioritize, and Aggregate Production Requirements

sP3.2: Identify, Assess, and Aggregate Production Resources

sP3.3: Balance Production Resources with Production Requirements

sP3.4: Establish Production Plans

sP4 Plan Deliver

sP4.1: Identify, Prioritize, and Aggregate Delivery Requirements

sP4.2: Identify, Assess, and Aggregate Delivery Resources

sP4.3: Balance Delivery Resources with Delivery Requirements

sP4.4: Establish Delivery Plans

sP5 Plan Return

sP5.1: Identify, Prioritize, and Aggregate Return Requirements

sP5.2: Identify, Assess, and Aggregate Return Resources

sP5.3: Balance Return Resources with Return Requirements

sP5.4: Establish and Communicate Return Plans

sS SOURCE

sS1 Source Stocked Product

sS1.1: Schedule Product Deliveries

sS1.2: Receive Product

sS1.3: Verify Product

sS1.4: Transfer Product

sS1.5: Authorize Supplier Payment

sS2 Source Make-to-Order Product

sS2.1: Schedule Product Deliveries

sS2.2: Receive Product

sS2.3: Verify Product

sS2.4: Transfer Product

sS2.5: Authorize Supplier Payment

sS3 Source Engineer-to-Order Product

sS3.1: Identify Sources of Supply

sS3.2: Select Final Supplier(s) and Negotiate

sS3.3: Schedule Product Deliveries

sS3.4: Receive Product

sS3.5: Verify Product

sS3.6: Transfer Product

sS3.7: Authorize Supplier Payment

sEP Enable Plan

sEP.1: Manage Business Rules for Plan Processes

sEP.2: Manage Performance of Supply Chain

sEP.3: Manage Plan Data Collection

sEP.4: Manage Integrated Supply Chain Inventory

sEP.5: Manage Integrated Supply Chain Capital Assets

sEP.6: Manage Integrated Supply Chain Transportation

sEP.7: Manage Planning Configuration

sEP.8: Manage Plan Regulatory Requirements and Compliance

sEP.9: Manage Supply Chain Risk

sEP.10: Align Supply Chain Unit Plan with Financial Plan

sES Enable Source

sES.1: Manage Sourcing Business Rules

sES.2: Assess Supplier Performance

sES.3: Maintain Source Data

sES.4: Manage Product Inventory

sES.5: Manage Capital Assets

sES.6: Manage Incoming Product

sES.7: Manage Supplier Network

sES.8: Manage Import/Export Requirements

sES.9: Manage Supply Chain Source Risk

sES.10: Manage Supplier Agreements

sM MAKE

sM1 Make-to-Stock

sM1.1: Schedule Production Activities

sM1.2: Issue Product

sM1.3: Produce and Test

sM1.4: Package

sM1.5: Stage Product

sM1.6: Release Product to Deliver

sM1.7: Waste Disposal

sM2 Make-to-Order

sM2.1: Schedule Production Activities

sM2.2: Issue Product

sM2.3: Produce and Test

sM2.4: Package

sM2.5: Stage Finished Product

sM2.6: Release Finished Product to Deliver

sM2.7: Waste Disposal

sM3 Engineer-to-Order

sM3.1: Finalize Production Engineering

sM3.2: Schedule Production Activities

sM3.3: Issue Product

sM3.4: Produce and Test

sM3.5: Package

sM3.6: Stage Finished Product

sM3.7: Release Product to Deliver

sM3.8: Waste Disposal

sD DELIVER

sD1 Deliver Stocked Product

sD1.1: Process Inquiry and Quote

sD1.2: Receive, Enter, and Validate Order

sD1.3: Reserve Inventory and Determine Delivery Date

sD1.4: Consolidate Orders

sD1.5: Build Loads

sD1.6: Route Shipments

sD1.7: Select Carriers and Rate Shipments

sD1.8: Receive Product from Source or Make

sD1.9: Pick Product

sD1.10: Pack Product

sD1.11: Load Vehicle and Generate Shipping Docs

sD1.12: Ship Product

sD1.13: Receive and Verify Product by Customer

sD1.14: Install Product

sD1.15: Invoice

sD2 Deliver Make-to-Order Product

sD2.1: Process Inquiry and Quote

sD2.2: Receive, Configure, Enter, and Validate Order

sD2.3: Reserve Inventory and Determine Delivery Date

sD2.4: Consolidate Orders

sD2.5: Build Loads

sD2.6: Route Shipments

sD2.7: Select Carriers and Rate Shipments

sD2.8: Receive Product from Source or Make

sD2.9: Pick Product

sD2.10: Pack Product

sD2.11: Load Product and Generate Shipping Docs

sD2.12: Ship Product

sD2.13: Receive and Verify Product by Customer

sD2.14: Install Product

sD2.15: Invoice

sD3 Deliver Engineer-to-Order Product

sD3.1: Obtain and Respond to RFP/RFQ

sD3.2: Negotiate and Receive Contract

sD3.3: Enter Order, Commit Resources, and Launch Program

sD3.4: Schedule Installation

sD3.5: Build Loads

sD3.6: Route Shipments

sD3.7: Select Carriers and Rate Shipments

sD3.8: Receive Product from Source or Make

sD3.9: Pick Product

sD3.10: Pack Product

sD3.11: Load Product and Generate Shipping Docs

sD3.12: Ship Product

sD3.13: Receive and Verify Product by Customer

sD3.14: Install Product

sD3.15: Invoice

sD4 Deliver Retail Product

sD4.1: Generate Stocking Schedule

sD4.2: Receive Product at the Store

sD4.3: Pick Product from Backroom

sD4.4: Stock Shelf

sD4.5: Fill Shopping Cart

sD4.6: Checkout

sD4.7: Deliver and/or Install

sR RETURN

sSR1 Source Return Defective Product

sSR1.1: Identify Defective Product Condition

sSR1.2: Disposition Defective Product

sSR1.3: Request Defective Product Return Authorization

sSR1.4: Schedule Defective Product Shipment

sSR1.5: Return Defective Product

sSR2 Source Return MRO Product

sSR2.1: Identify MRO Product Condition

sSR2.2: Disposition MRO Product

sSR2.3: Request MRO Return Authorization

sSR2.4: Schedule MRO Shipment

sSR2.5: Return MRO Product

sSR3 Source Return Excess Product

sSR3.1: Identify Excess Product Condition

sSR3.2: Disposition Excess Product

sSR3.3: Request Excess Product Return Authorization

sSR3.4: Schedule Excess Product Shipment

sSR3.5: Return Excess Product

sDR1 Deliver Return Defective Product

sDR1.1: Authorize Defective Product Return

sDR1.2: Schedule Defective Return Receipt

sDR1.3: Receive Defective Product (Includes Verify)

sDR1.4: Transfer Defective Product

sDR2 Deliver Return MRO Product

sDR2.1: Authorize MRO Product Return

sDR2.2: Schedule MRO Return Receipt

sDR2.3: Receive MRO Product

sDR2.4: Transfer MRO Product

sDR3 Deliver Return Excess Product

sDR3.1: Authorize Excess Product Return

sDR3.2: Schedule Excess Return Receipt

sDR3.3: Receive Excess Product

sDR3.4: Transfer Excess Product

sEM Enable Make

sEM.1: Manage Production Rules

sEM.2: Manage Production Performance

sEM.3: Manage Make Information

sEM.4: Manage In-Process Products (WIP)

sEM.5: Manage Make Equipment and Facilities

sEM.6: Manage Transportation (WIP)

sEM.7: Manage Production Network

sEM.8: Manage Make Regulatory Environment

sEM.9: Manage Supply Chain Make Risk

sED Enable Deliver

sED.1: Manage Deliver Business Rules

sED.2: Assess Delivery Performance

sED.3: Manage Deliver Information

sED.4: Manage Finished Goods Inventory

sED.5: Manage Deliver Capital Assets

sED.6: Manage Transportation

sED.7: Manage Product Life Cycle

sED.8: Manage Import/Export Requirements

sED.9: Manage Supply Chain Deliver Risk

sER Enable Return

sER.1: Manage Business Rules for Return Processes

sER.2: Manage Performance of Return Processes

sER.3: Manage Return Data Collection

sER.4: Manage Return Inventory

sER.5: Manage Return Capital Assets

sER.6: Manage Return Transportation

sER.7: Manage Return Network Configuration

sER.8: Manage Return Regulatory Requirements and Compliance

sER.9: Manage Supply Chain Return Risk

SCOR Best Practices

A best practice is a unique way to configure a process or a set of processes. The uniqueness can be related to the automation of the process, a technology applied in the process, special skills applied to the process, a unique sequence for performing the process, or a unique method for distributing and connecting processes between organizations.

SCOR recognizes that several different types of practices exist within any organization:

- Leading or Emerging practices
- Best practices
- Common practices
- Poor practices

These practice categories go by other names as well. What's important to understand is that different practices have different performance expectations. The classification of a practice will vary by industry. For some industries a practice may be common, whereas the same practice may be considered a leading or best practice in another industry.

The SCOR Best Practices section contains management practices, software solutions, and definitions associated with each process. These practices can contribute to best-in-class performance in supply chain optimization (SCOR), supply chain risk management, and environmentally responsible supply chain management (GreenSCOR). SCOR best practices were selected by SCOR practitioners from a diverse range of industries. It is understood that not all best practices will yield the same results for all industries or supply chains.

Supply Chain Practice Categories

MODERATE / HIGH RETURNS	**Best Practices** Best practices are current, structured, and repeatable practices that have had a proven and positive impact on supply chain performance. › **Current:** Not emerging, not outmoded. › **Structured:** Feature a clearly stated goal, scope, process, and procedure. › **Proven:** Demonstrated in a working environment, and linked to key metrics. › **Repeatable:** Proven in multiple organizations and industries.	**Leading Practices** Leading practices introduce new technology, knowledge, or radically different ways of organizing processes. Leading practices may yield a steep change in performance by redefining the playing field within an industry. Leading practices may not be easy to adopt because of proprietary technology, or special knowledge may prevent wider adoption. Leading practices generally have not been proven in a wide variety of environments and industries.
NEGATIVE / LOW RETURNS	**Common Practices** Common practices are how a wide range of organizations have historically done business by default or happenstance. These well established practices do the job, but don't provide a significant cost or competitive advantage over other practices (except over bad practices).	**Poor Practices** Poor practices represent ways of doing business, which can be widespread, that have proven to result in poor supply chain performance as indicated by key metrics.
	‹ LOW / MODERATE RISK	HIGH RISK ›

SCOR Best Practices

Best Practice: Supply Chain Risk Management

Supply chain risk management is the systematic identification, assessment, and mitigation of potential disruptions in logistics networks with the objective to reduce their negative impact on the logistics network's performance. Potential disruptions can either occur within the supply chain (e.g. insufficient quality, unreliable suppliers, machine breakdown, uncertain demand, etc.) and outside the supply chain (e.g. flooding, terrorism, labor strikes, natural disasters, etc.). Both are considered in an integral multi-phase approach for supply chain risk management.

Establish Context	Define and document the objective and scope (internal and external) for managing risk.
Identify Risk	Collect and document all potential risk events that may impact the organization from meeting its goals.
Assess Risk	Collect and document for each potential risk the causes, probability, and consequences (Understand the Value at Risk).
Evaluate Risk	Determine for each risk whether mitigation actions are required or the risk is acceptable; prioritize risks.
Mitigate Risk	Determine the actions required to eliminate, reduce, or accept and monitor the risks (Risk Mitigation Plan).
Monitor Risk	Continuously monitor effectiveness of mitigation plans; identify emerging risks and changes in internal and external context.

Best Practice: GreenSCOR

The following strategic environmental metrics allow the SCOR model to be used as a framework for environmental accounting:

- Carbon Emissions (Tons CO2 Equivalent)
- Air Pollutant Emissions (Tons or kg)
- Liquid Waste Generated (Tons or kg)
- Solid Waste Generated (Tons or kg)
- Recycled Waste (Percent)

The SCOR framework ties emissions to the originating processes, providing a structure for measuring environmental performance and identifying where performance can be improved. The hierarchical nature of the model allows strategic environmental footprint goals to be translated to specific targets and activities.

SCOR People

Talented people are at the heart of supply chains that effectively respond to and capitalize on growth opportunities. The SCOR skills framework provides a global view of the needs and issues surrounding skills management for supply chain professionals, including the technical skills, aptitude, and experience required to manage an effective supply chain. This allows supply chain leaders to align the skills of their people and organizational structure with strategic objectives.

The skills management framework within SCOR complements process reference, metrics reference, and practice reference components with an integrated view of supply chain skills in four areas:

1. Baseline skills necessary for the overall process area (e.g., Sourcing or Planning) and for the individual process.
2. Critical skills that differentiate leaders in a particular process area from those who only perform at a baseline level.
3. Performance measures through SCOR metrics that relate to continuous assessment of job performance in each process area.
4. Credentialing of supply chain skills, including training or certification programs, related to the specific process areas.

Key Elements of SCOR People

Skill – A Skill is the capacity to deliver predetermined results with minimal input of time and energy. Skills are further defined by Experience, Aptitude, Training, and Competency levels. Examples of supply chain skills include: master scheduling, import/export regulations, production planning, and risk mitigation.

Experience – Experience is the knowledge or ability acquired by observation or active participation. Experience is obtained by doing the work in a real-life environment and responding to a variety of challenges that require different responses and actions. Example experiences include: cycle counting, cross docking, and hazardous materials handling.

Aptitudes – An Aptitude is a natural, acquired, learned, or developed ability to perform a certain kind of work at a certain level. Example aptitudes include: accuracy, analytical, and leadership.

Training – Training develops a skill or type of behavior through instruction. Examples of training are SCOR-P certification and APICS CPIM certification. This element also includes on-the-job training.

Competency – Competency levels describe the level or state of qualification to perform a certain role or tasks. SCOR recognizes five commonly accepted competency levels:

1. Novice – Untrained beginner, no experience, requires and follows detailed documentation to be able to perform the work.
2. Experienced beginner – Performs the work; limited situational perception.
3. Competent – Understands the work and can determine priorities to reach organizational goals.
4. Proficient – Oversees all aspects of the work and can prioritize based on situational aspects.
5. Expert – Intuitive understanding. Experts can apply experience patterns to new situations.

SCOR links each skill to Experiences, Aptitudes, and Trainings. Competency level is to Skill what Maturity level is to Process. SCOR does not list or suggest competency levels.

Use SCOR to Match Supply Chain Team Skills to Organization Strategy

The SCOR people elements help supply chain and human resource leaders find and develop people with the requisite technical expertise and experience. It improves the ability to match job responsibilities with candidates' skills and avoid costly hiring mistakes. It makes outsourcing or in-sourcing decisions more clear, and it can help preserve organizational effectiveness and knowledge as retirees leave the workforce.

SCC Members and SCOR Users

SCOR has provided value to a wide range of global, mid-sized, and small organizations across all industries. The following SCC members—representing commercial industry, nonprofit, academic, and government organizations—have applied the SCOR model within their supply chains or helped other organizations apply the model.*

A.T. Kearney, Inc
ABB
Abbott Japan Co., Ltd.
Accenture
ADVA AG Optical Networking
Air Products and Chemicals Inc.
Akzo Nobel
ALCON
Alfa Laval KK
APQC
Andersen Corporation
Aotearoa Fisheries Limited
Applied Materials, Inc.
Aspen Pharmacare Port Elizabeth
AstraZeneca
Avineo
Avnet, Inc.
Avon Products, Inc.
Axia Consulting
Axsens SAS
Babcock International Group
Baden-Württemberg Cooperative State University
BAE Systems
Baptist Health South Florida
Barloworld Logistics (Pty) Ltd
BASF AG
Battelle
Baxter Healthcare
Bayer Group
BearingPoint
Beiersdorf AG
Biotronik AG
Booz Allen Hamilton Inc.
Boston Consulting Group
BP
Bristlecone, Inc.
Bristol-Myers Squib
Bugaboo International
Bulgari SPA
Cabot Corporation
Cafina AG
Capgemini
CH Robinson Worldwide
Chubu Electric Power Co., Inc.
Chuden CTI Co., Ltd
Chugoku Electric Power Co., Inc.
Church of Jesus Christ of Latter-day Saints
Cielo S.A
Cincinnati State Technical and Community College
Cirrelt / Université Laval
Cisco Systems
Clemson University
Cliffstar Corporation
Coca-Cola FEMSA
Cognizant Technology Solutions
Cologne University of Applied Science
Columbia Sportswear
Competitive Capabilities International
Comprehensive Nuclear Test Ban Treaty Organization
Computer Sciences Corporation
Concurrent Technologies Corporation
Coors Brewery Limited
Corning Incorporated
Cranfield School of Management
Cummins Inc.
Danfoss Trata, d.o.o.
Darden Business School, University of Virginia
Delft University of Technology
Dell Inc.
Deloitte Consulting LLP
Deloitte Tohmatsu Consulting Co., Ltd
Denel (Pty) Limited
Department of Veterans Affairs
Douglas Pharmaceuticals
Dow Chemical Company
DSN Innovations
DuPont Company
Eaton Corporation
Embraer Empresa Brasileira de Aeronautica SA
Environmental Defense Fund
Ericsson AB
Federal University of Sao Carlos
Flanders Institute for Logistics
Fujifilm Corporation
Fujitsu Limited
Gartner
GlaxoSmithKline
Goizueta Business School, Emory University
Greif, Inc
Griffith Laboratories
Grupo Farmacos Especializados, S. A. de C. V.
Harley-Davidson Motor Company
Harvard Research Group
Heineken
Hewlett Packard Company
Hi Essence Cable Sdn Bhd
Hitachi East Japan Solutions, Ltd.
Hochschule Ulm
Hokkaido Electric Power Co., Ltd.
Holland International Distribution Council
Honda Trading America Corporation
HORUS Consulting bvba
Hospira, Inc.
Huawei Technologies Co., Ltd.
Huber & Suhner AG
Humana Milchindustrie GmbH
IBIS
IBM Corporation
ICIMSI, University of Applied Sciences of Southern Switerland
Infineon Technologies AG
Intec
Intel Corporation
Itheca Group
J&M Management Consulting AG
JDA Software
Jet Propulsion Laboratory
Johnson & Johnson
Kaiser Permanente
Kerry Group plc.
Kluber Lubrication Lubrificantes Especiais Ltda
Knorr Bremse
Kohler Co.
KONE Oyj
KPMG
Kraft Foods
KYOCERA Corporation
Kyushu Electric Power Co., Inc.
Leighs Paints
Lenovo, Inc.
Lifeway Christian Resources of the SBC
Limited Logistics Services, Inc.
Linear Logics Corp.
Locanis AG
Lockheed Martin
Logica
MAN Diesel SE
Manhattan Associates
Massachusetts Institute of Technology
McCormick & Company, Inc.
MeadWestvaco Corporation
Merck KGaA
Miami University
Michigan State University
Micron Technology, Inc.
Microsoft Corporation
Mitsubishi Aircraft Corporation
Mitsui & Co. Ltd.
National Institute of Development Administration
NEC Corporation
New South Wales Electoral Commission
New Zealand Defence Force
Newell Rubbermaid
Niram Gitan Group
Novaquest
NOVATECH
Nycomed GmbH
Olam Information Services Pvt. Ltd
Oliver Wight
Olympus Corporation
Omnia Group
Ontario Government
Oracle Corporation
Ossur Americas Inc.
Pakistan Institute of Management
Panasonic
Penn State University
Petrobras - Petroleo Brasileiro SA
Pfizer, Inc.
Pieralisi Maip spa
Plannja AB
Polymer Group Inc
PolyOne Corporation
Polytechnic of Namibia
Pontificia Universidad Javeriana
PRAGMATEK Consulting Group, Ltd.
PricewaterhouseCoopers
PricewaterhouseCoopers Consultants Co, Ltd.
Procter & Gamble
PRTM Management Consultants, Inc.
Pyramid Applied Solutions B.V.
QAD Inc.
QMI Solutions
QUNIE Corporation
R&G Global Consultants CE BV
Rail Cargo Austria AG
Rand Corporation
Realize Corporation
Redland City Council
Republic Polytechnic
Research in Motion
Revlon Consumer Products
Ritsumeikan University
Roche Diagnostics GmbH
Royal Dutch Shell
Royal Philips
Rutgers Business School
Saab AB
Sandvik AB
SAP AG
Sasol Limited
Saudi Goody Products Marketing Co. Ltd
Schenker International (H.K.) Ltd
Schick Manufacturing Inc.
Schlumberger
Shikoku Electric Power Co.,Inc
Shin Shin Co Ltd
Siemens AG
Sonoco Products Company
SRA International Inc
St Jude Medical Japan Co Ltd
Sterling Commerce
Sunergos LLC
Supply Risk.Org
Syracuse University
Systems Planning Institute
TechTeam Government Solutions
Telenet NV
Tempur - Pedic
Thales AES
The Asaba Group, Inc.
The Boeing Company
The Chartered Institute of Logistics and Transport
The Chinese University of Hong Kong
The Linde Group
The Norwegian Computer Society
The University of Alabama - Supply Chain Institute
The Walt Disney Company
ThyssenKrupp AG
Tieto Corporation
Tokyo Electric Power Company
Tokyo Gas Co., Ltd.
Tokyo Institute of Technology
Toshiba Corporation
Toyo Business Engineering Corp
Transitive Management SPRL
Transplace
Trex Company
TruEconomy Consulting Holding B.V.
Tsinghua University
Turku School of Economics
Ultriva Inc.
Unilever Plc
United Nations World Food Programme
United Space Alliance, LLC
United States Air Force
United States Coast Guard
United States Department of Defense
United States Marine Corps
Universidad de la Sabana
University of California at Irvine
University of Michigan
University of Puerto Rico
University of South Africa
University of the Witwatersrand
Upline Consultoria em Gestao Empresarial
Upsher-Smith Laboratories, Inc.
US Army Logistics University
UTI Worldwide
Vallourec & Mannesmann Tubes
Vietnam Supply Chain Community
Villeroy & Boch AG
Volvo AB
W.R. Grace & Co.
Wacker Chemie AG
WASEDA Univ. School of Science & Engineering
Watson Pharmaceuticals
Weleda AG
Wyeth Pharmaceuticals
Xelocity Ltd.
ZAO United Metallurgical Company

*This member list is not comprehensive. For the list of current SCC members go to: **supply-chain.org/membership/members**

Learn More

Trainings

SCC offers many supply chain management and SCOR education opportunities. Every year we host trainings in cities around the world that introduce and explain how to integrate SCOR into supply chain management programs. With a focus on execution, our training program explores the technical details, specific management roles, and tasks for applying SCOR within any enterprise.

For example, our SCOR Project training takes participants through the 20 to 25 discrete steps of a SCOR project. SCOR Benchmarking training breaks the benchmarking process into seven well-characterized and repeatable steps that flow from initial scoping (supply chain identification matrix) to strategy, SCORcards, and the benchmark itself.

SCOR trainings include:

- SCOR Framework
- SCOR Project
- SCOR Integration
- SCOR Benchmarking (SCORmark℠)
- DCOR Framework
- Performance Based Logistics Using SCOR
- Six Sigma & Lean Using SCOR
- Supply Chain Risk Management Using SCOR

In-House Training

If you need to train multiple employees, you can send them to a public training or invite SCC instructors to conduct training at your facility. No matter where you are around the world, our instructors are available to support your needs. In-house training saves time, reduces travel costs, and lowers the average training fee per employee. Above all, in-house training customized to your industry and organization allows your employees to discuss how to immediately adapt the newly learned tools and techniques to your organization's unique challenges.

Visit supply-chain.org/training to:

- View training locations and dates.
- Read detailed descriptions.
- Access special pricing for members, affiliates, or groups.
- Learn about group training options.

Certification

Supply Chain Council's certification programs enable individuals to demonstrate their SCOR knowledge and skills. Like the SCOR model itself, SCOR certification is based on real-world techniques for measuring and managing a global supply chain, not on concepts or abstractions. Certification allows organizations to rapidly assess the competencies of current personnel and recruits, and evaluate the effectiveness of training.

The SCOR Professional (SCOR-P) certification program establishes a consistent global standard for excellence in using SCOR. SCOR-P certification requires a minimum of five years of supply chain management experience. The SCOR Scholar (SCOR-S) certification is designed for university students who do not yet possess significant work experience. SCOR-S certification demonstrates understanding of supply chain management as interpreted via the SCOR framework. It is the only program of its type in the world that provides professional certification of supply chain knowledge to students.

supply-chain.org/certification

Events

Every year the staff, regional directors, and representatives of Supply Chain Council organize and participate in many business and supply chain management events around the world. SCC hosts Supply Chain World conferences in Europe, Asia, and North America; regional Executive Summits; and SCC regional meetings. Many of our events are open to nonmembers and members of affiliated associations.

supply-chain.org/events

Online

The SCC website (supply-chain.org) offers an array of information on the SCOR frameworks, SCOR benchmarking, and SCOR usage guidelines. It also details SCC member services and benefits, upcoming trainings, our webinar schedule, major industry conferences, and a variety of other supply chain management resources.

Membership

Join Us

Our members represent the full spectrum of people and organizations working and serving the supply chain process area. They include practitioners from every industry, representatives of consulting and software firms providing tools or expertise to supply chain organizations, and academics teaching future supply chain professionals. SCC operates on a global basis with local chapters in key regions. Membership options allow you to participate in one region or globally.

Membership is organization-wide

Every supply chain professional in your organization will have access to the SCOR models, online library, benchmarking, and peer networking. Everyone also receives member discounts on training and events.

To help you get started each new membership includes one complimentary seat at a public training course in the first year of membership as a standard or global member. Learn more about how SCC membership addresses your specific supply chain needs.

supply-chain.org/membership

A Word of Appreciation

Each refinement of the SCOR model is driven by a collaborative team of practitioners from a cross section of industry, government, and nonprofit organizations. These volunteers keep SCC in touch with current industry thinking and best practices and support the development of new membership programs. Supply Chain Council continues to express our deep appreciation to the many volunteers around the world who give their time, energy, and extraordinary expertise to moving the SCOR model forward. Without your contributions our mission to help organizations improve the performance of their supply chains would not be possible.

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change management

organizational and personal change management, process, plans, change management and business development tips

Here are some rules for effective management of change. Managing organizational change will be more successful if you apply these simple principles. Achieving personal change will be more successful too if you use the same approach where relevant. Change management entails thoughtful planning and sensitive implementation, and above all, consultation with, and involvement of, the people affected by the changes. If you force change on people normally problems arise. Change must be realistic, achievable and measurable. These aspects are especially relevant to managing personal change. Before starting organizational change, ask yourself: What do we want to achieve with this change, why, and how will we know that the change has been achieved? Who is affected by this change, and how will they react to it? How much of this change can we achieve ourselves, and what parts of the change do we need help with? These aspects also relate strongly to the management of personal as well as organizational change.

See also the modern principles which underpin successful change.

Refer also to Psychological Contract theory, which helps explain the complex relationship between an organization and its employees.

Do not 'sell' change to people as a way of accelerating 'agreement' and implementation. 'Selling' change to people is not a sustainable strategy for success, unless your aim is to be bitten on the bum at some time in the future when you least expect it. When people listen to a management high-up 'selling' them a change, decent diligent folk will generally smile and appear to accede, but quietly to themselves, they're thinking, "No bloody chance mate, if you think I'm standing for that load of old bollocks you've another think coming..." (And that's just the amenable types - the other more recalcitrant types will be well on the way to making their own particular transition from gamekeepers to poachers.)

Instead, change needs to be understood and managed in a way that

people can cope effectively with it. Change can be unsettling, so the manager logically needs to be a settling influence.

Check that people affected by the change agree with, or at least understand, the need for change, and have a chance to decide how the change will be managed, and to be involved in the planning and implementation of the change. Use face-to-face communications to handle sensitive aspects of organisational change management (see Mehrabian's research on conveying meaning and understanding). Encourage your managers to communicate face-to-face with their people too if they are helping you manage an organizational change. Email and written notices are extremely weak at conveying and developing understanding.

If you think that you need to make a change quickly, probe the reasons - is the urgency real? Will the effects of agreeing a more sensible time-frame really be more disastrous than presiding over a disastrous change? Quick change prevents proper consultation and involvement, which leads to difficulties that take time to resolve.

For complex changes, refer to the process of project management, and ensure that you augment this with consultative communications to agree and gain support for the reasons for the change. Involving and informing people also creates opportunities for others to participate in planning and implementing the changes, which lightens your burden, spreads the organizational load, and creates a sense of ownership and familiarity among the people affected.

See also the excellent free decision-making template, designed by Sharon Drew Morgen, with facilitative questions for personal and organizational innovation and change.

To understand more about people's personalities, and how different people react differently to change, see the personality styles section.

For organizational change that entails new actions, objectives and processes for a group or team of people, use workshops to achieve understanding, involvement, plans, measurable aims, actions and commitment. Encourage your management team to use workshops with their people too if they are helping you to manage the change.

You should even apply these principles to very tough change like making people redundant, closures and integrating merged or acquired organizations. Bad news needs even more careful management than routine change. Hiding behind memos and middle managers will make matters worse. Consulting with people, and helping them to understand does not weaken your position - it strengthens it. Leaders who fail to consult and involve their people in managing bad news are perceived as weak and lacking in integrity. Treat people with humanity and respect and they will reciprocate.

Be mindful that the chief insecurity of most staff is change itself. See the process of personal change theory to see how people react to change. Senior managers and directors responsible for managing organizational change do not, as a rule, fear change - they generally thrive on it. So remember that your people do not relish change, they find it deeply disturbing and threatening. Your people's fear of change is as great as your own fear of failure.

responsibility for managing change

The employee does not have a responsibility to manage change - the employee's responsibility is no other than to do their best, which is different for every person and depends on a wide variety of factors (health, maturity, stability, experience, personality, motivation, etc). Responsibility for

managing change is with management and executives of the organisation - they must manage the change in a way that employees can cope with it. The manager has a responsibility to **facilitate** and **enable** change, and all that is implied within that statement, especially to understand the situation from an objective standpoint (to 'step back', and be non-judgemental), and then to help people understand reasons, aims, and ways of responding positively according to employees' own situations and capabilities. Increasingly the manager's role is to interpret, communicate and enable - not to instruct and impose, which nobody really responds to well.

change must involve the people - change must not be imposed upon the people

Be wary of expressions like 'mindset change', and 'changing people's mindsets' or 'changing attitudes', because this language often indicates a tendency towards imposed or enforced change (theory x), and it implies strongly that the organization believes that its people currently have the 'wrong' mindset, which is never, ever, the case. If people are not approaching their tasks or the organization effectively, then the organization has the wrong mindset, not the people. Change such as new structures, policies, targets, acquisitions, disposals, re-locations, etc., all create new systems and environments, which need to be explained to people as early as possible, so that people's involvement in validating and refining the changes themselves can be obtained.

Whenever an organization **imposes** new things on people there will be difficulties. Participation, involvement and open, early, full communication are the important factors.

Workshops are very useful processes to develop collective understanding, approaches, policies, methods, systems, ideas, etc. See the section on workshops on the website.

Staff surveys are a helpful way to repair damage and mistrust among staff - provided you allow allow people to complete them anonymously, and provided you publish and act on the findings.

Management training, empathy and facilitative capability are priority areas - managers are crucial to the change process - they must enable and facilitate, not merely convey and implement policy from above, which does not work.

You cannot impose change - people and teams need to be empowered to find their own solutions and responses, with facilitation and support from managers, and tolerance and compassion from the leaders and executives. Management and leadership style and behaviour are more important than clever process and policy. Employees need to be able to trust the organization.

The leader must agree and work with these ideas, or change is likely to be very painful, and the best people will be lost in the process.

change management principles

1. At all times involve and agree support from people within system (system = environment, processes, culture, relationships, behaviours, etc., whether personal or organisational).
2. Understand where you/the organisation is at the moment.
3. Understand where you want to be, when, why, and what the measures will be for having got there.
4. Plan development towards above No.3 in appropriate achievable measurable stages.
5. Communicate, involve, enable and facilitate involvement from people, as early and openly and

as fully as is possible.

John P Kotter's 'eight steps to successful change'

American John P Kotter (b 1947) is a Harvard Business School professor and leading thinker and author on organizational change management. Kotter's highly regarded books 'Leading Change' (1995) and the follow-up 'The Heart Of Change' (2002) describe a helpful model for understanding and managing change. Each stage acknowledges a key principle identified by Kotter relating to people's response and approach to change, in which people **see**, **feel** and then **change**.

Kotter's eight step change model can be summarised as:

1. **Increase urgency** - inspire people to move, make objectives real and relevant.
2. **Build the guiding team** - get the right people in place with the right emotional commitment, and the right mix of skills and levels.
3. **Get the vision right** - get the team to establish a simple vision and strategy, focus on emotional and creative aspects necessary to drive service and efficiency.
4. **Communicate for buy-in** - Involve as many people as possible, communicate the essentials, simply, and to appeal and respond to people's needs. De-clutter communications - make technology work for you rather than against.
5. **Empower action** - Remove obstacles, enable constructive feedback and lots of support from leaders - reward and recognise progress and achievements.
6. **Create short-term wins** - Set aims that are easy to achieve - in bite-size chunks. Manageable numbers of initiatives. Finish current stages before starting new ones.
7. **Don't let up** - Foster and encourage determination and persistence - ongoing change - encourage ongoing progress reporting - highlight achieved and future milestones.
8. **Make change stick** - Reinforce the value of successful change via recruitment, promotion, new change leaders. Weave change into culture.

Kotter's eight step model is explained more fully on his website www.kotterinternational.com.

Related to Kotter's ideas, and particularly helpful in understanding the pressures of change on people, and people's reactions to change, see a detailed interpretation of the personal change process in John Fisher's model of the process of personal change.

ideas on illustrating change management issues

When people are confronted with the need or opportunity to change, especially when it's 'enforced', as they see it, by the organization, they can become emotional. So can the managers who try to manage the change. Diffusing the emotional feelings, taking a step back, encouraging objectivity, are important to enabling sensible and constructive dialogue. To this end, managers and trainers can find it helpful to use analogies to assist themselves and other staff to look at change in a more detached way.

On this site there are several illustrations which can be used for this purpose, depending on the type of change faced, and the aspect that is to be addressed. Here are a few examples, useful for

team meetings, presentations, one-to-one counselling or self-reminder, particularly to help empathise with others facing change:

On the Stories section look at 'Murphy's Plough' (negative thinking = obstacle to change) and 'We've always done it that way' (not questioning need for change). Both good aids for understanding and explaining why people - all of us - find it difficult to change assumptions, conditioned thinking, habit, routine, etc.

Look also at the Monkey Story, as to how policies, practices, attitudes and even cultures can become established, and how the tendency is to accept rather than question.

Just as the state of 'unconscious incompetence', needs to be developed into 'conscious competence' to provide a basis for training, so a person's **subjective emotion** needs to be developed into **objectivity** before beginning to help them handle change. None of us is immune from subjectivity, ignorance or denial. The lessons and reminders found in stories and analogies can help to show a new clear perspective.

Aesop's Fables section has other short and beautifully simple analogies useful for illustrating aspects of causing or dealing with change, for example (all on the Aesop's Fables section):

The Crow and the Pitcher (change being provoked by pressure or necessity)

The North Wind and the Sun (gentle persuasion rather than force)

The Lion and The Ass (enforced change - might is right)

The Crab and his Mother (lead by example and evidence - or you'll not change people)

The Miller, his Son and the Ass (no single change is likely to please everyone - everyone wants something different)

The Oak and the Reeds (the need for tolerance - changer or 'changees')

The Rich Man and the Tanner, (time softens change - given time people get used to things)

The Ass and the Mule (agree to reasonable change now or you can risk far worse enforced change in the future)

job reorganization, task analysis, job transfer due to IT development or outsourcing etc

First see the modern principles which underpin successful change. It's not always easy or perhaps even possible to consider matters at such depth, but try to if you can, or try to persuade others above in their ivory towers to think about the fundamental integrity of the situation, instead of short-term profit, or satisfying greedy shareholders.

There are various approaches to task analysis and job reorganization, whether prompted by outsourcing or IT development. Generally change process of this sort is pragmatic, and it's difficult to identify transferable processes, templates, etc. Examples of projects don't generally find their way into the public domain, although the likelihood is increasing of government project pdf's becoming available on the web as this sort of information is increasingly required to be available to

the public. IT vendor case studies and trade journals of the IT and outsourcing sectors can also provide indicators of best practice or transferable processes. There are some useful software tools now available, which are helpful, especially if the change involves a high level of complexity and a large scale.

As a broad guide when managing this sort of change, these aspects are important for the process:

Really understand and clarify mutual expectations about the level of detail and cost that the project requires. Sometimes it's possible to see it what you need on a table napkin. The organisational context, and other strategic drivers, personalities and politics are often more significant influences than the task analysis.

If you are a consultant or project manager, agree expectations on a pragmatic basis. Agree the templates and systems to be used and the the level of report data required for the decisions to be made.

Assume that the situation can be improved - it generally can be, so while it's essential to capture all activities based on current jobs, many of these can be absorbed, superseded, updated, etc., when you begin to look at the ideal situation ('blank sheet of paper') possibilities, so;

A new overview analysis enables fresh unencumbered look at the whole, which suggests new and better ways of doing things. A flip chart and a few creative minds are the main pre-requisites. It makes a great workshop session and is good for creating ownership and buy-in for major change. It's a good process also to cascade down to departments to bring out ideas for improved processes and new ways of doing things.

In terms of capturing all current processes and inputs, the individual job analysis templates need to enable jobs to be broken down into sub-tasks, and elements within sub-tasks.

This is a tricky one, and not practicable in certain X-Theory cultures, nevertheless, be aware of the high probability of upsetting people whose jobs are threatened by change and try to develop a way of anticipating and reducing damaging fall-out. Treat people at risk with the respect they deserve and avoid keeping them in the dark - involve threatened people wherever possible so they can see what's happening and why. If possible encourage the executive team to take the same humane approach, and try to establish counselling and support resources if none exist already.

Analyses are more helpful if they identify critical vs essential task elements - this will help you to help the decision-makers to be more pragmatic (not least because by applying pressure to some of the 'essential' elements will reveal them to be habitual dispensable or traditional replaceable elements).

Flow diagrams identify subtask linkage (inter and intra), variation and chronology.

Behaviour needs identifying aside from processes.

Standards, performance tolerance, % reliability, etc., should be indicated in task analysis as applicable to the sub-task or activity concerned.

other points about people and change

Strong resistance to change is often rooted in deeply conditioned or historically reinforced feelings.

Patience and tolerance are required to help people in these situations to see things differently. Bit by bit. There are examples of this sort of gradual staged change everywhere in the living world.

The Psychological Contract is a significant aspect of change, and offers helpful models and diagrams in understanding and managing change - potentially at a very fundamental level.

Also, certain types of people - the reliable/dependable/steady/habitual/process-oriented types - often find change very unsettling.

People who welcome change are not generally the best at being able to work reliably, dependably and follow processes. The reliability/dependability capabilities are directly opposite character traits to mobility/adaptability capabilities.

Certain industries and disciplines have a high concentration of staff who need a strong reliability/dependability personality profile, for example, health services and nursing, administration, public sector and government departments, utilities and services; these sectors will tend to have many staff with character profiles who find change difficult.

See the personality styles page to help understanding about different types of people.

Age is another factor. Erik Erikson's fascinating Psychosocial Theory is helpful for understanding that people's priorities and motivations are different depending on their stage of life.

The more you understand people's needs, the better you will be able to manage change.

Be mindful of people's strengths and weaknesses. Not everyone welcomes change. Take the time to understand the people you are dealing with, and how and why they feel like they do, before you take action.

business development driven change

Business development potentially includes everything involved with the quality of the business or the organization. Business development planning first requires establishing the business development aims, and then formulating a business development strategy, which would comprise some or all of the following methods of development.

- sales development
- new product development
- new market development
- business organization, shape, structure and processes development (eg, outsourcing, e-business, etc)
- tools, equipment, plant, logistics and supply-chain development
- people, management and communications (capabilities and training) development
- strategic partnerships and distribution routes development
- international development
- acquisitions and disposals

Generally business development is partly scientific, and partly subjective, based on the feelings and wishes of the business owners or CEO. There are so many ways to develop a business which achieve growth and improvement, and rarely is just one of these a single best solution. Business development is what some people call a 'black art', ie., difficult to analyse, and difficult to apply a replicable process.

fast changing environments

Planning, implementing and managing change in a fast-changing environment is increasingly the situation in which most organizations now work.

Dynamic environments such as these require dynamic processes, people, systems and culture, especially for managing change successfully, notably effectively optimising organizational response to market opportunities and threats.

Key elements for success:

Plan long-term broadly - a sound strategic vision, not a specific detailed plan (the latter is impossible to predict reliably). Detailed five years plans are out of date two weeks after they are written. Focus on detail for establishing and measuring delivery of immediate actions, not medium-to-long-term plans.

Establish forums and communicating methods to enable immediate review and decision-making. Participation of interested people is essential. This enables their input to be gained, their approval and commitment to be secured, and automatically takes care of communicating the actions and expectations.

Empower people to make decisions at a local operating level - delegate responsibility and power as much as possible (or at least encourage people to make recommendations which can be quickly approved).

Remove (as far as is possible) from strategic change and approval processes and teams (or circumvent) any ultra-cautious, ultra-autocratic or compulsively-interfering executives. Autocracy and interference are the biggest obstacles to establishing a successful and sustainable dynamic culture and capability.

Encourage, enable and develop capable people to be active in other areas of the organization via 'virtual teams' and 'matrix management'.

Scrutinise and optimise ICT (information and communications technology) systems to enable effective information management and key activity team-working.

Use workshops as a vehicle to review priorities, agree broad medium-to-long-term vision and aims, and to agree short term action plans and implementation method and accountabilities.

Adjust recruitment, training and development to accelerate the development of people who contribute positively to a culture of empowered dynamism.

'troubleshooting' tips for investigating apparent poor

performance

If you are ever give the job of 'troubleshooting' or investigating (apparent) poor performance, perhaps in another location or business belonging to your own organisation, or perhaps as a consultancy project, here are some simple tips:

Actually 'troubleshooting' isn't a great word - it scares people. Use 'facilitator' or 'helper' instead. It sets a more helpful and cooperative tone.

On which point, you could well find that the main issue will be people's resistance and defensiveness to someone coming in to their organisation do what you are doing. When you overcome that challenge, then you can start comparing what's happening with what the organisation sets out to do (mission, values, goals, priorities, targets, key performance indicators, processes, measures); how the people feel about things (staff turnover, retention, morale, attitudes); and how customers and suppliers feel about things too (actually go out and visit customers, and ex-customers particularly).

You must observe protocols very diligently - introduce yourself properly to people and explain who you are and what you are doing. Don't assume that your task gives you the right to be secretive, or to have access to anyone or anything without permission. Ask for help. Ask for introductions. Ask for permission. Be polite and courteous. Respect people more than you would do normally, because they will be sensitive, understandably so.

Look at the Sharon Drew Morgen facilitation method, which helps with the style and approach you should use. You must aim to help, enable and facilitate discovery and clarity, not work in splendid isolation, as an outsider, who's come to 'sort things out'.

And then be led by the people there as to what can be improved. You should adopt the role of a researcher and enabler rather than a problem solver.

Plan lots of questions that will help people to tell you how they feel about things - customers and staff and suppliers - and what they think can be done to improve things.

Avoid asking 'why' unless they're really trusting you and working with you. Used early, 'why' puts people on the defence and you'll not find out anything.

Look at the customer relationship materials as well - customers will tell you what's best to focus on, and will give you an early opportunity to facilitate some improvement responses. Also look at the employee motivation survey material.

It's likely that you'll have to write a report and recommendations afterwards, in which case try wherever possible to involve the people in what you say about them. Let there be no surprises. Be constructive. Accentuate the positive. Be straight and open with people.

Enjoy the experience. Be respectful and helpful to people and they'll be respectful and helpful to you.

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see also

The Psychological Contract

John Fisher's personal change theory

Conscious Competence - a personal change model in learning and development

Elisabeth Kübler-Ross's Five Stages of Grief - primarily for dealing with death and bereavement, but helpful for understanding change reaction to other types of major shock and loss

Modern principles which underpin successful change in organisations

Sharon Drew Morgen's Facilitation model - for change, coaching, decision-making and selling

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Data, Information, and Knowledge - Relevance and Understanding

Abstract

It ain't what we don't know that hurts us, it's what we know that ain't so."[1]

"We also study Cisco. What comes through from our class discussion is that Cisco thought they knew it all and had no need for corroboration. The conflicting data was available; they chose not to look at it."[2]

"I have no data yet. It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."[3]

Here we have three of several issues associated with data, information, and knowledge.

1. Data that does not represent truth.
2. Hubris of thinking we know all we need to know.
3. Succumbing to the temptation to make a decision before the relevant data is in.

This note takes up a general set of considerations regarding data management.

[1] Mark Twain

[2] James Drogan, "Lean SCM vs the Crisis," e-mail to David Livingston et. al., May 19, 2009

[3] (Doyle)

Data, Information, and Knowledge

Data, information, and knowledge are not identical.[4]

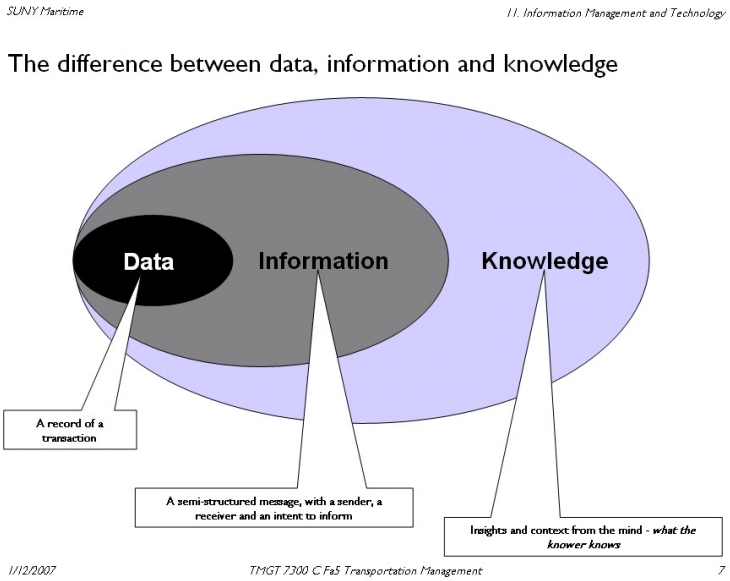

Figure 1 The Difference Between Data, Information and Knowledge

Some points:

1. Data is a prerequisite for information and information is a prerequisite for knowledge. This places a premium on the correctness of the data. Data are attributes of objects (e.g., age of a person, location of a shipment).
2. The cost of acquisition of data and subsequent development of information and knowledge increases as one moves from the left to the right in Figure 1.
3. The value of decisions made on the basis of data, information, and knowledge increases as one moves from the left to the right in Figure 1.
4. Human involvement in an information system increases as one moves from left to the right in Figure 1.
5. The skills and experience required of the human to be an effective participant in an information system increases as one moves from left to the right in Figure 1. The apprentices are to the left, the adepts to right.

Relevance

Consider the following sequence.[5]

1. What business decisions must be made and why? Here we are seeking to write declarative sentences that look something like "We need to make a decision about … because it will affect how we …" These need to be decisions of significance to the firm.

[4] (Drogan 2006)

[5] (Drogan 2005a)

2. How will these decisions be made and why? By how I mean the general approach to making the decision. For example, a decision on which container to move next will be based upon a) the value of the goods to the shipper and 2) the value of the shipper to the organization. It's useful to also write declarative sentences to help answer these questions.
3. What data is required and what will be its source?

Relevance is a measure of the ability of the data, information, and knowledge to support the process for making decisions.

1. Is there a strong relationship between the data, information, and knowledge and the process for making the decision?
2. Is the data, information, and knowledge available within the decision window?

The Decision Window

A few words are in order regarding the decision window.[6]

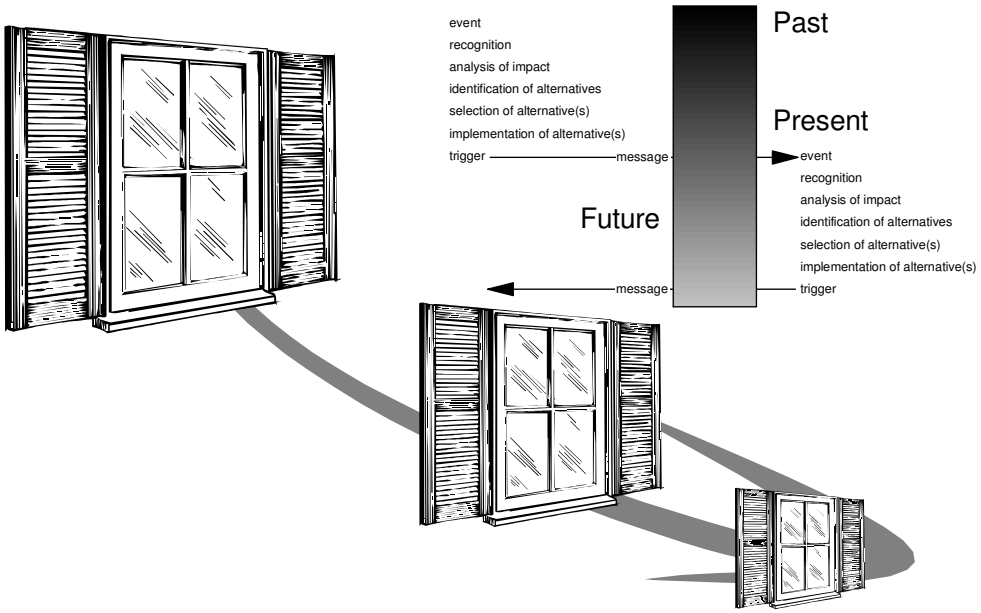

Figure 2 Decision Window

The decision window is opened by the initial event and closed by the resulting outcome. Any intervention to change the outcome must come within this window. The windows continue to grow smaller due, I think, to the ubiquitous of data, information, and knowledge; pervasive global communications (always on, always connected, always transacting[7]); the speed at which business is conducted; and, last but not least, the embracing of risk and uncertainty as representing opportunities for competitive success.

I include here a portion of the contents of an e-mail exchange on this subject which may shed additional light on my thinking.[8] The original material is in *italics*. I have added additional explanations into the original e-mail in regular typeface.

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[6] (Drogan 1999a)

[7] (Drogan 2003)

[8] J. Drogan to D. Livingston, RE: Homer, Great Books and Modern Life, e-mail, December 28, 2006

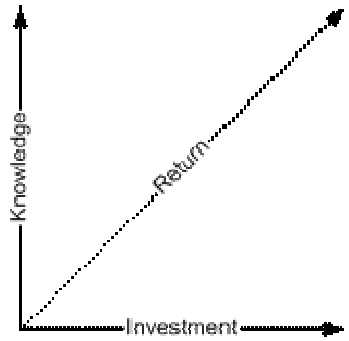

Figure 3 Investment in Developing Knowledge

In this case I'm suggesting that an investment in time/effort results in the acquisition of knowledge and a subsequent return on the investment through the actions predicated on that knowledge.

> The greater the investment, the greater the knowledge acquired, and the greater is the expectation for return.

The return line is anchored at the origin and rotates counterclockwise or clockwise depending upon one's capacity (greater or lesser, respectively) to absorb and internalize the knowledge. The length of the line is a function of the commitment one makes to the investment. Lifetime learning is represented by long lines.

One could, I suppose draw, at worst, a horizontal line indicating the level of knowledge required to resolve certain issues. At best, I suspect this line probably rises as one goes from left to right. The three box model for describing a supply chain *was satisfactory at one time, but the five box model is to be preferred, and someone has had had the temerity to suggest five is not enough.*[9]

The investment line suggests that there is a limit (one cannot invest an infinite amount for an indefinite time) *to the amount of investment that one is willing (boredom arrives) or able (the decision window has closed;* investment is no longer available*) to make.*

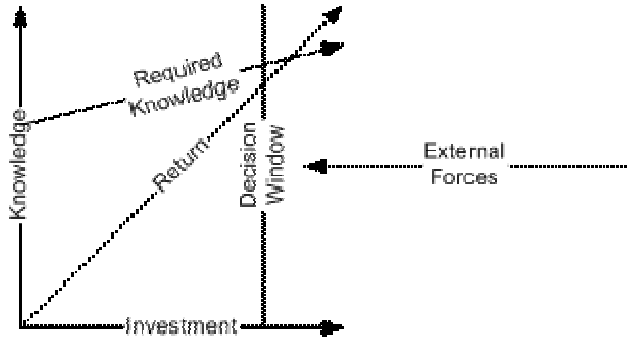

Figure 4 Required Knowledge and the Decision Window

In the second case, external forces are tending to push the limit set by the decision window to the left. Unless one changes the return line one will, over time, have less and less knowledge available to resolve increasingly complex issues. I think the decrease in the size of decision windows is an unstoppable force. The only thing that one can do to cope is to rotate the return line counterclockwise.

Hence, what we need is to find a way to rotate the return line counterclockwise. I understand the line may shorten (an implication to be worked through later).

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[9] The three box and five box models are supply chain descriptions. I have suggested that the five box model is insufficient.

I see only two ways to do this. Improving the K-12 educational system, at a minimum, but also extending this to improvement into higher education (at least to the Masters level). We have discussed this at some length.

The second way is to improve collaboration. Technology helps here, but there is also a change in mind set required. My experience is that you can dump a lot of pretty smart people into the SIDAL [Sense, Interpret, Decide, Act, Learn] *process, but they will not necessarily form a high performance team.*[10] *The notion of collaboration ought to be on our discussion list.*

Oops, a third way pops up. Increase the return by focusing only on relevant knowledge. That, of course, is what fact-based hypothesis-driven reasoning is all about. And this calls into question the value of the Great Books (this alone ought to provoke some sort of response from you). Eruditeness may, in fact, be a burden in the future world. On the other hand, those that traffic in imagination, to whom you refer in the last part of your note, may be of great value.

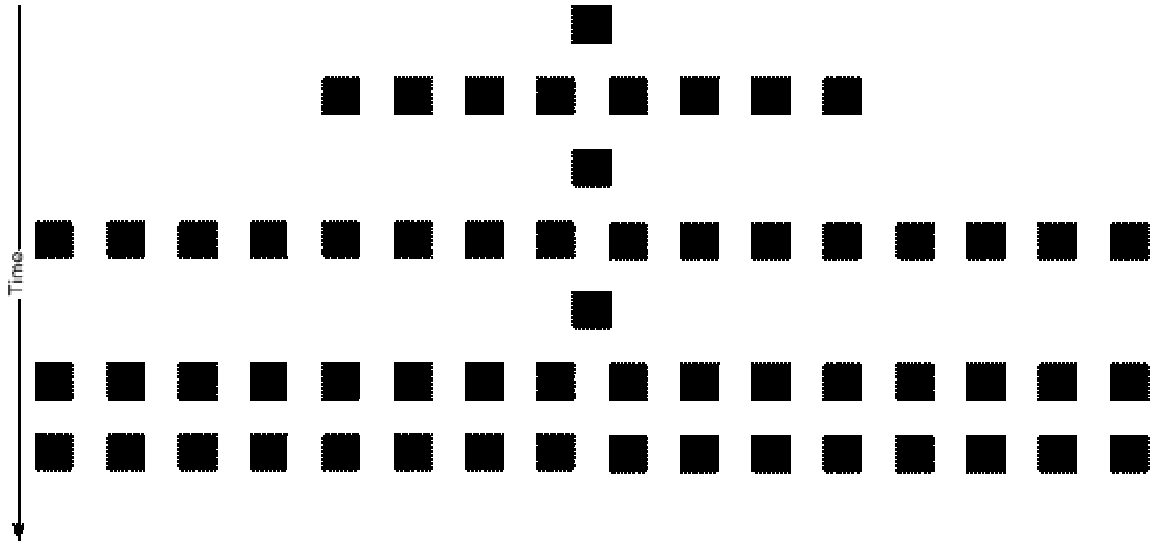
As to the matter of boredom, the option here is to find a way to make the seemingly boring actually exciting. That's what good teachers are all about. I think we can agree we have too few of these.

However, I think there is and will always be the need for the person that understands the picture to be made from all the little pieces. Where are they to be found? How are they to be nurtured and retained?

Maybe Homer and Great Books do not fit with Modern Life. This may be seen as in opposition to what I have often maintained prior to this note. Indeed, I think it may well be. If Homer and the Great Books can be considered as representative of the knowledge of the person that understands the picture to be made from all the little pieces, then I [sic] *what I am leading towards* [is] *this person as the composer, orchestrator, and maestro (COM; acronym is required because I sense I'm going to come back to this idea). We need more of these.*

And we need the members of the orchestra, the specialists, for which Homer and the Great Books are not what is required.

Now the following should come as no great surprise.



Over time, as technology and our understanding of collaboration has developed, the COM (the single box) can direct an increasing number of specialists. Collaboration is not represented, in my mind, by blogger babble, but rather by such things as open source and Wikipedia. The COMs must understand and must apply Homer and Great Books while the specialists should be content with the Red Books (IBMese).[11]

[10] (Hackman 2002)

[11] By Red Books I meant specific, detailed expertise.

What seems so straightforward, blissful even, is set upon by culture, Maslow's Hierarchy, myopia, and all the related diseases that hinder our ability to pay attention, to listen and hear, to understand, to practice tolerance, to accept and, ultimately, to work in a more positive way for the common good. There are, as you have often pointed out, cures for the diseases if only the patients will be willing to take the waters

So there you are. It's all about incentive. Unfortunately, incentive generally arrives when one is under duress (think IBM in the early 90s). In the pace of today's and tomorrow's world that may well be too late. It becomes harder and harder to get on top and stay on top of the wave. I'm pretty sure that we in higher education are not dealing with this as effectively as we ought.

All this does not, in my mind, obsolete SIDAL.

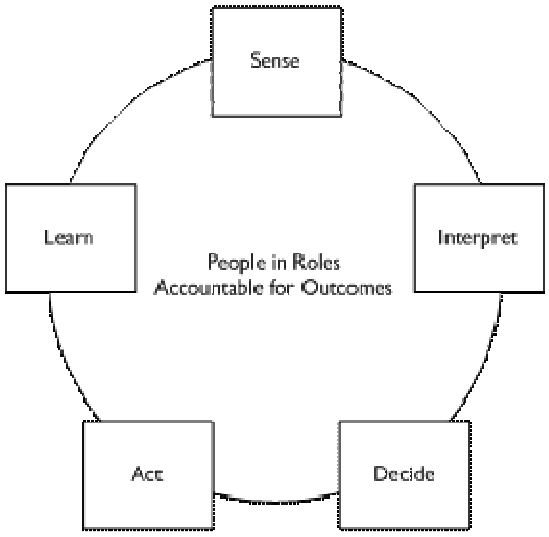


Figure 5 The SIDAL Loop

It does suggest to me that we ought to moving towards structures characterized by a (large) number of small, fast SIDAL cycles operating in a collaborative, associative manner (much like the brain?), all under the direction of COM.

I think I can see this and how it would work. Doubtless there are existing examples of this construct. The critical issue is getting from here to there. I think this requires significant behavioral change on the part of a significant number of people. Ah, yes, there we have that word again – change.

The argument here is our notion of relevance of data, information, and knowledge may very well be changing. That is, for the reasons given above, we may need to accept less relevance (accuracy, precision, relationship to need, timeliness or completeness) because we must act before the decision window closes. Our decision processes may require more collaboration because of the breadth and depth of the relevant data, information, and knowledge.[12]

[12] Drogan's First Law: Know what you know, know what you don't know, and know who knows what you don't know.

Finding the Knowledge Kernel

By "knowledge kernel" I mean the set of most appropriate data, information, and knowledge.

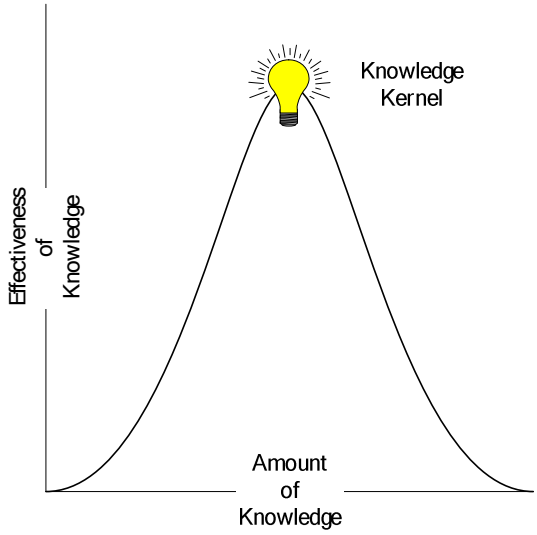


Figure 6 The Amount and Effectiveness of Knowledge of Technology

Figure 6 captures this notion. To the left of the mean lie the less qualified, to the right the over qualified. Subject to certain forces (e.g., planning and control levels, function responsibilities, to be discussed below, and time) the knowledge kernel changes. In a sense, what got us here will not keep us here.

The required knowledge kernel (used hereinafter to mean data, information, and knowledge) is defined by breadth, depth, and currency.[13]

[13] This section is taken from (Drogan 2009)

Breadth, Depth, and Currency

The level of knowledge one requires is commensurate with one's role and responsibility in the organization. One determinant of role and responsibility is the planning and control level.[14]

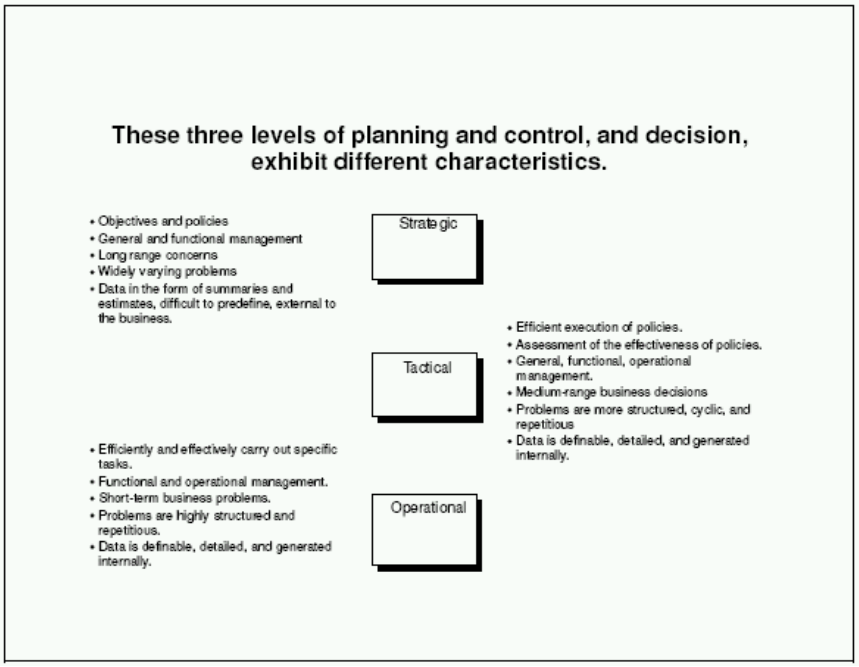


Figure 7 Planning and Control Levels

Towards the top of this chart one is interested in knowledge in support of competitive advantage. Senior executives are concerned about the health of the entire organization and, therefore, need a broad set of knowledge.

Towards the bottom of this chart one is interested in knowledge that leads to the desired return. In most organizations, people at the lower level of planning and control have narrower knowledge needs (see the following table[15]) and therefore take a narrower view of this matter.

Accounting and Finance
Administration
Executive
Intermodal
Maintenance and Engineering
Marketing
Sales
Transportation

Table 1 Functional Areas

[14] (Drogan 2008)

[15] (Drogan 2008). The functions listed here are based on those one might find in a freight railway.

Personnel in the transportation function may be concerned about GPS to enable real-time tracking of the firm's assets. This is likely not to be a concern of accounting and finance. Accounting and finance will, however, be concerned with the nature of investment required for this capability.

Together, Figure 7 Planning and Control Levels and Table 1 Functional Areas also helps us deal with the question of currency.

By currency, I mean how up-to-date the knowledge is. Data that is one second old may be more current than data that is one hour old, but may also be less relevant.

At the strategic planning and control level knowledge does not to be as current as at the operational level.

The currency characteristic is also shaped by the functional area. For example, changes in the knowledge that affects administration are likely to be less frequent than those affecting transportation.

Simply put, then, what one needs to know depends on where one sits in the organization.

Knowledge arriving after the decision window has closed may not only useless, but have an unacceptable opportunity cost.

It becomes incumbent on us, after defining the required "knowledge kernel," to determine the actions we need to undertake to keep the kernel current.[16]

Keeping current ought to be a regular task in your day. Get the process organized and scheduled.

[16] As an example, almost every day I scan some 65 RSS feeds, nine websites, two e-mail accounts, and three social networking sites. In addition I meet on a regular basis with my colleagues at the college and three external groups, scan and/or read two daily newspapers, one weekly news magazine, a number of less frequently published trade, business, and political journals, and am actively reading as many as four books. Keeping current is a lot of work.

It's Not that Simple

Were it that simple we could sit in our offices, ask questions, and come to a conclusion as to the breadth, depth, and currency of knowledge required by our job. However, other forces come into play.

For example, culture shapes what one needs to consider regarding the knowledge kernel.[17]

Figure 8 Consideration of Culture

What knowledge can one get to operate successfully in a culture that exhibits significant power distance?[18]

[17] (Javidan and House 2001)

[18] "Power Distance is defined as the degree to which members of a society expect power to be unequally shared. It represents the extent to which a community maintains inequality amongst its members by stratification of individuals and groups with respect to power, authority prestige, status, wealth, and material possessions. It also reflects the establishment and maintenance of dominance and control of the less powerful by the more powerful." (Javidan and House 2001)

The knowledge kernel is shaped by industry and company size. To stretch the point to make the point one might reasonably conclude that the knowledge kernel required to be a hair dresser is simple, in a Snowden sense, whereas that required to lead a global team exploring for oil is complicated.

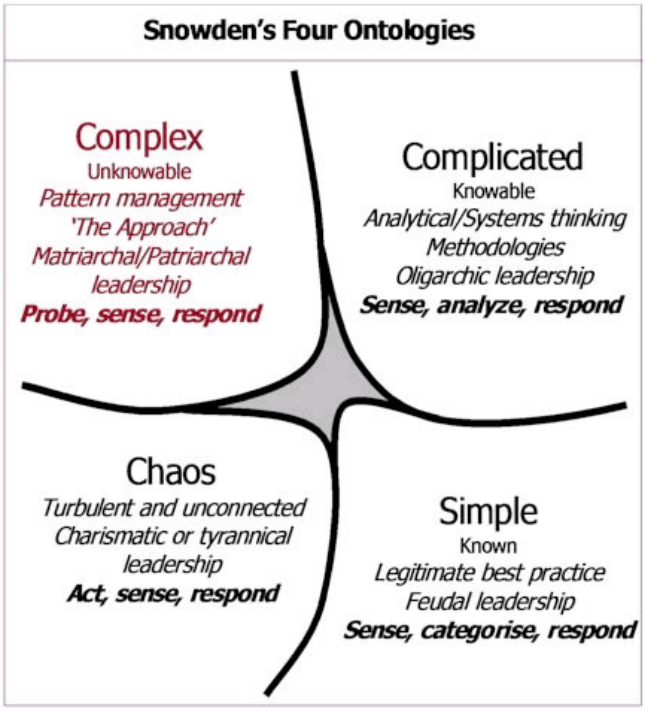


Figure 9 Snowden's Four Ontologies[19]

It seems reasonable to me, then, that the tasks of discovering and keeping current the knowledge kernel is very much a function of the industry and company size.

Corroboration

> *Cor·rob·o·ra·tion*
>
> *n.*
>
> *[Cf. F. corroboration.]*
>
> *1. The act of corroborating, strengthening, or confirming; addition of strength; confirmation; as, the corroboration of an argument, or of information.*
>
> *2. That which corroborates.*[20]

No longer can we simply accept what we see and hear at face value. Confirmation of the facts is becoming increasingly important. But confirmation takes time and I have previously argued that time is an increasingly critical resource.

> "I believe that we're about to witness what may turn out to be the last competitive frontier business will see. It's going to be a war over the one priceless resource. Time. And when it comes, trust may turn out to be the best investment anyone's made."[21]

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[19] http://blogs.salon.com/0002007/images/ontologies.jpg [September 1, 2009]

[20] Webster 1913 Dictionary. Patrick J. Cassidy, 1913. Answers.com 14 Jan. 2007. http://www.answers.com/topic/corroboration

[21] Jim Kelly, CEO of UPS, Remarks to the Commonwealth Club of San Francisco & Oakland Chamber of Commerce, February 23, 2000.

Can one trade collaboration for trust and thereby better cope with the relentless move of the decision window line to the left in Figure 4 Required Knowledge and the Decision Window on page 4? And if one can't, what is the alternative for coping?

Understanding

One of my students wrote:

> "One must be cognizant of words being used as some words have multiple meanings and understand which one is being used or to use. Some words carry a different meaning between different countries. For example: My office in the U.S. refers to the word demurrage free-time and detention free-time as terminal free-time and equipment free-time, respectively. In the Callao, Peru office, they refer to demurrage free-time and detention free-time as equipment free-time and detention free-time, respectively."[22]

This brings me to principles of communication.

1. The grammar and syntax of the messages being exchanged are understood.
2. The information communicated in the messages is relevant.
3. The medium of communication is acceptable.
4. There is a desire to communicate.
5. There is confirmation of understanding.

The data, information, and knowledge required to make decisions has its roots in communication. Language and culture become major hurdles to assuring that the parities communicating have a common understanding of the data, information, and knowledge.

I don't think you can be comfortable with judging relevance in the absence of understanding. Further to this point, while researching for this note, I uncovered the following.

Summary

> *Relevancy assumes a critical importance in control system operation because of the large amount of information available. The information deluge impacts the following areas: If information is presented at too high a rate or in too large blocks, the operators may not comprehend it. If useless data is often presented in a given display, the operators may ignore all data presented by that display. If the context of the data is not presented, the data may be meaningless to the operators. If the control and display systems are not properly designed, peaks in the message generation rate may choke the system. This paper describes the techniques in use and under development at the Clinton P. Anderson Meson Physics Facility for increasing the relevance of data both for real-time operations and for long-term analysis of accelerator performance. Data sifting and organization for presentation and for compact storage is discussed.*[23]

The message here is to be heeded.

Management

Implicit in any discussion of relevance and understanding is that an underlying management system for data, information, and knowledge exists.

The argument I am advancing is that one needs a "knowledge kernel" and it is the management system that defines and maintains the value of this kernel. Caution here. In the modern world it's very easy to

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[22] J. Kou, TMGT 7200.1 Written Assignment, January 11, 2007

[23] (Swain 1975)

prefix the phrase "management system" with words like data, information, and knowledge. From there it is but an easy step to get into a discussion of supporting information technology (e.g., RAD arrays, SQL).

My experience suggests that the most important decisions regarding knowledge are made by the business. The role of information technology is to support the implementation of those decisions.

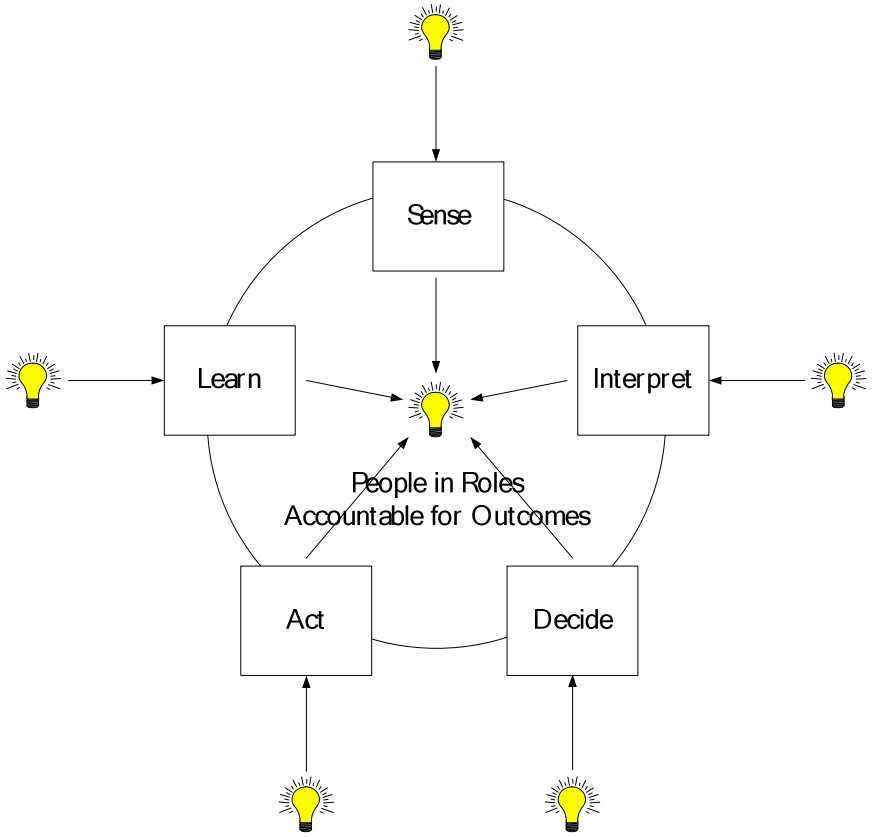

Figure 10 The Interplay Between SIDAL and Knowledge Kernels

Our ability to manage a business, represented by the SIDAL loop in Figure 10, is informed by the knowledge kernels shown to the outside of the loop. Execution of the loop should enhance the value of these knowledge kernels, represented by the single kernel in the middle of the figure. If we do this well these arrows represent virtuous loops that improve the effectiveness and efficiency of our business system.

Coda

What is critical in the context of the role and responsibilities of senior executives, and the decisions they make, is knowledge.

The notion of breadth, depth, currency, and application is summed up in this figure.

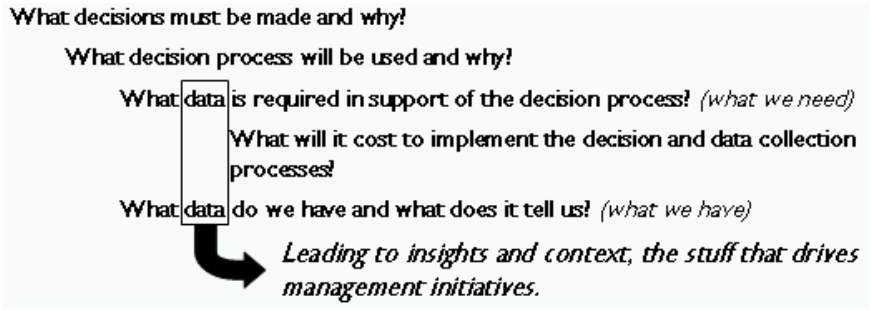

Figure 11 Determination[24]

Figure 11 is process whereby one determines what data is required to support decisions. You do not want to collect data unless you know what it is to be used for.

This note has described an approach to defining the all-important knowledge kernel and an approach to applying that kernel to improve the performance of an organization.

I have not aimed at being prescriptive, but rather at being illustrative. My sense is that as your role and responsibilities change to be more encompassing of the goals and objectives of a firm you must take additional responsibility for managing the value of the knowledge kernel. Of course you may have a staff to help you, but at the end of the day, you are the one holding the authority and will be held accountable for the results. The excuse that your staff did not perform is unlikely to be looked upon favorably.

James Drogan
September 1, 2009

[24] (Drogan 1999b)

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