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Patrick T. Hester
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Systemic Thinking

Fundamentals for Understanding Problems and Messes

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To my wife for her encouragement, my children for their comic relief, and my parents for their support

Patrick T. Hester

To the men of the U.S. Navy's submarine force, who practice attention-to-detail every minute of every day

Kevin MacG. Adams

Preface

Quick, think about a problem that vexes you. Too easy, right? The only difficulty you'd likely face is narrowing it down to a singular problem. Now think of another one. But this time, dig deep into your brain. Think of a problem that keeps you up at night, one that bothers you day in and day out, one that is seemingly intractable. Got one? Good, now think about what it is that characterizes this problem. What makes it hard? Why haven't you solved it yet? Well, for starters, it probably includes many of the items on the list below, identified by noted Psychologist Joachim Funke ([1] pp. 186–187) as characterizing complex problem solving situations:

- *Intransparency*: Intransparency refers to the lack of availability of information in our problem. An intransparent problem represents a situation in which all variables cannot be directly observed. In this case, we may have to infer information about the underlying state of the system, or too many variables exist, leading to our selection of only a handful for observation and analysis.
- *Polytely*: From the Greek words *poly* and *telos* meaning *many goals*. This set of goals can be thought of in many forms. We may have many individuals associated with our problem, and each harbors their own needs and wants. These interests are likely not to be directly aligned; thus, they compete for our attention, requiring trade-offs. Similarly, objectives within our problem are not typically straightforward. Complex problems involve multiple, conflicting objectives. Finally, our problem will likely require competition for resources. We do not have unlimited resources; thus, we are limited in our ability to address our problem in the most straightforward and effective manner.
- *Complexity*: This element concerns the number of variables, the connectivity between these variables, and the nature of their relationship (i.e., linear vs. nonlinear). Funke [1] summarizes complexity as:

  > A complex problem-solving situation is not only characterized by a large number of variables that have to be considered, but also by their complex connectivity pattern, by the possibilities to control the system, and by the dynamic aspects of the system. The growing complexity of situational demands may conflict with the limited capacity of the problem solver. (pp. 186–187)

- *Variable connectivity*: A change in one variable is likely to affect the status of many other variables. Given this high connectivity, consequences are difficult to predict. That is, there is substantial unpredictability in the behavior of the problem. Even the most tried-and-true of modeling techniques fail to capture the behavior of modern problems—events such as Hurricanes Katrina or Sandy, the housing market crash, and other so-called Black Swans. These unpredictable phenomena go beyond the bounds of our uncertainty analysis techniques and require us to consider the robustness of our institutions, organizations, and supporting systems. Considering these phenomena in concert with shrinking resources, we have a quandary. More resources are required to plan for unpredictability, yet we lack sufficient resources to address these concerns completely. Thus, we must make compromises to account for this inherent contradiction.
- *Dynamic developments*: There is often considerable time pressure to address problems before they worsen. Positive changes also occur, but these changes could lead to further unpredictability. This is complicated by humans' bias for action. Most people are uncomfortable with situations that are unresolved. We want an answer and we want it now. One must simply look at the increase in information availability over the last decade to understand how the world has transformed into an instant gratification generation. No longer are we content to pull an encyclopedia off our bookshelf (that is, if we even own an encyclopedia anymore) and look up the answer to a question. Instead, we pull out our smart phone and *Google it*, expecting an instant answer, and grumbling when our Internet connection hits a snag. This behavior is problematic when considering problems of substantial complexity. Choosing to act, to get an answer *right now*, rather than to obtain additional information may lead to an inferior choice based on insufficient information. We must carefully weigh the desire to obtain more information with our potential for loss and what may have been. To put it another way, we must choose between *getting it right* or *getting it right now*.
- *Time-delayed effects*: Effects often occur with a time delay. This requires patience on the part of the individual concerned with the problem. This is in direct contrast to the need for near-term action discussed in the previous element.

To this list we add two criteria:

- *Significant uncertainty*: Complex problems have substantial uncertainty. That is, there are unknown elements which plague our problem. Some are so-called *known unknowns* such as the fact that market demand for a new product is unknown. These uncertainties come from the variables that are known to exist in a problem (but that have some level of random behavior associated with them that can be expressed by probability distributions). These types of uncertainties are present in any real-world problem due to the inherent variability of the natural world. So we use probabilistic information to reason about and predict these phenomena. More difficult to deal with are *unknown unknowns* such as the fact that we don't know what our competitors will do. This type of uncertainty comes from lack of knowledge of the larger system of problems (which we will later classify as a mess) of which our problem is a part. Will we be instantly outclassed by our competitors the day our new product is introduced to the market (or worse, before we even release our product)? To estimate these uncertainties, we typically turn to experts for their insight. Both sources of uncertainty, known and unknown unknowns, complicate our problem landscape but cannot be ignored.

- *Humans-in-the-loop*: Designing a mechanical system given a set of specifications may be straightforward, but designing the same system while incorporating human factors, including such elements as ergonomics, fatigue, and operator error prevention, is substantially more complex. Once we insert humans into our problem system, all bets are off, so to speak. In many ways, humans are the ultimate trump card. They represent the one factor that seemingly ignores all the hard work, all the calculations, all the effort, that has gone into the development of a solution to our problem. They exploit the one weakness or vulnerability in our problem system that no amount of simulations, trial runs, mock-ups, or counterfactuals could have accounted for. They are intransparent, uncertain, competitive, unpredictable, and have a bias for action, all factors that we've indicated make a problem hard. To boot, they are not mechanistic; they have feelings and emotions and difficult problems are often especially emotional issues. Think about some of the most difficult problems facing our current society, e.g., health care or higher education; they are highly emotional topics likely to elicit an emotionally charged response from even the most level-headed of individuals. Thus, even when we think we have it all figured out, humans enter the equation and blow it all apart.

So, what is one to do? Well, we could avoid all problems exhibiting one or all of these factors. This leaves a very small, uninteresting subset of the world to deal with. Alternatively, we suggest that all hope is not lost. We simply need a new way to reason about these problems that goes beyond the traditional methods we employ. Full disclosure—the authors of this book are engineers by education. But we've worked in industry and the military for many years and we've come to understand that no single discipline can solve truly complex problems. Problems of real interest, those vexing ones that keep you up at night, require a discipline-agnostic approach. They require us to get out of our comfort zone a little bit, to reach across the aisle, and embrace those fundamental concepts of other disciplines that may be advantageous to our effort. Simply, they require us to think *systemically* about our problem.

Fundamentally, we need a novel way to *think* about these problems, and more specifically, to *think systemically*, hence the title of this book. It is the hope of the authors that, after reading this book, readers will gain an appreciation for a novel way of thinking and reasoning about complex problems that encourages increased understanding. We intend to provide this in a manner that is not predicated on the reader being either an engineer or a scientist. Indeed, most of the real, complex problems vexing us are not engineering or scientific problems, at least in the strictest sense. So, you'll see us draw from engineering and science to be sure, but we'll also draw from psychology, mathematics, sociology, management, and many other fields in an effort to develop a robust approach to thinking about problems. To support this approach, the book is divided into two major parts: (1) A Frame of Reference for Systemic Thinking and (2) A Methodology for Systemic Thinking.

Part I focuses on the underlying theoretical basis necessary for thinking about problems in a meaningful manner. Chapter 1 discusses why current approaches to problem analysis lead to routine and predictable errors and why a new method for thinking about problems is necessary. Chapter 2 discusses the difference between problems (such as the mechanical design problem above) and messes (such as the healthcare crisis), and it addresses how to formulate an initial problem for investigation. Chapter 3 discusses the difference between traditional *systematic* approaches for reasoning about problems and our proposed *systemic* approach, introducing our methodology for *systemic thinking*. Chapter 4 completes Part I by providing the discipline-agnostic, theoretical basis necessary for systemic thinking. Completion of Part I will provide the reader with all of the knowledge necessary to understand a problem systemically from a theoretical basis. It will offer little guidance, however, in the way of practical deployment of such an approach. Such guidance is provided in Part II.

Part II provides a practical methodology for thinking systemically about *any* situation. For reasons that will become apparent after reading Chap. 3, Part II is divided into seven chapters, with the first six chapters answering the fundamental questions of who, what, why, where, how, and when as they pertain to your problem of interest. Chapter 5 addresses the *who* question by discussing stakeholder analysis and management. Chapter 6 addresses the *what* question by discussing problem decomposition into relevant elements such as outputs and outcomes. Chapter 7 answers the *why* question by addressing the motivational factors that influence stakeholders involved in a problem. Chapter 8 is focused on the *where* question, with emphasis placed on characterizing the context and boundaries of our problem. Chapter 9 is the *how* chapter which discusses mechanisms we can utilize in support of our problem analysis. Chapter 10 addresses the *when* question, discussing the stability and maturity of our problems. Finally, Chapter 11 brings all of these six perspectives together, introducing a systemic perspective which allows for a more holistic problem understanding. Once the reader has completed this book, it is the intent of the authors that he or she will possess a thorough understanding of the theory underlying systemic thinking (Part I), as well as how to actually utilize systemic thinking (Part II).

This book is intended for use by systems practitioners or in a graduate or advanced undergraduate class. Given its discipline-agnostic nature, it is just as appropriate for use in a business, sociology, or psychology course as it is in an engineering or scientific course. Regarding its instruction, Part I should be taught in order of appearance in the book to provide the proper theoretical foundation. Chapters 5–10 in Part II can be taught in any order, although, lacking any other preference, they can be taught in the order in which they appear. Chapter 11 should follow their instruction as it builds on techniques developed in Chaps. 5–10.

One final note before moving on. Before beginning the book in earnest, we ask you to skip ahead to Appendix A and complete our Systemic Thinking Self-Assessment. This brief questionnaire will enable you to self-assess your current perspective on systemic thinking. When you have finished reading the book, we ask you to return and complete it again, to compare your results and see if your perspectives have changed.

Reference

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Patrick T. Hester

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Kevin MacG. Adams

Contents

Part I A Frame of Reference for Systemic Thinking

Part II A Methodology for Systemic Thinking

Part I

A Frame of Reference for Systemic Thinking

Chapter 1
Introduction

Abstract The first step to solving a problem is recognizing you have one. It is with this notion in mind that the authors begin their discussion. This chapter begins with the first tenet of systemic thinking which we term the TAO approach, a general approach for increasing our understanding about problems. Then, a discussion of systems errors is presented. In order to mitigate these errors, we discuss the importance of observation as it pertains to making conclusions about our problems. Issues associated with observation and the effects of bias are then discussed.

1.1 The TAO Approach

As we said before, we've all got problems. Some are big, some are small. Some are fleeting, while some are nagging and persistent. All could benefit from a structured way of reasoning about them. To that end, we provide an initial perspective for reasoning that we deem the TAO approach, for **T**hink, **A**ct, and **O**bserve. The relationship between these elements is pictured in Fig. 1.1. While there are many approaches to undertaking each of these steps, this book concentrates in large part on discussing the systemic thinking approach, a method for undertaking the *Think* step.

Knowing that we have problems and more importantly, knowing that we need approaches to deal with these problems, requires us to first understand what systematic mistakes we make that may be avoided. To this end, we turn to a discussion of systems errors.

1.2 Systems Errors

As we discussed in the preface, most difficult problems can be characterized by (1) intransparency, (2) polytely, (3) complexity, (4) variable connectivity, (5) dynamic developments, (6) time-delayed effects, (7) significant uncertainty, and

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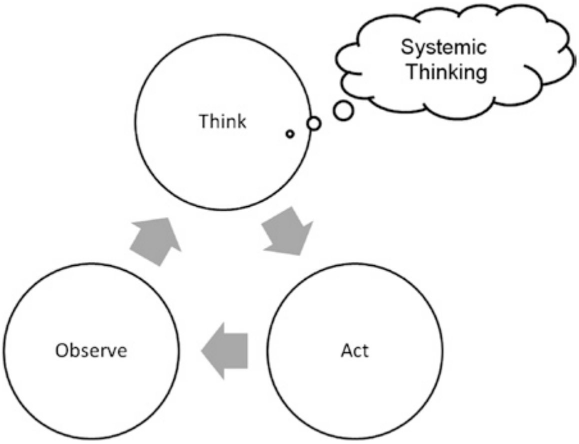

Fig. 1.1 TAO approach to reasoning

Table 1.1 Science sector and field of science that have conducted inquiry on errors (adapted from [3])

Science sector	Field of science	Reference
Social sciences	Educational sciences	Betz and Gabriel [6], Kaufman et al. [23], Marascuilo and Levin [32, 33], Onwuegbuzie and Daniel [44], Rosnow and Rosenthal [46, 47]
	Psychology	Games [13], Kaiser [22], Leventhal and Huynh [28], Levin and Marascuilo [29, 30], Meyer [34], Mitroff [36], Mitroff and Featheringham [37]
	Economics and business	Boal and Meckler [7], Umesh et al. [54]
Natural sciences	Mathematics	Kimball [24, 38,40–42], Tracz et al. [50]

(8) humans-in-the-loop. Each of these has a substantial element of human perception and interpretation. The way in which a problem is thought about, acted on, and observed is a major determinant of the degree of uncertainty, competition, and unpredictability associated with the problem context. Reasoning about a complex problem routinely employs the use of one of a number of systems-based approaches [18–20]. Analytical and interpretational errors are common while thinking about, acting on, and observing problems; however, none of these systems approaches explicitly addresses these potential errors. Further, despite their prominence, there is not an agreed-upon taxonomy for errors in problem solving approaches. Thus, the authors have worked to establish an initial taxonomy for error classification [2, 3]. This taxonomy has drawn from research performed by researchers representing four of the 42 fields of science [43], as depicted in Table 1.1.

Based on our review of the literature in Table 1.1, we were able to develop a taxonomy of seven common errors that individuals are prone to encounter while thinking about, acting on, and observing problems. For reasons that will become clear once this discussion is complete, we will not discuss the errors in numerical order; rather, we begin with discussion of the Type III error.

1.2.1 Type III Error

The extant literature on the Type III (γ) error originated in statistics. Frederick Mosteller [1916–2006], one of the most eminent statisticians of the 20th century, reported:

> In other words it is possible for the null hypothesis to be false. It is also possible to reject the null hypothesis because some sample O_i has too many observations which are greater than all observations in the other samples. But the population from which some other sample say O_j is drawn is in fact the right-most population. In this case we have committed an error of the third kind. (p. 61)

This is commonly referred to as "the error associated with solving the wrong problem precisely" [36, p. 15].

Type III errors normally occur during the formulation of problems, the phase in which the actual details surrounding the reported problem are exposed, validated and verified as part of the process of problem reformulation (reformulation is where the initial *reported* problem statement is validated by relevant stakeholders). We denote this revised problem statement the *formulated* problem, to differentiate it from the reported problem. Failure to reformulate the reported problem is the most common source for a Type III error.

Adams and Hester [2] devise a medical analogy to explain the Type III error:

> The systems practitioner faced with a reported problem needs to act much like a physician. The physician listens to the symptoms reported by a patient, but does not accept the diagnosis of the patient. The physician cannot rely solely on the patient's story and symptoms, but must gather empirical data by conducting tests, taking physiological measurements, and conducting a physical examination. The systems practitioner is in a similar professional relationship with the client that has a systems problem. Problem reformulation ensures that the scope of the problem is properly abstracted from the real-world and defined. The problem system must be adequately bounded, include empirical data of both the quantitative and qualitative types, and include an understanding of both the environment and relevant stakeholders. (p. 28)

Mitroff and Featheringham [37] elaborate on the importance of proper problem formulation.

> The initial representation or conceptualization of a problem is so crucial to its subsequent treatment that one is tempted to say that the most important as well as most difficult issue underlying the subject of problem solving is precisely 'the problem of how to represent problems.' (p. 383)

Failure to properly define the scope of the problem results in inadequate problem statements and is commonly referred to as "the error committed by giving the right answer to the wrong problem" [22]. Once we have appropriately formulated our problem (i.e., thought about it), we must decide what to do about this problem (i.e., act on it). In acting (or abstaining from action), we may encounter a number of errors, to which we now turn.

1.2.2 Type IV Error

A review of the extant literature on Type IV (δ) errors shows that this type of error has been discussed principally in the psychology and the educational sciences. To the authors' knowledge, the first mention of the Type IV error in the literature was by Marascuilo and Levin [32]. They define the Type IV (δ) error as:

> A Type IV error is said to occur whenever a correct statistical test has been performed, but is then followed by analyses and explanations that are not related to the statistical test used to decide whether the hypothesis should or should not have been rejected [33].

The primary discussion related to Type IV errors has been associated with statistical testing, most notably ANOVA models [23, 46, 47, 54]. We prefer, however, to endorse the Type IV error as one concerned with a higher level of abstraction, most notably as "the incorrect interpretation of a correctly rejected hypothesis" ([32], p. 398).

Boal and Meckler [7] elaborate on the problems caused by a Type IV error, introducing the concept of solutions as iatrongenic:

> Acting to solve a problem, be it the right problem or the wrong problem, can create other difficulties. Sometimes solutions are 'iatrogenic,' meaning that they create more, or bigger problems than they solve. Faced with such a possibility the decision maker should thoroughly examine all the potential system effects, and perhaps refrain from action. In the case that it was an attempted solution to the right initial problem, one important problem is now replaced by another, perhaps worse problem. (p. 333)

Thus, even though the problem has been correctly identified (i.e., thought about), the action identified to resolve the problem is incorrect. Further, there is potential in this situation for the identified actions to actually exacerbate the problem.

Adams and Hester [3] continue their medical analogy:

> This type of error also has a medical analogy. This could be the case where the physician commits a Type IV (δ) error by correctly diagnosing the problem and prescribes the right medication. However, the medication side-effects for a particular patient are worse than the original symptoms. The systems practitioner is prone to committing this error. The most typical instance is when the practitioner has properly reformulated and defined the client's problem and then applies an improper solution approach (i.e., methodology, method, or technique) in an attempt to resolve this problem. Failure to match the solution method to appropriate solution of a problem has been an important subject in the systems literature [4, 17, 21]. (pp. 320–321)

1.2.3 Type V Error

The Type V error, like the Type IV error, concerns actions taken in support of problem resolution. The field of cybernetics and the systems *principles of homeostasis* [8] and *homeorhesis* [55] inform individuals that systems have the ability to self-regulate to maintain a stable condition. Thus, some problems may solve themselves by simply allowing a natural order to restore itself. The converse of this is that many problems require intervention in order to be addressed and simply wishing for a problem to disappear on its own will not make it go away. There is a substantial risk in not acting when action is called for. Boal and Meckler [7] discuss this sentiment as the Type V (ε) error:

> Deciding to take no action, when no action is called for, is the correct solution. However, falsely believing that the problem will either solve itself or simply go away is an error of the 5th kind. Such errors allow the situation to linger, at best, or to fester and worsen requiring greater resources to solve. (p. 334)

In the medical analogy of this error, the physician commits a Type V error when he or she correctly diagnoses an ailment (i.e., thinks about the problem properly), yet fails to take corrective action to resolve the problem. The reason for the failure to act in this case may reside in the physician's belief that the ailment will simply resolve itself.

Causes for the Type V error are many. Lack of stakeholder consensus (e.g., the doctor, insurance company, and patient do not agree on treatment options) may lead to inaction due to the lack of a singular prevailing option, or due to a predominant stakeholder forcing an inaction strategy (e.g., the insurance company denies a request for an MRI, leading to a wait-and-see approach). Further, there may be a fundamental lack of understanding which permeates the analysis of the problem. This may lead to the stakeholders being unable to generate a plausible scenario for resolving the problem. Finally, stakeholders may fear worsening the problem by interfering. While this is a valid concern, we must weigh the balance between the Type IV and Type V errors, that is, between taking the wrong action and taking no action. Once we have acted, we must now observe the effects of our actions. In observation, there are also opportunities for committing errors.

1.2.4 Type I and Type II Errors

The extant literature on the Type I and Type II errors is founded in the mathematics (i.e., statistics) field of science, originating with Neyman and Pearson [40–42]. The Type I and Type II errors have been explored extensively in the literature associated with these fields. They are driven by discussions of statistical inference; specifically, they are motivated by the traditional two-sided hypothesis test. In such a test, there are only two possible error conditions: (1) deciding that a difference exists when, in fact, there is none (i.e., committing a Type I (α) error), and (2) deciding there is no difference when, in fact, there is a difference (i.e., committing a Type II (β) error) [22]. Table 1.2 contains a representation of and definitions for the Type I and Type II errors framed in terms of the testing of a null hypothesis, H_0.

To continue our medical analogy, there are two classic examples from the medical world of the Type I (α) and Type II (β) error, based on the premise of H_0 being the hypothesis that a person does not have a disease:

- *Type I (α) error*: A medical test indicates a person has a disease that they do not actually have.
- *Type II (β) error*: A medical test indicates a person does not have a disease that they do actually have.

Table 1.2 Type I and type II errors

	Actual condition	
Test result	H_0 true	H_0 false
Reject H_0	*Type I Error* (α) False positive	Correct action True positive
Fail to reject H_0	Correct decision True negative	*Type II Error* (β) False negative

Both of these errors typically occur after the problem has been thought about and acted on (and after practitioners hopefully have avoided committing a Type III, IV, or V error). Thus, this phase is considered to be the observation phase (observation, as we intend it, will be elaborated on later in this chapter). Another potential error of observation is the Type VI error.

1.2.5 Type VI Error

Here we introduce a Type VI (θ) error as one that is well known yet not characterized in error terms traditionally. This error is that of unsubstantiated inference. Succinctly, Holland [16] states famously, "Correlation does not imply causation…" (p. 945). Given two variables, A and B, we can measure the strength of the relationship between these variables, known as their correlation. If we continue our medical analogy, denoting A as the number of tests taken to diagnose an illness and B as money spent on treatment, then we see what is termed a positive correlation between these two variables, meaning that the more tests that are performed, the more money that is spent. We can now change B to money remaining in your bank account. As additional tests are ran, assuming they are being paid for by you, your bank account balance decreases, indicating a negative correlation. The correlation coefficient measures the strength of the relationship between these two variables.

Causation is not as straightforward, however, and it is often erroneously taken as a given when correlation is present. For example, if we have two additional events, (1) a man receives a positive test for a given disease (A) and (2) his brother receives a positive test for the same disease (B), we may be able to establish correlation. However, inferring that A caused B or B caused A is faulty, unless we have information (more specifically, observations) that corroborates this assumption, e.g., the disease in question is a blood-borne disease and the brothers admit to sharing needles during drug use. In this case, we might be able to establish causality. More often than not, however, our notion of causality is simply conjecture. This behavior represents the Type VI error. In fact, there are four possible outcomes for any two correlated variables, A and B:

1. A could cause B.
2. B could cause A.

3. An additional third variable, C, could be contributing to the change in both A and B.
4. It may simply be a coincidence that the two events have a correlation.

We must be careful not to infer causality regarding A and B in an effort to explain unknown phenomena. Establishing causality requires significant observation and should not be done erroneously.

1.2.6 Type VII Error

A Type VII (ζ) error occurs when errors of Types I–VI compound to create a larger, more complex problem than originally encountered. Boal and Meckler [7] elaborate on the nature of Type VII errors:

> …the resulting problem may no longer be recognizable in its original form. The problems are not easily diagnosable, the resources and choices available become less sufficient or desirable, the solution is not readily apparent, and the solution not so attainable. (p. 336)

Complex systems problems that are open to multiple errors may be referred to as messes [1] and are in sharp contrast to those denoted as *tame* by Boal and Meckler [7]. It is the Type VII error that we must truly be concerned about. Complex problems are further exacerbated by committing a Type VII error, a "system of errors" ([2], p. 30) to complement Ackoff's characterization of messes as "systems of problems" ([1], p. 100).

Adams and Hester [2] complete their medical analogy by discussing this error:

> …a Type [VII] error can be conceived as one that first involves a physician diagnosing an incorrect problem for a patient, perhaps due to incorrect information provided by the patient (thus committing a Type III error). Let's suppose for the sake of argument that the patient is uninterested in receiving a true diagnosis of his symptoms as he fears grave news from the physician, so he downplays his symptoms. Given this incorrect (and underemphasized) problem, the physician decides to take no action to a problem otherwise requiring action (thereby committing a Type V error). His reasoning, based on the information he's received, is that the problem will go away on its own. The problem, untreated, worsens, thereby resulting in an inoperable condition, such as the progression of a benign cancer to a stage at which treatment is unavailable. Clearly, this system of errors has exacerbated the original in a form unimaginable by the original stakeholders (i.e., the patient and physician). (p. 30)

1.2.7 Analysis of Errors

We have discussed seven classifications of errors that may be experienced while thinking about, acting on, or observing a problem. A taxonomy of the seven systems errors is presented in Table 1.3.

Recalling the TAO approach, we can see when individuals may be prone to these errors. *Thinking* is prone to the Type III error, *acting* to the Type IV or V

Table 1.3 Taxonomy of systems errors (adapted from [2])

Error	Definition	Issue
Type I (α)	Rejecting the null-hypothesis when the null-hypothesis is true	False positive
Type II (β)	Failing to reject the null-hypothesis when the null-hypothesis is false	False negative
Type III (γ)	Solving the wrong problem precisely	Wrong problem
Type IV (δ)	Inappropriate action is taken to resolve a problem as the result of a correct analysis	Wrong action
Type V (ε)	Failure to act when the results of analysis indicate action is required	Inaction
Type VI (θ)	Inferring causation when only correlation exists	Unsubstantiated inference
Type VII (ζ)	An error that results from a combination of the other six error types, often resulting in a more complex problem than initially encountered	System of errors

error, and *observation* to the Type I, II, or VI errors. In order to correctly address a problem, all of these errors must be avoided as follows:

1. The Type III error must be overcome; that is, the correct problem must be formulated. This is, in large measure, the focus of this book. *Thinking systemically* about a situation allows us to ensure we have formulated the correct problem for action and observation.
2. Once we have thought systemically about our problem, we must now act (or not). This offers the opportunity for three possible outcomes:
    a) We act incorrectly, when action is warranted (committing a Type IV error).
    b) We fail to act, when action is warranted (committing a Type V error).
    c) We act correctly, when action is warranted (committing no error).
    Thus, we must choose the appropriate course of action for a particular problem, given that choosing not to act is also a feasible choice. This can only be achieved if we first think systemically about our problem, ensuring our ensuing actions appropriately address the problem we are dealing with.
3. Finally, we must observe the effects of our actions (or lack thereof). This must include consideration of avoiding the Type I and Type II errors by conducting appropriate statistical analyses and making appropriate conclusions based on these analyses. Further, we must avoid the Type VI error by ensuring our conclusions are supported by evidence and not by conjecture. More on this observation process is presented in the next section.

To illustrate the potential interaction of these errors with the TAO approach, Table 1.4 illustrates the TAO approach applied to reasoning about a disease.

The timeline in Table 1.4 can continue, ad infinitum. That is, you may continue to think, act, and observe with respect to your headache problem. This series of steps is shown graphically in Fig. 1.2 in a manner adapted from Boal and Meckler [7] and (Adams and Hester [2, 3]), but focused on the probabilities associated with

Table 1.4 Example TAO timeline and potential errors

TAO stage	Situation description	Potential error(s)
Think	Recurring headaches cause you to try to figure out their source. Lacking an obvious environmental trigger, you decide to make an appointment to see your primary care provider	Type III
Act	You make an appointment with your doctor based on your thinking	Types IV, V
Observe	Your doctor observes you, asks you questions, and collects information	Types I, II, VI
Think	Based on the information provided and their own perspectives, the doctor reasons about your condition	Type III
Act	The doctor, with your consent, agrees to schedule you for an MRI	Types IV, V
Observe	Your insurance company collects the request from your doctor, and considers it in concert with your medical history. Given your lack of prior concerns and lack of current evidence, the insurance company denies your claim	Types I, II, VI
Think	Given the reduced options available, your doctor thinks about your situation. Your doctor suggests you go home and start an activity log to keep track of your food, sleep, and activity habits to identify any underlying patterns	Type III
Act	You maintain your activity log for two weeks	Types IV, V
Observe	You return to the doctor and the doctor observes your activity log, making recommendations based on the results (to include a second attempt at securing insurance approval for an MRI)	Types I, II, VI
And so on…	You can continue to think, act, and observe. Even though the problem may seem resolved (i.e., your headaches go away), there is likely to be an implicit recognition of the danger of their recurrence. Thus, you may devote brain power to the awareness of their presence, no matter how distant they are in memory. The problem, as you see it may evolve from "How can I make these headaches go away?" to "How can I ensure these headaches do not return?"	Types I–VII

particular paths available to an individual. It is worth noting that Type VII errors are represented by the different error combinations presented in Fig. 1.2 (i.e., a Type III error followed by a Type I error). Note that P(α), P(β), P(γ), P(δ), P(ε), P(θ), and P(ζ) represent the probability of a Type I-VII error, respectively.

Note that the shaded boxes represent the only scenario in which no errors are committed. It is easy to see, qualitatively, how prone we are to errors based purely on the number of opportunities for us to commit one (or more) errors. Combining these error probabilities together, we can devise an equation for the calculation of the probability of a correctly addressed problem. This can be computed as shown in (Eq. 1.1).

$$P(correctly\,addressed\,problem) = 1 - [[1 - P(\gamma)][1 - (P(\delta) + P(\varepsilon))]\\ [1 - (P(\alpha) + P(\beta) + P(\theta))]] \tag{1.1}$$

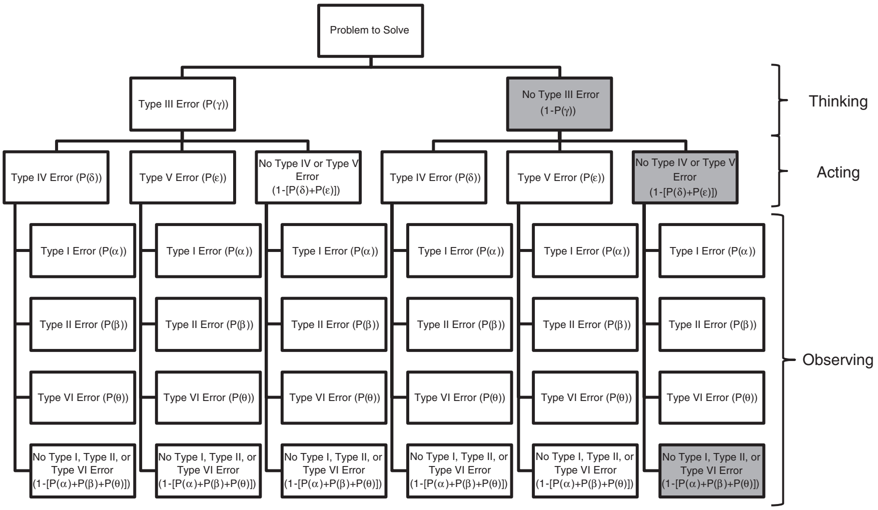

Fig. 1.2 Tree depiction of systems errors

Correctly addressing a problem requires that we think about, act on, and observe the situation appropriately, thus, we do not commit any Type I-VI (and, by definition, Type VII) errors. While we can calculate $P(\alpha)$ and P(β) in a very straightforward manner, the remaining quantities are more difficult, if not impossible, to discern. It is more important to understand that errors are serial; thus, our approach to understanding is only as strong as its weakest link, be it in our thinking, acting, or observation. Committing any error drastically reduces the likelihood that we correctly addressed our problem. Thus, we must be diligent in addressing each of these errors.

1.3 Observation

Here we elaborate on the notion of observation as it pertains to the TAO process and to systemic thinking in general. Observation is the central source of knowledge gained from exposure to the real world. This is true whether the knowledge is being generated in a controlled laboratory or in a natural setting.

> Observation is being understood in a very broad way here, to include all kinds of sensory contact with the world, all kinds of perception [14, p. 156].

Observation is the operation where raw sensory inputs are filtered by the human thought process. The physiological capacity for sensory perception in humans is limited by the five senses: (1) hearing, (2) sight, (3) smell, (4) taste, and (5) touch. Over time, raw perceptions are converted by the human thought process and begin

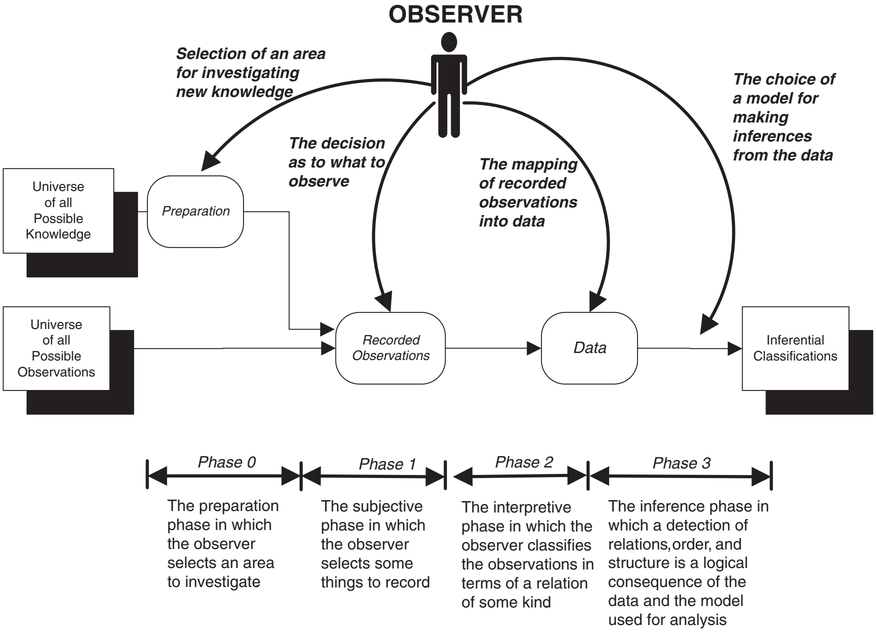

Fig. 1.3 Flow diagram of observable to inference

to form impressions, which are stored for future use. Stored impressions and their relationships with one another are formed into constructs that permit the individual to develop more complex implications and associations from the sensory inputs.

In a literature too vast to summarize here, theorists have argued that observation is already cognition and that we cannot describe a fact without implying more than the fact. As a result, Clyde H. Coombs [1912–1988] proposed that the term *data* be used for observations already interpreted in some way. The diagram in Fig. 1.3 depicts the scope of Coombs' [9] theory of data.

Figure 1.3 depicts how an observer's interpretation of the universe of all possible observations can lead to logical inferences as a result of four distinct phases conducted during the process of observation. The graphic has additional importance when considered with the following statement from Coombs [9] pertaining to those phases after Phase 0:

> The scientist enters each of these three phases in a creative way in the sense that alternatives are open to him and his decisions will determine in a significant way the results that will be obtained from the analysis. Each successive phase puts more limiting boundaries on what the results might be. At the beginning, before phase 1, there are perhaps, no limits on the potential conclusions; but each phase then constrains the universe of possible inferences that can be ultimately drawn from the analysis. (p. 5)

It is important to note that the observer depicted in Fig. 1.3 directly influences the data in many ways. Table 1.5 provides a glimpse of the how the observer influences the observations during the four phases and associated stages.

Table 1.5 How and where an observer exhibits influence during observation

Phase	Stage	Description
0—preparatory	Knowledge area	Selection of an area for investigating new knowledge
	Preparation	Preparatory reading in the area's existing body of knowledge
1—subjective	Selection	Selection of things to observe
	Method	The sensors and methods used to record and measure the observation
2—interpretive	Analysis	The observer interprets the data
	Classification	The observer classifies the observations
3—inferential	Inference	The observer makes an inference based on the order structure and model used in analysis and classification
	Publication	The observer reports the interpretation of the new knowledge

Table 1.5 demonstrates that the potential to influence observations is problematic and must be mitigated during the conduct of all research and problem solving efforts. Thus, in terms of the stages of observation and their relation to our systems errors, we must be careful to avoid the Type I and II errors in Phase 2 and the Type VI error in Phase 3.

This leads the discussion to the notion that all observation is impacted by the observer's personal beliefs in what is termed *theory-laden observation.*

1.3.1 Theory-Laden Observation

Based upon the notion that observation has already been subjected to analysis, a number of major scholars in the field of Philosophy of Science have argued that observation is theory-laden [12, 26]. Specifically,

> Observation cannot function as an unbiased way of testing theories (or larger units like paradigms) because observational judgments are affected by the theoretical beliefs of the observer [14, p. 156].

Paul K. Feyerabend [1924–1994] [12] cautions all observers of empirical data to separate the observation from the consequent description:

> We must carefully distinguish between the 'causes' of the production of a certain observational sentence, or the features of the process of production, on the one side, and the 'meaning' of the sentence produced in this manner on the other. More especially, a sentient being must distinguish between the fact that he possesses certain sensation, or disposition to verbal behavior, and the interpretation of the sentence being uttered in the presence of this sensation, or terminating this verbal behavior. (p. 94)

Many theories and models exist for further reading into awareness, observation, and cognition. While this subject area is beyond the scope of this text, the reader is referred to literature on situation awareness [11], the recognition-primed decision (RPD) model [25], and gestalt psychology [10] for further guidance on the topic. We turn to the Dynamic Model of Situated Cognition as one model for observation.

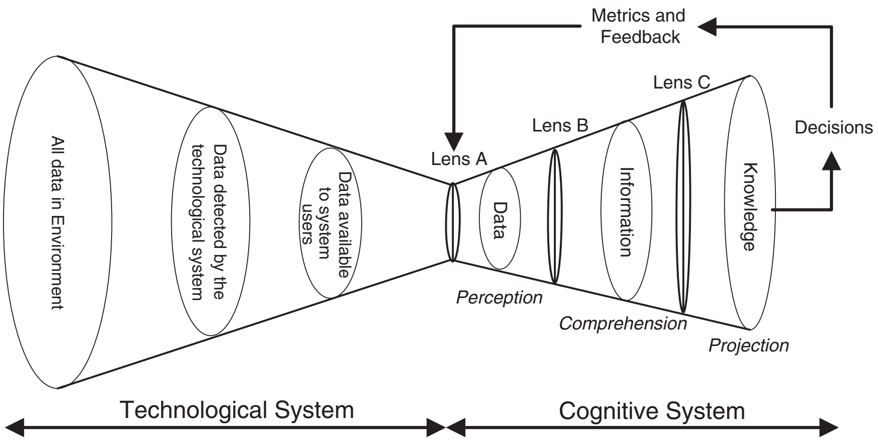

Fig. 1.4 The dynamic model of situation cognition

1.3.2 Dynamic Model of Situated Cognition

The theory-laden observation process must involve consideration of both technological and human elements and can be thought of as residing within a larger construct. A model to describe this observation process is the Dynamic Model of Situated Cognition (DMSC), which captures both the human and technological components of systems in a single model that depicts how observation is influenced by a variety of agents [35, 49]. Figure 1.4 is our depiction of the DMSC, that aligns the terminology of Miller and Shattuck to be consistent with Coombs and ours'; specifically, Coombs' central thesis was that *data* are recorded observations that have already been subjected to analysis.

The final output of the DMSC is used to make decisions, which are then measured with metrics and then used as feedback to the system. The key insight from Fig. 1.4 is a graphical representation of the observation to decision process. In translating observations to usable data, we intentionally (and unintentionally, based on our own perceptions and technological limitations) remove observations from consideration, as all observation is theory-laden and influenced by our human biases.

1.3.3 Measurement

Good science is based upon four generally accepted criteria that ensure quality: (1) truth value, (2) applicability, (3) consistency, and (4) neutrality [31]. The third criterion addresses the consistency in the generation of knowledge and establishes guidelines for ensuring consistency and stability during generation (i.e., design and technique), of new knowledge. The ability to accurately repeat observations, independent of the original observer, is an essential element. The requirement for independent reproducibility ensures that observations by different observers are comparable. Because the physiological capacity for input perception in humans is subjective and qualitative (i.e., the five senses react differently from human to human) this makes them difficult to record and hence, compare.

The concept for measurement evolved to permit different human observers to record and compare observations made at different times and places. Measurement consists of using observation to compare the real-world phenomena being measured to an established standard which can be reliably reproduced for use by multiple, independent observers. Measurement's goal is to reduce an observation to a discrete measure which can be recorded and used as the basis for comparison with other measures.

Quality criterion such as reproducibility may be invoked through the use of formal methods and measurement. However, the nagging issue and difficulties generated by the presence of theory-laden observation must be addressed by an understanding of how bias is introduced into the process. This leads the discussion to the mitigation of bias as an element of personal beliefs during observation.

1.3.4 Bias and Heuristics

Our ability to observe is affected, both negatively and positively, by our own biases and heuristics. First, we discuss bias, defined as:

> Any process at any stage of inference which tends to produce results or conclusions that differ systematically from the truth [48, p. 60].

Bias may be introduced during each and every stage and phase depicted in Fig. 1.3. As a result, the observer must ensure that the process depicted in Fig. 1.3 provides reasonable controls that mitigate bias.

> The difficulties generated for scientific inquiry by unconscious bias and tacit value orientations are rarely overcome by devout resolutions to eliminate bias. They are usually overcome, often only gradually, through self-corrective mechanisms of science as a social enterprise [39, p. 489].

Part of understanding how to mitigate human bias requires knowledge of the source and major types of unconscious bias. Because all human beings have unintentional cognitive biases that affect their decision making, knowledge of the types of bias may help improve their detection and elimination. Cognitive biases include behaviors that are labeled *heuristics*. Table 1.6 lists a variety of definitions for the term heuristic.

The unintentional biases and heuristics that operate at the subconscious level are the most difficult to prevent. The sections that follow will provide a short discussion of major heuristics and how to mitigate their effect.

Table 1.6 Definitions for heuristic

Definition	Source
A heuristic is a procedure for achieving a result which does not consist simply in applying certain general rules which are guaranteed to lead to the result in question	[45, p. 165]
A rule or solution adopted to reduce the complexity of computational tasks, thereby reducing demands on resources such as time, memory, and attention	[5, p. 379]
Heuristics are 'rules of thumb' that are used to find solutions to problems quickly	[27, p. 242]

1.3.4.1 Availability Heuristic

The availability heuristic refers to the practice of basing probabilistic evidence on an available piece of information from one's own set of experiences [51, 52]. That is to say, humans estimate the likelihood of an event based on a similar event that they can remember, which is by definition, from a biased and unrepresentative sample in their memory. Further, since newer events provide greater saliency in one's mind, they influence an individual's reasoning to a larger degree than do older events. Additionally, events with unusual characteristics stand out in one's mind (i.e., you don't remember the hundreds of times you went to a given restaurant, but you definitely remember the time you got food poisoning). Furthermore, humans may be biased based on the retrieval mechanism that is utilized to obtain the experience from their memory. Depending on who is asking the question, for example, an individual may consciously or unconsciously block memories. In order to mitigate this problem, observers should include mechanisms that account for how their experiences bias the data they retrieve about a particular set of observations.

1.3.4.2 Representativeness Heuristic

The representativeness heuristic refers to the phenomena when individuals assume commonalities between objects and estimate probabilities accordingly [52]. The determination of similarity between objects is typically performed by comparing their known attributes. Individuals compute a running tally of matches versus mismatches and then estimate whether or not the item fits a category based on the total. Once the item is categorized, automatic category-based judgments are made about the member item. Using this type of analysis has its issues. To combat this bias, individuals must use base rates (i.e., unconditional, or prior, probabilities) to compare the underlying category probability versus the specific scenario. Then, the base rate can be adjusted to accurately reflect the specific scenario's characteristics (i.e., its conditional factors).

It should be noted that availability and representativeness are often confused, but they are not the same phenomenon. With availability, individual instances are retrieved and a judgment concerning the frequency of the item is made based on the item's saliency and ease of information retrieval. Alternatively, representativeness involves retrieving information about generic concepts and then a similarity match is made between the item in question and a proposed category. The category association, along with goodness-of-match or degree of similarity, produces confidence or a frequency estimate.

1.3.4.3 Conjunction Fallacy

Another bias that individuals may be prone to is the conjunction fallacy [53]. Tversky and Kahneman [53] introduce this phenomenon with the following example: Linda is 31, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice and also participated in antinuclear demonstrations. Is she more likely to be (a) a bank teller, or (b) a bank teller and active in the feminist movement?

The overwhelming majority of survey respondents answered *b*, despite the fact that *b* is more restrictive (and therefore less probable) than *a*. People report the more complicated scenario as being *more real* or that it *made more sense*. The conjunction fallacy is counteracted by analyzing individual event probabilities and then combining them.

1.3.4.4 Anchoring and Adjustment Heuristic

Another bias is the anchoring and adjustment heuristic [51]. Humans establish anchors as starting points for their judgments and base subsequent observations on the initial value that was provided to them. In other words, early values will be given higher weights than subsequent values and as such will serve as *anchors* for future analysis. Anchors tend to bias future information that is sought and included in one's analysis. The status quo is a powerful anchor. It is often easier for individuals to take an existing value and adjust it to their specifications. The anchoring and adjustment effect can be either beneficial or detrimental and may be combated by independently generating values prior to the observation of values in the real-world.

1.3.4.5 Recognition Heuristic

The recognition heuristic refers to the heuristic by which an individual selects an alternative that is the most familiar to them [15]. While it seems to be a fundamentally unsound approach to decision making, Goldstein and Gigerenzer [15] discovered experimentally that this approach often outperforms more rigorous approaches to decision making. It can be useful for *on the fly* decision making in inconsequential scenarios such as deciding on a restaurant while on a road trip based on restaurants you recognize (e.g., McDonald's or Subway) or buying a pair of shoes based on brands that you've worn in the past and know to be reliable (e.g., Nike or Adidas). However, this approach has both positive and negative effects and should be avoided in conducting empirical observations.

1.4 Summary

Complex problems demand approaches that can account for their inherent complexity, rather than ignore it and hope it goes away. That is the underlying premise of this book. To that end, this chapter introduced the TAO approach to thinking systemically about a problem. We then discussed a taxonomy for errors that we are prone to when seeking increasing understanding. We continued with a discussion of observation and its importance in mitigating errors. Finally, we discussed biases and heuristics and their effect on observation.

After reading this chapter, the reader should:

1. Understand the TAO approach;
2. Have an appreciation for errors and how to avoid them; and
3. Understand how to conduct bias-free observation.

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Chapter 2
Problems and Messes

Abstract As problems have evolved from simple systems to complex systems, so too must the methods we use to address them. However, machine age problems, consisting of simple systems, have traditionally been viewed from a largely technical perspective. In systems age complex problems, a predominantly technical perspective continues to be used at the expense of other complementary perspectives. Complex problems have been viewed, and hence, addressed, with a single predominant lens which has often been unsuccessful in solving many ill-structured, wicked, or messy problems. The development of multiple perspectives requires those faced with solving complex problems to include additional perspectives in order to achieve understanding. This includes the integration of hard and soft perspectives to ensure that, in addition to the technical perspective, the equally important organizational, political and human perspectives have been included. The application of multiple perspectives offers a more inclusive framework through which complex problems may be viewed. The integration of technical, organizational, political and human perspectives widens the aperture through which a problem is analyzed, which then increases the probability of correctly addressing ill-structured, wicked, and messy problems. Embracing these complementary perspectives, guidance is given on how to begin to decompose our mess into a number of discrete problems for analysis.

2.1 Introduction to Complex Problems

This section will give a brief historical background for the emergence of the systems age and how problems in the systems age are differentiated from those in the machine age.

P. T. Hester and K. M. Adams, *Systemic Thinking*, Topics in Safety, Risk, Reliability and Quality 26, DOI: 10.1007/978-3-319-07629-4_2,

2.1.1 Historical Background for Complex Problems[1]

The genesis for most approaches for handling ill-structured, wicked, or messy problems has been attributed to the increase in the complexity of these problems. Early pioneers in the systems field[2] emphasized increasing system complexity as the principal driver for new approaches, although they recognized that this was far from a complete explanation [10, 11]. To explain this, some historical background is warranted.

Problem solvers have been approaching complex problems using a predominantly technical perspective since the advent of large-scale systems in the fledgling radio, television, and telephone industries in the United States during the 1930s. This was a result of the recognized need for an approach to deal with problems encountered during the development of modern telecommunications services. The Radio Corporation of America (RCA) and its subsidiary, the National Broadcasting Company (NBC), were interested in the expansion of their television broadcast domain. At the same time, the Bell Telephone Company was interested in the expansion of their long-distance telephone network. Both companies initiated technical studies aimed at increasing their markets through the use of new broadband technologies that were beginning to emerge in the early 1940s. Most of the exploratory studies and experimentation in the commercial sector were interrupted by the Second World War.

During the Second World War, the American military used large numbers of scientists and engineers to help solve complex logistical and strategic bombing problems related to the war effort. Many of these efforts made significant contributions to the philosophy and techniques of what was then called Operations Research. At the same time, the need for many novel types of electronic gear for airborne use gave rise to a wide variety of component devices, popularly known as *black boxes*. "These were ingenious devices, but their application in terms of the entire system of which they were merely parts was a matter of improvisation" [10]. Inevitably, many of the engineers and scientists working on these *black boxes* were required, by necessity, to look ahead to the ultimate goal—the system. When the war ended, a number of corporations (most notably the RAND Corporation, the Bell Telephone Laboratories, and RCA) hired much of this pool of talented scientists and engineers to provide services to both the government and the telecommunications industry. These seasoned practitioners were able to capitalize upon the lessons from their war-time experiences in the development and implementation of the modern telecommunications and electrical power systems. The telecommunications system development efforts provided an impetus for much of the early literature on systems approaches [11, 12].

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[1] Much of this information comes from a conference paper by Adams and Mun [5].

[2] The early systems field included operations research, systems analysis, and systems engineering.

Table 2.1 Ackoff's machine age and systems age characteristics

	Machine age	Systems age
Description	Simple system	Complex system
Boundary	Closed	Open
Elements	Passive parts	Purposeful parts
Observable	Fully	Partially
Method of understanding	Analysis and reductionism	Synthesis and holism

2.1.2 The Machine Age and the Systems Age

Russell Ackoff [1919–2004, 1] used the terms *machine age* and *systems age* to refer to eras that were concerned with two different types of systems problems. The machine age was concerned with simple systems, and the systems age is concerned with complex systems. Table 2.1 contrasts the most basic characteristics of the machine and systems ages.

Ackoff [2] recognized that the technical perspective of the machine age was inadequate for coping with what he termed the *messy* situations present in the systems age, where human activity systems were predominant. Ackoff coined the concept of a *mess* and *messes* in 1979 when he used the idea in two papers where he was arguing that operational research was passé and that a more holistic treatment of systems problems was required [2, 3]. He foresaw that a wide variety of disciplines would be necessary to solve systems problems. Ackoff's [2] definition of a mess and messes is worthy of review:

> Because messes are systems of problems, the sum of the optimal solutions to each component problem taken separately is not an optimal solution to the mess. The behavior of the mess depends more on how the solutions to its parts interact than on how they interact independently of each other. But the unit in OR is a problem, not a mess. Managers do not solve problems, they manage messes. (p. 100)

The bottom line is that complex problems in the real-world must include a definition of human activity in the development of the contextual framework for the problem. For Ackoff [2], context was the essential element that modern systems age problem solvers would need to include in each problem formulation if complex systems were to be understood and later resolved. He argued that the utility of operations research had been diminished because most of the established machine age techniques were unable to account for the complexity caused by humans that were present in almost all systems age problems. Burrell & Morgan [8] support Ackoff's contention, stating:

> Mechanical models of social systems, therefore, tend to be characterized by a number of theoretical considerations and are thus of very limited value as methods of analysis in situations where the environment of the subject is of any real significance. (p. 61)

In short, the methods and techniques of traditional operations research are "... mathematically sophisticated but contextually naïve and value free" [14]. Ackoff's work established the need for a clear understanding of specific or relevant context as fundamental to understanding and analyzing systems age problems.

Additional support for Ackoff's notions was provided by Nobel laureate Herb Simon [1916–2001] who addressed what he labeled the *ill-structured problem*. Simon [23] states that "an ill-structured problem is usually defined as a problem whose structure lacks definition in some respect" (p. 181). A systems age problem is ill-structured when circumstances and conditions surrounding the problem are potentially in dispute, not readily accessible, or lack sufficient consensus for initial problem formulation and bounding. There may be multiple and possibly divergent perspectives or worldviews, rapidly shifting and emergent conditions that render stable solution methods innocuous, and difficulty in framing the problem domain such that the path forward can be engaged with sufficient alignment of perspectives to remain viable. Rittel and Webber [20] termed this a *wicked problem*, where:

> The information needed to understand the problem depends upon one's idea for solving it. That is to say: in order to describe a wicked-problem in sufficient detail, one has to develop an exhaustive inventory of all conceivable solutions ahead of time. The reason is that every question asking for additional information depends upon the understanding of the problem—and its resolution—at that time. Problem understanding and problem resolution are concomitant to each other. Therefore, in order to anticipate all questions (in order to anticipate all information required for resolution ahead of time), knowledge of all conceivable solutions is required. (p. 161)

The immediate result of a wicked problem is the questionable ability of traditional approaches based upon a single technical perspective to be successful.

2.2 Dealing with Systems Age Messes

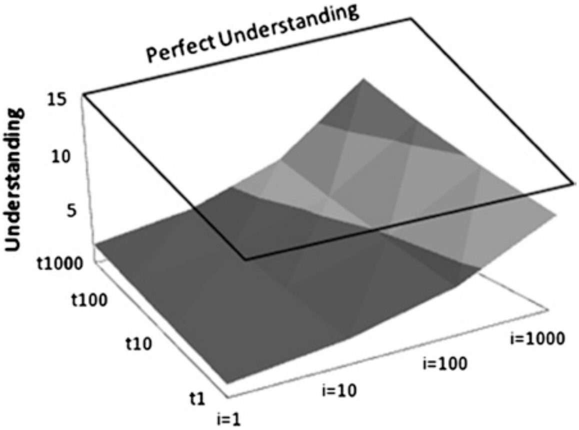
Most systems age messes include those factors we identified in the preface, namely (1) intransparency, (2) polytely, (3) complexity, (4) variable connectivity, (5) dynamic developments, (6) time-delayed effects, (7) significant uncertainty, and (8) humans-in-the-loop. From our point of view, it seems reasonable to assume that the way in which a systems age mess is perceived by its solution participants is a major determinant of the degree of these factors that each of the solution participants is able to clearly identify as part of the problem analysis.

2.2.1 Perspectives in Complex Problems

Because there is not a single true reality or correct perspective of any systems age problem, the systems *principle of complementarity* [7] must be applied. The principle simply states:

> Two different perspectives or models about a system will reveal truths regarding the system that are neither entirely independent nor entirely compatible.

Fig. 2.1 Depiction of increased understanding as a function of Time (t) and Perspectives (i)



If we think of a perspective as the state of one's ideas or the known facts, then we can represent the world-view of the observer as a function of the number (i) of perspectives (P_i) utilized to represent the problem under study. Equation 2.1 [4] is a mathematical representation of contextual understanding for a limited number of perspectives (n).

$$Contextual\ Understanding = \sum_{i=1}^{n} P_i \tag{2.1}$$

Perfect understanding requires complete knowledge of the infinite number of perspectives, a fact that problem solvers struggle to control when bounding messy, ill-structured, or wicked problems. Equation 2.2 [4] is a mathematical representation of perfect understanding.

$$Perfect\ Understanding = \sum_{i=1}^{\infty} P_i \tag{2.2}$$

A depiction of these concepts is shown in Fig. 2.1. This figure shows that as both time (t) and the number of perspectives increases, our understanding increases dramatically. Perfect understanding (i) is depicted as a plane that we attempt to attain but cannot reach no matter how much time passes or how many perspectives we consider.

Because, by definition, our scope of perspectives is limited, we can never have perfect understanding, and thus, we must strive to increase the value of our contextual understanding.

Table 2.2 Attributes of hard and soft systems approaches [4, p. 167]

Attributes	Hard systems view	Soft systems view
World view	A real world exists external to the analyst	Perspectives of reality are dynamic & shifting
Data	Factual, truthful and unambiguous data can be gathered, observed, collected, and objectively analyzed	Data is subjective in collection and interpretation—analysis strives for transparency
System	The system in focus is unaffected by either the analysis or the analyst	The system in focus is affected by both the analysis as well as the analyst
Analysis results	The results of analysis are replicable	Results of analysis are *credible* and capable of compelling *reconstruction*
Value	The analysis can be conducted free of value judgments	The analysis and interpretation of analysis is value-laden
Boundaries	The system in focus can be bounded and the analysis can be controlled—this is both possible and desirable	Bounding of the system in focus is problematic, control of the analysis is questionable—emergence is dominant

2.3 Holistic Understanding

Holistic understanding of systems age messes requires problem solvers to formally account for elements contained in both hard and soft approaches to complex problems. A hard system perspective includes notions such as objectivity, unitary viewpoints, and quantitative assessment, while a soft systems perspective evokes subjectivity, pluralistic perspectives, and qualitative assessments. The attributes of the hard and soft systems approaches are depicted in Table 2.2.

The contrast between the views represented by the soft and hard systems approaches leads to significantly different perspectives of the problems encountered by the problem solver or problem solving team. The soft perspective considers organizational, managerial, policy, political, and human factors, while the hard perspective tends to deal with only technical elements, those that can be reduced to objective measures. The hard perspective is more appropriate as a standalone approach for dealing with machine age problems concerned primarily with technical solutions, whereas the soft perspective is more concerned with social systems, ones that are primarily devoid of technical considerations. Figure 2.2 shows how both approaches contribute to the development of understanding for systems age messes. Messes occur at the intersection of these two perspectives and thus, require both a soft and hard perspective to be considered in order to achieve an appropriate level of understanding.

The most fundamental, and therefore first, step in achieving a holistic understanding of a mess is to first formulate its constituent problems in a manner that is conducive to further exploration.

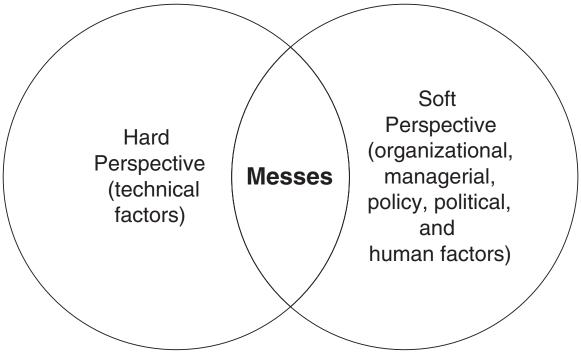


Fig. 2.2 Messes as the intersection between hard and soft perspectives

2.4 Problem Formulation

It's one of the most fundamental questions we are routinely faced with and yet one of the most vexing—*what's the problem*? In order to begin a discussion of *problems*, we first define what we intend when we use the term. A problem is "an undesirable situation or unresolved matter that is significant to some individual or group and that the individual or group is desirous of resolving" [22, p. 232]. Sage [22] goes on to define four basic characteristics of problems:

> 1. There is a detectable gap between a present state and a desired state, and this creates a concern.
> 2. It may be difficult to bring about concordance between these two states.
> 3. This situation is important to some individual or group.
> 4. The situation is regarded as resolvable by an individual or group, either directly or indirectly. Solving a problem would constitute a direct resolution. Ameliorating or dissolving a problem, by making it go away, is an indirect resolution of a problem. (p. 232)

Newell et al. [18], studying problem solving and formulation, define a problem more succinctly as existing "whenever a problem solver desires some outcome or state of affairs that he does not immediately know how to attain" (p. 1). This perspective motivated their work in developing a General Problem Solver, their attempt to generate a universal problem solving computer algorithm. This work introduced the notion of means-ends analysis, whereby a goal is established (this can be thought of as Sage's notion of a desired state) for a situation. This desired state is contrasted with a current state. Your problem represents your difference, or delta, between the two. If your current state is equal to your desired state, then you don't have a problem. Newell et al. [18] provide a simple example which explains means-ends analysis:

> I want to take my son to nursery school. What's the difference between I have and what I want? One of distance. What changes distance? My automobile. My automobile won't work. What's needed to make it work? A new battery. What has new batteries? An auto repair shop. I want the repair shop to put in a new battery; but the shop doesn't know I need one. What is the difficulty? One of communication. What allows communication? A telephone…And so on. (pp. 8–9)

The universe of acceptable decisions available to you to move from your current state to desired state is your *problem space*. This problem space may include several intermediate steps which each move the current state incrementally closer to your desired end state. Identification of the delta between our current and desired states is a useful and practical means for us to articulate our problem. Readers interested in more on means-ends analysis, problem solving computer algorithms, and early developments in artificial intelligence are referred to Newell and Simon [19].

Even knowing these basic characteristics doesn't make problem formulation any easier. It is not a straightforward endeavor, for many of the reasons we've talked about so far, e.g., any time we have multiple divergent perspectives, the complexity of our situation increases substantially. Vennix [24] agrees, stating of messy problems:

> One of the most pervasive characteristics of messy problems is that people hold entirely different views on (a) whether there is a problem, and if they agree there is, and (b) what the problem is. In that sense messy problems are quite intangible and as a result various authors have suggested that there are no objective problems, only situations defined as problems by people. (p. 13)

As such, problem identification is not trivial. Further, the question of problem identification can have different levels of importance depending on the situation that we are facing—discerning that our stomach pains are really appendicitis likely is more important than choosing what we will have for dinner, and yet both situations may be perceived to meet Sage's four criteria. Indeed, problems are omnipresent and, often times, overwhelming.

To assist individuals in dealing with their problems (or more appropriately, their messes), we suggest modern approaches to reductionist problem solving are insufficient, not because they suggest we decompose a problem, but because, after analysis of this singular problem, they often ignore the reintegration of this problem into the context of which it is a part. Just like no man is an island, no problem exists in isolation. Our appendicitis problem must also consider insurance, transportation to the doctor, family history, alcohol and drug use, and diet, while our dinner choice must consider our finances, social obligations, fellow diners, availability of cuisine, and time constraints.

After problem-centered analysis, all conclusions concerning problem understanding must be considered as part of a coherent whole in order to holistically reason about our mess, as shown in Fig. 2.3. Thus, we suggest, during the thinking stage of the TAO approach, first articulate a mess as best as possible by identifying problems associated with it (there are five shown in Fig. 2.3, with two being grayed out, suggesting either they weren't identified or purposefully chosen to be ignored for the purposes of the analysis). Each of the selected problems (P_1–P_3 in the case of Fig. 2.3) is then analyzing using the methods detailed in Chaps. 5–10. These perspectives are then reintegrated as detailed in Chap. 11, in order to provide for understanding at the mess level. This increased understanding acts as an input to the act and observe stages of the TAO approach.

Thus, within the thinking step of the TAO approach, we begin by asking the most fundamental initial question, namely, *What problems are we trying to solve*?

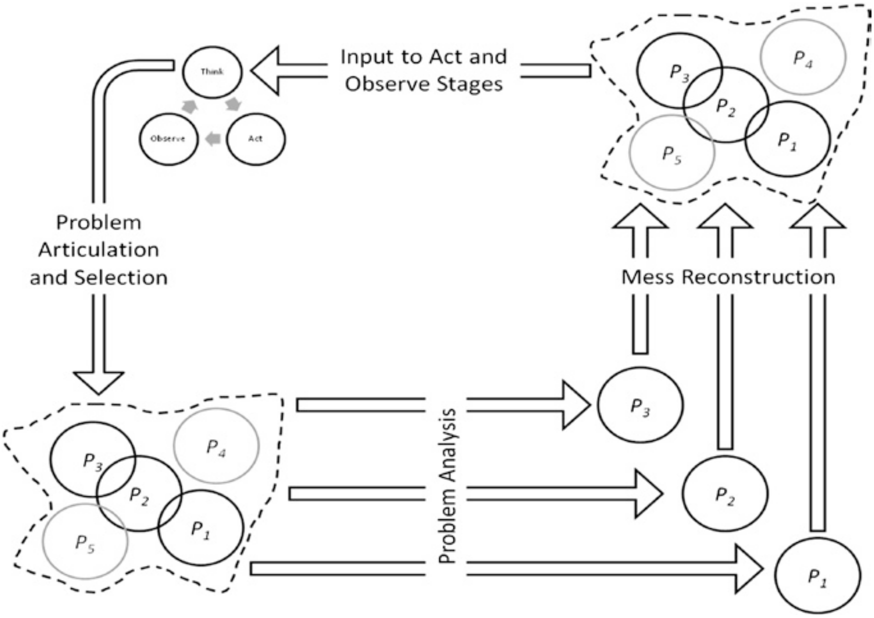


Fig. 2.3 Illustration of mess decomposition and reconstruction

Each mess will contain *many* problems, and we must think systemically about each in order to reason about our mess.

Hammond et al. (2002) discuss the importance of problem formulation: "The way you state your problem frames your decision. It determines the alternatives you consider and the way you evaluate them. Posing the right problem drives everything else" (p. 15). Formulation of your problem must include an appreciation for characteristics of the systems they are associated with. Churchman and Ackoff [9] noted a number of similarities in purpose-built objects (i.e., man-made systems). Three of these similarities are important to our study of messes and to the formulation of our problem:

1. Presence of Choice: "The basis of the concept of purpose is the awareness of voluntary activity" ([21], p. 19). Choice is essential to identify purpose.
2. Inclusion of Time: "Purposive behavior can only be studied relative to a period of time" [9, p. 35].
3. Production Requirement: "The purposive object or behavior is at least a potential producer of some end-result (end, objective, goal)" [9, p. 35].

Purposive behavior, a characteristic of all man-made systems, requires a system to have choices (alternatives) and to produce some desired behavior over a period of time. In order to identify and formulate our problem (or accompanying mess), one must appreciate the underlying purpose of its associated system. Ignorance of purpose will no doubt result in inappropriate analysis and a propensity for committing a Type III error [15–17]. It is in our best interest to ensure that this problem truly reflects the concerns of relevant stakeholders in order to avoid this error. This is sometimes easier said than done as we don't always have complete latitude over this exercise, however. In fact, our problem may be predefined by some authority (such as a customer) or the organization in which we work. Hammond et al. [13] agree, urging decision makers to consider the trigger, the initiating force, behind their problems. They caution, "Most triggers come from others…or from circumstances beyond your control…Because they're imposed on you from the outside, you may not like the resulting decision problems" (pp. 18–19). In this case, at a minimum, we should work with other stakeholders to refine the problem in a manner conducive to gaining further understanding. If we can influence our problem formulation, we need to consider what triggered the problem so that we can ensure we've identified the root problem.

In all, problem formulation is neither trivial nor to be taken lightly. "Defining the problem is sometimes the most difficult part of the process, particularly if one is in a rush to 'get going'" [6, p. 48]; recall our notion of humans having a bias for action. Hammond et al. [13] warn of the pitfalls in taking problem formulation lightly:

> Too often, people give short shrift to problem definition…In their impatience to get on with things, they plunge into the other elements of decision making without correctly formulating the problem first. Though they may feel like they're making progress in solving their problem, to us they seem like travelers barreling along a highway, satisfied to be going 60 miles an hour—without realizing they're going the wrong way. (p. 26)

One final point on problem formulation. We should be careful to specify a problem that is unique enough to be relevant to our concerns, yet not so specific that it predefines a solution. This is important because a true problem may have predispositions towards a solution, but if we already have a solution, then we don't have a problem (i.e., we've got nothing to solve and we've violated the problem criteria suggested by Sage [22]). Only once we've formulated our problems and are satisfied they are representative of the concerns we wish to explore, can we begin to change our way of thinking about the problems in question. At this point, we are ready to think systemically.

2.5 Summary

Complex problems continue to be viewed from a largely technical perspective. Adopting a single technical perspective has been unsuccessful in solving many ill-structured, wicked, or messy systems problems. The application of multiple perspectives offers a more inclusive framework through which complex problems may be viewed.

The integration of technical, organizational, political and human perspectives during the analysis of the problem widens the aperture and provides an increased probability of correctly addressing systems age problems. Finally, it is worth noting that the range of variability of individual perspectives, objectives, and perceived interests may be so divergent that sufficient alignment necessary to move forward may be unattainable. Many traditional approaches assume a unitary perspective where there is assumed agreement on the problem context. We have found that most systems age problem domains have deeply rooted or philosophical divergence which add to the difficulty in developing a mutually agreeable problem formulation. Divergence may involve such issues as allocation of scarce resources, power distribution, control, personal preferences or interests, and other areas that may exist at a tacit level. Assuming alignment in systems age problem domains may be problematic.

In order to move forward, we must decompose the messes we wish to further understand into tractable problems about which we may reason, and then reconstruct them in order to obtain systemic understanding of our mess. Simply decomposing them, as many methods do, is insufficient, as it fails to holistically consider the context in which each problem operates.

After reading this chapter, the reader should:

1. Understand the difference between systems age problems and machine age messes;
2. Appreciate the importance of considering multiple perspectives in a system's effort;
3. Understand the characteristics of hard and soft perspectives; and
4. Be able to formulate a mess and its constituent problems.

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Chapter 3
Systemic Thinking

Abstract As machine age problems have given way to systems age messes, the underlying complexity associated with understanding these situations has increased exponentially. Accordingly, the methods we use to address these situations must evolve as well. Unfortunately, however, many antiquated methods for dealing with situations remain prominent. Systems engineering is traditionally viewed as the practical application of procedural problem solving, typically geared toward the acquisition of large-scale systems. The underlying paradigm for solving problems with this approach, and other similar approaches, can be characterized as *systematic thinking*. While quite appropriate for machine age problems, it lacks the theoretical rigor and systemic perspective necessary to deal with systems age messes. Thus, a new paradigm of *systemic thinking*, conceptually founded in systems theory, is necessary. This chapter provides a brief historical background on the development of systems approaches, contrasts systems approaches and systems engineering and their underlying paradigm with systemic thinking, and introduces practical guidelines for the deployment of a systemic thinking approach that will provide the foundation for the remainder of this book.

3.1 A Brief Background of Systems Approaches

While we don't intend for this text to represent a purely engineering-centric perspective, both authors are engineers by training and we would be remiss if we didn't address the contribution that systems engineering has made in the formulation of our thoughts about this text (both positive and negative). An understanding of the evolution of systemic thinking must first begin with a brief introduction to systems engineering [6], from which systemic thinking derives its roots. To start, a definition of what is intended by the term *systems engineering* is necessary. Many definitions exist for systems engineering; we adopt the one provided by the Institute of Electrical and Electronics Engineers (IEEE) both for its brevity

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and for the IEEE's recognition and role in providing high-quality standards for the practice of systems engineering. The IEEE standard for systems and software vocabulary defines systems engineering as the "interdisciplinary approach governing the total technical and managerial effort required to transform a set of customer needs, expectations, and constraints into a solution and to support that solution throughout its life" (IEEE and ISO/IEC [39, p. 361]). It is clear that such a perspective is not predicated on an engineering-centric viewpoint and thus, is in line with the discipline-agnostic aim of this book.

The two earliest books on engineering for systems were written by Goode [1909–1960] of the University of Michigan and Machol [1917–1998] of Purdue University [32] and Hall [1925–2006] of Bell Telephone Laboratories [33]. Goode and Machol list 145 references and make no reference to any other books on the engineering of systems. The closest they come is to reference two texts on Operations Research [48, 54]. Hall lists two texts on the engineering of systems [26, 32] and two on Operations Research [23, 54]. It is interesting to note that the book by Flagle et al [26] retained Operations Research in the lead position in the title, despite its focus on the engineering of systems.

A review of the Goode and Machol text shows a great deal of emphasis on probability, the design of experiments, and a variety of mathematical problem solving techniques drawn from Operations Research. Goode and Machol also touch briefly on information theory, cybernetics, servomechanism theory, and human engineering.

In 1962, Hall published the second text on systems engineering. Hall's topics included three new areas of emphasis: (1) the concept of value in decision making, including extensive discussion of economics, (2) a comprehensive, integrated general methodology for systems engineering, and (3) a discussion of the fundamental concepts of systems. The inclusion of economics as a core element of decision making is a change from Goode and Machol, who had relegated the topic of economics to the epilogue of their text. Hall formally introduces econometrics as an essential part of large-scale formal analysis methods. He also introduces a formal methodology for the analysis and synthesis of large scale systems. This methodology continues to act as the framework for many of the current systems engineering models in use today. Possibly the most significant new element is Hall's inclusion of a discourse on some fundamental concepts for engineering systems. Hall [33] states:

> It happens that certain properties apply to systems in general, irrespective of the nature of the systems or of the fields in which they are normally studied. While it is true that not all of the most general properties are useful in an operational sense for applied work, they have considerable conceptual value in more deeply understanding creative or developmental processes. This fact is the real justification for including them in this chapter (p. 59)

Hall [33] acknowledges the notion of a general systems theory and states that " …sometimes very difficult systems problems are greatly illuminated by looking at them in the light of the appropriate generalized property" (p. 65). Hall's book remained the major text for engineering systems for a number of years. It is worth noting that both Hall's and Goode and Machol's texts on the subject of systems engineering are substantially more general in nature than their successors and do not predicate their discussion on engineering disciplines. To them, *engineering is problem solving*; there is no distinction. To think about engineering systems was to think about how systems interacted with one another, how they functioned, how they could be understood, designed, and improved. This perspective has changed, however, as systems engineering has moved to a more process-focused discipline; engineering became proceduralized problem solving. Indeed, arguably the three most widely used academic text books on engineering of systems, as of this writing, are:

- *Systems Engineering and Analysis* by Benjamin Blanchard and Wolter Fabrycky of Virginia Polytechnic Institute and State University.
- *Systems Engineering: Principles and Practice* by Alexander Kossiakoff, William Sweet, Sam Seymour and Steven M. Biemer of the Johns Hopkins Applied Physics Laboratory.
- *Introduction to Systems Engineering* by Andrew Sage of George Mason University and James Armstrong of the United States Military Academy.

Each of these texts expends substantial intellectual resources discussing the *process* of systems engineering. That is, current systems engineering practice, most appropriately, can be characterized as *systematic engineering*, where *systematic* connotes the methodical, process-based nature of processes for systems engineering espoused by organizations such as the Department of Defense's Defense Acquisition University (DAU) [25] and NASA [55] steeped in their practice and *engineering* connotes the practical application of scientific principles reflected in those same organizations. Thus, systems engineering, as currently practiced, is by and large the practical application of procedural problem solving (most traditionally problems concerning the acquisition of systems). Further, the underlying paradigm for solving these problems can be characterized as *systematic thinking*. Systems engineering is not the only method to complex problem solving that exists, of course; many other systems methods are in use as well. Jackson [41] portrays systems methods using a typology that has four Types: (1) goal seeking and viability; (2) exploring purposes; (3) ensuring fairness; and (4) promoting diversity, which are presented in Table 3.1.

Jackson [40] states that the role of systemic thinking in each of the methods "serves them by adding greater conceptual rigor within their theoretical formulations and/or by enabling translation of these formulations into guidelines for practical action" (p. 105). Many of them are focused on systematic approaches to gaining understanding. While systematic thinking is appropriate for machine age systems, it loses its effectiveness when problems increase in complexity as we transition to systems age messes. Thus, a new paradigm of *systemic thinking*, conceptually founded in systems theory, is necessary. This new paradigm must be discipline-agnostic and theoretically-derived, two foundations upon which our perspective of systemic thinking is founded.

Table 3.1 Systems-based methods based upon Jackson's framework

Approach	Systems method	Primary proponent(s) of the method
Type A: goal seeking and viability	Operations research	[36]
	Systems analysis	[31]
	Systems engineering	[13, 56]
	System dynamics	[28–30, 44]
	Soft systems thinking	[57]
	Viable system model	[9–11]
	Complexity theory	[42, 60]
Type B: exploring purposes	Social systems design	[21, 22]
	Strategic assumption and surfacing technique (SAST)	[45, 46, 51–53]
	Interactive planning	[1, 4]
	Soft systems methodology	[18, 19]
Type C—ensuring fairness	Critical systems heuristics	[63, 64]
	Team syntegrity	[12]
Type D—promoting diversity	Participatory appraisal of needs and the development of action (PANDA)	[62, 65, 66]
	Total systems intervention	[27]

3.2 What is Systemic Thinking?

Systemic thinking,[1] as a term, has been gaining traction in recent literature (e.g., [15, 35, 49, 50]), but it is our belief that the term has been used without specificity or universality. Our goal in this book is to articulate our unique perspective on systemic thinking which differentiates it from those systems approaches previously identified, and to demonstrate its utility in helping individuals to increase their understanding about problems and messes of any size, complexity, or discipline. The characteristics differentiating systematic thinking and systemic thinking, as we see them, are outlined in Table 3.2, with a discussion of each of the eight elements to follow.

3.2.1 Age

The first distinguishing characteristic separating systematic and systemic thinking concerns the age each is designed to address. The machine age was concerned

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[1] Much of the text presented in Sect. **3.2** appeared previously in Hester and Adams [35]. Although we have retained the copyright to this text, the authors wish to acknowledge this publication.

Table 3.2 Characteristics of systematic versus systemic thinking

Element	Systematic thinking	Systemic thinking
Age	Machine	Systems
Unit of analysis	Problem	Mess (system of problems)
Stopping criteria	Optimization	Satisficing
Goal	Problem solution	Increased understanding
Underlying philosophy	Reductionism	Constructivism and reductionism
Epistemology	Analysis	Synthesis and analysis
Discipline scope	Multidisciplinary and interdisciplinary	Transdisciplinary
Approach	Prescriptive	Exploratory

with simple systems and the systems age is concerned with complex systems, or more approspriately for purposes of systemic thinking, messes. Refer to Chap. 2 for a further distinction of these characteristics. Ackoff [3] speaks of the inability of machine age paradigms to appropriately handle systems age messes. The relevant takeaway is that, when we are faced with a mess, we will be unable to appropriately address it with methods designed for solving machine age problems. While these methods, such as operations research and systems engineering, certainly have their place, this place is not in addressing systems age messes, which require methods, and an accompanying theoretical basis, that appreciate their complex nature.

3.2.2 Unit of Analysis

Systematic thinking focuses on a singular problem. Due to its broader scope, systemic thinking has a larger, more abstract unit of analysis, that of a mess [3]. A mess represents a system of problems. Thus, many problems are contained in a mess, but their analysis is not merely summative. Thus, analysis of a mess is exponentially more complicated than a singular problem. This relationship is depicted in Fig. 3.1.

In Fig. 3.1 there are five problems, P_1, $P_2 \ldots P_5$ and a mess, M_1, consisting of these five problems and their problem context. Succinctly, $M_1 = \mathrm{f}(P_1, P_2 \ldots P_5)$. It is in the interaction of these constituent problems and their associated context where the mess truly arises:

> Problems are elements abstracted from messes; therefore, problems are to messes what atoms are to planets….the behavior of the mess depends more on how the solutions to its components problems interact than on how they act independently of each other [2, pp. 4–5]

Viewing this mess as a whole truly requires a systemic perspective.

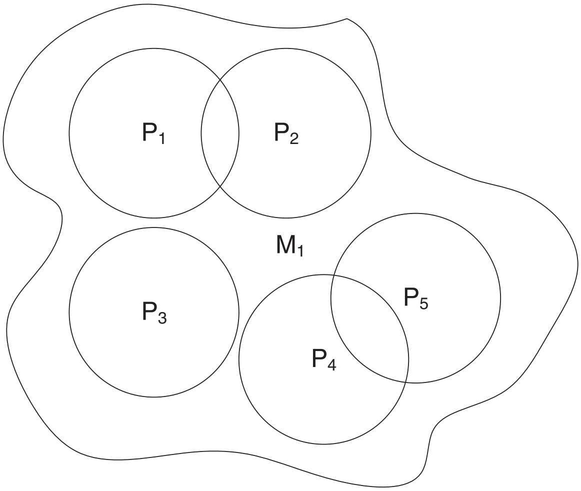


Fig. 3.1 Depiction of mess and constituent problems

3.2.3 *Stopping Criteria*

When analyzing a complex situation, it is imperative to think about global criteria associated with the desired end state of the analysis. That is, as a systems practitioner, am I searching for a globally optimal, “best (maximum or minimum) value of the objective function” [61], a singular *solution* to a problem, or am I merely seeking a satisfactory resolution to my problem? The answer, as always, depends.

Given the relatively constrained perspective of a singular problem, it is easy to conceive that the stopping criteria for a problem analysis using a systematic thinking paradigm is optimization. The end goal of this machine age problem is to develop a best answer to the problem at hand. Thus, we speak of the *best* design for a structural component of a larger system, or the *best* portfolio selection from among a number of choices. Systemic thinking, however, requires a more delicate balancing act to be observed. Given that any systemic thinking effort will involve two or more constituent problems, and the solution to each problem assessed independently represents a unique global solution to the mess, we must consider the principle of suboptimization [37] in our analysis of these messes. Maximizing overall mess performance (i.e., optimizing the mess) requires that its constituent problem solutions be constrained, thus violating the notion of suboptimization. Ackoff [2] echoes the difficulty in achieving an optimal solution to a mess:

> There is an important systems principle, familiar to all of you, that applies to messes and problems: that the sum of the optimal solutions to each component problem considered separately is not an optimal solution to the mess….It is silly to look for an optimal solution to a mess. It is just as silly to look for an optimal plan. Rather we should be trying to design and create a process that will enable the system involved to make as rapid progress as possible towards its ideals, and to do so in a way which brings immediate satisfaction and which inspires the system to continuous pursuit of its ideals (pp. 4–5).

Thus, if each system (i.e., problem) chooses to pursue (and thus, optimize) its own interests, then the mess will necessarily operate at less than maximum performance. Balancing the interests of constituent problems is one of the most difficult aspects of systemic thinking. A mechanism for doing so is known as *satisficing*. Satisficing is a term coined by Herb Simon [58, 59] to describe how individuals make rational choices between available options and within a constrained environment. Simon argued that decision makers are rarely able to obtain and evaluate all the information which could be relevant to the making of a decision. Instead, they work with limited and simplified information to reach acceptable compromises (you satisfice, a portmanteau of satisfy and suffice) rather than to obtain a globally optimal strategy where a particular objective is wholly maximized. This relaxation from optimal-seeking problem solution approaches represents a departure from traditional OR solution techniques, one appropriate for mess analysis.

3.2.4 Goal

Given systematic thinking's focus on the problem as a unit of analysis and optimization as its desired end state, it is clear that the goal of a systematic thinking endeavor is to determine a problem solution. As such, a problem solution effort aims to determine the globally best answer to the particular problem of interest and recognizes that there is a preferred solution for the endeavor in question. Systemic thinking endeavors, however, are not so straightforward. Given their focus on satisficing and messes, it is clear that a singular view of *best* is not only not achievable, but also not necessary. Instead, the goal of a systemic thinking endeavor is achieving increased understanding of a mess (recall the notion of perfect understanding discussed in the previous chapter; the assumption that we'll have complete understanding of our mess is both arrogant and foolhardy). Increased understanding does not presuppose that our situation will reach a conclusive state. Rather, we may end up trapped in a do-loop until conditions within our situation's environment change. Thus, the question we must ask is, how are we going to move toward increased understanding of our situation? This exploration may lead to a set of solutions, each of which may apply to the constituent problems of a mess, or it may lead simply to a greater understanding of the mess being faced. This increased knowledge may manifest itself in a recognition that we cannot do anything to improve or alter the current state. More importantly, perhaps, is the understanding that we may not want to intervene, for fear that we'll upset the dynamic equilibrium [24] of the underlying system. The field of cybernetics and the systems principle of homeostasis [17] inform systems practitioners that systems have the ability to self-regulate to maintain a stable condition. Often times, intervention will cause negative feedback rather than improvement. Understanding of this concept helps us to avoid the Type IV error [14] that we introduced in Chap. 1, where the correct analysis leads to an inappropriate action taken to resolve a problem. So, in achieving increased understanding we may learn that inaction is the best action. Hester [34] puts the notion of increased understanding in context by introducing the concept of finite causality, stating:

> …the outcome of the operation of any system is neither infinitely good nor infinitely bad. As more information is gained, the expected bounds surrounding this range of potential outcomes narrows, but never…meets at a point; in other words, it never reaches an optimal solution. Rather, the best we can hope to achieve is a set of potential outcomes that are boundedly rational and, by definition, neither infinitely good nor infinitely bad (p. 274).

So, we should not despair at the lack of a singular optimal solution, but rather continue to work toward increased understanding in an effort to reduce the bounds on our solution.

3.2.5 Underlying Philosophy

Philosophy is based in a world view which ultimately drives the understanding of a mess. Aerts et al. [7] define world view as "….a system of co-ordinates or a frame of reference in which everything presented to us by our diverse experiences can be placed" (p. 9).

Ackoff [5] discusses the concept of a world view as:

> Every culture has a shared pattern of thinking. It is the cement that holds a culture together, gives it unity. A culture's characteristic way of thinking is imbedded in its concept of the nature of reality, its world view. A change of world view not only brings about profound cultural changes, but also is responsible for what historians call a "change of age." An age is a period of time in which the prevailing world view has remained relatively unchanged (p. 4).

This consistency in world view is what Checkland [18] refers to as *weltanschauung*, the image or model of the world that provides meaning. Each of these definitions hints at the idea of a world view as a shared perspective or frame of reference for understanding the world. Ackoff's [3] talk of a transition in ages implies a shift in philosophical world view. The philosophical worldview has changed from reductionism in the machine age to constructivism in the systems age.

Reductionism, first introduced to Western civilization by René Descartes [1596–1650] in his *Discourse on Method* and later expanded by Isaac Newton [1643–1727] in his *Principia Mathematica* focuses on reducing a system to its barest elements in order to provide for an understanding of a system. Focusing on biological complexity, Mazzocchi [47] discusses several limitations of applying a purely reductionist perspective to understanding complex systems:

- *…the reductionist approach is not able to analyse and properly account for the emergent properties that characterize complex systems…* (p. 11)
- *…reductionism favours the removal of an object of study from its normal context. Experimental results obtained under given particular conditions or from a particular model—such as a mouse,* in vitro *cell cultures or computer models—are often extrapolated to more complex situations and higher organisms such as humans. But this extrapolation is at best debatable and at worst misleading or even hazardous.* (p. 12)

- *…reductionism is also closely associated with determinism—the concept that every phenomenon in nature is completely determined by preexisting causes, occurs because of necessity, and that each particular cause produces a unique effect and* vice versa*. This, naturally, also sustains the idea of predictability…. Nonetheless, complex…systems cannot be fully understood on a purely deterministic basis.* (p. 12)
- *…to better understand complex…systems and their adaptive behaviour, we need to consider the phenomenon of self-organization….* (p. 12)

Mazzocchi [47] continues:

> An epistemological rethink is needed to instigate a paradigm shift from the Newtonian model that has dominated science, to an appraisal of complexity that includes both holism and reductionism, and which relaxes determinism in favour of recognizing unpredictability as intrinsic to complex systems (p. 13).

It is clear that much is to be gained from adapting a world view focused on holism, or constructivism. This perspective focuses on assembling system components into a purposeful whole in order to provide for an understanding of the entire system. However, this isn't the only way to gain understanding. Within the construct of systemic thinking, we must first use reductionism to deconstruct our mess into discernible elements, understand these individual elements, and then use constructivism to rebuild them in an effort to gain a holistic understanding of our mess. This unique world view, focused on ***the use of both reductionism and constructivism***, underlies systemic thinking and helps to provide for its epistemological basis, discussed in the following section.

3.2.6 Epistemology

Epistemology refers to the theory of knowledge and thus, addresses how knowledge is gained about a particular situation. It is informed by a particular world view and thus, given their divergent world views, the epistemology underlying systematic and systemic thinking is quite divergent as well. Ackoff [3] succinctly describes the steps in analysis as:

> …(1) taking apart the thing to be understood, (2) trying to understand the behavior of the parts taken separately, and (3) trying to assemble this understanding into an understanding of the whole… (p. 8)

Analysis relies on observation, experimentation, and measurement for its knowledge gathering. It is largely quantitative in its attempts to explain and understand the world.

On the other end of the epistemological spectrum is synthesis. Synthesis involves identification of a system to be studied. It then explores the environment in which the system resides, in order to understand its behaviors and purpose. Thus, rather than decomposing the system, synthesis aggregates a system into larger and larger systems in order to infer meaning. Synthesis relies on understanding, complementarity of perspectives [16], and social construction for its meaning. Its emphasis on understanding (vice solution) and complementary, subjective evaluation of meaning should be comforting to individuals who focus on messes.

Neither epistemology alone is sufficient. We must invoke both synthesis and analysis, as appropriate, in order to increase our understanding of our mess and its constituent problems.

3.2.7 Disciplinary Scope

Although the terms are often erroneously used interchangeably, multidisciplinary, interdisciplinary, and transdisciplinary each have a unique meaning (see, e.g., [43, 67, 68]). A succinct summary of the three terms is provided by Choi and Pak [20]:

> We conclude that the three terms are used by many authors to refer to the involvement of multiple disciplines to varying degrees on the same continuum. Multidisciplinary, being the most basic level of involvement, refers to different (hence "multi") disciplines that are working on a problem in parallel or sequentially, and without challenging their disciplinary boundaries. Interdisciplinary brings about the reciprocal interaction between (hence "inter") disciplines, necessitating a blurring of disciplinary boundaries, in order to generate new common methodologies, perspectives, knowledge, or even new disciplines. Transdisciplinary involves scientists from different disciplines as well as nonscientists and other stakeholders and, through role release and role expansion, transcends (hence "trans") the disciplinary boundaries to look at the dynamics of whole systems in a holistic way (p. 359).

A graphical depiction of multidisciplinary, interdisciplinary and transdisciplinary is shown in Fig. 3.2. Note that D_1 and D_2 in the figures refer to Discipline 1 and Discipline 2, respectively.

A truly transdisciplinary scope is required for systemic thinking. This is further demonstrated by the holistic perspective demanded by systemic thinking. Multidisciplinary and interdisciplinary perspectives represent too narrow a focus for understanding the bigger picture encouraged by a systemic lens.

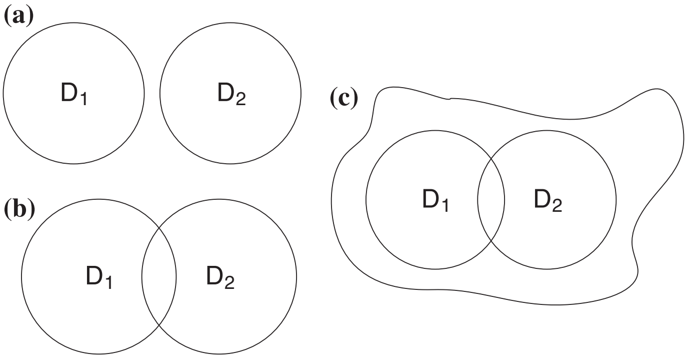


Fig. 3.2 **a** Multidisciplinary, **b** interdisciplinary, and **c** transdisciplinary depictions

3.2.8 Approach

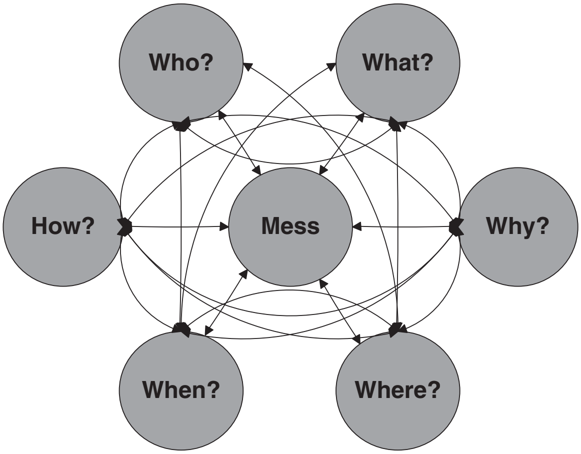
The final distinguishing characteristic that separates systematic thinking from systemic thinking is that of the approach employed by each. As discussed earlier, systematic thinking is, quite obviously, systematic, and thus, procedural. This means it is largely prescriptive and largely holds to a detailed process for undertaking it. In the world of cooking, systematic thinking would involve strict adherence to a recipe; in driving, step-by-step navigation barked out by a GPS; in engineering, a standard such as IEEE Std. 1220 [38], with many rules and procedures to follow. Systemic thinking, on the other hand, is much more exploratory. It is normative in that it is driven by a flexible way of thinking which adheres to norms, or general descriptors of behavior without strict rules. The emergent behavior [8] exhibited by the messes it is intended to support are well suited to an exploratory approach. Thus, returning to previous examples, systemic cooking would suggest a general framework for a meal and perhaps a set of suggested ingredients, but it would refrain from providing precise measurement quantities or detailed instructions. Similarly, systemic navigation would account for emergent behavior expected by anyone who's ever gone anywhere in a car, and who has had to account for elements such as traffic, road construction, and weather. It might exist on a continuum, at one end merely providing a map with a *You are here* sticker and leaving the explorer to his or her devices, and at the end other end providing a set of suggested routes, but leaving the explorer to determine deviations from the suggested route in an ad hoc fashion and adjusting accordingly. Finally, with respect to engineering, systemic thinking provides a general methodology for *thinking* about a mess, yet it stops short of detailed prescription and procedural instructions necessary in traditional systematic endeavors. This lack of prescription allows for the systems practitioner to adjust to real world nuances impossible to be captured by prescriptive approaches to understanding complex scenarios. It is this general methodology that we now turn our attention to as the authors attempt to introduce a general approach for systemic thinking applicable to all messes.

3.3 A Methodology for Systemic Thinking

The key to *systemic thinking* is consideration of the “5 W's and How?” That is, who, what, why, where, when, and how? The relevance of each is explained below.

- *Who* is relevant to understanding our mess? *Who* concerns holistic consideration for the stakeholders involved in a situation. Stakeholder analysis and management is discussed in detail in Chap. 5.
- *What* are we trying to achieve in understanding our mess further? This concerns the mess itself. What are the outputs and outcomes we wish to achieve? These and other questions are discussed in Chap. 6.
- *Why* are we interested in this mess? We all only have 24 h in a day with which to expend our resources. Why does this mess demand our resources and efforts? What motivations exists for our involvement in this mess? These questions are discussed in Chap. 7.

Fig. 3.3 Methodology for systemic thinking



- *Where* does our situation reside? What are the characteristics of the context of our mess? Where are the boundaries on our system? Attention is given to these elements in Chap. 8.
- *How* do we achieve improved understanding of our mess? This question discusses mechanisms for understanding our mess. How do we deploy mechanisms in order to achieve our aims? This is the focus of Chap. 9.
- *When* do we want to have increased mess understanding by? This question explores maturity- and stability-related concerns. When should we intervene in a system to create the largest impact? These questions are addressed in Chap. 10.

Finally, Chap. 11 brings all of these elements back together to demonstrate how to form a systemic perspective of a mess. Attempting to answer these questions forms the methodology for systemic thinking developed in this text. Figure 3.3 illustrates the interaction of these questions with one another.

While this figure seems innocent enough, one could imagine it increasing substantially in complexity if we were to decompose the mess as shown in Fig. 3.4. We have to account for the relationships between elements, e.g., the resources of one problem being tied to those of another. In these interactions and conflicts our mess truly arises.

Given that systemic thinking is exploratory in its approach, there is no singular starting point or initial step. However, in the absence of any predisposition for acting otherwise, the authors suggest starting with the *Who* step (Chap. 5) and proceeding through the chapters in a linear fashion. This will allow the reader the best opportunity for understanding the authors' approach to systemic thinking. It is important to note, however, that any step can lead to any other (as depicted in Fig. 3.3) and steps may (and often will) be revisited throughout the course of an analysis. Thus, the reader is encouraged to find a pattern that fits his or her own comforts. This pattern is likely to be mess-dependent, however, and attempting to always follow the same path may prove problematic. While we suggest in

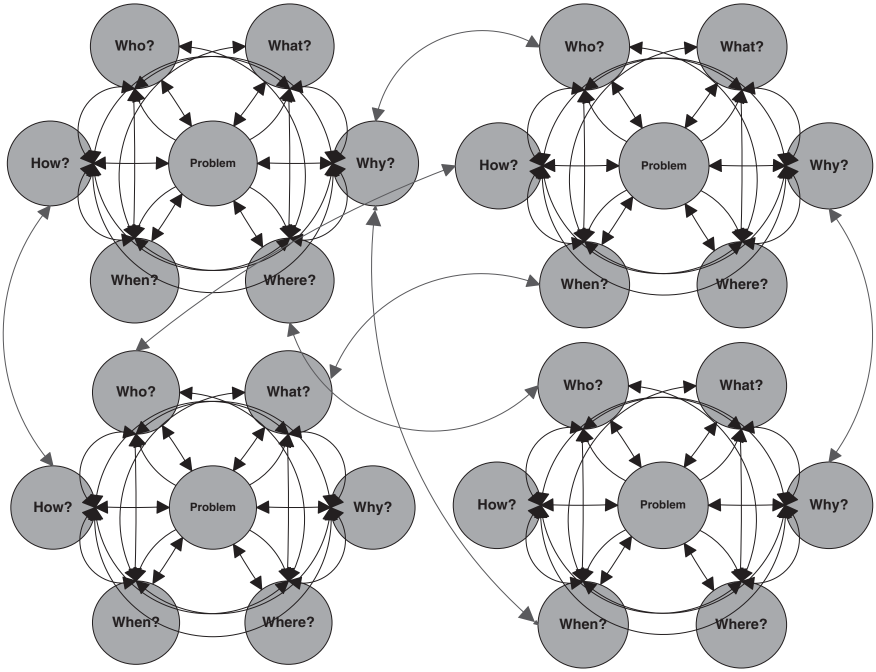


Fig. 3.4 Relationship among several problems and systemic thinking elements

the absence of other guidance to begin with stakeholder analysis and management (*Who?*), there may be reason to do otherwise. For example, stakeholders of your mess may be predetermined, with their roles clearly defined. Thus, it may behoove us to explore the *What* or the *Why* first. There is no wrong answer.

The flexibility of this approach owes itself to its foundation on the theoretical framework of systems theory. Systems theory provides the foundational underpinning for systemic thinking. This generalized theoretical underpinning provides rigor for the use of this approach by way of systemic thinking. This theory and its historical origins are discussed in detail in the following chapter.

3.4 Summary

Systems age messes are much grander and more complex than their machine age problem predecessors. Thus, accompanying methods to understand them must also account for this additional complexity. Practice shows that this is not the case and many methods and their underlying paradigms of systematic thinking are still quite prevalent in today's world. This chapter introduced a methodology for systems thinking and contrasted it with traditional systematic thinking. The aim of the remainder of this book is to present the methodology underlying systemic thinking such that the reader, upon completion, will understand how to put the approach into practice in a manner which will garner increased understanding for systems age messes.

After reading this chapter, the reader should:

1. Understand the evolution of systems approaches;
2. Be able to articulate the distinction between systematic and systemic thinking; and
3. Identify the six perspectives of systemic thinking.

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Chapter 4
Systems Theory

Abstract Systems theory is a term that has been used inconsistently in a variety of disciplines. Further, few of these disciplines provide any type of formal definition for the term. As such, it is often subject to misunderstanding when used between disciplines. We believe that systems theory provides the foundation for improved understanding when dealing with systems and their attendant problems and messes. Before exposing you to a formal definition for systems theory, we will present a classification and high-level view of the major streams of thought that have addressed systems theory (i.e., the historical roots of systems theory). This will be followed by our definition of systems theory and the axioms and supporting propositions (i.e., systems principles) that we feel apply to all systems. Finally, we'll present a linkage of the principles of systems theory to the systemic thinking perspectives.

4.1 Historical Roots of Systems Theory

The six major historical classifications for systems theory and their major contributors, are presented in Table 4.1.

For a more detailed discussion of these streams of thought and their relationship with systems theory the reader is encourage to review [2, 3]. Each of these classifications will be discussed in the following sections.

4.1.1 General Systems Theory

The proponents of what is classified as General Systems Theory (GST) were Ludwig von Bertalanffy, Kenneth Boulding, Anatol Rapport, and Ralph Gerard. In 1954 they founded the Society for General Systems Research (SGSR), now the

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Table 4.1 Historical classifications for systems theory [3, p. 4102]

Stream of thought	Major contributor(s) with selected references
1. General systems theory	Bertalanffy [13–15], Boulding [18]
2. Living systems theory	Miller [60]
3. Mathematical systems theory	Mesarovic [58], Wymore [88], Klir [47]
4. Cybernetics	Rosenblueth et al. [72], Wiener [86], Ashby [7–10], Forrester [37–39]
5. Social systems theory	Parsons [67–69], Buckley [20, 21], Luhmann [52, 53]
6. Philosophical systems theory	Laszlo [49–51], Bunge [22–25]

International Society for Systems Science (ISSS). The purpose of the society was outlined in its original by-laws as follows [40]:

1. To investigate the isomorphy of concepts, laws, and models from various fields, and to help in useful transfers from one field to another
2. To encourage development of adequate theoretical models in fields which lack them
3. To minimize the duplication of theoretical effort in different fields; and
4. To promote the unity of science through improving communications among specialists (pp. 435–436).

The SGSR by-laws were modified to include the practical application of systems concepts and models in planning and decision-making processes [40]. However, founders and members of the SGSR had significant differences and the stated goals and objectives for the SGSR and GST diverged to the point where their unified theory for general systems became muddled and of reduced utility as a theory for systems practitioners.

4.1.2 Living Systems Theory

Living Systems Theory describes living systems, how they are organized, how they work, how they evolve and how they die. James Grier Miller [1916–2002], the originator of living systems theory [60], defines living systems as being open systems (i.e., they interact richly with their environment) that exhibit self-organization and have the special characteristic of life, thereby including both biological and social systems. A principle element of Living Systems Theory is the hierarchy and organization for systems which includes a hierarchy of eight levels and 20 processes which are integrated into a table of 160 cells. This 160 cell matrix can be used to classify all living systems.

4.1.3 Mathematical Systems Theory

The proponents of Mathematical Systems Theory use the rigor of mathematics to construct models that explain systems. They use axiomatic approaches that include set theory to characterize and classify systems. Further description of these models is beyond the scope of this book, but interested readers are referred to the work of Mesarovic [57], Wymore [88, 89], and Klir [47].

4.1.4 Cybernetics

The original proponent of Cybernetics, Norbert Wiener [1894–1964] used the concepts of regulation and command as his central thought [86]. Both of these concepts, more commonly characterized as communication and control, rely on feedback within a system for the transmission of operational properties related to the systems' performance. Feedback is the mechanism that controls, guides, or steers the system to ensure performance of its goals. In fact, the term cybernetics comes from the Greek word kybernetes, for pilot or steersman.

W. Ross Ashby [1903–1972], a physician, expanded upon Wiener's work and used the human body as a model for understanding systems [7, 8, 10].

Finally, Jay Forrester of MIT developed a technique (system dynamics) for modeling complex systems which operationalizes the concepts of cybernetics [37–39]. The feedback principle is the foundation for system dynamics which uses causal loop diagrams that contain information feedback and circular causality to model the dynamic interplay in the real world system under consideration.

4.1.5 Social Systems Theory

Social Systems Theory uses relationships between human beings to form the structural elements for social systems. Talcott Parsons [1902–1979] stated that it was the actions of the human actors that constituted the system [67–69]. This contrasts sharply with the ideas of Niklas Luhmann [1927–1988] who considered communication processes as the elements which constituted the social system [52, 53]. The work done in social systems theory provides a systems-based foundation for the analysis of human-organizational systems.

4.1.6 Philosophical Systems Theory

Not surprisingly, the proponents of Philosophical Systems Theory chose to approach systems from a higher-level. Ervin Laszlo "proposes a systems language that enables the understanding between scientific disciplines now separated by specialized concepts and terms" [3, p. 4107]. Laszlo [49–51] is really interested in ensuring that systems practitioners are not thwarted in their efforts to communicate, which is most often caused by the trappings and limitations of the unique language and concepts attributable to a specific discipline. The ability to think about systems at the philosophical level, using language, concepts, ideas, and terms that are uniformly accepted and understood, increases the chance that each perspective may contribute, in a meaningful way, to improved understanding of the complex system under study.

Mario Bunge's approach [22–25] focuses on systemism where mechanism is a process of a system and may not be separated from the system. Bunge states:

> Mechanism is to system as motion is to body, combination (or dissociation) to chemical compound, and thinking to brain. [In the systemic view], agency is both constrained and motivated by structure, and in turn the latter is maintained or altered by individual action. In other words, social mechanisms reside neither in persons nor in their environment - they are part of the processes that unfold in or among social systems. . . . All mechanisms are system-specific: there is no such thing as a universal or substrate-neutral mechanism. [24, p. 58]

Bunge's utilization of mechanism (a process of a system) as a means for explaining a system is unique, expansive, and philosophical in nature.

4.1.7 Historical Roots of Systems Theory Summary

The six (6) systems theory streams of thought just presented do not provide a generally accepted canon of general theory that applies to all systems. However, each identifies some notions and elements that apply to all systems. The next section of this chapter will provide a more focused definition and supporting construct for systems theory.

4.2 Systems Theory

Although used frequently in the systems literature, the term Systems Theory is a weakly defined term. As such, it is open to much misinterpretation and sharp attacks. In order to cogently present a theory for systems, any theory must contain both a syntactic definition (i.e., words) and a supporting construct.

The syntactic definition for systems theory is as follows:

> a unified group of specific propositions which are brought together to aid in understanding systems, thereby invoking improved explanatory power and interpretation with major implications for systems practitioners. [4, p. 114]

The seven axioms comprising systems theory are [4, pp. 116–119]:

1. *Centrality Axiom*—states that central to all systems are two pairs of propositions: emergence and hierarchy, and communication and control. The centrality axiom's propositions describe the system by focusing on (1) a system's hierarchy and its demarcation of levels based on emergence and (2) systems control which requires feedback of operational properties through communication of information.
2. *Contextual Axiom*—states that system meaning is informed by the circumstances and factors that surround the system. The contextual axiom's propositions are

those which bound the system by providing guidance that enables an investigator to understand the set of external circumstances or factors that enable or constrain a particular system.

3. *Goal Axiom*—states that systems achieve specific goals through purposive behavior using pathways and means. The goal axiom's propositions address the pathways and means for implementing systems that are capable of achieving a specific purpose.
4. *Operational Axiom*—states that systems must be addressed in situ, where the system is exhibiting purposive behavior. The operational axiom's propositions provide guidance to those that must address the system in situ, where the system is functioning to produce behavior and performance.
5. *Viability Axiom*—states that key parameters in a system must be controlled to ensure continued existence. The viability axiom addresses how to design a system so that changes in the operational environment may be detected and affected to ensure continued existence.
6. *Design Axiom*—states that system design is a purposeful imbalance of resources and relationships. Resources and relationships are never in balance because there are never sufficient resources to satisfy all of the relationships in a systems design. The design axiom provides guidance on how a system is planned, instantiated, and evolved in a purposive manner.
7. *The InformationAxiom*—states that systems create, possess, transfer, and modify information. The information axiom provides understanding of how information affects systems.

Each axiom of the theory contains a number of propositions that support the axiom and are a representation of principles that may be applied to real-world systems. It is important to note that the propositions that support the axioms come from a wide variety of scientific fields as depicted in Fig. 4.1.

Note that there are 6 major fields of science in Fig. 4.1: (1) natural sciences, (2) engineering and technology, (3) medical and health sciences, (4) agricultural sciences, (5) social sciences, and (6) humanities. Each of the six major fields has a number of individual fields, which are represented by the 42 sectors. Figure 4.1 is unique in that it also includes a series of inner rings which indicate the type and level of knowledge contribution that is being made. The knowledge contributions are hierarchical and structured as shown in Table 4.2.

The knowledge structure is important. As knowledge contributions move from the philosophical level to the level of technique, they become less generalizable and easier to use. Conversely, as knowledge contributions move from the level of a technique toward the philosophical, they lose specificity, are harder to use, and increase in generalizability. This concept is depicted in Fig. 4.2.

Systems theory is a unified group of axioms and supporting propositions (depicted in Fig. 4.1), linked with the aim of achieving understanding of systems. Systems theory can help systems practitioners to invoke improved explanatory power and predictive ability by using the seven axioms and their supporting propositions (from the 42 fields of science) as the foundation for thinking related to the

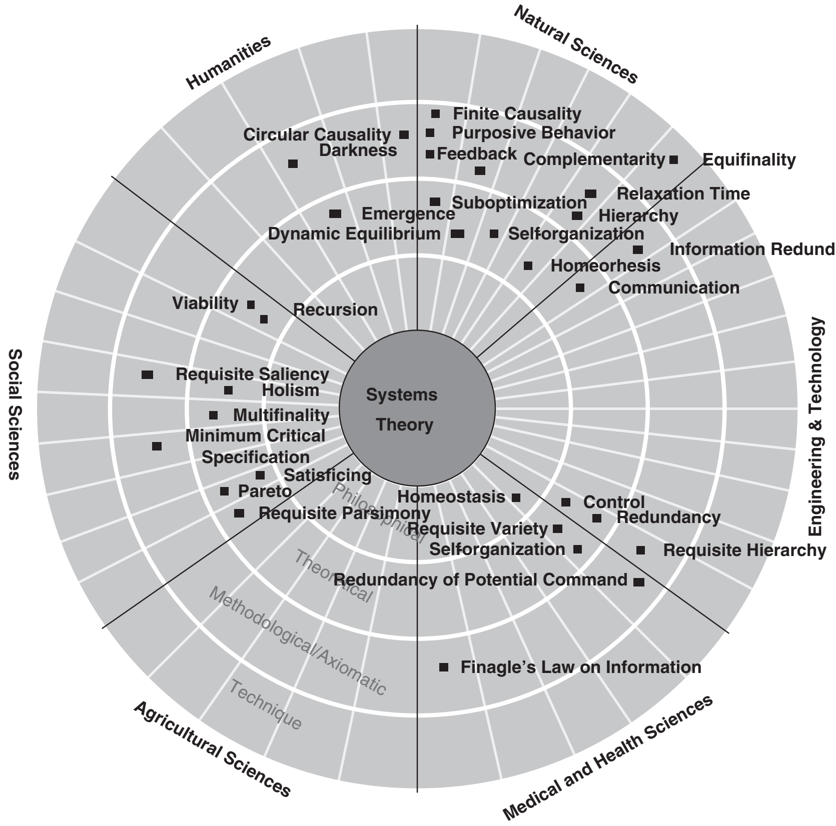


Fig. 4.1 Systems theory and the major fields of science. Updated version of [4, p. 120]

Table 4.2 Structure for knowledge contributions adapted from Adams et al. [4, p. 113]

Level	Basic description
Philosophical	The emerging system of beliefs providing grounding for theoretical development
Theoretical	Research focused on explaining phenomena related to scientific underpinnings and development of explanatory models and testable conceptual frameworks
Methodological	Investigation into the emerging propositions, concepts, and laws that define the field and provide high level guidance for design and analysis
Technique	Specific models, technologies, standards, and tools for implementation

formulation, analysis, and solution of systems problems. It is in this manner that Systems Theory provides the truly transdisciplinary foundation for systemic thinking as described in Chap. 3.

The seven axioms and the 31 supporting propositions for systems theory will be discussed in the following sections.

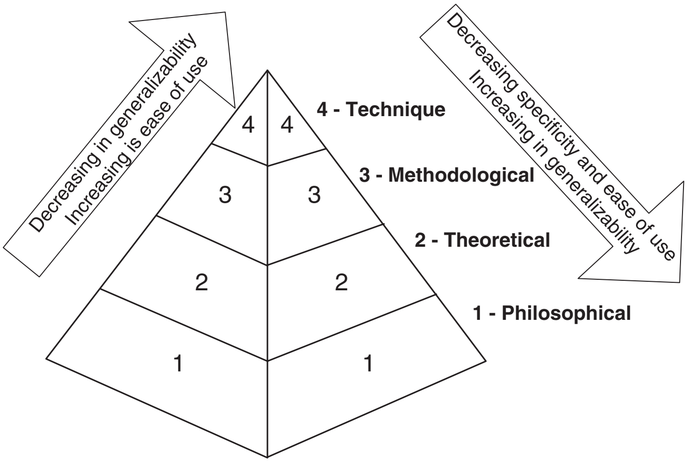


Fig. 4.2 Hierarchical nature of knowledge contributions

4.3 Centrality Axiom

The Centrality Axiom states:

> Central to all systems are two pairs of propositions; emergence and hierarchy, and communication and control. [4, p. 116]

The centrality axiom has four principles: (1) emergence, (2) hierarchy, (3) communication, and (4) control.

4.3.1 Emergence

Emergence is expressed simply by the statement that the whole is more than the sum of the parts. More formally:

> Emergence is the principle that whole entities exhibit properties which are meaningful only when attributed to the whole, not its parts – e.g. the smell of ammonia. Every model of human activity system exhibits properties as a whole entity which derive from it component activities and their structure, but cannot be reduced to them. [27, p. 314]

Emergence is a concept that has a wide reach and roots in a number of mathematical and scientific disciplines; it exists in systems as diverse as natural phenomenon such as weather patterns, snowflake symmetry, and sand dunes to social systems such as language, to man-made systems such as traffic systems and open source software.

4.3.2 Hierarchy

“Hierarchy is the principle according to which entities meaningfully treated as wholes are built up of smaller entities which are themselves wholes … and so

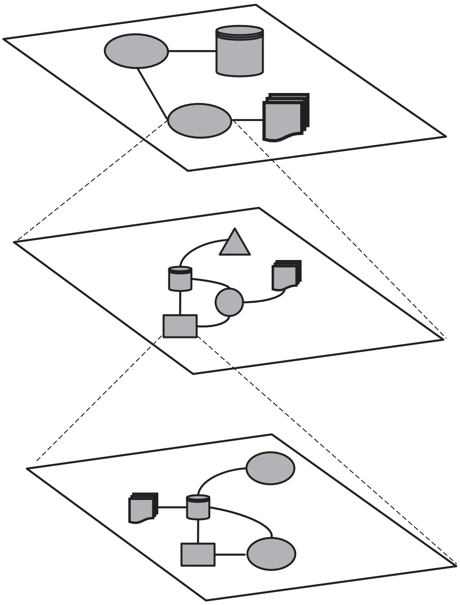


Fig. 4.3 Three level system hierarchy

on. In a hierarchy, *emergent properties* denote the levels" [27, p. 314]. The hierarchy principle is used in all aspects of systems design and analysis. Systems in design start from a high-level concept and are then developed by allocating functions to subsystems and components and so on. During analysis a systems is broken into smaller parts, understood, and then reassembled. In a systems hierarchy, emergent properties denote the transition from one level to another. More formally:

> … there exists a hierarchy of levels of organization, each more complex than the one below, a level being characterized by emergent properties which do not exist at the lower level. [27, p. 78]

A simple three-level systems hierarchy is depicted in Fig. 4.3.

4.3.3 Communication and Control

Communication and control are the pair-set that enable transmission of operational properties related to a systems' performance. Without the ability to communicate essential operating properties control would not be possible. Control is the principle that permits the system to adapt and remain viable. More formally:

> … a hierarchy of systems which are open must entail processes of communication and control if the systems are to survive the knocks administered by the systems' environment. [27, p 83]

4.4 The Contextual Axiom

The Contextual Axiom states:

> System meaning is informed by the circumstances and factors that surround the system. The contextual axiom's propositions are those which bound the system by providing guidance that enables an investigator to understand the set of external circumstances or factors that enable or constrain a particular system. [4, p. 119]

The contextual axiom has three principles: (1) holism, (2) darkness, and (3) complementarity.

4.4.1 Holism

Holism is the philosophical position which holds that understanding a system is based not solely in terms of the functions of the component parts, but by viewing the system as a whole. It may be thought of as being in direct opposition to the scientific position of reductionism that states that systems can be explained by reduction to their fundamental parts. More formally:

> It is very important to recognize that the whole is not something additional to the parts: it is the parts in a definite structural arrangement with mutual activities that constitute the whole. The structure and the activities differ in character according to the stage of development of the whole; but the whole is just this specific structure of parts with their appropriate activities and functions. [81, p. 104]

The synthetic nature of holism is in sharp contrast with reductionism. A holistic perspective permits expanded thought and improved understanding. Candace Pert [1946–2013], distinguished neuroscientist and pharmacologist frames the holistic perspective as follows:

> The Cartesian era, as Western philosophical thought since Descartes has been known, has been dominated by reductionist methodology; which attempts to understand life by examining the tiniest pieces of it, and then extrapolating from these pieces to overarching surmises about the whole. Reductionist Cartesian thought is now in the process of adding something new and exciting - and holistic. [71, p. 18]

It is important to note that when we speak of holism we do so in a systemic fashion. We do not advocate the replacement of reductionist methods with the synthetic, but advocate their use, together, in a complementary fashion. “This more holistic approach complements the reductionist view, expanding it rather than replacing it, and offers a new way to think…” [71, p. 19].

4.4.2 Darkness

System darkness states that no system can be completely known [1, p. 128]. This is based upon the fact that the human observer has limited sensory capabilities and may never be able to truly see all aspects of a system. This does not mean giving up, but does provide some humility to the scientific observer when treating observations as absolutes. For the systems practitioner it is important in that:

> Each element in the system is ignorant of the behavior of the system as a whole, it responds only to information that is available to it locally. This point is vitally important. If each element 'knew' what was happening to the system as a whole, all of the complexity would have to be present in that element. [33, pp. 4–5]

4.4.3 Complementarity

Complementarity addresses the aspect that no single perspective or view of a system can provide complete knowledge of the system. Niels Bohr [1885–1962], the 1922 Nobel Laureate in Physics, coined this term during his experiments on particle physics. Bohr stated that if two concepts are complementary, an experiment that clearly illustrates one concept will obscure the other complementary one. For example, an experiment that illustrates the particle properties of light will not show any of the wave properties of light [1, p. 128].

Once again, this does not mean giving up, but requires the observer to gain additional perspectives in order to improve understanding. In the limit, an infinite number of perspectives will reveal perfect understanding. Realizing that an infinite number is not realistic, it informs the observer that each additional perspective of a system will reveal additional truths.

4.5 The Goal Axiom

The Goal Axiom states:

> Systems achieve specific goals through purposeful behavior using pathways and means. The goal axiom's principles address the pathways and means for implementing systems that are capable of achieving a specific purpose. [4, p. 119]

The goal axiom has six principles: (1) equifinality, (2) multifinality, (3) purposive behavior, (4) satisficing, (5) viability, and (6) finite causality.

4.5.1 Equifinality and Multifinality

An essential difference between most man-made and living systems can be expressed by the principle of equifinality, a principle that can be summed up by the famous idiom, all roads lead to Rome. Most man-made systems are closed systems, while living systems are open or vital systems. "Open systems are exchanging materials with the environment and can exhibit equifinal behavior. However, a closed system must obey the 2nd law of thermodynamics which states that entropy (the property of matter that measures the degree of randomization or disorder at the microscopic level) can be produced but never destroyed" [1, p. 129].

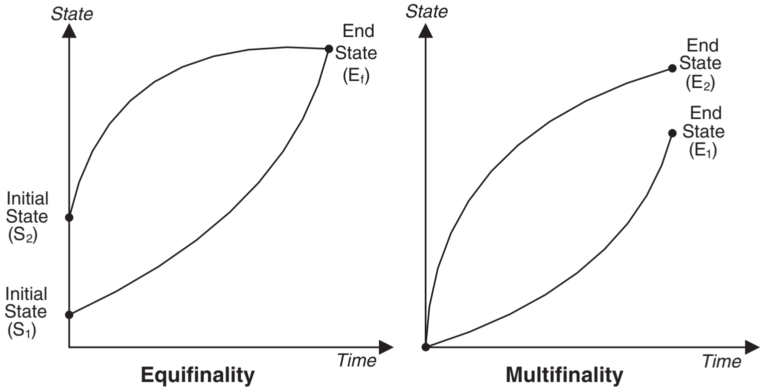


Fig. 4.4 Contrast between the principles of equifinality and multifinality

Equifinality states:

> If a steady state is reached in an open system, it is independent of the initial conditions, and determined only by the system parameters, i.e. rates of reaction and transport. [15, p. 142]

This can be sharply contrasted with multifinality where "similar initial conditions may lead to dis-similar end-states" [20, p. 60]. Figure 4.4 shows that shows that multifinality is a state in which similar initial conditions lead to dissimilar end-states, and equifinality is a state in which dissimilar initial conditions lead to a similar end-state.

4.5.2 Purposive Behavior

All man-made systems display purposive (or purposeful, we, like many authors in the field, e.g., Churchman and Ackoff [32], use the terms interchangeably) behavior. Purposive behavior is defined as:

> Purposeful behavior is meant to denote that the act or behavior may be interpreted as directed to the attainment of a goal-i.e., to a final condition in which the behaving object reaches a definite correlation in time or in space with respect to another object or event. [72, p. 18]

In man-made systems purposive behavior is a function of the systems' mission, goals, and objectives. Churchman and Ackoff [32] noted a number of similarities in purpose-built objects (i.e. man-made systems). Three of these similarities are important elements of this systems principle.

1. Presence of Choice: "The basis of the concept of purpose is the awareness of voluntary activity" [72, p. 19]. Choice is essential to identify purpose.
2. Inclusion of Time: "Purposive behavior can only be studied relative to a period of time" [32, p. 35].
3. Production Requirement: "The purposive object or behavior is at least a potential producer of some end-result (end, objective, goal)" [32, p. 35].

In summary, purposive behavior, to which all man-made systems prescribe, requires the system to have choices, and to produce some end result over a period of time. In order to provide a complete view of the objectives of a system an understanding of the systems' purpose is necessary. Comprehension of purpose provides the foundation for framing the objectives that result from the purpose.

4.5.3 Satisficing

Herbert A. Simon [1916–2001], the 1978 Nobel Laureate in Economics, questioned the utility of traditional economic and statistical theories of rational behavior and their applicability as the foundation for human decision making. He stated:

> Both from these scanty data and from an examination of the postulates of the economic models it appears probable that, however adaptive the behavior of organisms in learning and choice situations, this adaptiveness falls far short of the ideal of 'maximizing' postulated in economic theory. Evidently, organisms adapt well enough to 'satisfice', they do not, in general, 'optimize'. [76, p. 129]

Simon's observation is keen and utilizes elements of the contextual axiom to propose that humans do not have complete information for decision making and that best results are not optimal but satisficing in nature. Once again, it DOES NOT mean ignoring the optimum by not striving for the most satisfactory in the decisions that support a system's purpose, goal or objectives. It does mean knowing that there is incomplete information with which to make the optimal decision and that the any solution will be, at best, a *satisficing*, or mostly satisfactory, solution. In other words, satisficing can be thought of as the best possible solution given the information, which is always incomplete, that you have at the present time.

4.5.4 Viability

The systems viability principle tells us that a system is in constant tension, and must maintain balance along two dimensions: change and control. This tension is present along two axes.

The first axis is that of autonomy and integration. Systems desire to be autonomous and to perform the purpose, goal, and functions for which they created. However, systems do not exist in a vacuum and must co-exist with other systems. By interfacing with other systems some level of autonomy must be sacrificed. This is the first critical tension.

The second axis of tension is stability and adaptation. When a systems fails to adapt its continued viability is challenged. With adaptation there is a loss of stability due to the loss of control.

4.5.5 Finite Causality

The principle of finite causality states that the outcome of any operation within a system is finite in nature. Considered in the context of the goal axiom, this principle allows us to understand there are bounds on the outcome of our system's operations. Hester [41] elaborates:

> As more information is gained, the expected bounds surrounding this range of potential outcomes narrows, but never…meets at a point; in other words, it never reaches an optimal solution. Rather, the best we can hope to achieve is a set of potential outcomes that are boundedly rational and, by definition, neither infinitely good nor infinitely bad. (p. 274)

This aligns with our earlier discussion of perspectives in Chap. 2. Given that we can never have complete understanding of our mess, we will never converge on a singular perfect understanding of our system. So, in terms of our goal, we will never have 100 % certainty that we will reach it. While this may be unsettling to some, it is simply a fact of life when analyzing complex systems. Thus, we must strive to increase the number of perspectives we consider and, in turn, narrow the bounds on the output of our system in order to increase our confidence in achieving our goals.

4.6 The Operational Axiom

The Operational Axiom states:

> Systems must be addressed 'in situ', where the system is exhibiting purposeful behavior. The operational principles provide guidance to those that must address the system in situ, where the system is functioning to produce behavior and performance. [4, p. 119]

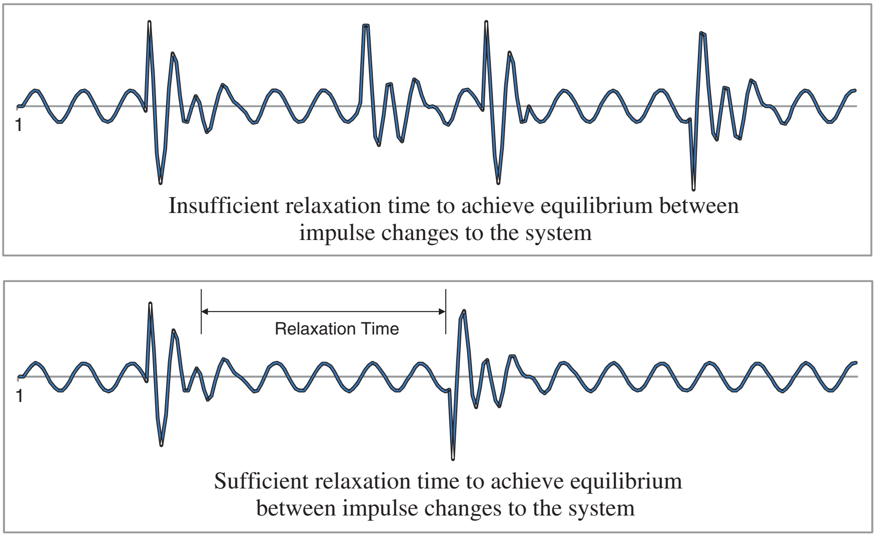
The operational axiom has seven principles: (1) dynamic equilibrium, (2) relaxation time, (3) basins of stability, (4) self-organization, (5) homeostasis and homeorhesis, (6) suboptimization, and (7) redundancy.

4.6.1 Dynamic Equilibrium

Dynamic equilibrium, as proposed by Jean D'Alembert [1717–1783], is the principle (1743) that states "for a system to be in a state of equilibrium, all subsystems must be in equilibrium. All subsystems being in a state of equilibrium, the system must be in equilibrium" [1, p. 134]. As a result of this principle we know that systems will stay in their initial condition until some sort of interaction is made with them.

4.6.2 Relaxation Time

The relaxation time principle states that "system stability is possible only if the system's equilibrium state is shorter than the mean time between disturbance" [1, p. 134].



Insufficient relaxation time to achieve equilibrium between impulse changes to the system

Sufficient relaxation time to achieve equilibrium between impulse changes to the system

Fig. 4.5 Relaxation time

In the top portion of Fig. 4.5 the system does not achieve equilibrium based on its standard relaxation time (shown in the lower portion of the figure) because it has been perturbed by another disturbance before it can achieve equilibrium. This 2nd disturbance places the system in a more complex series of amplitude shifts and decreased related relaxation times. Figure 4.5 is a depiction of relaxation time.

"The number of disturbances over time determines whether the system can possibly maintain internal stability and return to an equilibrium state" [1, p. 134]. Systems practitioners may apply the principle of relaxation time to many generalized systems as an aid during the analysis of specific system states.

4.6.3 Basins of Stability

Stuart Kauffman, a well-known complex systems researcher at the Sante Fe Institute states that complex systems have three regimes: (1) order, (2) chaos, and (3) phase transition. Order is where the system is stable (i.e., in equilibrium). This is referred to as a basin of stability, or simply a basin [82]. The basin is not a permanent place or state. The complex system may be subject to change (i.e., through self-organization or external impetus) and will shift from order to chaos. The period of time during the shift is labeled the transition phase and signifies that the system is moving to or from order to chaos. A system in order or chaos is fairly easy to identify. However, it is the *thresholds of instability*, the areas between chaos and order, that are difficult to recognize. This is an important concept for the systems practitioner to understand when working with complex systems, potentially poised on the edge of chaos.

4.6.4 Self-Organization

Simply stated, the principle of self-organization is "the spontaneous emergence of order out of the local interactions between initially independent components" [1, p. 138].

Self-organization is a well-established principle in the physical sciences [62]. Self-organization is the characteristic and ability of a system (and its constituent parts) to determine its structure and features. A leading cybernetician, W. Ross Ashby [1903–1972], proposed what he called the principle of self-organization [8] when he noted that "dynamic systems, independently of their type or composition, always tend to evolve towards a state of equilibrium" [1, p. 136].

Knowledge of this principle provides insight into the functioning of most of the complex systems surrounding the world today. Attempts to manage or control self-organizing systems may run into severe limitations because, by design, self-organizing systems resist external changes. In fact, efforts at control often achieve results very different from the desired effect, and may even result in the loss of viability and eventual destruction of the system.

4.6.5 Homeostasis and Homeorhesis

Homeostasis has played an important role in the development of the field of cybernetics. The term was created to describe the reactions in humans which ensure the body remains in steady state [26].

The principle of homeostasis is "the property of an open system to regulate its internal environment so as to maintain a stable condition, by means of multiple dynamic equilibrium adjustments controlled by interrelated regulation mechanisms" [5, p. 497].

Homeostasis may be used to depict how a system may superficially appear to be unchanged over time. If Fig. 4.6 is examined superficially the number of elements and structure at time (a) and time (b) appear to be the same. However, when the observer more carefully examines the system, they recognize that input, output, and cell elements have changed, representing the actual exchange of materials, information, and energy.

Homeorhesis is a dynamic extension of the idea presented in homeostasis. In the case of homeorhesis the equilibrium is dynamic, where in homeostasis the equilibrium is static [87]. The term *homeorhesis* is attributed to Waddington [83, 84] who described the regulation in a living particle as moving along some defined time path, from its initial creation through various life stages that end at senescence.

> The regulation that occurs in such particle is a regulation not necessarily back to a static stable equilibrium, as in homeostasis, but to a more general stable mode, some future stretch of the time path. The appropriate notion to describe this process is homeorhesis. [83, p. 32]

Homeorhesis is the self-regulating process through which the living particle, cell, or organism is maintaining its internal stability while adjusting dynamical conditions required for its survival. The stability attained as a result of homeorhesis

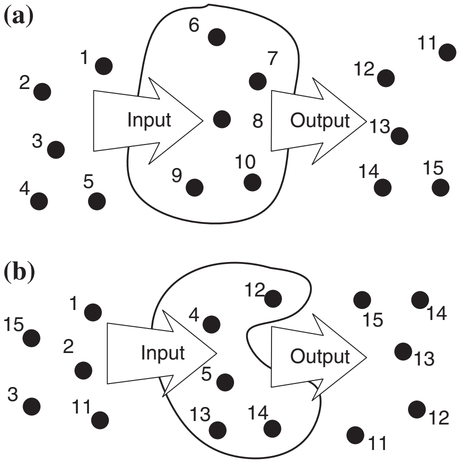


Fig. 4.6 Homeostasis in Cell at (**a**) time *t* and (**b**) time $t + s$

is dynamic, which makes sense in environments where conditions are continuously changing. This has direct application in man-made dynamic systems where certain physical mechanisms are present [29, 90].

4.6.6 Suboptimization

The concept of suboptimization was first recognized during analysis and optimization experiences by those conducting operations research in support of a number of localized and global efforts Second World War. Renowned RAND scientist, DoD Comptroller, and University of California President Charles Hitch [1910–1995] found that efforts at optimization related to the detection and sinking of German U-boats during the localized Battle of the Atlantic involved lower level criteria than those used to prosecute the larger global war as a whole:

> The optimal (or less ambitiously, good) solutions sought by operations research are almost always "sub-optimizations" in the sense that the explicit criteria used are appropriate to a low (or at least not the highest) level with which the researcher and his client are really concerned. [42, p. 1; 43, p. 87]

This elegant principle may be restated such that "if each subsystem, regarded separately, is made to operate with maximum efficiency, the system as a whole will not operate with utmost efficiency" [1, p. 135].

The principle is important during both design and development and operation and maintenance of subsystems and the larger super-systems in which they work. By applying this principle the systems practitioner acknowledges that attempts at optimization within each subsystem independently will not in general lead to a system optimum. In fact, improvement of a particular subsystem may actually worsen the overall performance of the larger system.

4.6.7 Redundancy

Simply stated, the redundancy principle is the duplication of critical components or functions of a system with the intention of increasing reliability of the system [64].

The introduction of redundancy in the operational axiom is to ensure that the system has redundant, or excess, resources in order to operate successfully. Recognizing that operational systems exist in the real-world, where they are often subject to changing resources, unstable environments, and changing requirements, levels of redundancy are provided to ensure stability in the system.

4.7 The Viability Axiom

The Viability Axiom states:

> Key parameters in a system must be controlled to ensure continued existence. The viability principles address how to design a system so that changes in the operational environment may be detected and affected to ensure continued existence. [4, p. 119]

The viability axiom has five principles: (1) requisite variety, (2) requisite hierarchy, (3) feedback, (4) circular causality, and (5) recursion.

4.7.1 Requisite Variety

Variety is a measure of complexity. Specifically, it is a measure of the number of different system states that may exist. A simple equation for calculating the variety of a system is presented in Eq. 4.1 [36, p. 26].

$$V = Z^n \tag{4.1}$$

where

V Variety or potential number of system states
Z Number of possible states of each system element
n Number of system elements

A simple example shows how the variety measure relates to complexity. Suppose there is a system with six operators working on five different machines where the machines may only have one of two states: on or off. This gives us 30 possible system elements. The formula for variety may be used to calculate the system variety which in this case is 2^{30}, or 1,073,741,824. So, for a relatively simple system the number of states is greater than 1 billion.

The example shows that the potential variety rapidly exceeds what is both comprehendible and controllable. Systems practitioners should recognize that variety is a function of the system inputs and outputs and that in an unbounded or open system, the variety is infinite. There are two methods for controlling variety: (1) properly defining the system boundary and (2) introducing the use of regulators (variety attenuators). Each method, has, as its primary purpose, the reduction of inputs to control the variety and the overall complexity of the system. Ashby's law of requisite variety simply says "variety can destroy variety" [10, p. 207].

Systems practitioners must ensure that their designs contain control variety that is greater than or equal to the variety of the element being controlled.

4.7.2 Requisite Hierarchy

In many cases, a regulator of sufficient variety does not exist. In this case the systems practitioner may apply the Principle of Requisite Hierarchy. Requisite hierarchy states that "regulatory ability can be compensated for, up to a certain amount, by a greater hierarchy in organization" [1, p. 142]. So, in order to supplement the variety in a single regulator, a hierarchy of regulation may be constructed.

4.7.3 Feedback

Feedback is the central tenet of cybernetics and the foundation for the study of all control mechanisms present in living systems and in man-made systems. Feedback is the basic element that systems use to control their behavior and to compensate for unexpected disturbances.

The use of feedback, in many forms, is the primary method for maintaining or regulating system parameters. Feedback is an essential element of systems design and in satisfying the objectives, goals, outputs and outcomes of a system.

4.7.4 Circular Causality

The principle of circular causality states:

> An effect becomes a causative factor for future effects, influencing them in a manner particularly subtle, variable, flexible, and of an endless number of possibilities. [48, p. 12]

"Circular causality addresses the impact or effects that one system may have on another…. The utility of the principle of causality arises from the fact that systems must be treated carefully and that a range of disturbances and events, no matter how seemingly trivial they seem, may directly impact one another" [1, p. 146].

Circular causality refers to a complex of events that reinforce themselves through series of feedback loops (e.g., causal loops). There are labels that may be used for these two highly specialized loops:

1. *Virtuous Circles*: “What is a vicious circle for one party, then, is a virtuous circle for another” [54, pp. 30–31]. A virtuous circle has favorable results.
2. *Vicious Circles*: “A deviation amplifying loop (i.e., actions loops) with counterproductive results” [54, p. 16]. A vicious circle has detrimental results.

4.7.5 Recursion

The principle of recursion is closely related to the hierarchy principle. “The principle of recursion states that the fundamental laws governing the processes at one level are also present at the next higher level. The principle can be expressed by understanding the following” [1, p. 147]:

- although level n + 1 is more complex than level n, the fundamental laws present at level n are still present at level n + 1
- when you apply the principle of recursion, you can deduce the fundamental principles of level n + 1 from empirical observations at level n.

This principle aid systems practitioners in gaining improved understanding for the presence of properties across the levels of a hierarchy. In software engineering this principle is termed *inheritance* where “a semantic notion by which the responsibilities (properties and constraints) of a subclass are considered to include the responsibilities of a superclass” [46, p. 175].

4.8 The Design Axiom

The Design Axiom states:

> System design is a purposeful imbalance of resources and relationships. The design principles provide guidance on how a system is planned, instantiated, and evolved in a purposive manner. [4, p. 119]

The design axiom has four principles: (1) requisite parsimony, (2) requisite saliency, (3) minimum critical specification, and (4) Pareto.

4.8.1 Requisite Parsimony

The Law of Requisite Parsimony is an outcome of a seminal paper by George Miller [59] titled *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capability for Processing Information*. Miller states that human beings have a limit on the number of items they can process simultaneously and that this number is between five and nine observations. Miller’s research showed that the *magical number seven* applies to a number of areas, including (1) span of attention, (2) span of immediate memory, and (3) span of absolute judgment.

On a practical level the systems practitioner should invoke the Law of Requisite Parsimony and ensure that system goals, objectives, concepts, hierarchies, configuration items, design levels, etc. are maintained between five and nine. This is particularly important when judgments are being made.

4.8.2 *Requisite Saliency*

Kenneth Boulding was interested in how designers selected the most important features (i.e., salient features) in a design [19]. After careful research he proposed the principle of requisite saliency which states:

> The situational factors that require consideration in developing a design Target and introducing it in a Design Situation are seldom of equal saliency. Instead there is an underlying logic awaiting discovery in each Design Situation that will reveal the relative saliency of these factors. [85, p. 34]

Requisite saliency is particularly important during systems design because analysis-of-alternatives (AoA) and design tradeoffs process data into information, information into knowledge, and use knowledge to make decisions on a routine basis. Requisite saliency allows the design team to rank the systems design parameters and treat them accordingly. Systems practitioners should ensure that all analysis, design, and solution processes include a specific provision that reveals relative saliency for all system design factors.

4.8.3 *Minimum Critical Specification*

The principle of minimum critical specification "…has two aspects, negative and positive. The negative simply states that no more should be specified than is absolutely essential; the positive requires that we identify what is essential" [30, p. 155].

Because engineers invoke the principle of redundancy to ensure safety, many designs include significant over-design. By applying this principle, the systems practitioner is bound to ensure designs specify only those elements which are essential. There is another highly compelling reason for placing bounds on design activities. This seems to sharply contrast with the principle of redundancy, which requires redundancy for both safety and to absorb shock to the system. However, both principles are important and requisite saliency must be applied. Because of the principle of darkness, where designers never have complete knowledge of a system, many of the benefits planned through specification often become obsolete as the human, social, political and organizational elements that surround the design become known. Therefore, specifying only what is required, especially in the early design phases, may mitigate the crippling effects caused by the evolving changes in context.

4.8.4 *Pareto*

The Pareto Principle states “that in any large complex system 80 % of the output will be produced by only 20 % of the system. The corollary to this is that 20 % of the results absorb 80 % of the resources or productive efforts” [1, p. 147].

For the systems practitioner, this principle may be applied to any number of design and problem solving elements. Of particular importance is the notion that improvements in the systems design, beyond a certain threshold, becomes prohibitively expensive in time, human effort, and materials.

4.9 The Information Axiom

The Information Axiom states:

> Systems create, possess, transfer, and modify information. The information principles provide understanding of how information affects systems. [4, p. 119]

The information axiom has three principles: (1) information redundancy, (2) redundancy of potential command, and (3) Finagle’s Laws on Information.

4.9.1 *Information Redundancy*

Information redundancy is “the fraction of the structure of the message which is determined not by the free choice of the sender, but rather by the accepted statistical rules governing the use of the symbols in question…one minus the relative entropy is called the *redundancy*” [73, p. 13].

The system practitioner may view information redundancy from both positive and negative viewpoints. The negative perspective views redundancy as the amount of wasted space used to transmit certain data. The positive perspective may view redundant checksums as a highly desirable method of error detection when communicating over a noisy channel of limited capacity.

4.9.2 *Redundancy of Potential Command*

The studies that produced this principle were associated with the transmission of signals between the brain and the nervous system conducted in the 1950s by Warren McCulloch and his staff at the MIT electronics laboratory. The studies uncovered the importance played by auxiliary information channels during nervous systems transmissions. The researchers found that the auxiliary channel was transmitting, just like the primary channel, so that two signals were being delivered. Neither signal was feedback, but signals based on the primary stimulus. Dual channels transmitting redundant information [55].

McCulloch likened this to an actual experience he had during his stint in the U.S. Navy in World War I.

> Every ship of any size or consequence receives information from the others and sweeps the sky for hundreds of miles and water for tens of miles with its own sense organs. In war games and in action, the actual control passes from minute to minute from ship to ship, according to which knot of communication has then the crucial information to commit the fleet to action. This is neither the decentralized command proposed for armies, nor a fixed structure of command of any rigid sort. It is a redundancy of potential command wherein knowledge constitutes authority. [56, p. 226]

This concept is particularly true within the most complex system known; the human body. Early reductionist views of the human body proposed that the brain was the central source of information and control. A modern, holistic view of the human body (i.e., the mind-body perspective which requires the synthesis of views held by the physiologists with those of the neurologists), proven in the laboratory, has shown that this is not true.

> … the flow of chemicals arose from many sites in the different systems simultaneously - the immune, the nervous, the endocrine, and the gastrointestinal - and that these sites formed nodal points on a vast superhighway of internal information exchange taking place on a molecular level. We then had to consider a system with intelligence diffused throughout, rather than a one-way operation adhering strictly to the laws of cause and effect, as was previously thought when we believed that the brain ruled over all. [71, p. 310]

The principle of redundancy of potential command states that "effective action is achieved by an adequate concatenation of information. In other words, power resides where information resides" [1, p. 151]. The systems practitioner may use this principle to ensure that signals used for feedback are sourced as close to the primary stimulus as possible.

4.9.3 Finagle's Laws on Information

Finagle's Laws on Information, which are less a set of laws and more of an aphorism, is an information principle that is generally accepted and applied in the Public Health Profession [11, 66]. The principle focuses on data, and its processed forms (i.e., information and knowledge), and they should be viewed as an element of improved understanding when dealing with complex systems, their messes and constituent problems. Finagle's Laws on Information state [45, 61]:

- The information you have is not what you want.
- The information you want is not what you need.
- The information you need is not what you can obtain.

Further, Opit [63] adds a fourth law, which states:

- The information you can get costs more than you want to pay.

Application of this aphorism warns the practitioner to not take data, information and knowledge for granted when working on messes and problems and to go the extra mile in ensuring the accuracy, validity, and reliability of data.

Table 4.3 Linkage of systems principles to systemic thinking perspectives

Axiom	Proposition and primary proponent	Affiliated systemic thinking perspective					
		Who?	What?	Why?	Where?	How?	When?
Centrality	Communication [74, 75]	X				X	
	Control [28]						X
	Emergence [6]		X				
	Hierarchy [70]		X				X
Contextual	Complementarity [17]	X	X		X		
	Darkness [33]	X	X		X		
	Holism [80]				X		
Design	Minimum critical specification [30, 31]		X				
	Pareto [65]		X				
	Requisite Parsimony [59]		X	X			
	Requisite Saliency [19]		X				
Goal	Equifinality [14]		X				X
	Multifinality [20]		X				
	Purposive Behavior [72]		X	X			
	Satisficing [78, 81]		X			X	
	Viability [12]					X	X
	Finite causality [41]		X				
Information	Information redundancy [73]		X				
	Redundancy of potential command [55]	X					
	Finagle's laws on information [45, 61, 63]				X	X	

(continued)

Table 4.3 (continued)

Axiom	Proposition and primary proponent	Affiliated systemic thinking perspective					
		Who?	What?	Why?	Where?	How?	When?
Operational	Basins of stability [82]						X
	Dynamic equilibrium [35]			X			X
	Homeostasis [26] and Homeorhesis [83, 84]			X			X
	Redundancy [64]					X	
	Relaxation time [43]					X	X
	Self-organization [9]		X				X
	Suboptimization [43]	X	X				
Viability	Circular causality [48]			X			
	Feedback [86]			X	X		X
	Recursion [12]						X
	Requisite Hierarchy [10]			X			
	Requisite variety [10]					X	

The information axiom and the elements of information theory contained within it are important tools for systems practitioners. “Information theory releases us from the trap of reductionism and its tenets of positivism, determinism, and objectivism” [71, p. 261]. By including information theory as an element of our systemic perspective we are supplementing the mechanistic view (which focuses solely on matter and energy) with the concept of information as a common denominator for viewing and understanding systems.

4.10 Linkage of Systems Principles to Systemic Thinking Perspectives

Table 4.3 shows how each of the perspectives in systemic thinking are related to the principles discussed in this chapter. It is important that each of the principles be addressed in at least one perspective in our systemic thinking methodology as they form the underlying theoretical construct that provides rigor for our approach. It is worth noting that there is not a one-to-one relationship between any of the axioms and a singular perspective.

4.11 Summary

Systems theory, as described in this Chapter, provides the underlying theoretical foundation for understanding systems. Understanding the laws, principles, and concepts that underlie all systems understanding, in conjunctions with the thought process developed in systemic thinking, are necessary first steps in approaching messes and the problems that are contained within the mess.

Our concept of systemic thinking is focused on the solution of complex problems through the pragmatic application of the laws, principles, and concepts that apply to each and every system. Application of systems theory will serve to provide the formalism and framework for the inclusion of systems laws, principles, and concepts that can be used in the Chapters that follow.

Readers interested in reviewing additional principles of systems theory are encouraged to consult Skyttner [79, pp. 92–96], Clemson [34, pp. 199–257], and Adams [1].

After reading this chapter, the reader should:

1. Be familiar with the historical roots of our notion for systems theory;
2. Understand the construct for our notion of systems theory and its seven axioms;
3. Be familiar with the principles that support the axioms of systems theory; and
4. Be prepared to associate the systems principles with the affiliated systemic thinking perspectives that will be discussed in Chaps. 5–11.

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Part II
A Methodology for Systemic Thinking

Chapter 5
The *Who* of Systemic Thinking

Abstract The main focus of the *who* question of systemic thinking is on the stakeholders associated with our mess. We take the occasion in this chapter to discuss our approach for the analysis and management of stakeholders. First, the introduction provides a brief background of stakeholder analysis and an overview of our approach to stakeholder analysis, which is then followed by a detailed discussion of each of these steps. Finally, a framework is presented for stakeholder analysis and management.

5.1 Introduction

Hester and Adams [13] offer a succinct introduction to stakeholder analysis:

> Stakeholder analysis was first explored by Freeman [11] as a methodology to assist business organization leadership with their strategic management functions. Stakeholder analysis has since expanded beyond the corporate arena. Stakeholders exist at the center of any complex problem solving effort and holistic consideration of them is a key element of analyzing a problem systemically. Stakeholders are the customers, users, clients, suppliers, employees, regulators, and team members of a system. They fund a system, design it, build it, operate it, maintain it, and dispose of it. Each stakeholder contributes their own value-added perspective, as described by the systems principle known as complementarity. (p. 337)

It is with this perspective in mind that we propose the following six step process for stakeholder analysis and management:

1. Brainstorm stakeholders
2. Classify stakeholders
3. Evaluate stakeholder attitudes
4. Determine stakeholder engagement priority
5. Develop a stakeholder management plan
6. Manage stakeholders.

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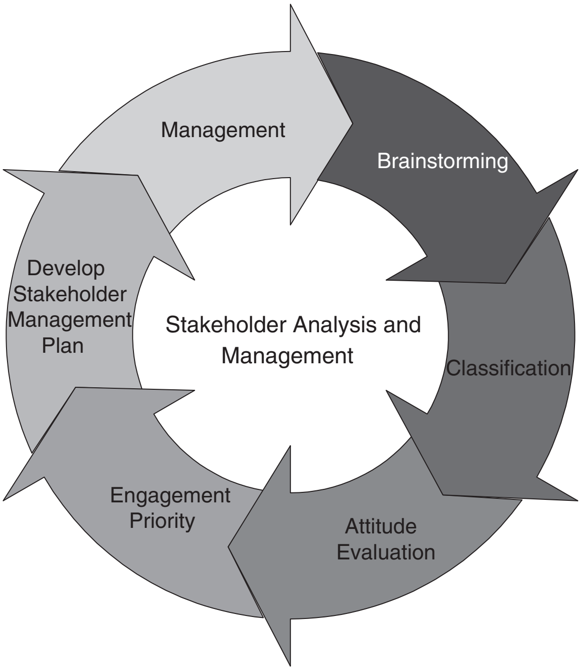


Fig. 5.1 Stakeholder analysis and management process

Much like other elements of systemic thinking, stakeholder analysis and management is an iterative process as depicted in Fig. 5.1.

Thus, while we begin with brainstorming, as systemic thinkers, we recognize that we'll likely have to revisit our steps as our understanding of our system and problem evolves. The following sections provide details regarding each of the six steps, and a framework for undertaking stakeholder analysis and management, which is demonstrated on a simple example concerning real estate rezoning.

5.2 Brainstorm Stakeholders

The first step necessary for stakeholder analysis is arguably the most straightforward, that is, identifying the stakeholders relevant to the problem being analyzed and speculating as to their desires. It should be noted that the issue of which came first, the stakeholder or the problem, is a classic chicken-or-egg issue. We must have some notion of our problem before we can brainstorm who might be relevant to the problem solving process, however, we need those very stakeholders to help us clearly formulate (and later reformulate) our problem. Thus, we must in all but the simplest of cases start with a Revision 0 and iterate on both stakeholders and problem definition (as well as our context). This naturally leads to the question of what a stakeholder is. While the notion of a stakeholder is fairly ubiquitous, we will show throughout the course of this chapter that analysis of them is anything but trivial.

In order to brainstorm stakeholders we must first consider the "the principle of who or what really counts" [12, p. 413]. One of the earliest and broadest definitions of a stakeholder comes from Freeman [11], who defines a stakeholder as someone who "can affect or is affected by the achievement of the organization's objectives" (p. 46). Mitchell et al. [18] expand on these notions, questioning, "… who (or what) are the stakeholders of the firm? And to whom (or what) do managers pay attention?" (p. 853). That is, how can we identify our stakeholders and how do we decide on strategies to engage these stakeholders in support of problem solution strategies? These two questions are the keys to stakeholder analysis.

With this frame of reference in mind, we can see why stakeholder analysis is a crucial element in systemic thinking. Stakeholders influence every aspect of our problem. The choice of Freeman's definition, admittedly an intentionally broad definition, is purposeful. Systemic thinking involves taking a broad perspective on a problem and, in the case of stakeholders, we ought to err on the side of inclusion rather than exclusion. Step 1 of the stakeholder analysis process truly is a brainstorming exercise. At this point it is up to the systems practitioner and other identified participants to brainstorm answers to a question form of Freeman's notion of stakeholders, that is, *who can affect or is affected by the problem solution*? This list may include users, customers (users who spend money), a project financier, regulatory agencies, those responsible for maintenance, competitors, and others. The next question we must ask ourselves is, *what does the stakeholder want as a result of problem resolution*? Articulation of a stakeholder desire is a simple narrative summarizing what a stakeholder may wish to achieve as the result of a successful problem resolution. This allows us to brainstorm what the stakeholder wants from the intervention or, if possible, simply ask the stakeholder about their desires with respect to the problem (this of course is the most straightforward manner to obtain this information but it may not be feasible or desirable). This analysis will be vital in determining stakeholder engagement priority in Step 4. It is worth noting that the focus is on what a stakeholder *wants* and not what they *need* due to the suboptimization principle [15]; that is, everyone will not get what they want in order for the problem system to achieve its goal in the most effective manner.

The output of this step is simply a list of individuals and groups that *may* be considered as stakeholders and their desires. The following is an example list of stakeholders and their associated expectations that might be generated by a real estate development company after they have been awarded a contract for a new commercial real estate development:

1. The real estate developer *wants* financial gain.
2. City council wants to be reelected.
3. State government wants tax revenue.
4. Zoning commission wants compliance from any new development.
5. Tenants of the proposed development want a nice place to live at an affordable price.
6. Customers of proposed commercial entities want attractive shopping.
7. Environmentalists want a development with minimal environmental impact.

Table 5.1 Stakeholder attribute definitions

Attribute	Definition	Sources
Power	"A relationship among social actors in which one social actor, A, can get another social actor, B, to do something that B would not" [18, p. 869]	[9, 22, 27]
Legitimacy	"A generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, definitions" [18, p. 869]	[26, 27]
Urgency	"The degree to which stakeholder claims call for immediate attention" [18, p. 869]	[18]

8. Rival real estate developers want the development to fail.
9. Safety personnel for ADA related concerns wants compliance of the design with ADA standards.
10. Tourists want additional attractions to consider during their visit.
11. The Chamber of Commerce wants additional members.
12. and so on….

It is clear that this list can grow quite large rather rapidly. The key to this step is to capture all of these entities in Step 1, without regarding for classification, attitude, or priority of these stakeholders in any manner. Consideration for these elements will be accounted for in subsequent steps of the stakeholder analysis process. If we think that they may affect or be affected by the problem, then they should be included as potential stakeholders.

5.3 Classify Stakeholders

As we complete Step 1, we have a potentially overwhelming list of stakeholders to consider in our problem solving process. In order to begin to make sense of this list, we must first classify these stakeholders. To do so, we draw from Mitchell et al. [18], who developed a typology in order to enable organizations to analyze and decide which stakeholders demanded the greatest organizational attention. Their typology specifies three key stakeholder attributes: (1) power, (2) legitimacy, and (3) urgency. These terms are defined in Table 5.1 in terms of their scholarly origins and the definitions provided for them by Mitchell et al. [18].

For each stakeholder, one should answer the question of whether or not each attribute is exhibited by the stakeholder in a simple binary fashion. Stakeholders may exhibit zero, one, two, or all three of these attributes. The number and type of attributes possessed help to define the class for each stakeholder. Mitchell et al. [18] go on to classify each of the eight possible combinations of these attributes as shown in Fig. 5.2.

Further, these stakeholders can be classified in terms of the number of attributes they exhibit; thus, any given stakeholder classification contains one or more class of stakeholders. Individuals who exhibit none of the attributes are considered to be *Non-stakeholders*. Stakeholders exhibiting any one of power, legitimacy, or urgency are

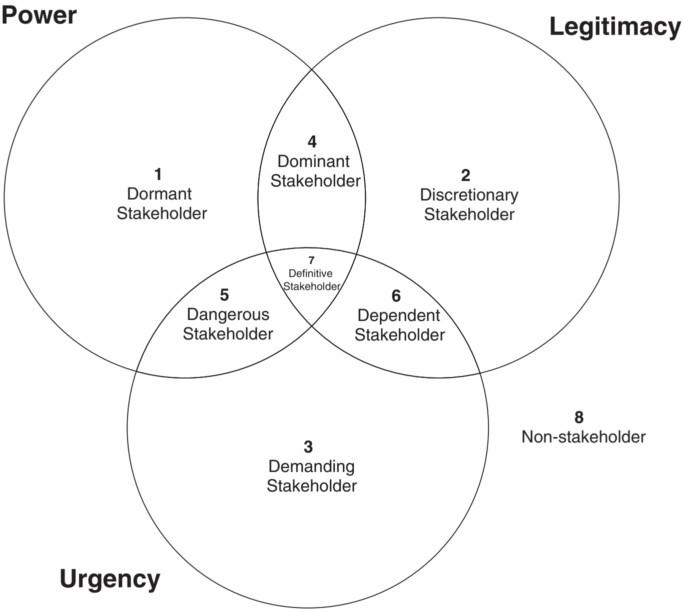


Fig. 5.2 Stakeholder typology, adapted from Mitchell et al. [18]

Table 5.2 Stakeholder class, attributes, and classifications

Stakeholder class	Stakeholder attribute			Stakeholder classification
	Power	Legitimacy	Urgency	
Dormant	Yes	No	No	Latent
Discretionary	No	Yes	No	
Demanding	No	No	Yes	
Dominant	Yes	Yes	No	Expectant
Dangerous	Yes	No	Yes	
Dependent	No	Yes	Yes	
Definitive	Yes	Yes	Yes	Definitive
Non-stakeholder	No	No	No	Undefined

classified as *Latent* (either dormant, discretionary, or demanding). Latent stakeholders have little expectation for influence on an associated system, and “managers may not even go so far as to recognize those stakeholders’ existence” [18, p. 874]. Stakeholders exhibiting any two attributes can be classified as *Expectant* (dominant, dangerous, or dependent), individuals who “are seen as ‘expecting something,’ because the combination of two attributes leads the stakeholder to an active versus a passive stance, with a corresponding increase in firm responsiveness to the stakeholder’s interests” [18, p. 876]. Finally, *Definitive* stakeholders exhibit all three stakeholder attributes. With these individuals, “managers have a clear and immediate mandate to attend to and give priority to that stakeholder’s claim” [18, p. 878]. Table 5.2 illustrates stakeholder class, attributes, and classification as they relate to one another.

While this is a useful typology and Mitchell et al. [18] make some initial recommendations regarding actions to deal with stakeholders based on their classification, we contend that it is insufficient. Their typology fails to account for the underlying attitude of the stakeholder, to which we now turn our attention.

5.4 Evaluate Stakeholder Attitudes

As we transition to Step 3 of the stakeholder analysis process, we have brainstormed our stakeholders and classified them according to their prominence within the context of the problem we are addressing. A strategy for engaging stakeholders based solely on their relative classification is insufficient as it does not account for stakeholder support or opposition to a particular endeavor. For example, if a stakeholder is supportive of a project, while they may not be classified as definitive, it still may be advantageous for us to engage them in developing the solution to a complex problem. Thus, it is imperative that we evaluate the attitude of our stakeholders with respect to our particular effort. For this classification, the authors draw on work by Savage et al. [23], who categorize stakeholder attitude according to two characteristics: (1) potential for threat and (2) potential for cooperation, as shown in Fig. 5.3.

Savage et al. [23] propose four strategies for dealing with stakeholders of varying attitude:

1. *Involve*: Leverage key relationships and network, possibly engage in an active champion role.
2. *Collaborate*: Enter strategic alliances or partnerships, educate if necessary.
3. *Defend*: Move towards reducing dependency on stakeholder.
4. *Monitor*: Gather information and observe.

To this set of four strategies, we add the strategy of *no action*. As we will show in the following discussion, this is a valid approach for particular stakeholder classifications and attitudes. Figure 5.4 shows all of these strategies in what Hester et al. [14] term a *continuum of stakeholder involvement*.

The continuum of stakeholder involvement shows the strategies available for an organization to use when dealing with a stakeholder. As the strategies progress from left to right, stakeholders become more involved, thereby requiring substantially more resources at every step, thus, *monitor* is more resource intensive than *no action*, *defend* is more resource intensive than *monitor*, and so on. Savage et al. [23] propose the following strategies for their four stakeholder types:

- *Involve* supportive stakeholders
- *Collaborate* with mixed stakeholders
- *Defend* against non-supportive stakeholders
- *Monitor* marginal stakeholders.

Aligning the appropriate strategy with a stakeholder's attitude toward a problem is critically important. Expending too many resources on a stakeholder is at best a

Fig. 5.3 Stakeholder attitude characterization, adapted from Savage et al. [23]

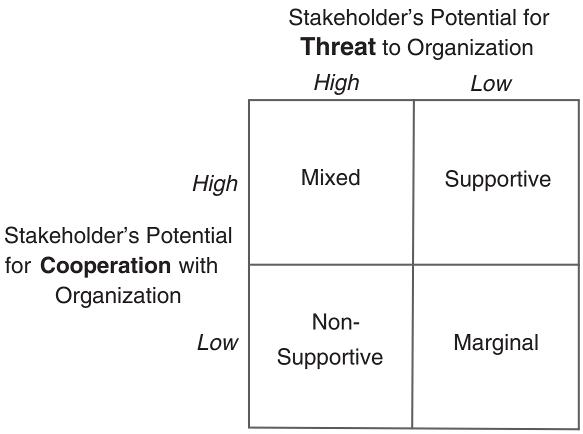
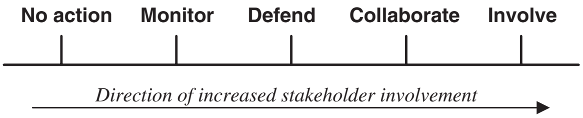


Fig. 5.4 Continuum of stakeholder involvement, adapted from Hester et al. [14]



resource waste, and at worst a risk. We risk alienating that particular stakeholder and turning their attitude into one that is in opposition to our endeavor. Thus, if we involve a non-supportive stakeholder, they will consume resources which are better spent on stakeholders who may otherwise have supported our effort. Conversely, spending insufficient resources on a stakeholder means that we have wasted an opportunity. Merely collaborating with a supportive stakeholder means that we missed out on an opportunity to involve them in the solution process.

Savage et al. [23] devote specific attention to the dangers of the collaborate strategy. Collaborating with a mixed stakeholder can result in either a positive outcome (they become supportive) or a negative one (they become non-supportive). Thus, once again with an eye toward resource conservation, we must be careful as to which stakeholders we choose to engage with and to what extent. While offering an additional stepping stone toward a complete set of stakeholder strategies, we must point out a deficiency of the approach developed by Savage et al. [23], namely that it doesn't account for the relative importance of the stakeholder. Using the typology of Mitchell et al. [18], we understand the importance of investing more heavily in ensuring that definitive stakeholders (e.g., those with power, legitimacy, and urgency) maintain a supportive attitude toward our endeavor. Thus, both approaches provide insights into the stakeholder problem, yet neither paints a complete picture. For a more comprehensive approach to dealing with stakeholders, Hester et al. [14] develop a hybrid approach. They proposed an approach to dealing with stakeholders that combines the classification typology developed by Mitchell et al. [18] and the attitude classification schema developed by Savage et al. [23]. This approach is shown in Fig. 5.5.

Stakeholder Attitude	Stakeholder Classification			
	Undefined	*Latent*	*Expectant*	*Definitive*
Supportive	**No action**	**Involve**	**Involve**	**Involve**
Mixed	**No action**	**Defend**	**Collaborate**	**Involve**
Non-supportive	**No action**	**Defend**	**Defend**	**Collaborate**
Marginal	**No action**	**Monitor**	**Monitor**	**Defend**

Fig. 5.5 Stakeholder strategies based on classification and attitude

Those stakeholders identified as undefined (non-stakeholders) using the Mitchell et al. [18] typology should be left to their own devices. Any investment of resources is a waste as these individuals have neither power, legitimacy, nor urgency, regardless of their attitude. Moving to the right in Fig. 5.5, we encounter the latent stakeholder. Latent stakeholders, per Mitchell et al. [18], should demand very few resources from management. This is largely due to their relative lack of importance in the overall problem being addressed. Thus, they are only collaborated with when supportive, as they offer some goodness (based on the fact that they exhibit one attribute), but mixed or non-supportive latent stakeholder should merely be defended against (informing them, yet not overemphasizing their involvement). Similarly, marginal latent stakeholders should merely be monitored to ensure they do not turn non-supportive (or to ensure they are transitioned to an involvement role if they become supportive). Continuing again to the right in Fig. 5.5, the expectant stakeholder is next. Strategies to engage this stakeholder align precisely with those specified by Savage et al. [23]. This reflects their fair amount of importance (as demonstrated by exhibiting two of the three stakeholder attributes), but not over-emphasizing their importance on par with a definitive stakeholder. Finally, strategies to deal with the definitive stakeholder are slightly more aggressive than the expectant stakeholder. This reflects the fundamental importance of the definitive stakeholder as one who possesses power, legitimacy, and urgency. Supportive definitive stakeholders should very clearly be involved based on their importance and attitude toward the project. Mixed definitive stakeholders should also be involved. While there is a risk in doing so, the importance of these stakeholders outweighs any associated risk. Non-supportive definitive stakeholders should be collaborated with. Again a risk, there is a greater risk in simply defending

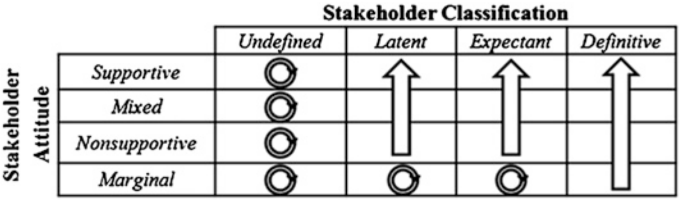


Fig. 5.6 Transformation of stakeholders, adapted from Hester et al. [14]

or monitoring these individuals because we already know they are non-supportive; ignoring them (in their eyes) would most certainly be detrimental to the project. Even marginal definitive stakeholders should be defended against due to their importance. The goal of each of these strategies is to ensure all active stakeholders (latent, expectant, and definitive) are supportive and involved. Figure 5.6 illustrates the outcome when implementing the strategies based on Fig. 5.5.

Examination of Fig. 5.6 provides some insight regarding stakeholder treatment. We are content to allow stakeholders who are undefined, marginally latent, or marginally expectant stakeholders to remain that way. All others, however, we would like to secure as supportive. Of course, this becomes a resource constraint issue as engagement of stakeholders is a resource-intensive process that is not without risk. Thus, practitioners are advised to work from right to left in the transformation of stakeholders (i.e., only address expectant stakeholders when all definitive stakeholders have been addressed fully, and so on). This practical advice, coupled with the set of stakeholder strategies presented in Fig. 5.6, provides systems practitioners the tools necessary to deal with stakeholders effectively. However, the issue of what to do in the case of multiple stakeholders who share the same attitude and classification remains unanswered. We now turn our attention to this question by examining stakeholder engagement priority.

5.5 Determine Stakeholder Engagement Priority

The fourth step in the stakeholder analysis process is to determine the priority with which we should engage stakeholders to gain increased understanding about our problem. At this point, we've brainstormed appropriate stakeholders, and determined both their attitude and classification. However, we lack the ability to prioritize our efforts regarding stakeholder engagement. This is crucial to our endeavor as we must focus our stakeholder management efforts on the stakeholders who can affect the largest amount of change. In order to determine engagement priority, we must think about our stakeholders in relation to one another. Since the darkness principle [8] informs us we are not capable of complete knowledge of a mess, we must consider multiple perspectives (i.e., stakeholders) and their relation to one another. Our suggested mechanism for capturing these relationships is with a network-based representation of stakeholders and their relationships.

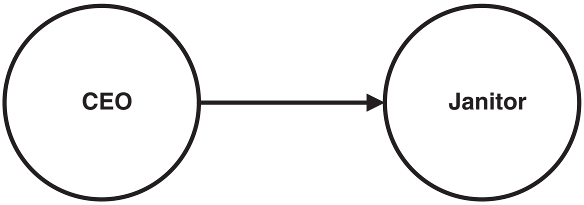


Fig. 5.7 Illustration of unidirectional stakeholder influence

Table 5.3 Freeman's measures of centrality [10]

Measure of centrality	Description	Comments
Degree	The number of nodes that a given node is adjacent to	While this is a simple, and therefore appealing, measure, it lacks the ability to account for the relative importance of the nodes to which a given node is connected to
Closeness	The inverse sum of shortest distances to all nodes from a given node	This has problems when networks have unconnected nodes, a problem that is of particular concern in a directed graph, where connections may not be symmetric
Betweenness	The degree to which a node lies on a shortest path between any other two nodes	Its appearance along a shortest path indicates that the node acts as a conduit for information flow, and thus, is an important contributor to network information transfer

Nodes within a network may be thought to represent stakeholders, while a connection between two nodes indicates an influence between the two nodes. More specifically, a directed graph can be constructed, where the directionality of arrows between nodes may represent the direction of influence exerted by one stakeholder on another (e.g., the CEO of a company may exert influence over the company janitor and this influence is likely not symmetric, thus in this case their relationship is unidirectional). A depiction of this relationship is shown in Fig. 5.7.

In order to fully capture the relationship between stakeholders, we can explore various notions of what is termed node centrality [3–6, 10]. Centrality is a measure of determining the importance of a node within a network. Table 5.3 is a list of three formalized measures of centrality as formalized by Freeman [10].

There are several issues with the measures present in Table 5.3. Directed graphs are problematic to assess using the *closeness* measure as many nodes in a directed graph may be unconnected with one another (i.e., we can't travel from node A to node B). Further, most networks have a large proportion of non-shortest-path nodes that therefore are each equally determined to have zero *betweenness*, and thus, no influence on the network. Finally, the measures in Table 5.3 were intended only for binary networks, i.e., those with arcs whose values are either one of zero. This is problematic as stakeholders are likely to have varying degrees of influence

Table 5.4 Stakeholder influence

Influence i exerts on j	w_{ij}
High	1
Medium	0.5
Low	0.25
None (no arc between i and j)	0

on one another and thus, a more sophisticated measure is necessary. Barrat et al. [2], Brandes [7], and Newman [19] attempted to generalize the work of Freeman [10] to weighted networks, but their work focused on weighted arcs and not on the number of connections of a particular node.

If we explore *degree*, recent research has provided adequate evolution to consider its use in directed graph. Freeman's original notion of degree can be defined using nomenclature from Opshal et al. [20]:

$$k_i = C_D(i) = \sum_{J}^{N} x_{ij} \tag{5.1}$$

where C_D is the degree centrality, i is the node of interest, j represents all other nodes, N is the total number of nodes, and x_{ij} is the adjacency matrix, defined as 1 if an arc exists between i and j, and 0 otherwise.

Degree has generally been revised [2, 20, 21] for weighted networks as the sum of arc weights and redefined as *strength* as follows:

$$s_i = C_D^W(i) = \sum_{j}^{N} w_{ij} \tag{5.2}$$

where C_D^W is the weighted degree centrality, and w_{ij} is the weighted adjacency matrix, defined as the weight of the connection between i and j (>0) if i is connected to j, and 0 otherwise. This weight can be determined directly by assigning a strength of influence that one stakeholder holds over another. Table 5.4 shows the values used to evaluate weight (w_{ij}) based on the influence node i exerts on node j.

This is a qualitative assessment by the systems practitioner regarding how much influence one stakeholder is able to impose upon another. This must take into account stakeholder desires (i.e., similar desired outcomes between stakeholders may allow for influence between them, whereas opposing desires may make influence more problematic). This measure of influence can be conceptualized as a proxy for the communication principle [24, 25]; i.e., if a strong influence exists between two stakeholders, then a strong communication channel can be thought to exist between the two, whereas the absence of influence is an indicator of poor communication. Two additional elements are worth noting for this assessment. The first element is that the relationships are likely not to demonstrate symmetric behavior. That is, the CEO discussed in Fig. 5.7 likely has a high influence on the Janitor, yet the feeling is likely not to be mutual. Further, we can think of entities that exhibit no influence on one another as not having a linkage between them.

Thus, in the network depiction of the problem, no arc exists between any stakeholders who have no influence between them (i.e., $w_{ij} = 0$).

Simply evaluating their strength, however, is insufficient. "Since degree and strength can be both indicators of the level of involvement of a node in the surrounding network, it is important to incorporate both these measures when studying the centrality of a node" [20, p. 246]. Based on this assertion, Opsahl et al. [20] developed a measure which combines degree and strength as follows:

$$C_D^{W\alpha}(i) = k_i \left(\frac{s_i}{k_i}\right)^{\alpha} = k_i^{(1-\alpha)} s_i^{\alpha} \tag{5.3}$$

where α is a positive tuning parameter used to adjust the relative importance of degree and strength. If $\alpha = 0$, the measure reduces to degree, as shown in Eq. 5.1. If $\alpha = 1$, the measure reduces to strength, as shown in Eq. 5.2. We suggest adopting an α of 0.5 for the purposes of this analysis, thereby insuring that the effect of both strength and degree are accounted for.

Use of this measure is complicated somewhat by the fact that our stakeholder network is directed. Opsahl et al. [20] elaborate on this issue:

> Directed networks add complexity to degree as two additional aspects of a node's involvement are possible to identify. The activity of a node, or its gregariousness, can be quantified by the number of ties that originate from a node, k^{out}. While the number of ties that are directed towards a node, k^{in}, is a proxy of its popularity. Moreover, since not all ties are not necessarily reciprocated, k^{out} is not always equal to k^{in}. For a weighted network, s^{out} and s^{in} can be defined as the total weight attached to the outgoing and incoming ties, respectively. However, these two measures have the same limitation as s in that they do not take into account the number of ties. (p. 247)

Opshal et al. [20] go on to define *activity* and *popularity*, respectively, as:

$$Activity(i) = C_{D-out}^{W\alpha}(i) = k_i^{out} \left(\frac{s_i^{out}}{k_i^{out}}\right)^{\alpha} \tag{5.4}$$

$$Popularity(i) = C_D^{W\alpha}(i) = k_i^{in} \left(\frac{s_i^{in}}{k_i^{in}}\right)^{\alpha} \tag{5.5}$$

Activity is a measure of the amount of reach that a stakeholder has in a network. It is a function of both the number of outgoing connections and the strength of these connections. Individuals with high activity are seen as highly connected and therefore important because their perspective carries a great deal of weight within the network. Recall that the redundancy of potential command principle [17] informs us that "power resides where information resides" [1, p. 151]. Those individuals with high activity are perceived to have power in our stakeholder network. They can disseminate information rapidly to many individuals. Thus, even though they may not be the CEO of an organization, their connectedness affords them power.

Table 5.5 Intersection of popularity and activity

		Popularity	
		Low	High
Activity	High	Important and easy to influence	Important but hard to influence
	Low	Not important but easy to influence	Not important and hard to influence

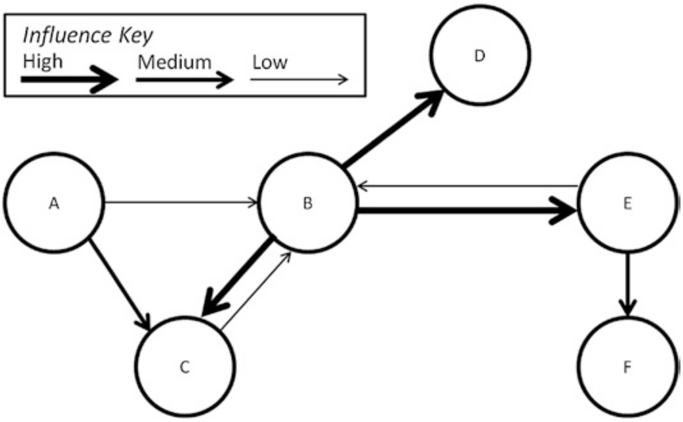


Fig. 5.8 Illustrative influence network

Popularity can be conceptualized of as the inverse of the ease with which someone is able to be influenced. That is to say, those with high popularity have a high number of incoming perspectives and are difficult to influence as a result. Those with low popularity have a small number of incoming perspectives and should be easier to influence with less dissenting opinions to deal with. Popularity considers both the number of incoming connections and the strength of those connections.

In terms of engaging our stakeholders, we must consider both their popularity and their activity. We want to influence individuals that are easy to influence, but that are important. The relationship of these two elements is important and is shown in Table 5.5.

A simple illustrative example demonstrates the calculation of activity and popularity and how we would use these characteristics to prioritize our stakeholders. We adopt an illustrative example provided by Opsahl et al. [20] and shown in Fig. 5.8 with directionality added and influence defined in accordance with Table 5.4.

Table 5.6 illustrates the Popularity and Activity results for this network, including the supporting calculations necessary for strength and degree.

Examination of Table 5.6 shows that the most active node is B. This makes sense as B has more outgoing influences than any other node and these are all rated as high. Further examination shows that the least popular (i.e., easiest to influence) node is node A. This also makes sense as it has no incoming

Table 5.6 Illustrative network characteristics

Node	k_i^{in}	k_i^{out}	s_i^{in}	s_i^{out}	Popularity	Activity
A	0	2	0	0.75	0.0	1.2
B	3	3	0.75	3	1.5	3.0
C	2	1	1.5	0.25	1.7	0.5
D	1	0	1	0	1.0	0.0
E	1	2	1	0.75	1.0	1.2
F	1	0	0.5	0	0.7	0.0

Table 5.7 Illustrative prioritization of stakeholders

Node	Popularity	Activity	Engagement priority
B	1.5	3	1
A	0	1.2	2
E	1	1.2	3
C	1.7	0.5	4
F	0.7	0	5
D	1	0	6

influences and therefore, no outside detracting opinions to contend with. Accounting for popularity and activity to determine stakeholder engagement priority should been done with an eye for accomplishing the movement of all stakeholders towards a supportive role (as shown in Fig. 5.6). It is our belief that, in order to do this, all stakeholders should be sorted by activity first (in descending order), and then, if multiple individuals share the same activity level, by popularity (in ascending order). This order reflects the order in which stakeholders should be engaged in support of an effort. Table 5.7 illustrates the prioritization values for the illustrative example.

One final element should be considered in engaging stakeholders. Each of the stakeholders A–F has a unique strategy associated with it, defined by the taxonomy shown in Fig. 5.5. Stakeholders with a more involved strategy (i.e., involve or collaborate) will require more resources to engage than a stakeholder demanding a more passive strategy (i.e., defend, monitor, or no action). This is a problem for us as we struggle with how to dispatch our scarce resources as we likely will have less resources than we have stakeholders. Resources must be utilized in a manner which gives us the most *bang for the buck*, a measure consistent with the approach presented here.

Before moving on the next step of the stakeholder analysis process, we would be remiss in not pointing out that, while we believe our first order approach to engagement priority is sufficient, we have investigated other higher order approaches involving Leontief [16] input–output modeling; the reader is referred to Hester and Adams [13] for details of this approach. The approach presented in this book is intended to provide the reader with an approachable method for determining stakeholder priority without sacrificing resultant method insight. We believe the presented approach does just that.

Table 5.8 Construct for a stakeholder management plan (SMP)

Stakeholder Name	Wants	Classification	Attitude	Priority of engagement	Strategy

5.6 Develop a Stakeholder Management Plan

At this point in the stakeholder analysis process, we have brainstormed stakeholders, classified them, determined their attitude, and calculated their engagement priority. The fifth step is the development of a Stakeholder Management Plan (SMP). The SMP allows us to track stakeholders and maintain a plan for dispatching resources to secure and maintain a stakeholder's support for our effort. At a minimum, a SMP should include:

- Stakeholder name/identifier (from Step 1)
- Stakeholder wants (from Step 1)
- Stakeholder classification (from Step 2)
- Stakeholder attitude (from Step 3)
- Stakeholder engagement priority (from Step 4)
- Strategy (defend, collaborate, etc.) for dealing with stakeholder, based on their attitude and classification (from Step 3)
- Method for engagement (e-mails, in-person, etc.)
- Frequency of engagement (e.g., monthly, weekly)
- Responsible party who pursues the identified strategy
- Notes that are necessary for housekeeping purposes.

Table 5.8 is the construct for a SMP. Several columns have been eliminated for ease of reading, namely the method for engagement, frequency of engagement, responsible party, and notes.

Once a stakeholder management plan is generated, stakeholders should be sorted by their priority of engagement. This presents a ranking of the order in which stakeholders should be engaged. Consideration of the stakeholder wants will assist in determining the strategy for engagement.

Recalling that the strategy for engagement is determined as a function of both classification and attitude, this provides a first pass at what level of involvement we should wish to afford a particular stakeholder. We wish to heavily involve those stakeholders that are both important (i.e., having a classification of definitive or expectant) and willing (i.e., having an attitude of supportive). However, in most complex problems the myriad number of stakeholders involved will likely result in redundant engagement strategies across stakeholders. For example, multiple individuals will be assigned the strategy of *Involve*. Thus, stakeholder activity and popularity are used to determine engagement priority.

5.7 Manage Stakeholders

Once a stakeholder management plan has been generated, the organization is charged with executing it. That is to say, we must *follow through* on the strategies outlined by the SMP. The stakeholder analysis process does not end here, however. Thus, after establishing a SMP, we may wish to revisit our brainstorming exercise to identify stakeholders, perhaps streamlining our list as our knowledge gained from the process informs us that many of our previously identified stakeholders are no longer relevant to the problem at hand. Given its recursive and iterative nature, the process will necessarily continue throughout the resolution of our problem.

5.8 Framework for Addressing *Who* in Messes and Problems

Undertaking a stakeholder analysis requires an individual to complete the six-step process outlined in this chapter as it pertains to an identified problem, namely:

1. Brainstorm stakeholders
2. Classify stakeholders
3. Evaluate stakeholder attitudes
4. Determine stakeholder engagement priority
5. Develop a stakeholder management plan
6. Manage stakeholders.

Each of these six steps is required to completely account for stakeholders in our messes and constituent problems.

The example stakeholder analysis presented here is derived from the example discussed briefly in Hester et al. [14]. It concerns a real estate developer's desire to rezone a parcel of land and is analyzed from the point of the real estate developer. This rezoning must take into account the values of important stakeholders (e.g., neighbors, local government) in order to ensure project success. In this example, a local developer sought to rezone portions of an upscale, single family home residential neighborhood to a condominium complex. The example is being discussed from the perspective of the developer, who is seeking to determine which stakeholders they will need to garner support from. The developer has been included as a stakeholder in the analysis.

5.8.1 Example Stakeholder Brainstorming

Brainstorming stakeholders for the rezoning problem yields the following stakeholders and their associated wants:

1. The real estate developer *wants* financial gain from the project.
2. Nine local communities *want* to maintain their property values and quality of life.

Table 5.9 Example stakeholder classification

Stakeholder	Stakeholder attribute			Stakeholder class	Stakeholder classification
	Power	Legitimacy	Urgency		
The real estate developer	Yes	Yes	Yes	Definitive	Definitive
Nine local communities	Yes	Yes	Yes	Definitive	Definitive
City planning commission	Yes	Yes	No	Dominant	Expectant
City council	Yes	Yes	No	Dominant	Expectant
Local media	No	Yes	No	Discretionary	Latent
City staff	No	Yes	No	Discretionary	Latent

3. Local media *want* news stories that sell.
4. City Staff *wants* minimal disruption.
5. City Planning Commission *wants* compliance with regulations.
6. City Council *wants* to be reelected.

While many more individuals and groups could be added into the analysis, it was thought that an initial stakeholder analysis should include, at a minimum, these six entities and their associated desires.

5.8.2 Example Stakeholder Classification

Table 5.9 shows evaluations of the attributes and class for each of the stakeholders identified in the previous section. They have been sorted according in decreasing order of importance according to their assigned stakeholder class.

Clearly, the two stakeholders who hold the most power are the real estate developer and the local community affected by the developers' efforts. This is fairly intuitive as both of these groups possess all three attributes of power, legitimacy and urgency. Moving to the dominant stakeholders, the City Planning Commission and the City Council, they both have power and legitimacy, but they are unlikely to possess the urgency to place a priority on the execution of this particular project. Finally, the local media and assorted city staff have legitimacy in that they should be involved in the planning process, but they have neither power nor urgency; they cannot directly influence the other members of the problem and they don't appear on the surface to have the urgency to see the project's execution occur.

5.8.3 Example Stakeholder Attitude Evaluation

Table 5.10 shows evaluations of the potential for threat and potential for cooperation for each of the stakeholders identified in the previous section. These two parameters provide an identification of the attitude of each stakeholder. They have been sorted in decreasing order of support according to their assigned stakeholder attitude.

Table 5.10 Example stakeholder attitude evaluation

Stakeholder	Potential for threat	Potential for cooperation	Attitude
The real estate developer	Low	High	Supportive
City staff	Low	High	Supportive
City planning commission	High	High	Mixed
City council	High	High	Mixed
Local media	High	High	Mixed
Nine local communities	High	Low	Non-supportive

Both the real estate developer and City Staff are seen as supportive of this effort. The developer's support is obvious, while perception of the City Staff as supportive comes from their unwillingness to object to the project's development. The City Planning Commission, City Council, and local media all have a high potential for cooperation as they would like to see the project succeed, but their high potential for threat demonstrates their unwillingness to be a champion for project success at the cost of their more prominent desires. Thus, these three stakeholder groups possess a mixed attitude. Finally, the nine local communities pose a high potential for threat and a low potential for cooperation. They have a vested interest in seeing the project fail as they are opposed to it on fundamental grounds (i.e., it will likely reduce their property values). They are therefore non-supportive of the effort.

5.8.4 Example Stakeholder Engagement Priority

With classification and attitude defined in the previous two sections, Fig. 5.9 shows a comprehensive stakeholder relationship map, including the classification, attitude, and influence (direction and magnitude) for all identified stakeholders involved in the problem.

Three keys are necessary to truly understanding this map. They include attitude, classification, and influence and are presented together in Fig. 5.10.

In order to calculate the stakeholder engagement priority for all the stakeholders in the real estate development project, we need to calculate k_i^{in}, k_i^{out}, s_i^{in}, s_i^{out}, *Popularity*, and *Activity*, in accordance with Eqs. 5.1–5.4. These results are shown in Table 5.11.

We then sort the stakeholders them by activity first (in descending order), and then, by popularity (in ascending order). Table 5.12 illustrates the order in which stakeholders should be engaged in support of this effort.

It is clear that the nine local communities should be prioritized in terms of their engagement in the development project. This makes intuitive sense given the stakeholder relationships shown in Fig. 5.9. On the other end of the spectrum, the city staff should be the final entity engaged. They have no influence on any other stakeholder and, thus, should be given a low priority in terms of their engagement.

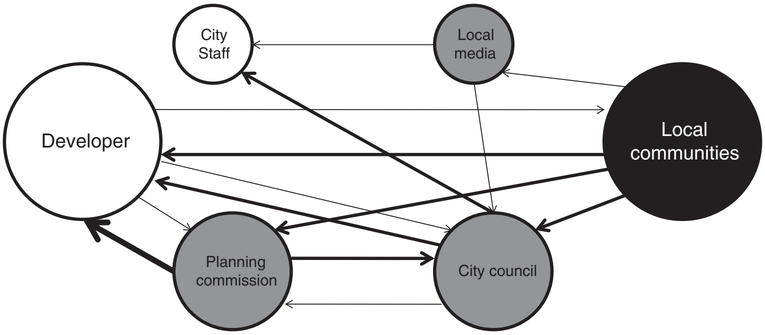


Fig. 5.9 Stakeholder relationship map

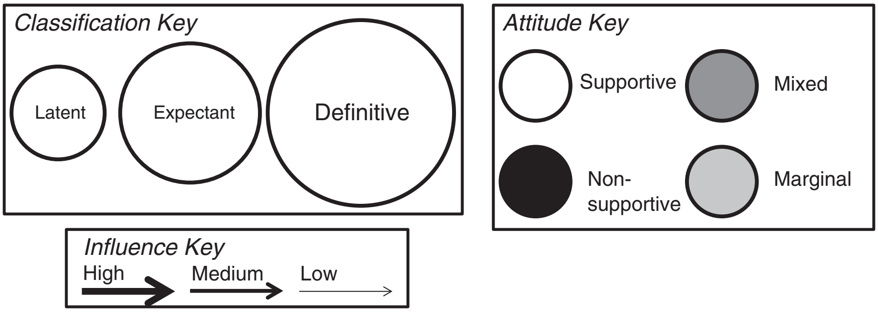


Fig. 5.10 Keys for stakeholder relationship map

Table 5.11 Real estate network characteristics

Stakeholder	k_i^{in}	k_i^{out}	s_i^{in}	s_i^{out}	Popularity	Activity
The real estate developer	3	3	2	0.75	2.45	1.50
City staff	2	0	0.75	0	1.22	0.00
City planning commission	3	2	1	1.5	1.73	1.73
City council	4	3	1.5	1.25	2.45	1.94
Local media	1	2	0.25	0.5	0.50	1.00
Nine local communities	1	4	0.25	2	0.50	2.83

Table 5.12 Real estate stakeholder prioritization

Stakeholder	Activity	Popularity	Engagement priority
Nine local communities	2.83	0.50	1
City council	1.94	2.45	2
City planning commission	1.73	1.73	3
The real estate developer	1.50	2.45	4
Local media	1.00	0.50	5
City staff	0.00	1.22	6

Table 5.13 Example stakeholder management plan

Stakeholder name	Wants	Classification	Attitude	Priority of engagement	Strategy
Nine local communities	Property values and quality of life	Definitive	Non-supportive	1	Collaborate
City council	Reelection	Expectant	Mixed	2	Collaborate
City planning commission	Regulation compliance	Expectant	Mixed	3	Collaborate
Local media	Stories that sell	Latent	Mixed	4	Defend
City staff	Minimal disruption	Latent	Supportive	5	Collaborate
The real estate developer	Financial gain	Definitive	Supportive	n/a	Involve

5.8.5 Example Stakeholder Management Plan

The final step in analyzing this example is to develop a stakeholder management plan. An example stakeholder management plan is shown below in Table 5.13. Two elements should be noted. Just like in Table 5.8, several columns have been eliminated for ease of reading, namely the method for engagement, frequency of engagement, responsible party, and notes. Second, as this stakeholder assessment is being performed by the real estate developer, their priority of engagement is a non-issue. They are inherently a part of the stakeholder management process. Thus, although they were identified in the previous step as #5 in terms of priority, they are moved to the bottom of the list.

Using this stakeholder management plan, we can clearly see that the number one priority for the real estate developer is to collaborate with the nine local communities. In order to do so, they should consider the wants of the communities. Given that the want to maintain their property values and quality of life, the real estate developer must work with them to assuage their concerns in these areas. This is directly counter to their chosen strategy of simply ignoring the communities. Had they undertaken a thorough stakeholder analysis, they might have saved themselves from the eventual failure of their project. Unfortunately for them, they did not [14].

5.9 Summary and Implications for Systemic Thinking

Because stakeholders exist at the center of all systems problems and serve as the principal contributors to the solution of these problems, we must formally address them as part of the solution to any systems problem. In this chapter, we developed a six step approach to stakeholder analysis and management. This approach includes identification of stakeholders, classification of these stakeholders, assessment of their attitude, calculation of their engagement priority, developing a plan

Table 5.14 Implications of *who* perspective on other perspectives

Perspective	Implications
What (outcomes, outputs)	Stakeholders are the ones who accomplish things in our system. Without them, there are no outputs or outcomes. So, we need them to help shape what we are trying to achieve
Why (motivation)	Motivation of stakeholder is key to understanding them. If we fail to understand their motivations, we will be unable to convince them to support our efforts
Where (contextual and boundary considerations)	A large element of context is culture. Culture is defined by the individuals that make it up. Understanding our stakeholders and their relationships will help us to understand the culture they are a part of. Also, understanding the context in which stakeholders operate will help us to understand stakeholder relationships
How (mechanisms)	Understanding our stakeholders means we understand what knowledge, skills, and abilities they possess. A key element of mechanism deployment is identification of necessary the resources to achieve our goals. If we already have certain knowledge and resources within our organization, our path forward will be much easier
When (temporal considerations)	Understanding the *who* question includes the need for appreciation of temporal considerations of human interactions. This may include consideration of scenarios such as when do we disseminate bad news to individuals at lower levels of our organizational hierarchy versus alerting management or when do we take corrective action to interfere with a personnel issue rather than take a wait and see approach

for managing them, and carrying out the plan (i.e., managing them). This comprehensive technique is an important discriminator enabling systems practitioners with an effective method for dealing with stakeholders appropriately. Table 5.14 shows the implications of the *who* question on each of the other systemic thinking perspectives.

After reading this chapter, the reader should:

1. Be able to identify and classify stakeholders for a problem;
2. Be able to evaluate stakeholder attitudes;
3. Be capable of identifying stakeholder engagement priority; and
4. Understand how to develop a stakeholder management plan.

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Chapter 6
The *What* of Systemic Thinking

Abstract The main focus of the *what* question of systemic thinking is on attributes of the problem that we are trying to gain increased understanding of. Given that a mess is a system of problems as we describe it in Chap. 2, we take the occasion in this chapter to dissect a given problem and the structured decision analysis and associated concerns that may be employed to gain further insight regarding its parent mess. While it is beneficial to have undergone stakeholder analysis prior to proceeding with this chapter, it is not necessary. The problem analysis phase focuses on decomposition of a problem in a manner that allows for identification of outcomes, their derivative outputs, the outputs' goals, and the relative importance of these outputs in determining goal attainment and the relative importance of outcomes in achieving problem understanding. This chapter first discusses the basics of decision analysis. We then discuss the anatomy of a problem. Finally, a framework for addressing the *what* question is presented and this framework is demonstrated on a realistic problem.

6.1 Decision Analysis

Keeney and Raiffa [1] describe decision analysis as a "*prescriptive* approach…to think hard and systematically about some important real problems" (p. vii). Thus, it is a description of how individuals *should* solve problems and not necessarily how they solve problems. Further complicating this prescriptive discussion is the introduction of subjective evaluations. Keeney and Raiffa [1] further elaborate on the nature of decision analysis and subjectivity:

> It is almost a categorical truism that decision problems in the public domain are very complex…It would be nice if we could feed this whole mess into a giant computer and program the superintellect to generate an 'objectively correct' response. It just can't be done!…We believe that complex social problems--and, for that matter, complex business problems--demand the consideration of subjective values and tradeoffs. (p. 12)

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In order to utilize decision analysis concepts to increase understanding of a problem, a brief history is first necessary. Formal exploration of any method for decision analysis must begin with consideration of Bernoulli's [2] 300 year-old concept of utility maximization as well as von Neumann and Morgenstern's [3] much more recent formalization of a theory of utility, founded on four axioms with which decision-makers can construct utility functions whose maximized values represent decision-maker preferences. These four axioms are:

- Completeness. Given two alternatives, A and B, a decision-maker either prefers A to B, prefers B to A, or is indifferent between A and B;
- Transitivity. If A is preferred to B and B is preferred to C, then A is preferred to C;
- Continuity. If $A < B < C$, then there exists a unique probability, p, such that the following relationship can be constructed: $pA + (1 - p)C = B$; and
- Independence. For any $A > B$, $pA + (1 - p)C > pB + (1 - p)C$. That is, introduction of a third alternative does not influence the original preference of one alternative over another.

Savage [4] promotes key elements of a systemic approach by extending the utility concept to include subjective evaluations derived from personal preferences and subjective probabilities, where individuals' sense of utility would be subjectively determined as expected values. Keeney [6], too, provides for complex value structures with an additive, "multiattribute utility function" (p. 22) model allowing for functions of three or more weighted "attributes" (p. 22). His model further suggests that values of individual utility functions and incorporated weights be confined to the interval [0, 1], a characteristic precluding the rather meaningless concern for infinitely good or bad solutions to any problem (and in keeping with the principle of finite causality, Hester [7]). Smith and Clark [8] offer one more utility-related feature that the authors suggest observing, a requirement that a utility function provide for aggregation and decomposition; in other words, that evaluations of utility of any problem's constituent subsystems mathematically support evaluations of the utility of the entire system (or, at a higher level of abstraction, mess). This notion is supported by the systems principle of hierarchy [9], which states that all systems exist within a higher-level system and can be decomposed into lower level sub-systems.

Characterization of a problem is a necessary first step in undertaking the *what* step of systemic analysis. Keeney and Raiffa [1] discuss a taxonomy of problems composed of the following four types, which we shall call cases:

1. Single attribute, no uncertainty
2. Single attribute, uncertainty present
3. Multiple attributes, no uncertainty
4. Multiple attributes, uncertainty present.

Case 1 is trivial, at least conceptually. It simply requires that we contrast all feasible alternatives and choose the one with the best possible objective function value. However, few, if any, realistic problems reside within this quadrant. Generalizing to cases of uncertainty (Case 2), multiple attributes (Case 3), or both (Case 4),

Table 6.1 Systems principles demanding consideration of uncertainty

Principle	Rationale
Emergence	Accounting for emergence means accepting that there will be uncertain, unpredictable phenomena occurring within our mess
Darkness	We can never truly know a system completely. As such, there will always be uncertainty surrounding those elements of our mess that are unknown
Equifinality	Since there are multiple paths that may lead to a singular end point, it may be difficult for us to predict what trajectory a problem will take in its resolution. Further, it is uncertain as to whether or not it matters. The phrase "the end justifies the means" is appropriate here
Multifinality	Once our system has departed from its initial conditions, and given the uncertainty present in our system, it may follow many trajectories to radically disparate paths. These end states are uncertain
Self-organization	Order arises out of seemingly independent and unrelated components of a system. Especially when we are assessing a sociotechnical system, and humans are part of the equation, this self-organization is rather uncertain and difficult to predict

Table 6.2 Systems principles requiring multiple attributes

Principle	Rationale
Complementarity	Complementarity ensures that no singular, unified, wholly correct perspective of a system exists. Thus, consideration of multiple attributes is necessary to capture these divergent perspectives
Requisite saliency	Multiple attributes are necessary to fully capture the complexity of a mess. While each contributes to our understanding, the principle of requisite saliency informs us that each of these attributes is likely to have its own relative importance (weight) which contributes to the overall system and its goals
Suboptimization	Suboptimization requires us to understand that competing objectives exist within our system. If we optimize any singular objective, we in turn suboptimize the entire system. Thus, consideration of all relevant attributes ensures we don't suboptimize our system
Hierarchy	On one level, i.e., at the system level, a particular set of attributes may be rolled-up or decomposed as appropriate. This structure requires multiple attributes to capture the nuances of these hierarchical relationships

requires additional thought and structure. However, multiple attributes and uncertainty are a fact due to the principles underlying a mess (recall our discussion from the Preface and Chap. 1), and they characterize all but the most trivial of problems. Thus, it is only of interest for us to consider Case 4. Table 6.1 lists those principles demanding consideration of uncertainty, which drive those concerned with systemic thinking toward problems categorized by Case 4.

Similarly, Table 6.2 lists those principles requiring multiple attributes which drive those concerned with systemic thinking toward problems categorized by Case 4.

Systemic consideration of a mess requires us to think using a paradigm that supports both multiple objectives and uncertainty. Additionally, given this presence of multiple objectives and uncertainty, and the pluralistic nature of messes, it behooves us to elicit multiple perspectives in order to invoke the principle of complementarity [5]. Keeney and Raiffa [1] agree, elaborating:

> In many situations, it is not an individual but, instead, a group of individuals who collectively have the responsibility for making a choice among alternatives. Such a characterization is referred to as a group decision problem. With each group decision, there is the crucial metadecision of selecting a process-oriented strategy by which the group decision is to be made. (p. 26)

Thus, before addressing the decomposition of a problem, we take a slight detour to address concerns relevant to group decision making.

6.1.1 Group Decision-Making

Group decision-making involves a broad spectrum of approaches intended to support two or more individuals pursuing some collective decision. Given these likely disparate perspectives, we advocate approaches invoking the notion of group consensus defined, in accordance with Susskind [10], as follows:

> Consensus has been reached when everyone agrees they can live with whatever is proposed after effort has been made to meet the interests of all stakeholding parties.… Participants in a consensus building process have both the right to expect that no one will ask them to undermine their interests and the responsibility to propose solutions that will meet everyone else's interests as well as their own.

Susskind [10, p. 7] continues:

> Most dispute resolution professionals believe that groups or assemblies should seek unanimity, but settle for overwhelming agreement that goes as far as possible toward meeting the interests of all stakeholders.…It is absolutely crucial that the definition of success be clear at the outset of any consensus building process.

A focus on agreement among stakeholders means that consensus is a requirement that is more strict and therefore more time-consuming then other, more authoritarian decision-making approaches. However, in an environment where increasing understanding is the end state (as is the purpose of this book), it is important that relevant stakeholders buy-into both the formulation and proposed resolution of a given problem. These conditions are only truly possible in an environment that supports consensus. Consensus is not without caveats, however. Carpenter [11] cautions of the need for stakeholders to have a willingness to negotiate and be open-minded in order to support such an approach. Organizational support of such an approach goes a long way in ensuring stakeholders will participate willingly.

It is worth noting that while consensus is a ubiquitous term, it is advantageous for stakeholders to clarify its parameters before attempting to pursue a systemic thinking effort. We invoke the characteristics of consensus espoused by Wooldridge and Floyd [12]. They are:

- **Degree**. Degree of consensus references the uniformity of subject matter expert perspectives required before consensus may be recognized. Do we require all stakeholders to be willing to accept a given solution or articulation without reservation? Or, do we relax this constraint and require a less-stringent version of consensus such as *consensus minus one* or some other number of stakeholding parties, thereby accounting for the conflict we may anticipate occurring during the analysis of a complex problem?
- **Scope**. "Scope refers to who participates in consensus" (p. 296). This requires us to clearly articulate who the stakeholders are that will be participating in such an effort. Answering the *who* question of systemic thinking (as discussed in Chap. 5) will provide this answer for us.
- **Content**. "The content of consensus refers to what decision-makers agree about" (p. 296), which we will want to ensure includes only those elements that we truly want to achieve consensus on. Given the time and effort required for consensus, this characteristic ensures we choose our battles wisely.

Once we have established procedures for our group decision making processes, we can turn to discussion of the anatomy of a problem with an eye toward development of an approach capable of incorporating multiple objectives, uncertainty, and multiple perspectives.

6.2 Anatomy of a Problem

There are many ways in which a problem may be decomposed. Each is value-added and can be used adequately for this discussion. For the sake of simplicity, we begin by introducing standard terminology of *problem*, *outcome*, *output*, and *goal*. These terms, and their definitions as we will use them, are found in Table 6.3.

A note on terminology is necessary before we proceed. While we prefer *outcome* and *output* as they provide a better articulation of the notions we are trying to emphasize, the decision analysis literature favors *objective* and *attribute*, respectively. Similarly, we will draw from the test and evaluation literature, which invokes *measure of effectiveness* and *measure of performance*, respectively. It is our opinion that these perspectives differ largely on semantics and not truly on the underlying meaning of the terms.

Figure 6.1 shows a notional example of the relationship between the elements shown in Table 6.3. The key insights from this graphic are twofold: (1) the typically one-to-many relationship between problems and outcomes and outcomes and outputs, and (2) the interconnectedness of these elements. Improving understanding of a given problem is a difficult undertaking and requires, at a minimum, that one be aware of the external elements that influence the problem being explored.

Table 6.3 Problem terminology

Term	Definition
Problem	A problem is "an undesirable situation or unresolved matter that is significant to some individual or group and that the individual or group is desirous of resolving" [40]. It may be ambiguous or generic, and is without question an emergent construct; thus, we are unlikely to be able to clearly articulate a singular problem associated with our mess. Rather, it will likely have multiple problems. All problems may be decomposed into multiple outcomes
Outcome	An intangible characteristic of a singular problem that stakeholders wish to achieve. Outcomes are not necessarily unique to a particular problem and thus may be associated with multiple problems
Output	A tangible quantity that is used to measure performance of a system. There is typically a one-to-many relationship between outcomes and outputs
Goal	A target set for desired achievement with respect to outputs. "A goal is…either achieved or not" [1]

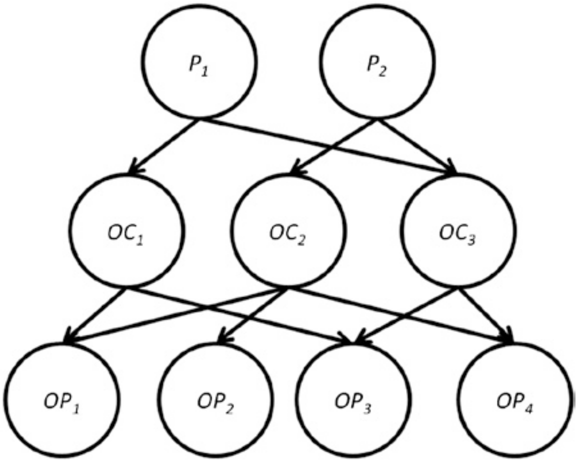

Fig. 6.1 Illustration of multiple problems (P_i), outcomes (OC_i), and outputs (OP_i)

There are multiple problems within a single mess, but we will concentrate on a singular problem of interest (from the potentially many generated per the guidance in Chap. 2) in this discussion in order to gain increased understanding.

6.2.1 Outcome Selection

Hammond et al. [13] get at the heart of outcome selection by suggesting we ask ourselves "What do you really want? What do you really need?" (p. 29). They provide a number of reasons for selecting outcomes:

- They help you determine what information to seek. Once outcomes are selected, we can determine what information we may need to increase our understanding or gain insight about a problem.

- They can help you explain your choice. Armed with a justifiable set of outcomes, an individual can explain the rationale of a particular choice to someone unfamiliar with the problem or to stakeholders of the problem, if necessary, to garner support.
- They determine a decision's importance, and thus, how much time or effort to spend on it. Effort spent to achieve purposes that are not identified as problem outcomes is ill-spent and should be avoided.

Hammond et al. [13] suggest outcomes take the form of a succinct statement consisting of a verb and an objective such as *Minimize expenses* or *Maximize revenue*. There are some guidelines we can utilize to appropriately decompose a problem into appropriate outcomes. MacCrimmon [14] identifies the following strategies for generating outcomes:

1. Examine relevant literature of similar problems,
2. Perform an analytical study by modeling the system under consideration, and
3. Observe individuals making decisions with the current system.

Keeney and Raiffa [1] add the following fourth strategy:

4. Consult a set of knowledgeable subject matter experts.

Using these strategies will help us to identify appropriate outcomes for a problem. A further distinction may be necessary, however, in order to avoid effort wasted on achieving inconsequential outcomes. Hammond et al. [13] talk about the importance of separating *means* from *fundamental* outcomes:

> Asking "Why?" will lead you to what you really care about–your fundamental [outcomes], as opposed to your means [outcomes]. Means [outcomes] represent way stations in the progress toward a fundamental [outcomes], the point at which you can say "I want this for its own sake. It is a fundamental reason for my interest in this decision." Fundamental [outcomes] constitute the broadest [outcomes] directly influenced by your decision alternatives. (p. 37)

Fundamental outcomes, once obtained, can be used to evaluate alternatives and to gain understanding about a problem. Further, "well-thought-out fundamental [outcomes] for similar problems should remain relatively stable over time" [13]. Once appropriate outcomes have been selected, it is necessary to characterize these outcomes using appropriate outputs.

6.2.2 Output Characterization

Outcomes are difficult to evaluate because they involve multiple outputs (e.g., *cost*, *schedule*, and *performance* are competing outputs for an outcome such as *design quality*), which are typically evaluated on individual scales (cost in dollars, schedule in days, and performance perhaps in miles per hour, gallons per minute, or any other appropriate performance measure) and integrating these individual utilities into a single global evaluation is not straight forward. This process is often complicated by the presence of so-called *negative correlations* between outputs, requiring tradeoffs between scoring high on one output and low on another (cheap designs are also often poor performing ones). Outcomes must be made measurable by identifying appropriate outputs on which to measure them. Keeney and Raiffa [1] agree and provide two criteria for outputs, that they be both comprehensive and measurable:

> …to some extent, comprehensiveness refers to the appropriateness of the [output] on theoretical grounds: Does it give us the information we would like to have, regardless of whether we can get it? And measurability refers to the practical considerations: Can we get the necessary assessments? (p. 39)

We must take care to ensure we've generated a sufficient number of outputs to fully capture the complexity of the associated outcomes:

> To generalize, a set of n [outputs] is complete if, by knowing the value of the n-dimensional vector [outputs] associated with the overall [outcome], the decision maker has a clear picture about the extent to which the overall [outcome] is met. [1]

They go on to discuss the necessary characteristics of a set of outputs for a given outcome:

> It is important in any decision problem that the set of [outputs] be complete, so that it covers all the important aspects of the problem; operational, so that it can be meaningfully used in the analysis; decomposable, so that aspects of the evaluation process can be simplified by breaking it down into parts; nonredundant, so that double counting of impacts can be avoided; and minimal, so that the problem dimension is kept as small as possible. [1]

To be *complete*, we should aim to separate outputs that are uniquely important in addressing, for example, height and weight in choosing a mate or speed and maneuverability when designing an aircraft. Thus, by specifying the height, weight, and other outputs of a potential mate, a neutral third party can determine the extent to which someone has identified an ideal mate. The requirement for completeness is reinforced by the principle of minimum critical specification which states that we must identify what is essential, but strive to specify no more than is absolutely necessary [15, 16]. This guiding principle provides bounds on our output set.

In order to be *operational*, a set of outputs:

> …must be meaningful to the decision maker, so that he can understand the implications of the alternatives. They should also facilitate explanations to others, especially in cases where the main purpose of the study is to make and advocate a particular position. [1]

A synonym for operational is usable. They must be able to used by the individual or individuals trying to solve a problem. This connotes the difficult nature of sociotechnical problems. Inclusion of the human element in the analysis of a problem introduces considerations which must be accounted for but which nonetheless provide no improvement in goal attainment. For example, management decisions regarding layoffs may need to be couched in terms of jobs saved in order to maintain organizational morale.

In order to be *decomposable*, a set of outputs must be able to be broken down into smaller subsets. This can be useful, for example, in decomposing outputs across lower-level outcomes. This also reinforces the principle of hierarchy [9]. Further, this requirement speaks to the complex nature of outputs. The output of profit, for example, may be composed of income and expenditures. Income can be further broken down into direct sales, indirect sales, tax revenue, etc. Direct sales can be broken down by item, region, etc. The appropriate level of abstraction must be chosen in a manner which is tractable and meaningful for the systems practitioner.

Nonredundancy is achieved by ensuring that outputs "should be defined to avoid double counting of consequences" [1]. A practical lower limit to redundancy is provided by the principle of information redundancy [17], which measures the amount of wasted information used in transmitting a message, thereby providing a lower bound for us to aim for (no redundant information), while also considering the principle of minimal critical specification. Adhering to these principles ensures that we do not avoid information that is necessary in order to fully capture our problem, while avoiding extraneous information.

On the criteria of *minimal*, Keeney and Raiffa note, regarding the number of outputs, "it is desirable to keep the set as small as possible" [1]. This is a limiting factor which ensures we address the other characteristics in the limit. For example, while our outputs are decomposable, we should only decompose them to the point where it is meaningful and not beyond, to avoid a level of granularity that is neither discernible nor meaningful to relevant stakeholders. George Miller's seminal work *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information* (1956) provides practical limits for human information capacity. The ensuing law of requisite parsimony [18, 19] states that humans can only deal simultaneously with between five and nine items at one time. Thus, creating a set of outputs of greater than nine would not only violate the criteria of minimal, but it would be unusable as well.

Finally, Keeney and Raiffa [1] provide a few other tips regarding output identification. Regarding the necessity for the uniqueness of outputs, they remark "A set of attributes is not unique for a specific problem…" (p. 53). While this seems obvious, it is worth noting that, as systemic thinkers, we will develop a set of outputs that may be of repeated use to us as we encounter new problems and messes. However, it is also worth noting that these stock outputs, or other readily identified outputs, may not always be the best choice. They elaborate:

> The process of specifying the [outcomes] is not done in a vacuum. At the same time, we may have relevant information about what data are accessible, the quality and quantity of other available resources (e.g., computers), various types of constraints that are in force (e.g., time, politics), the range of alternative courses of action, and so on. All of these factors might significantly affect the [outcomes] hierarchy and choice of [outputs]. [1]

Additional guidance on output development is found in the acronym SMART, developed by Doran [20] [1939–2011], who provided the following five criteria that can be used to develop appropriate outputs:

1. Specific—target a specific area for improvement.
2. Measurable—quantify or at least suggest an indicator or progress.
3. Assignable—specify who will do it.

4. Realistic—state what results can realistically be achieved, given available resources.
5. TimePhysical mechanisms-related—specify when the result(s) can be achieved (p. 36).

Armed with a number of guiding principles by which to develop a set of outputs, the next step stakeholders are faced with is to select goals for each of them.

6.2.3 Goal Selection

For each output, it is important that we select goals to aspire to. These goals serve two important functions, namely:

1. They avoid us having to expend extraneous resources of already-surpassed goals. If we are searching for an apartment and we set a cut-off of $1,000/month, why continue to pursue a cheaper apartment at the risk of not achieving our other goals?
2. They force us to think hard about what it is we really want to achieve. The higher standard that we set for ourselves, the more important it is to us. Easily-achieved goals are arguably less crucial to our overall problem resolution than those requiring more effort. Why? There is an implicit recognition of the commitment of organizational resources to difficult-to-achieve goals. After all, if a goal is hard to achieve, and we set it, aren't we in effect saying that it's worth it for us to expend some resources in trying to achieve it?

For each output, we should set a goal that allows us to say that particular output is satisfactorily achieved. There is a danger in such an approach. It is non-compensatory, or to put it another way, non-forgiving. If we are examining potential answers to our problem and we develop one that exceeds all of our expectations except one, we may be left frustrated by our rejection of such an option given its failure to meet even one goal. Inadequate performance, either higher or lower depending on the model, on any output cannot be offset by better performance on any other output. Failure of an output to meet the established cut-off point cannot be compensated by exceeding the levels established for other outputs [21]. Further, non-compensatory models fail to recognize the importance of one output when compared with another; all are treated as equally important. However, the law of requisite saliency [22] informs us that outputs will seldom be of equal importance. Thus, we must seek to utilize a method which overcomes these issues.

We can overcome the issue of a lack of attainment of goals by simply treating goals as aspiration levels and not as absolutes that must be achieved. Thus, they truly become goals, performance levels to aim for, but not necessarily parameters which derail our otherwise meaningful achievements. We can overcome the issue of equal output importance by selecting output weights. Selection of these weights is often a byproduct of a discovery process undertaken by system designers and users. However, it is important to determine an initial set of weights to serve as a baseline for analysis. This can help us in prioritizing our organizational resources when striving to achieve our goals (i.e., higher weighted outputs demand more organizational resources) and in trading off the achievement of our multiple outcomes.

6.2.4 Derivation of Weights

The next step in the addressing the *what* question is aggregation of our outputs into a coherent singular measure of performance at the outcome level. This singular measure allows for the evaluation of relevant stakeholders' desirability and satisfaction with the resolution of our identified problem. Although there are many mechanisms for doing so (enough to fill several volumes of scholarly literature), we will discuss only a high level framework for weighting and combining outputs. It should be noted that a similar approach can be invoked for the combination of multiple outcomes into a singular evaluation of a problem. The following discussion of weight derivation is predicated on the use of a linear additive utility model. For the purposes of such an approach, it is advised that individuals adhere to a simpler, rather than more complex, utility model. It requires that we adhere to the Neumann and Morgenstern's (1944) four axioms addressed earlier in this chapter. According to Velasquez and Hester [24], such an approach is simple to use and allows for any type of weight assignment. Further, they cite its widespread use in environmental, construction, transportation and logistics, military, manufacturing and assembly problems. Given its popularity and straightforward nature, the authors suggest the use of an additive utility model versus more cognitively demanding approaches such as the Analytic Hierarchy Process [27]. The general form of an additive utility function is shown in Eq. 6.1 for a given outcome.

$$OC_i(OP)_i = \sum_{j=1}^{OP} W_j OC_j\left(OP_{ij}\right) \tag{6.1}$$

where OP is the total number of outputs for a given outcome OC_i, W_j is the weight of the *jth* output, OC_i is the utility value of the *ith* alternative, OP_i is the vector of all the output values (OP_{i1}, OP_{i2}, … OP_{iA}) and $OC_i(OP_i)$ is a single output function. It is assumed that each individual output function can be calculated by an individual, although it is recognized that individual evaluation of any output may require substantial calculations or simulations to evaluate. Analytic hierarchy process [27], evidence theory [28, 29], fuzzy math [30], and psychometric scaling [31] are several of the mathematical tools which can be utilized to provide quantitative evaluations of otherwise qualitative outputs. In keeping with guidance provided by Keeney and Raiffa [1], the output weights must all sum to 1 as:

$$\sum_{j=1}^{OP} W_j = 1 \tag{6.2}$$

and all utility function evaluations are normalized within the interval [0, 1] as:

$$0 \le OC_j(\cdot) \le 1 \tag{6.3}$$

Just as there are with methods for combining output evaluations into a singular, global evaluation, there are also many mechanisms for generating weights to support this combination. Two such methods that are straightforward and easy to implement will be discussed here: rank order centroid (ROC) and Simple Multi-Attribute Ranking Technique.

The ROC method for weight determination is straightforward. Outputs are listed in descending order of importance, with 1 being the most important and *OP* corresponding to the least important. This ranking is then transformed into a weight using the following equation:

$$W_i = \frac{1}{OP}\sum_{j=i}^{OP}\frac{1}{j} \tag{6.4}$$

Thus, an illustrative set of weights using this method is as shown in Eqs. (6.5a)–(6.5c) for a set of *OP* outputs.

$$W_1 = \left(\frac{1}{1}+\frac{1}{2}+\frac{1}{3}+\cdots\frac{1}{OP}\right)\Big/ OP \tag{6.5a}$$

$$W_2 = \left(\frac{1}{1}+\frac{1}{2}+\frac{1}{3}+\cdots\frac{1}{OP}\right)\Big/ OP \tag{6.5b}$$

Barron and Barrett [32] show that other rank-based approaches to weighting (rank-reciprocal and rank-sum) are nearly always worse performing that ROC weights, adding further support for the use of ROC. The ROC method is useful when direct weights are not easily assigned, but a ranking of the outputs is. The ROC method is not a good choice when there are a high number of outputs and weights assigned using the ROC are highly dispersed [33].

$$W_{OP} = \left(0+0+0+\cdots\frac{1}{OP}\right)\Big/ OP \tag{6.5c}$$

Alternatively, if an individual or group is more comfortable with assigning weights directly, the Simple Multi-Attribute Ranking Technique (SMART) may be a better choice. SMART was developed by Edwards [34, 35] as a straightforward multi-attribute utility model. Weights can be assigned to outputs using any mechanism (absolute assignment, relative assignment, or a divide-the-pie approach). Once each output has a raw weight, RW_i, these weights can be normalized as follows:

$$W_i = \frac{RW_i}{\sum_{i=1}^{OP} RW_i} \tag{6.6}$$

Now that all quantities have been determined, attention can turn to evaluation of the attainment of the system in meeting its goals.

6.3 Model Evaluation

Evaluation of Eq. 6.6 yields an ordinal, or relative, evaluation of the goodness of a system's state, rather than a cardinal, or absolute evaluation. Configurations of outputs can be adjusted to improve outcome performance and, ultimately, meet goals set by stakeholders early in the analysis process. The operational axiom states that systems must be addressed in situ, where the system is exhibiting purposive behavior as part of attaining a desired goal [26, 25].

Two principles must be considered when evaluating, and trying to improve, the performance of a system with respect to its particular problem(s): (1) the Pareto principle and (2) satisficing. We will explore each in the following subsections.

6.3.1 The Pareto Principle

Messes are inherently complex as we have pointed out numerous times. In any complex system, we will have parts that are not of equal importance [22] and this importance is a dynamic characteristic of our mess. The Pareto Principle (Pareto, [23]) states, simply, that eighty percent of the outcomes of a system will be achieved through twenty percent of the means. The corollary of this principle is that 20 % of the results of a system absorb 80 % of the resources. This becomes an issue of diminishing returns. We must seek to concentrate on the most productive 20 % of our effort and avoid the limited marginal gains that accompany trying to wholly maximize our production (i.e., to reach 100 %). A disproportionately large amount of resources is necessary for this minimal gain. While the 80/20 distribution is a heuristic, it represents a general rule of thumb that highlights the highly non-linear relationship of cause and effect or resources and outcomes to be expected when dealing with complex systems. Further, this heuristic furthers the discussion from our goal selection section of this chapter. Namely, the establishment of goals act as a practical point for establishing the point of diminishing returns. Once we surpass our goal, we are acting inefficiently with respect to our organizational resources. This principle is exacerbated when considered in concert with the notion of optimality, to which we now turn.

6.3.2 Optimality

Given the configuration of weights, outputs, and outcomes determined by the steps outlined in this chapter, one could calculate a set of potential configurations that lie along what is known as an isopreference curve, along which all configurations have equal subjective value (i.e., we are indifferent between any solutions on this

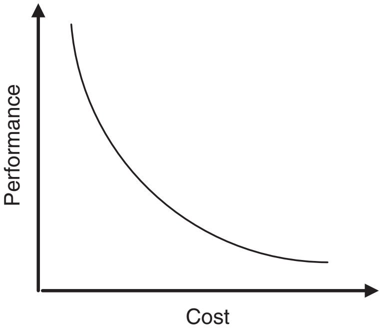

Fig. 6.2 Illustration of an isopreference curve

curve). This set consists of a set of possible answers for the multi-objective optimization problem represented by these established criteria. Theoretically, this set can yield an infinite number of solutions that the stakeholders can choose from. All points on the curve shown in Fig. 6.1: Illustration of Multiple Problems (*Pi*), Outcomes (*OCi*), and Outputs (*OPi*).

Figure 6.2, for example, lie on an isopreference curve. This notion is problematic if we are searching for *a* singular optimal solution to our problem, or if we are trying to optimize at all, as multiple, equally valued solutions may exist.

Given that the behavior of a mess involves emergent behavior and structure, the search for an optimal solution to a mess is problematic. "The structure as well as the parameters of problem situations continually change. Because optimal solutions are very seldom made adaptive to such changes, their optimality is generally of short duration" [36, p. 1]. While a singular evaluation may represent an approximately optimal solution, its utility will be fleeting. Ackoff [36] agrees, noting, "The effectiveness of a solution that is claimed to be optimal at the time of its implementation tends to deteriorate over time". (p. 2)

The inability for us to determine an optimal solution may be troublesome to some, while others may find it a stop-work of sorts, yet others may find it liberating. We side with the final camp. The principle of satisficing allows for a practical solution to our stakeholders' problem in the face of a desire for optimality. Satisficing is a term coined by Nobel Laureate Herbert Simon [37, 38] to describe how individuals make rational decisions between available alternatives in a constrained environment. Simon argued that individuals rarely, if ever, obtain all necessary information to analyze a decision scenario. Thus, they work with a limited scope of information in an effort to reach an acceptable compromise (they satisfice, i.e., satisfy and suffice) rather than attempt to obtain a globally optimal solution to a problem. Ackoff [36] agrees with the absurdity of attempting to optimize a mess, noting:

> It is silly to look for an optimal solution to a mess. It is just as silly to look for an optimal plan. Rather we should be trying to design and create a process that will enable the system involved to make as rapid progress as possible towards its ideals, and to do so in a way which brings immediate satisfaction and which inspires the system to continuous pursuit of its ideals. (p. 5)

Satisficing uses bounded rationality to select an alternative. Brown and Sim [39] elaborate on Simon's bounded rationality:

> One of the key principles from Simon's [37] bounded rationality model is that, rather than formulating and solving complicated optimization problems, real-world agents often can choose the first available actions, which ensure that certain aspiration levels will be achieved. In other words, given the computational difficulties in the rational model paradigm, a more sensible (and descriptively accurate) approach may in fact be to view profit not as an objective to be maximized, but rather as a constraint relative to some given aspiration level. (p. 71)

Hester [7] elaborates on the appropriateness of satisficing as a mechanism for analyzing complex problems:

> Satisficing, as a mechanism for evaluating a [mess] is not to be feared, to be regarded as a "less than optimal" solution to a problem, but rather it should be viewed as an approach to be embraced. Bounded rationality can be useful when a decision must be made and the decision maker does not have an eternity to exhaustively compare all alternatives and their resultant consequences …In this case, individuals gather information for a finite period of time and make a decision based on this subset of information (rather than exhaustively collecting all information regarding the decision). Additionally, bounded rationality allows us to incorporate decision costs into our approach to decision making. Sometimes, gathering information is detrimental. It is often said that "time is money." (pp. 273–274)

When we combine this perspective with our use of goals in evaluating system behavior, we can see that this is a satisficing approach to our mess. Thus, we can adjust the parameters of our system in an effort to achieve a satisfactory system rather than naively search for an optimal one.

6.4 Framework for Addressing *What* in Messes and Problems

Addressing the *what* in our messes and problems requires that we complete the following steps:

1. Identify a problem for decomposition.
2. Derive outcomes for the problem.
3. Select appropriate outputs to characterize the problem's outcomes.
4. Set goals for each of the outputs.
5. Derive weights for the problem's elements.
6. Evaluate our problem's current state.

Each of these six steps is demonstrated on a simple example that follows.

6.4.1 Problem Identification

Imagine you have just graduated from college and are planning your move to a new city in preparation for starting your new job. This is a mess, no doubt. You have concerns regarding fitting in at your new job, finding a place to live, finding your way around the city, etc. However, we will simply focus on a problem related to your residence. So, your problem is to *find satisfactory housing*. This doesn't preclude a particular solution (apartment/house, rental/purchase, etc.) and it gets at the core of what we're trying to achieve (satisfactory residence to support our new job in this new city).

6.4.2 Outcome Derivation

We can now derive outcomes for our problem. We might choose to decompose this problem into a small number of outcomes, perhaps:

- Minimize cost
- Minimize commute time

Cursory inspection of these outcomes, however, shows that we've not considered the *what* of our problem holistically. We can no doubt find cheap (i.e., minimal cost) and nearby (i.e., minimal commute time) housing. Is this sufficient? What if cheap, nearby housing is located in an unsafe neighborhood? What if the options available to us are too small and don't allow us to store all of our belongings? So, with these concerns in mind, we add two additional outcomes:

- Maximize safety
- Maximize living space

Clearly the latter two outcomes may provide negative correlations to the first two. No problem. We know how to deal with such a quandary and will address these concerns in short order. First, we have to decompose each of these outcomes into an appropriate number of outputs. We will do so by addressing each outcome independently.

6.4.3 Outcome Selection

Minimize cost can be decomposed in many ways. It should include costs of both moving in and routine costs associated with the particular choice. It can be evaluated by four outputs, namely initial cost (in dollars), monthly housing cost (in dollars), monthly utility cost (in dollars), and monthly maintenance cost (in dollars). *Minimize commute time* is straightforward and can be evaluated by one output, average commute time (in minutes). *Maximize safety* is very complex. There are many ways we can evaluate this outcome, however, let's assume, for example, that are you mostly concerned about violent crime, particularly murders and assaults. In this case, safety can be evaluated by two outputs, average number of murders in the candidate zip code (per month) and average number of assaults in the candidate zip code (per month). Finally, *maximize living space* can be thought of in many ways. However, perhaps you are most interested in both indoor and outdoor

Table 6.4 Example outputs and associated goals

Output	Goal
Initial cost	$750
Monthly housing cost	$1,500
Monthly utility cost	$200
Monthly maintenance cost	$150
Average commute time	10 min
Average number of murders in zip code	1 per month
Average number of assaults in zip code	3 per month
Outside living space	0 sq. ft
Inside living space	1,500 sq. ft

living space. Thus, you can measuring living space with two outputs, inside living space (in sq. ft.) and outside living space (in sq. ft.). An assessment of our suggested outputs with respect to our earlier guidelines seems to indicate that our proposed outputs are appropriate (i.e., complete, operational, decomposable, non-redundant, and minimal).

6.4.4 Goal Specification

We can now proceed to specifying goals for each of our outputs. Table 6.4 lists proposed goals for each specified output.

6.4.5 Weight Derivation

Next, we can specify the relative importance of each output with respect to its goal and of each outcome with respect to the overall problem, thereby providing us an ordering of the outputs for decision making and prioritization purposes. We will use the rank order centroid method. Results of this analysis are shown in Table 6.5, ranked first in descending order of each outcome's weight, and then in descending order of the importance of each output.

We can also view the results shown in Tables 6.4 and 6.5 together in a graphical format, as shown in Fig. 6.3.

6.4.6 Problem Evaluation

We can use this graphic to increase understanding about our problem. When evaluating a particular alternative (i.e., an apartment choice), we can view its characteristics relative to our overall problem structure and determine whether or not it's satisfactory. If it's not (e.g., it doesn't meet one or more of our goals), then we can use our weights to understand where it is the most important to try to improve.

Table 6.5 Example outputs and weights

Outcome	Rank	Weight	Output	Rank	Weight
Minimize cost	1	0.52	Monthly housing cost	1	0.52
			Initial cost	2	0.27
			Monthly utility cost	3	0.15
			Monthly maintenance cost	4	0.06
Maximize living space	2	0.27	Inside living space	1	0.75
			Outside living space	2	0.25
Minimize commute time	3	0.15	Average commute time	1	1
Maximize safety	4	0.06	Average number of murders in zip code	1	0.75
			Average number of assaults in zip code	2	0.25

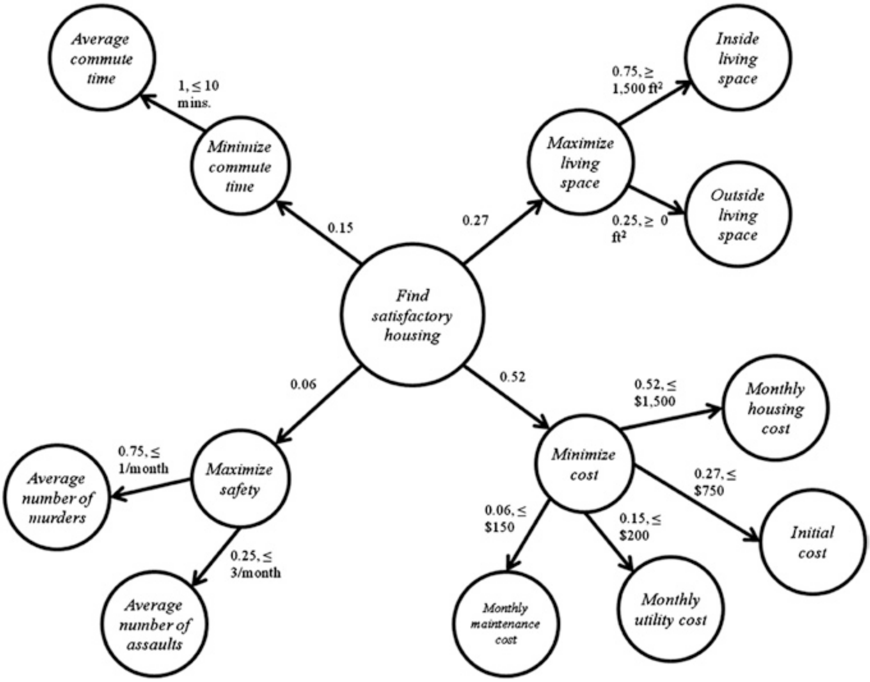

Fig. 6.3 Example problem, outcomes, outputs, goals, and weights

6.5 Summary and Implications for Systemic Thinking

This chapter began with some introductory information regarding utility theory and associated decision analysis concepts. Then, it discussed problem decomposition into outcomes and further into outputs. These outputs were then assigned goals and both outputs and outcomes had weights determined for them.

Table 6.6 Implications of *what* perspective on other perspectives

Perspective	Implications
Who (stakeholders)	Stakeholders will be the ones who have to live with the implications of our *what* analysis. It stands to reason that they will each want to have their perspective considered. Holistic consideration of the *what* question ensures that we will maximize stakeholder buy-in
Why (motivation)	Understanding what motivates stakeholders and setting up appropriate incentive structures will help us to ensure that we can achieve our outcomes in a much more efficient and effective manner
Where (contextual and boundary considerations)	Our ability to achieve (or not achieve) our goals is directly enabled (and constrained) by our contextual considerations. Failure to consider the two in concert with one another will inevitably make goal achievement problematic
How (mechanisms)	Understanding our outcomes, outputs, and goals will ensure that we can effectively determine the required mechanisms for our effort. Conversely, mechanism deployment means nothing in the absence of a set of outcomes to utilize for their prioritization
When (temporal considerations)	Certain outcomes may require compressed or elongated time frames. Understanding the *what* perspective ensures we appropriately assess the temporal nature of our problems and associated mess

Consideration of all of these elements together allows us to answer the *what* question of systemic thinking. However, this alone is insufficient. We need to consider the other perspectives of systemic thinking as well for holistic problem understanding. Table 6.6 shows the implications of the *what* question on each of the other systemic thinking perspectives.

After reading this chapter, the reader should:

1. Understand the basics of decision analysis;
2. Be able to decompose a problem into outcomes and outputs;
3. Be able to assign goals and weights to a problem; and
4. Know how to evaluate the current state of a problem with respect to its goals.

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Chapter 7
The *Why* of Systemic Thinking

Abstract The previous chapters in this section have addressed: (1) the who question through a discussion of problem stakeholders, their analysis, and management; and (2) the what question by decomposing the mess and constituent problems into relevant elements such as outputs and outcomes. In this chapter, we will address the why question through an analysis of motivation, and how each problem has a unique model of motivation and feedback between and among the stakeholders and the problem. The sections that follow will focus on the underlying fact or cause that provides logical sense for achieving goals and objectives as part of solving messes and their constituent problems. It will provide a short description of 20 theories of motivation that have informed the body of knowledge on the subject of motivation. Developing an understanding for the motives underlying the behaviors associated with why is the central tenet of each of these theories. The chapter will conclude by providing a theory or framework, for linking existing theories of motivation within a cybernetic model. The cybernetic model is provided as an aid in understanding the relationship between individual problems and the associated stakeholders, and the unique two-way relationship that contains both motivation and an associated feedback response.

7.1 *Why* as the Cause for Motivation

When humans attempt to answer the question *Why* …?, they are trying to determine either (1) a premise, reason, or purpose for why something is the way it is, or (2) what the causal relationship is between the event and the actions that caused the event to occur. As a result, *why* can be treated as either a noun or an adverb:

adverb—for what reason or purpose
noun—a reason or explanation

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Reason, purpose and some explanation of causality are central elements expected in any answer to the question *Why*? The underlying premise for the *why* question is most often based upon the following assumption:

> "Why" questions presuppose that things happen for a reason and that those reasons are knowable. "Why" questions presume cause-effect relationships, an ordered world, and rationality. "Why" questions move beyond what has happened, what one has experienced, how one feels, what one opines, and what one knows to the making of analytical and deductive inferences. [84, p. 363]

The answer to the *why* question relates reason through explanation.

> Often such reasons are causes, but even when 'cause' is not the natural description, 'Because - - - ' is the natural formula for answering why questions. 'Because - - - ' answers, usually becoming more informative in the process (the expansion will often indicate that the thing to be explained does some good, or—differently—aims at some good, these being two kinds of teleological explanation. [51, p. 957]

The notion of a teleological explanation is important. The teleological explanation is one in which there is a belief in or the perception of purposeful development toward an end. This is contained within the systems principle of purposive behavior [3] from Chap. 4 that states:

> Purposeful behavior is meant to denote that the act or behavior may be interpreted as directed to the attainment of a goal—i.e., to a final condition in which the behaving object reaches a definite correlation in time or in space with respect to another object or event. [88, p 18]

In *systemic thinking*, the attainment of specific, purposeful goals is the most desirable answer to *why*. The reason for attaining the goals has some underlying rationale which includes:

1. The basis or motive for the goals and supporting objectives.
2. A declaration made to explain or justify the goals and supporting objectives.
3. An underlying fact or cause that provides logical sense for achieving goals and objectives.

Items 1 and 2 were addressed in Chap. 6, *The What of Systemic Thinking*. The sections that follow will address item 3—the underlying fact or cause that provides logical sense for achieving goals and objectives as part of solving messes and their constituent problems.

7.2 Motivation

The underlying fact or cause that provides logical sense for achieving goals and objectives can be labeled motivation. Motivation is defined as [89, p 218]:

Motivation: Designation of the totality of motives operative in any given act of volition or of the mechanism of the operation of such motives. See *Motive*.

Motive: (Lat. *motus*, from *movere*, to move) An animal drive or desire which consciously or unconsciously operates as a determinant of an act of volition.

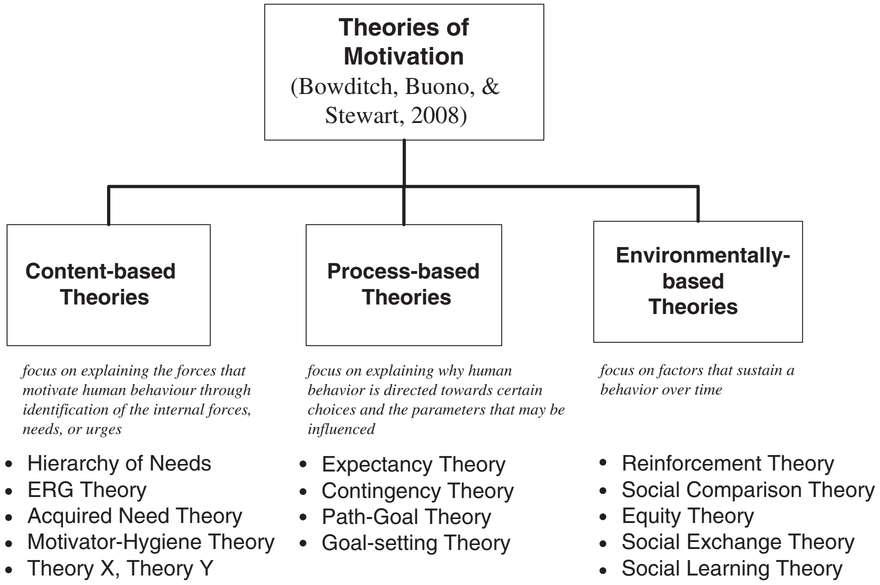


Fig. 7.1 Categorization of theories of motivation [15]

As defined, motivation is the property central in the explanation of intentional conduct. Specifically, a motivational explanation is “a type of explanation of goal-directed behavior where the explanans appeals to the motives of the agent” [9, p. 592]. Understanding the motives for the behaviors associated with *why* is the central tenet of theories associated with motivation.

7.3 Categorizing Theories of Motivation

There are a number of implicit theories for motivation in the literature. However, before we discuss the elements of these theories, it is important to understand how the scientific community has categorized theories of motivation. There are two generally accepted methods for categorizing these theories.

The first method for grouping motivation theories has three categories: (1) content-based theories of motivation; (2) process-based theories of motivation; and (3) environmentally-based theories of motivation [15]. Figure 7.1 is a depiction of this categorization.

The second method for grouping motivation theories also has three categories: (1) hedonic/pleasure-based theories of motivation; (2) cognitive/need-to-know-based theories of motivation; and (3) growth/actualization-based theories of motivation [87]. Figure 7.2 is a depiction of this categorization.

The two categorization schemas for motivation theories present twenty principal motivation theories, which are listed in Table 7.1. The theories are arranged

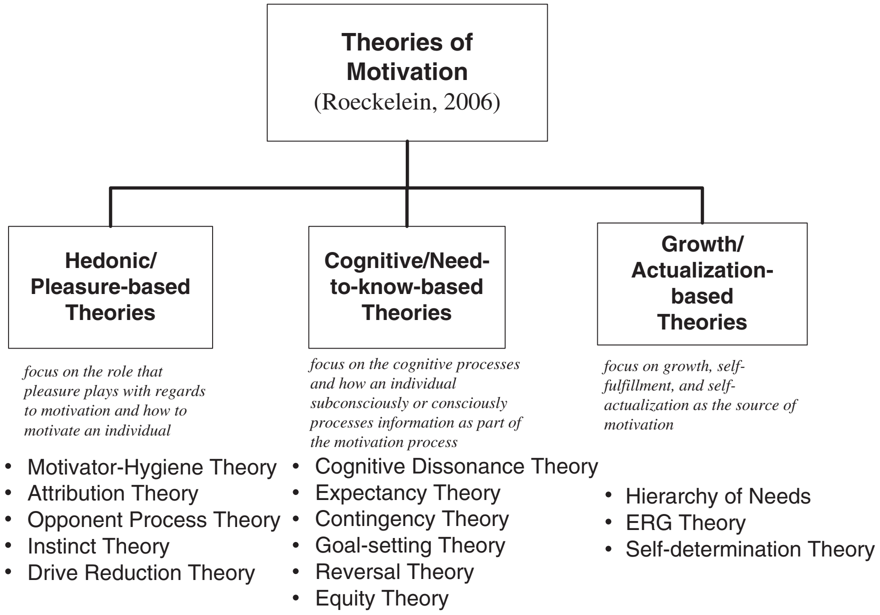


Fig. 7.2 Categorization of theories of motivation [87]

Table 7.1 Motivation theories and categorization schemas

Motivation theory and principal proponent (in chronological order)	Bowditch et al. [15]			Roeckelein [87]		
	C	P	E	H	CO	G
1. Instinct theory of motivation [59–61, 78]				X		
2. Drive reduction theory [55, 56]				X		
3. Hierarchy of needs [72–74]	X					X
4. Attribution theory [42, 62, 103, 104]				X		
5. Reinforcement theory [91, 92]			X			
6. Social comparison theory [32]			X			
7. Path-goal theory [37, 52]		X				
8. Social exchange theory [14, 49]			X			
9. Theory X, theory Y (McGregor [79] (1960))	X					
10. Cognitive dissonance theory [34]					X	
11. Equity theory [1]			X		X	
12. Social learning theory [11, 12]			X			
13. Expectancy theory [102] and contingency theory [85, 86]		X			X	
14. Motivator-hygiene theory [43]	X			X		
15. Acquired needs theory [75–77]	X					
16. ERG theory [4, 5]	X					X
17. Self-determination theory [23–25, 36]						X
18. Opponent-process theory [94, 95]				X		
19. Goal-setting theory [68, 70]		X			X	
20. Reversal theory of motivation [8]					X	

Note C Content; *P* Process; *E* Environmental; *H* Hedonic; *CO* Cognitive; *G* Growth and presented in chronological order to provide a contextual setting for how the theories were revealed over the last hundred or so years of research in this field. The section that follows will review each of these principal theories of motivation.

7.4 Theories of Motivation

The sections that follow will present each of the major theories of motivation in a very broad fashion. The reader is encouraged to consult the cited references for more in-depth explanations of each of these theories. Note that the theories are presented chronologically in the same order they appear in Table 7.1.

7.4.1 Instinct Theory of Motivation

The instinct theory of motivation suggests that all living beings are supplied with innate tendencies that enable them to remain viable. The theory suggests that motivational behaviors are driven by instincts where instincts are goal-directed and which have intrinsic tendencies that are not the result of learning or prior experience.

Wilhelm Wundt [1832–1920], the father of experimental psychology, coined the term *instinct* as a psychological term in the 1870s. Fellow psychologist William James [1842–1910] defined an instinct as an action which will "produce certain ends, without foresight of the ends, and without previous education in the performance" [61, p 355]. James believed that motivation through instinct was important for human behavior, and expounded upon 22 of these in the monthly journal *Popular Science* [59, 60].

This theory of motivation remained popular or generally accepted into the early 20th century. William McDougall [1871–1938] subscribed to the theory and felt that individuals are motivated by a significant number of inherited instincts, many of which they may not consciously comprehend, and which may lead to misunderstood and misinterpreted goals [78].

The main problem with this theory is that it did not really explain behavior; it just described it. The theory then led to the search for additional theories of motivation.

7.4.2 Drive-Reduction Theory of Motivation

The drive-reduction theory of motivation [55, 56] became popular during the 1940s and 1950s as a way to explain behavior, learning and motivation. The theory was created by behaviorist Clark Hull [1884–1952] and was based upon the systems principle of homeostasis which was discussed in Chap. 4. Hull extended [18] ideas on physiological homeostasis to human behavior, proposing that behavior was one of the ways that an organism maintains equilibrium.

Hull's drive-reduction theory uses the term *drive* to explain the state of tension that is caused by physiological needs. For instance, thirst and hunger are examples of specific drives caused by a physiological condition. In order to maintain equilibrium (i.e., homeostasis) the tension created by the drive must be balanced by an equal and opposite action— *reduction*, that will act to reduce the tension and return the human to a state of equilibrium. In the examples of thirst and hunger presented here, the human will act to reduce thirst by drinking and will act to reduce hunger by eating.

Hull, and his partner Spence [1907–1967] [96, 97], believed that drive-reduction was a major factor in learning and behavior. They classified primary drives as innate drives (e.g., thirst, hunger, and sex), and secondary drives as learned drives (e.g., wanting money). Hull understood that human beings are routinely subjected to multiple drives and must balance these drives in an effort to maintain equilibrium. He developed a mathematical formula to express how a human balances these behaviors. The formula accounts for this using a stimulus-response relationship where a stimulus (i.e., drive) is followed by a corresponding response (i.e., reduction), in an effort to maintain equilibrium. Hull theorized that satisfactory stimulus-response patterns would lead to learning. Hull's *Mathematico Deductive Theory of Behavior* [57] is presented in Eq. 7.1.

$$sEr = (sHr \times D \times K \times V) - (sIr + Ir) \pm sOr \tag{7.1}$$

where:

$sEr =$ Excitatory potential, or the likelihood that an organism will produce a response (r) to a stimulus (s)
$sHr =$ Habit strength, established by the number of previous conditioning
$D =$ Drive strength, determined by the hours of deprivation of a need
$K =$ Incentive motivation, or value of a stimulus
$V =$ The measure of connectiveness
$sIr =$ Inhibitory strength or number of non-reinforcers
$Ir =$ Reactive inhibition, or fatigue based on work for a reward
$sOr =$ Random error

The main problem with this theory is that it did not account for secondary or learned drives (i.e., wanting money) and how it reduces drives. An additional problem was that the theory does not account for why humans routinely increase tension by conducting exploratory ventures whether or not they were in a state of equilibrium. These shortcomings led researchers to search for more complete theories of motivation.

7.4.3 Hierarchy of Needs

The hierarchy of needs theory of motivation was proposed by Abraham Maslow [1908–1970] in the paper *A Theory of Human Motivation* [72]. In this paper, Maslow proposed that human needs are satisfied in an ordered hierarchy where critical lower-level needs would need to be satisfied before less critical higher level needs. The levels in the hierarchy, from bottom to top are (1) physiological, (2) safety, (3) love, (4) self esteem, and (5) self-actualization. In the 1943 paper, Maslow addresses the fixed order or *fixity* of the hierarchy and that “it is not nearly as rigid as we may have implied” (p. 386), and he goes on to list seven (7) exceptions to the general theory.

It is important to note that although this theory is often presented as a pyramid, none of Maslow’s published works [72–74] on the hierarchy of needs include a visual representation of the hierarchy. This section will avoid using the pyramid to support Maslow’s notions that the Hierarchy of Needs is neither a fixed nor rigid sequence of progression, that human needs are relatively fluid, and that many needs are simultaneously present.

Finally, Maslow also coined the term *metamotivation* to describe the motivation of people who go beyond the scope of the basic needs and strive for constant betterment [73].

While Maslow’s hierarchy of needs remains a very popular framework, it has largely been surpassed or replaced by newer theories of motivation.

7.4.4 Attribution Theory of Motivation

Psychological research into attribution theory as a source of motivation began with the work of Fritz Heider [1896–1988], who is often described as the *father* of attribution theory. Heider was interested in how people explain their behaviors. He found that people explain themselves by *attributing* a particular behavior as being caused by either internal or external forces. Internal forces are labeled *dispositions* and include personality, motives, attitudes, and feelings. External forces are labeled *situations* and include societal norms, acts of nature, and random chance.

Heider’s concepts were advanced by Kelley [1921–2003] [62, 63] who published a *co-variation model* that includes three main types of information from which to make attribution decisions about individual behavior. (1) *Consensus information* includes data about how other people, faced with the same situation, behave. (2) *Distinctive information* includes data about how an individual will respond based upon different stimuli. (3) *Consistency information* includes data related to the frequency of the individual’s behavior in a variety of situations. An observer may use this information when assessing the individual’s behavior as either internally or externally attributable.

Weiner [103, 104] expanded upon the work of both Heider and Kelley by proposing that individuals search for attributions and analyze casual relations based on the behaviors they experience. This is the *achievement attribution model*. When the attributions they assign to causes are positive (i.e., lead to successful outcomes), these attributions should lead to additional attempts in this area. However, when the attribution they assign to causes are negative (i.e., lead to unsuccessful outcomes), these attributions result in a reluctance toward future attempts.

In summary, attribution theory attempts to explain the motivation of individuals by evaluating the processes in which individuals explain the causes of behavior. The term attribution theory is an umbrella term for a variety of models in which individuals look for explanations or causes that can be attributed to their own success or failure.

7.4.5 Reinforcement Theory of Motivation

The reinforcement theory of motivation was first proposed by B.F. Skinner [1904–1990] during the 1950s. The theory links behavior and consequence. It is based upon Edward Thorndike's [1874–1949] *law of effect*, that was the result of his work on animal intelligence. Thorndike's *law of effect* proposed that responses that produce a satisfying effect in a particular situation are more likely to be repeated than responses that produce an uncomfortable effect in the same situation [100, 101].

Skinner applied the concept of *reinforcement* to the law of effect by rewarding desired behaviors in an effort to motivate individuals [91, 92]. This was a notable departure from theories of motivation which were concerned with the internal state of the individual (i.e., feelings, desires, instincts, etc.) and focused on the outcomes of the individual's actions. Reinforcement theory includes four aspects:

1. *Positive reinforcement*: when desired behaviors occur a reward is provided as motivation for continued behavior.
2. *Negative reinforcement*: when desired behaviors are problematic assistance is provided in order to modify the behavior.
3. *Punishment*: when desired behaviors are not achieved and harm arises then a punishment is given.
4. *Extinction*: when desired behaviors are not achieved on a continual basis and harm is present, then the individual will be disregarded and extinct.

Reinforcement theory also includes schedules for reinforcement that included both fixed and variable time intervals and fixed and variable ratios (based on the ratio of responses to reinforcements).

Reinforcement theory is important because it was relatively easy to understand and implement because the goal was to provide control through the manipulation of the consequences of behavior.

7.4.6 Social Comparison Theory of Motivation

The social comparison theory of motivation was first proposed by Leon Festinger [1919–1989]. Festinger's theory of social comparison is centered on the belief that "there exists, in the human organism, a drive to evaluate his opinions and abilities" [32, p. 117]. The theory also posits that "to the extent that objective, non-social means are not available, people evaluate their opinions and abilities by comparison respectively with the opinions and abilities of others" [32, p. 118].

Festinger's initial 1954 framework has been advanced to include:

1. Understanding of the motivations that underlie social comparisons and the particular types of social comparisons that are made [40].
2. The concept of downward comparison. Downward social comparison is a defensive tendency where the social comparison will be made with individuals who are considered to be worse off in order to make themselves feel better [106].
3. The concept of upward comparison. Research has suggested that comparisons with individuals that are considered to be better off can lower self-regard whereas downward comparisons can elevate self-regard [99].

Social comparison theory is important because it introduced the notion that an individual is capable of self-evaluation and that the drive to understand strengths and weaknesses exists in order to provide a more accurate view of the self.

7.4.7 Path-Goal Theory of Motivation

The path-goal theory of motivation was first proposed by House [52] and was based upon pioneering work conducted by Georgopoulos et al. [37] and Evans [31].

The original theory proposed that behavior in leaders is contingent upon the satisfaction, motivation and performance of subordinates in the organizational hierarchy [52] and the revised version of the theory proposes that leaders exhibit behaviors that complement the abilities of subordinates and often compensate for skill deficiencies in the organizational hierarchy [53].

> The essence of the theory is the meta proposition that leaders, to be effective, engage in behaviors that complement subordinates' environments and abilities in a manner that compensates for deficiencies and is instrumental to subordinate satisfaction and individual and work unit performance. (p. 323)

The theory maintains that leaders are required to modify their behavior by implementing leadership behaviors required by the situation they face. The leader is required to adjust the leadership style to support the unique needs presented by the dynamic nature of the mission, goals, and objectives of the organization. As such, leader behaviors are the independent variables in the theory and consist of the following:

- ***Directive path-goal clarifying leader behavior*** *is behavior directed toward providing psychological structure for subordinates: letting subordinates know what they are expected to do, scheduling and coordinating work, giving specific guidance, and clarifying policies, rules, and procedures.* [53, p. 326]
- ***Supportive leader behavior*** *is behavior directed toward the satisfaction of subordinates needs and preferences, such as displaying concern for subordinates' welfare and creating a friendly and psychologically supportive work environment. Supportive leader behavior was asserted to be a source of self confidence and social satisfaction and a source of stress reduction and alleviation of frustration for subordinates.* [54, p. 81]

- ***Participative leader behavior*** *is behavior directed toward encouragement of subordinate influence on decision making and work unit operations: consulting with subordinates and taking their opinions and suggestions into account when making decisions.* [53, pp. 326–327]

In summary, the independent variable in the path-goal theory is the leaders' behavior. As such, the theory relies heavily upon the notion that individuals in leadership positions are flexible enough and have the cognizant ability to modify their behavior based upon the situation they face.

7.4.8 Social Exchange Theory of Motivation

Social exchange theory was first proposed by sociologist George Homans [1910–1989] and was codified by sociologist Peter Blau [1918–2002]. [30] explains:

> …social exchange theory, …is not a theory at all. It is a frame of reference within which many theories-some micro and some more macro-can speak to one another, whether in argument or in mutual support. (p. 336)

Blau [14] describes that the frame of reference as "Social exchange as here conceived is limited to actions that are contingent on rewarding reactions from others" (p. 6). Social exchange proposes that as individuals interact over time, they develop the need to reciprocate favors. This need is termed the *norm of reciprocity* (see Blau [14] and Gouldner [38]).

Homan's concept of social exchange theory relies upon three basic propositions of social behavior:

1. *The Success Proposition*. "For all actions taken by persons, the more often a particular action of a person is rewarded, the more likely the person is to perform that action" [50, p 16].
2. *The Stimulus Proposition*. "If in the past the occurrence of a particular stimulus, or set of stimuli, has been the occasion on which a person's action has been rewarded, then the more similar the present stimuli are to the past ones, the more likely the person is to perform the action, or some similar action, now" [50, pp. 22–23].
3. *The Deprivation-Satiation Proposition*. "The more often in the recent past a person has received a particular reward, the less valuable any further unit of that reward becomes for him" [50, p. 29].

Despite the apparently clear nature of the theory, there are a number of complications that can arise and compromise the exchange relationships. Equivalent reciprocity requires that each returned favor have some value at least equal to the initial favor. Failure to ensure the favor is equivalent or of comparable benefit is subjective and can be the source of conflict and resentment. Placing value on favors is difficult and often involves qualities that are hard to measure (i.e., convenience, time, scarce resources, etc.).

Table 7.2 Characteristics of theory X and theory Y

Characteristic	Theory X	Theory Y
Attitude	Dislike work, find it boring, to be avoided	Want to work, find it interesting, can be enjoyed
Direction	Must be coerced into effort	Self directed toward effort
Responsibility	Avoid responsibility	Seek and accept responsibility
Motivation	Money and fear	Desire to realize personal potential

7.4.9 Theory X, Theory Y

Theory X, Theory Y are contrasting theories of motivation proposed by Douglas McGregor [1906–1964] in the 1960s. Theory X and Theory Y describe two models of workforce motivation from the view of management. Management feels that employees are motivated either by (1) authoritative direction and control or (2) integration and self-control.

In Theory X, management assumes that employees are inherently lazy and dislike work. As a result, employees require close supervision and a systems of controls must be developed to ensure compliance with work goals. In addition, a hierarchical structure of management and supervision is required.

In Theory Y, management assumes that employees are ambitious, self-motivated, and enjoy work. As a result, employees will seek out and accept responsibility. Due to these conditions, employees are able to meet goals and objectives based on self-direction and their personal commitment to work.

> At the heart of McGregor's argument is the notion that managers' assumptions/attitudes represent, potentially, self-fulfilling prophecies. The manager who believes that people are inherently lazy and untrustworthy will treat employees in a manner that reflects these attitudes. Employees, sensing that there is little in the job to spur their involvement, will exhibit little interest and motivation. Consequently, and ironically, the manager with low expectations will lament that 'you can't get good help nowadays', oblivious as to the actual nature of cause and effect. Closing the self-reinforcing cycle, the manager feels vindicated; that is, his/her low expectations were warranted. Conversely, the manager who believes that employees are generally trustworthy and desirous of growth will facilitate their achievement. [65, pp. 256–257]

The contrasting characteristics of Theory X and Theory Y are presented in Table 7.2.

Although McGregor's theories of motivation are seldom used explicitly, they have strongly influenced several generations of managers. A 2003 review of 73 established organizational behavior theories found that Theory X, Theory Y was tied for second in terms of recognition and in 33rd place with respect to importance [83].

7.4.10 Cognitive Dissonance Theory of Motivation

The cognitive-dissonance theory of motivation was first proposed by Leon Festinger [1919–1989]. Festinger's theory of cognitive-dissonance focuses on how individuals strive for internal consistency. When an inconsistent behavior (i.e., a dissonance) is experienced, individuals largely become psychologically distressed and have a desire to return to a state of equilibrium (i.e., homeostasis) [33] stated two basic hypotheses:

1. *The existence of dissonance, being psychologically uncomfortable, will motivate the person to try to reduce the dissonance and achieve consonance.*
2. *When dissonance is present, in addition to trying to reduce it, the person will actively avoid situations and information which would likely increase the dissonance.* (p. 3)

In the presence of dissonance an individual may return to equilibrium by adjusting their cognitions or actions. Adjustment results in one of three relationships between cognition and action:

- *Consonant relationship*—This occurs when two cognitions or actions are consistent with one another (e.g., not wanting to go swimming while at the beach and then going for a walk in the sand instead of swimming).
- *Irrelevant relationship*—This occurs when two cognitions or actions are unrelated to one another (e.g., not wanting to go swimming while hiking in the Mojave desert).
- *Dissonant relationship*—This occurs when two cognitions or actions are inconsistent with one another (e.g., not wanting to go swimming while surfing).

Cognitive dissonance theory posits that individuals desire consistency between expectations and the real-world. As a result, individuals invoke *dissonance reduction* to balance their cognitions and actions. Dissonance reduction provides a means for homeostasis, where there is a reduction in psychological tension and a return to equilibrium. [33, 34] stated that dissonance reduction can be achieved in one of three ways: (1) changing the behavior or cognition; (2) justifying the behavior or cognition by changing the conflict; or (3) justifying the behavior or cognition by adding a new cognition.

Early experiments showed that:

> 1. If a person is induced to do or say something which is contrary to his private opinion, there will be a tendency for him to change his opinion so as to bring it into correspondence with what he has done or said. 2. The larger the pressure used to elicit the overt behavior (beyond the minimum needed to elicit it) the weaker will be the abovementioned tendency. [35, pp. 209–210]

In later experiments researchers demonstrated cognitive-dissonance in a learning environment. For instance, school children who completed activities with the promise of a reward were less interested in the activity later, than those children who were offered no reward in the first place [69].

> Since it was presented by Festinger over 40 years ago, cognitive dissonance theory has continued to generate research, revision, and controversy. Part of the reason it has been so generative is that the theory was stated in very general, highly abstract terms. As a consequence, it can be applied to a wide variety of psychological topics involving the interplay of cognition, motivation, and emotion. [41, p. 5]

7.4.11 *Equity Theory of Motivation*

The equity theory of motivation was first proposed by Adams [1]. In this theory of motivation Adams proposed satisfaction and motivation in terms of an individuals' perception of the distribution of resources within an organizational or interpersonal setting. Adams [2] asserted that individuals maintain equity by comparing the inputs that they provide against the outcomes they receive against the perceived inputs and outcomes of others. The theory proposed that individuals highly value equitable treatment which in turn causes them to remain motivated in order to maintain the equitable conditions established between individuals or within an organization.

Equity theory posits that when individuals perceive themselves in an inequitable relationship, they will experience stress, placing them in a state where equilibrium is disturbed. In order to restore the equilibrium state, the individual must restore the equity in the relationship (either personal or organizational). True equality is not required by the theory. That is, equity is determined by analysis of fairness in the distribution of resources. Two parties do not have to have equality, however, the perceived ratio of contributions and benefits to each individual is what matters. Adams [2] proposed that anger is an outcome caused by underpayment inequity and guilt is caused by overpayment equity.

Criticism of equity theory has been focused on both the assumptions of the theory and application in the real-world. The simplicity of the elements of the theory has been questioned, with arguments that additional variables are important to an individuals' perceptions of equity. One such argument calls for a new construct that includes equity sensitivity, stating:

> The equity sensitivity construct suggests that individuals do not conform consistently to the norm of equity. Instead, individuals react consistently to specific, but different, preferences they have for the balance between their outcome/input ratios and that of a comparison other. Benevolents prefer that their outcome/input ratios be less than the comparison other's; Equity Sensitives, who adhere to the norm of equity, prefer balanced outcome/input ratios; and Entitleds prefer that their outcome/input ratios exceed the comparison other's. Furthermore, these general preferences for equity can be traced to internal standards that characterize the Benevolent as emphasizing own inputs exceeding own outcomes; the Entitled, own outcomes exceeding own inputs; and the Equity Sensitive, own outcomes equaling own inputs. [58, p. 231]

In summary, a generalized equity theory supports the notion that individuals value fair treatment, which causes them to remain motivated to maintain an equilibrium of fairness in the individual and organizational relationships. The structure of generalized equity is based on the ratio of contributions to benefits.

7.4.12 *Social Learning Theory of Motivation*

The social learning theory of motivation was proposed by Albert Bandura in the early 1960s. In social learning theory Bandura proposes that behavior is learned from the environment through the process of observational learning.

> In the social learning view, man is neither driven by internal forces nor buffeted helplessly by environmental influences. Rather, psychological functioning is best understood in terms of a continuous reciprocal interaction between behavior and its controlling conditions. [11, p. 2]

Bandura's theory postulates that new behavioral patterns can be learned through either (1) direct experience, or (2) by observing the behavior of others. The theory supports the notion of reinforcement and that individual learning is largely governed by the reward-punishment consequences that follow the actions. Reinforcement is proposed as having the following incentive functions:

- *Informative function*. Individuals observe the range of consequences that accompany their actions.
- *Motivational function*. Individuals use the results of prior experience to expect that certain actions will result in outcomes that either (1) have outcomes they value, (2) have no appreciable effect, or (3) have outcomes that are undesirable.
- *Cognitive function*. The onset of awareness in an individual is a function of the reward value of the actions' consequence.
- *Reinforcing function*. Individual responses can be strengthened through selective reinforcement imposed below the level of awareness.

Bandura [11] summarizes reinforcement as:

> The overall evidence reveals that response consequences can be informative, motivating, and reinforcing. Therefore, in any given instance, contingent reinforcement may produce changes in behavior through any one or more of the three processes. People can learn some patterns of behavior by experiencing rewarding and punishing consequences, but if they know what they are supposed to do to secure desired outcomes they profit much more form such experiences. (p. 5)

Most importantly, Bandura challenged the notion that behavior (B) was a function of (1) internal personal incentive (I) and (2) external or environmental pressure (E), where all behavior was a function of the joint effects of personal incentives and environmental pressures such that $B = f\ (I, E)$. Bandura noted that external, environmental pressure is not a fixed entity. In fact, it is only a *potentiality*, and can itself be subject to behavior and vice-a-versa, in a two-way causal process. In social learning theory internal personal incentives (e.g., pride, satisfaction, a sense of accomplishment) reinforce the cognitive element of the theory to cognitive developmental theories.

7.4.13 Expectancy Theory of Motivation

The expectancy theory of motivation was first proposed in the 1960s by Vroom [102] and expanded upon in the work of Porter and Lawler [85, 86].

The theory proposes that an individual will decide to behave or act in a certain way because they are motivated to select a specific behavior over other behaviors due to what they expect the result of that selected behavior will be. The motivation for how they will act is determined by the desirability of the outcome of the behavior or *expectancy*. Individual motivation is a product of the individual's expectancy that a certain effort will lead to the desired outcome. The theory has three variables that affect motivation:

- *Valence (V)*—the attractiveness or desirability of various rewards or outcomes.
- *Expectancy (E)*—the desirability of the result for the individual which the perceived relationship between effort and performance.
- *Instrumentality (I)*—is the perceived relationship between performance and rewards.

Motivation in expectancy theory is labeled motivation force (M_f) and is the product of these three components, as shown in Eq. 7.2.

$$M_f = V \times E \times I \tag{7.2}$$

Each of the variables in the expectancy theory of motivation require additional explanation.

Valence (V). Vroom defines valence as "…the affective orientation toward particular outcomes" [102, p. 15]. It is the attractiveness or desirability of various rewards or outcomes based on the value an individual places on the rewards of an outcome. The value is based on the unique needs, goals, values, and preferences of the individual. As such, valance is characterized by the extent to which a person values a given outcome or reward and is not an objective measure of satisfaction, but a subjective measure of the expected satisfaction of a particular outcome, for a particular individual.

> Outcomes desired by an individual are considered positively valent and those he wishes to avoid negatively valent; therefore valences are scaled over a virtually unbounded range of positive and negative values. Vroom emphasizes, as do most other expectancy theorists, the idea that the objective utilities associated with outcomes of working at a particular level are not of primary concern; rather, the crucial factor is the individual's perception of the satisfaction or dissatisfaction to be derived from working at a particular level. [13, p. 374]

Expectancy (E). "Expectancy is defined as a momentary belief on the part of an individual that acting in a particular way will actually be followed by a given outcome. The expectancy value associated with any action-outcome link may range from 0.00 (no relationship perceived) to 1.00 (complete certainty that acting in a particular way will result in the outcome)" [13, p. 374]. There are three components associated with the individual's Expectancy perception:

1. *Self efficacy*—the individual's belief about their ability to successfully perform a particular behavior.
2. *Goal difficulty*—the individual's belief about the ability to achieve the goal or performance expectation.
3. *Perceived Control*—the individual's belief in their ability to control their performance.

Instrumentality (I). "Instrumentality theory hypothesizes that a person's attitude toward an outcome (state of nature) depends on his perceptions of relationships (instrumentalities) between that outcome and the attainment of other consequences toward which he feels differing degrees of liking or disliking (preferences)" [39, p. 1]. In the perceived relationship between performance and rewards, rewards in organizations settings may be an increase in pay or responsibility, special recognition or award, or a personal sense of accomplishment.

Factors associated with the individual's instrumentality for outcomes are trust, control and policies. If individuals trust their superiors, they are more likely to believe their leaders' promises. When there is a lack of trust in leadership, people often attempt to control the reward system. When individuals believe they have some kind of control over how, when, and why rewards are distributed, instrumentality tends to increase. Formalized written policies impact the individuals' instrumentality perceptions. Instrumentality is increased when formalized policies associate rewards to performance.

7.4.14 Motivator-Hygiene Theory of Motivation

The motivator-hygiene theory of motivation was first proposed in the 1960s by Frederick Herzberg [1923–2000]. The theory, which is also referred to as the *two-factor theory* and *dual-factor theory* proposes that there are two sets of factors in the workplace that affect workers' satisfaction.

The motivator-hygiene theory [44, 45] has built upon Maslow's hierarchy of needs theory by proposing the presence of one set of factors or incentives that lead to satisfaction and a separate and unique set of factors or detractors that leads to dissatisfaction. Herzberg abandons the idea of a continuum of satisfaction (ranging from highly satisfied to high dissatisfied) and proposes two independent phenomena. The motivator-hygiene theory requires management to consider each factor when addressing worker motivation. Herzberg's [43] original list of motivators (lead to satisfaction) and hygiene (lead to dissatisfaction) factors were:

- *Motivators*: "achievement, recognition for achievement, intrinsic interest in the work, responsibility, and advancement" (p. 487).
- *Hygiene factors*: "company policy and administrative practices, supervision, interpersonal relationships, working conditions, and salary" (p. 487).

In summary, motivating factors are needed to shift an employee to higher performance and hygiene factors are needed to ensure an employee is not dissatisfied.

7.4.15 Acquired Needs Theory of Motivation

The acquired needs theory of motivation was first proposed by David McClelland [1917–1998] in 1965. In this theory, which is also referred to as the *three needs theory* and the *learned needs theory*, [75–77] proposed that individuals have three needs: (1) achievement, (2) affiliation, and (3) power, and that these motivations exist independent of age, sex, race, or culture. Furthermore, the dominant type of motivation that drives an individual is a function of the life experiences and the opinions of the culture in which the individual was immersed. The three needs are classified as:

1. *Achievement*: individuals with this need desire to excel and seek timely recognition for their efforts. Their efforts do not involve risks and require some gain for themselves. The possibility of failure is strictly avoided.
2. *Affiliation*: individuals with this need seek peaceful relationships and refrain from actions which would attract attention to themselves. They seek sufficient recognition and do not require over-justification for their work.
3. *Power*: individuals with this need require power in order to exercise control over other individuals. The power is acquired to serve their needs and to achieve objectives. These individuals do not seek recognition or approval, consider themselves superior, require direct compliance, and expect agreement with their decisions.

In summary, McClelland believed that every individual has one of three main driving motivators and that these motivators are not inherent, but developed based upon life experiences and the culture in which the individual was immersed.

7.4.16 ERG Theory of Motivation

The Existence, Relatedness, Growth (ERG) theory of motivation was first proposed by Clayton Alderfer in 1969. In this theory, Alderfer redefines Maslow's hierarchy of needs theory in new terms. [4] does this by re-categorizing Maslow's hierarchy of needs into three simpler and broader classes of needs.

1. *Existence needs*: "include all of the basic forms of material and physiological desires" (p. 145).
2. *Relatedness needs*: "include all of the needs which involves relationships with significant other people (p. 146).
3. *Growth needs*: "include all of the needs which involves a person making creating or productive effects on himself and the environment" (p. 146).

The ERG theory of motivation differs significantly from Maslow's hierarchy of needs. Unlike Maslow's theory, Alderfer's ERG Theory does not require the fulfillment of a lower level of need prior to moving to a higher level. In ERG theory, if a higher-level causes aggravation and cannot be fulfilled, then an individual may revert to increase the satisfaction of a lower- level need. This is labeled the *frustration-regression* aspect of ERG theory. In this manner ERG theory [5] explicitly states that any given point in time, more than one need may be operational.

7.4.17 Self-determination Theory of Motivation

The self-determination theory of motivation (SDT) was first proposed by Edward Deci and Richard Ryan in 1971 [26]. SDT proposes that individuals tend to be motivated by a need to grow and gain fulfillment. The first assumption of SDT is that individuals are activity-directed toward growth. While many theories propose that individuals are most often motivated extrinsically (i.e., external rewards such as money, prizes, and acclaim), SDT is focused on intrinsic motivation (i.e., need to gain knowledge or independence).

SDT proposes that in order to become self-determined, individuals need to feel the following:

- *Competence*: individuals need to gain mastery of tasks and control outcomes.
- *Relatedness*: individuals need to experience a sense of belonging and attachment to other people.
- *Autonomy*: individuals need to feel in control of their own behaviors and goals.

Once individuals achieve self-determination they are able to be intrinsically motivated. Deci [25] findings show that:

> The general findings of this study and the [23] studies suggest that one who is interested in developing and enhancing intrinsic motivation in children, employees, students, etc., should not concentrate on external control systems such as monetary rewards, which are linked directly to performance, but, rather, he should concentrate on structuring situations that are intrinsically interesting and then be interpersonally supportive and rewarding toward the persons in the situation. While large payments can lead to increased performance due to feelings of inequity, these payments will, however, be making the people dependent on the money, thereby decreasing their intrinsic motivation. (pp. 119–120)

In summary, Deci's and Ryan's SDT [27] proposes that three basic psychological needs motivate individuals. SDT states that these needs are said to be universal, innate and psychological and include the need for competence, autonomy, and psychological relatedness.

7.4.18 Opponent Process Theory of Motivation

The opponent process theory of motivation was first proposed by Richard Solomon [1918–1995] in 1965. In this theory, Solomon proposed that every process has a primary element called an *affective valence* (i.e., is it pleasant or unpleasant), and is followed by a secondary or *opponent process*. The secondary opponent process begins to take effect after the primary affective valence is quieted. As this sequence is repeated, the primary process tends to become weaker while the opponent process becomes stronger.

> The theory assumes that for some reason the brains of all mammals are organized to oppose or suppress many types of emotional arousals or hedonic processes, whether they

> are pleasurable or aversive, whether they have been generated by positive or by negative reinforcers. [93], p 698

Solomon and his collaborator John Corbit (1973, 1974) conducted experiments on work motivation and addictive behavior, showing (1) how the opponent-process theory applies to drug addiction and is the result of a pairing of pleasure (affective) and the symptoms associated with withdrawal (opponent), and (2) how, over time, the level of pleasure from using addictive substances decreases, while the levels of withdrawal symptoms increase, providing motivation to continue using the addictive substance despite a decreasing lack of pleasure.

In summary, the opponent process theory of motivation may be generalized beyond addictions to understand why situations that are distasteful or unpleasant may still be treated as rewarding.

7.4.19 Goal Setting Theory of Motivation

The goal setting theory of motivation was first proposed in the late 1970s by Latham and Locke [68]. The theory proposes that individuals will be motivated to the extent that they accept specific, challenging goals and receive feedback that indicates their progress toward goal achievement. Their goal-setting theory is fully consistent with social-cognitive theory in that both acknowledge the importance of conscious goals and self-efficacy. The goal-setting theory focuses primarily on motivation in work settings. The core components of goal setting theory include:

1. Goal specificity—the extent to which goals are detailed, exact, and unambiguous.
2. Goal difficulty—the extent to which a goal is hard or challenging to accomplish.
3. Goal acceptance—the extent to which people consciously understand and agree to goals.

The theory includes four mechanisms that directly affect performance:

1. Goals serve a directive function where they direct attention and effort toward goal-relevant activities and away from goal irrelevant activities.
2. Goals have an energizing function such that high goals lead to greater effort than low goals.
3. Goals affect persistence when participants are allowed to control the time they spend on a task, hard goals prolong effort.
4. Goals affect action indirectly by leading to the arousal, discovery, or use of task-relevant knowledge and strategies.

The theory states that goal moderators are factors that facilitate goal effects and include: (1) *Commitment*, whereby public recognition of the goal is enhanced by leaders communicating an inspiring vision and behaving supportively; (2) *Importance*, where leadership commits resources based upon the goals relative importance; (3) *Self-efficacy* or the extent or strength of leadership's belief in its

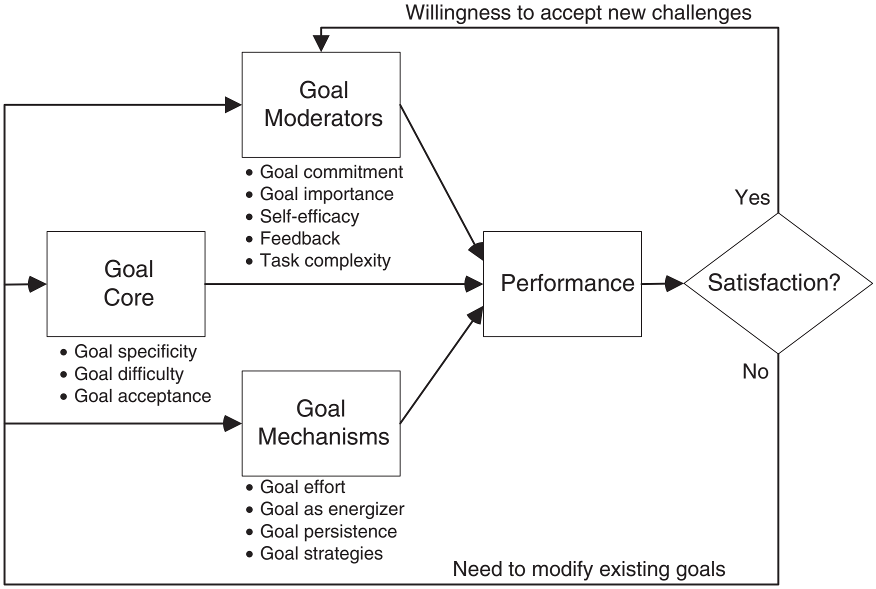


Fig. 7.3 Essential elements of goal-setting theory and the high-performance cycle (adapted from Locke and Latham [70, p. 714])

ability to complete tasks and reach goals by providing adequate training, positive role models, and persuasive communication; (4) *Feedback*, as an element stating that "for goals to be effective, people need summary feedback that reveals progress in relation to their goals" [70, p. 708]; and (5) *Task complexity*, as the complexity of tasks increase and higher level skills and strategies are required goal effects are dependent on the ability to provide proper resources and strategies for accomplishment.

Figure 7.3 depicts the integration of the essential elements of goal setting theory.

7.4.20 Reversal Theory of Motivation

The reversal theory of motivation was first proposed in 1975 by Michael Apter and Ken Smith and fully detailed in Apter's book *The Experience of Motivation* [7]. Reversal theory describes how individuals regularly reverse between psychological states, reflecting their motivational style and the meaning they attach to a specific situation at a unique point in time.

Because the theory is focused on mental life it is termed phenomenological [6], where the behavior of an individual can only be fully understood within the subjective meaning assigned to it by the individual. An example of a reversal is shown by the response to a simple cat's meow. Sometimes the meow evokes a warm memory and a smile; other times the meow can evoke a frown and a sense of annoyance.

The theory proposes that individual experience is structurally organized into meta-motivational states which are opposing pairs labeled as *domains,* where only one of each pair can be active or experienced at a time.

- *Means-Ends State*: *Telic* (serious) and *Paratelic* (playful) which refer to whether an individual is motivated by achievement and future goals, or the enjoyment of the moment.
- *Rules State*: Conforming and Rebellious which refer to whether an individual enjoys operating within rules and expectations; or whether the individual desires to be free and rebels against rigid rules and structure.
- *Interaction State*: Mastery and Sympathy relate to whether an individual is motivated by transacting power and control or by sympathetic reaction demonstrated by care and compassion.
- *Orientation State*: *Autic* (self) and *Alloic* (other) which refer to whether an individual is motivated by self interests or by the interests of others.

In summary, reversal theory proposes that individuals are changeable and move between different motivational states in the course of daily life. The theory serves as a means to understand why individual seem to contradict themselves in the pursuit of satisfaction and provides a framework for improved understanding.

7.5 Applying Theories of Motivation

The twenty principal theories of motivation provide a variety of theoretical explanations for what motivates both individuals and groups. Many of the theories have similar notions and often augment one another. Because both of the authors primarily think systemically, the idea that a single, holistic, meta-theory that could synthesize the ideas presented in the twenty theories has great merit with each of us (and as it turns out, with others as well).

The idea of a meta-theory, or framework, for linking existing theories of motivation has been proposed by both [67] and [64]. Klein's approach is to use control theory as an integrating framework for the theories of motivation. This has a great deal of appeal for systemic thinkers and will be presented as a functional framework for implementing a variety of useful aspects from the wide array of motivation theories.

7.6 Cybernetics and Control Theory

Tamotsu Shibutani [1920–2004] argues that two University of Chicago professors were responsible for introducing cybernetic features as important in explaining individual action long before Wiener [105] coined the term *cybernetics*.

Philosopher-educator John Dewey [1859–1952] and psychologist George Mead [1863–1931], close colleagues at the University of Chicago, were heavily invested in the evolutionary view of individual action and interaction. Both Dewey and Mead felt that the individual and the environment were intimately interdependent, in disagreement with the prevailing stimulus-response theory of psychology in vogue at the time [16]. During the late nineteenth century [28] commented that the existing stimulus-response model was inadequate to explain human behavior or action, stating:

> It is the motor response of attention which constitutes that, which finally becomes the stimulus to another act. (p. 363)

Dewey also introduced the notions of communication and control [29], which are two of the central principles of cybernetics and systems theory. Similarly, [80] commented about both the individual:

> An act is an impulse that maintains the life-process by the selection of certain sorts of stimuli it needs. Thus, the organism creates its environment… Stimuli are means, tendency is the real thing. Intelligence is the selection of stimuli that will set free and maintain life and aid in rebuilding it. (p. 6)

and the social act:

> The social act is not explained by building it up out of stimulus plus response; it must be taken as a dynamic whole—as something going on—no part of which can be considered or understood by itself—a complex organic process implied by each individual stimulus and response involved in it. (p. 7)

Both Dewey [28, 29] and Mead [80, 81] were pioneers in applying some fundamental features of a cybernetics to models of individual action. Cybernetics is the precursor to control theory and as such contains the foundation principles used to explain purposive action required in self-governing (i.e., cybernetic) models of human motivation.

7.7 Klein's Integrated Control Theory Model of Work Motivation

Klein [64] has constructed a framework, which is based on control theory, that houses the salient features of a number of motivation theories. The control theory model integrates the works of a number of researchers who have developed control theory approaches in human behavior [17, 19–22, 46–48, 71, 98]. The special features of Klein's model are:

- *Parsimony*: The proposed model contains definitive elements of a limited number of motivation theories. As new theories are proposed, and older ones are supplanted, they can be incorporated into the model with relative ease. This is because the model is a framework, and even as other theories are included "it can remain a simple heuristic" [64, pp. 150–151]. This feature is noteworthy because it is invoking the goal axiom‘s principle of requisite parsimony [82].

- *Goal-setting*: The framework includes the ability to establish specific goals and objectives. The feature is invoking the goal axiom‘s principle of purposive behavior where the behavior is directed toward the attainment of a specific goal [88].
- *Feedback*: The framework contains feedback loops where sensors and comparators are used to provide signals based on an established standard. This feature is invoking the viability axiom's principle of feedback [105]. "Feedback control shows how a systems can work toward goals and adapt to a changing environment, thereby removing the mystery from teleology" [90, p. 172].
- *Motivation Theories*: The framework includes expectancy and attribution theories and can be extended to include social learning theory.

Klein's model is based upon the simple feedback model from cybernetics, which includes (1) a *references standard*, (2) a *comparator* that differentiates between the signal and the standard, (3) *feedback* which is the actual performance signal detected by the sensors and its transmission signal, and (4) an *effector* that implements corrective action based on the values generated in the comparator. The unique element in Klein's model is the inclusion of formal processes between the comparator and the effector that are based on four motivation theories included in the model.

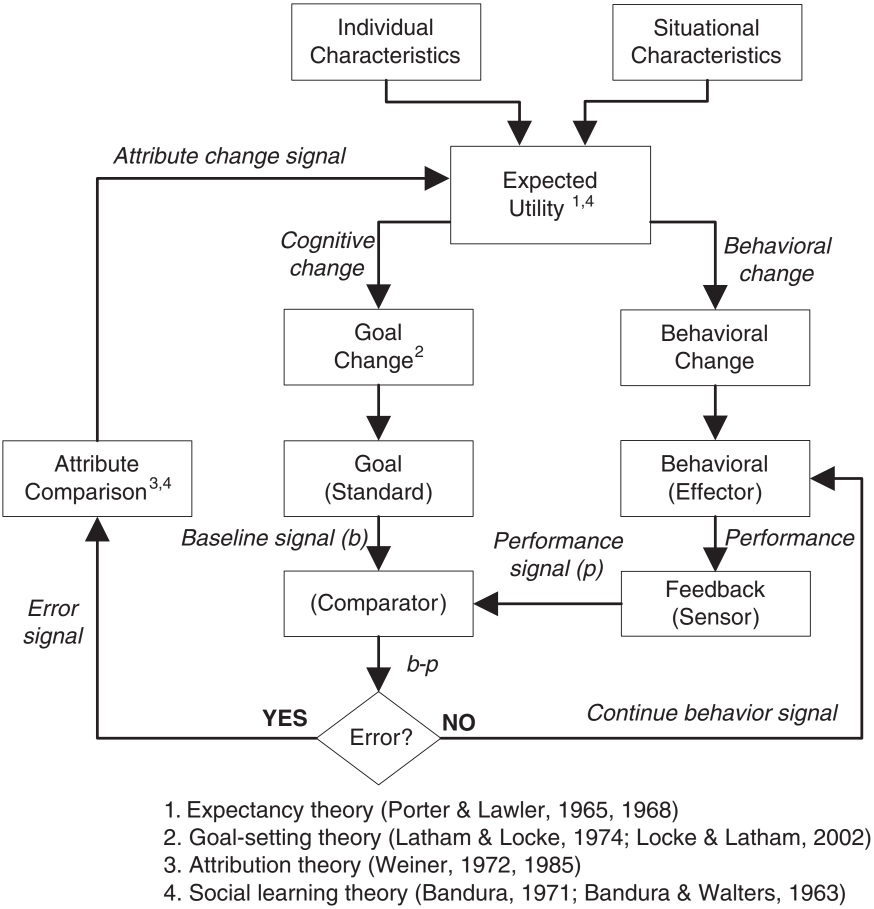
7.8 Framework for Addressing *Why* in Messes and Problems

Figure 7.4 is a generic control theory model of work motivation based upon Klein's model that may be used as a process model for motivation in understanding the underlying *why* question when determining either (1) a premise, reason, or purpose for why something is the way it is, or (2) what the causal relationship is between the event and the actions that caused the event to occur.

The generalized control theory model of motivation depicted in Fig. 7.4 can be used to understand the unique relationship between individual problems and the associated stakeholders. Each stakeholder has a motivational relationship with the problem and in some cases the relationship also extends to other stakeholders. The motivational relationship is two-way, that is, contains both a motivation and an associated feedback response. Figure 7.5 shows a two-way relationship between three stakeholders (S_1, S_2, and S_3) and a problem (P_1).

Each of the two-way lines in Fig. 7.5 is unique and based on the model in Fig. 7.4. As a result there are both motivational goal signals ($M_{i,j}$) and feedback response signals ($F_{i,j}$) occurring in each relationship. Figure 7.6 shows how each problem-stakeholder relationship contains a mini-model of motivation that serves as the source of motivation in each relationship.

Models of motivation based on problem-stakeholder relationships need not be quantified or formalized, but the fact that each stakeholder-problem (and stakeholder-stakeholder) pair have unique motivating factors is the important message.



1. Expectancy theory (Porter & Lawler, 1965, 1968)
2. Goal-setting theory (Latham & Locke, 1974; Locke & Latham, 2002)
3. Attribution theory (Weiner, 1972, 1985)
4. Social learning theory (Bandura, 1971; Bandura & Walters, 1963)

Fig. 7.4 Generic control theory of motivation (adapted from Fig. 2 in Klein [64], p 153)

Fig. 7.5 Problem-stakeholder relationships

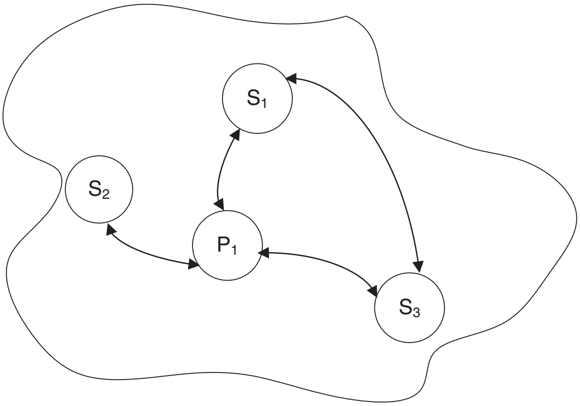


Fig. 7.6 Problem-stakeholder relationship with motivation (m) and feedback (f) signals

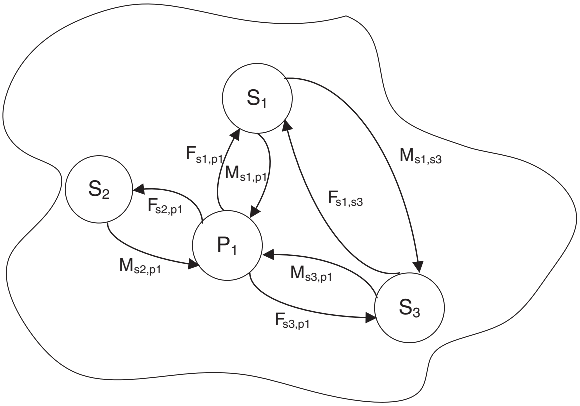


Table 7.3 Implications of *why* perspective on other perspectives

Perspective	Implications
Who (stakeholders)	Understanding the why questions helps us to influence the stakeholders involved with our mess such that we may increase our understanding
What (outcomes, outputs)	Goals are a direct element of the framework for motivation discussed in this chapter. Both what we are trying to accomplish and why we are trying to accomplish it are inextricably linked; we cannot separate the two concepts
Where (contextual and boundary considerations)	Motivations will influence the relevant context of the mess that we choose to embrace. We may choose to be a “big fish in a small pond” and restrict our context to a smaller scope or we may attempt to engage a larger mess if underlying motivations dictate us to do so
How (mechanisms)	Understanding the motivations of those stakeholders and groups associated with our mess may require us to utilize mechanisms in an effort to satiate concerns of those involved with our mess
When (temporal considerations)	Understanding the motivations of stakeholders may have a bearing on when we choose to intervene in a particular mess

Care should be taken regarding the use of feedback mechanisms so as to avoid vicious circles and promote virtuous circles, as described by the principle of circular causality [66]. Further, if singular feedback loops are insufficient, it may be necessary to use a hierarchy of regulation as described by the principle of requisite hierarchy [10], in order to achieve ample regulatory control and motivational feedback.

7.9 Summary and Implications for Systemic Thinking

Utilization of a formal model for motivation, based on the generic processes depicted in Fig. 7.4, may prove useful when attempting to understanding messes and their constituent problems. The initial and continued motivation serves as the incentive, the stimulus, and the inspiration for continued involvement. Using a cybernetic model with clear feedback loops ensures continued performance by ensuring goals remain synchronized with the individual and situational characteristics that form the context of the messes and constituent problems. This provides a congruent, current, and logical framework for achieving goals and objectives developed to address the elements of the messes and associated problems. Table 7.3 shows the implications of the *why* question on each of the other systemic thinking perspectives.

After reading this chapter, the reader should:

1. Understand the basic tenets of the 20 major theories of motivation;
2. Be able to apply the generic control theory model of work motivation as a process model for understanding the *why* and sources of motivation in messes and problems; and
3. Understand the importance of continued motivation and its roles in ensuring continued performance through the synchronization of individual incentives and situational characteristics that form the context of messes and problems.

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Chapter 8
The *Where* of Systemic Thinking

Abstract The previous Chapters in this Section have addressed: (1) the *who* question through a discussion of problem stakeholders, their analysis and management; (2) the *what* question by decomposing the mess and constituent problems into relevant elements such as outputs and outcomes; and (3) the *why* question through an analysis of motivation and how each problem has a unique model of motivation and feedback between and among the stakeholders and the problem. This Chapter will answer the *where* question. This *where* we refer to is not associated with physical location and geographic coordinates, but with the circumstances, factors, conditions, values and patterns that surround the problem, and the boundaries that separate the problem from its environment. The sections that follow will focus on two elements of *where*. The first section will review *context*—the circumstances, factors, conditions, values and patterns that surround messes and problems. The second section will review *boundaries*—the representations we use that provide lines of demarcation between messes and problems and the surrounding environment. A framework is then presented for addressing *where* in messes and problems.

8.1 Context

As problems have evolved from simple systems to complex systems, the associated complexity surrounding each problem has also increased. Problems are no longer (1) isolated from the surrounding environment, or (2) responsive to detached technical solutions. Modern complex systems problems require approaches that include additional complementary perspectives that encompass viewpoints beyond a simplified technical perspective. The aperture of the problem lens must be widened to include multiple perspectives, that is, perspectives that permit improved understanding of problem context.

The application of multiple perspectives offers a more inclusive framework through which complex systems problems may be viewed. The integration of technical, organizational, political and human perspectives widens the aperture

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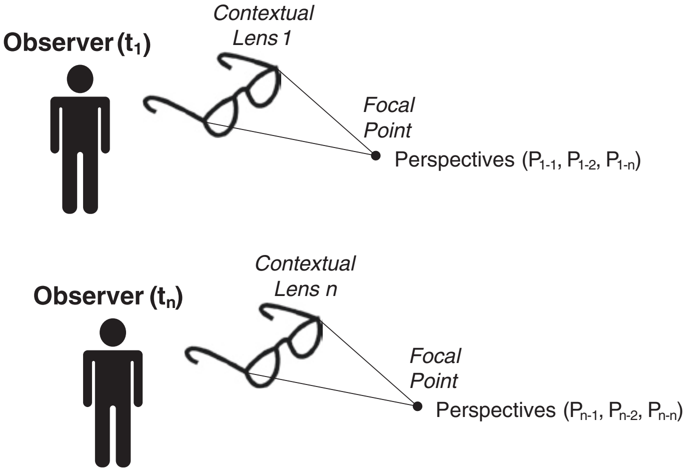


Fig. 8.1 Contextual lens and perspectives

to permit contextual elements that surround and within which the problem is embedded to be included as part of the solution domain. This section will discuss the development of perspectives using context, provide a description and some definitions for context, reveal the essential elements of context, relate the temporal aspect of context, define a relationship between data, information, knowledge and context, and explain how to extract procedural context.

8.1.1 Perspectives and Context

In order to achieve a *holistic* understanding in systems age problems, problem solvers must formally account for known contextual elements by invoking as many unique perspectives as possible. According to Eq. 2.2, an observer will need to include as many perspectives as possible in order to understand a problem accurately. As part of this understanding, an observer will employ a number of lenses to focus these observations, much like a microscope would do. The lenses are *contextual lenses*. A contextual lens serves to focus our powers of understanding onto a particular element of context. Figure 8.1 is a depiction of an observer with Contextual Lens 1 at time 1 serving to focus understanding on a series of related perspectives P_{1-1}, P_{1-2}, …, P_{1-n} and so on.

As an example, an observer who is about to embark on a research project will want to consciously select a research-related lens in order to develop a research view. The research lens will ensure that a unique number of research perspectives are included as part of the context (i.e., ontological, epistemological, axiological, and methodological perspectives) associated with the research project.

When a systems practitioner (always an observer) becomes involved with a complex systems mess and its constituent problems, there are a number of

Table 8.1 Contextual lenses used with complex systems

Contextual lens	Associated field of science	Associated perspectives
Individual	Psychology	Motivation, personality
Group	Sociology, management	Organizational behavior, control, finance, etc.
Political	Political science	Power, policies, etc.
Research	Philosophy of science	Ontological, epistemological, axiological, methodological, etc.
Engineering	Systems science, systems engineering	Systems-based methodologies, systems life cycle models, etc.
Science	Mathematics, physics, chemistry, biology	Logic, hierarchies, thermodynamics, etc.

contextual lenses that must be invoked. Table 8.1 is a representative sample of contextual lenses with the associated science and resulting perspectives used when developing context for complex systems.

The contrast between the various views focused by the contextual lenses leads to significantly different perspectives of the problem encountered by the problem solver or problem solving team. The *principle of holism* [28] requires that multiple perspectives be included as part of the development of problem context. The section that follows will define context and how it is assembled as part of the problem formulation.

8.1.2 Description and Definitions for Context

A number of formal definitions for context exist in the extant literature and are provided in Table 8.2.

From these nine definitions, a number of key words and concepts can be extracted:

- Definition 1—*condition*
- Definition 2—*situation, knowledge*
- Definition 3—*location, state, identity, person, place, object*
- Definition 4—*relevant, location, time, identity, preferences*
- Definition 5—*knowledge, relations*
- Definition 6—*setting, circumstances*
- Definition 7—*assumptions*
- Definition 8—*knowledge, salient*
- Definition 9—*perspectives*

At a high-level, problem context can be described as the circumstances, factors, conditions, values and patterns that surround a particular situation, person, place, or object.

Table 8.2 Definitions for context

Definition	Source
1 (a) The parts of a discourse that surround a word or passage and can throw light on its meaning. (b) The interrelated conditions in which something exists or occurs	[23, p. 270]
2 The set of all knowledge that could be evoked by a human being facing a situation, assuming that he has an unlimited time to think about it	[6, p. 230]
3 Any information that can be used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups, and computational and physical objects	[10, p. 106]
4 Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including location, time, activities, and the preferences of each entity	[10, p. 5]
5. Context has been shown to be an emergent as well as a generative property of knowledge. Indeed, contexts are sets of relations and not self-evident things in themselves. We must therefore be alive to the possibility that there are two parallel processes of construing context: for us from within our own bodies of knowledge; and for them within theirs	[11, p. 454]
6 Context may be defined loosely as the setting or circumstances in which an event or behavior of interest occurs. Context affects how we interpret the world around us	[16, p. 242]
7 Context is a generalization of a collection of assumptions … may correspond to an infinite and only partially known collection of assumptions	[20, p. 557]
8 Context is mainly considered as a way to cluster knowledge for search efficiency, for representing counter-factual or hypothetical situations, for circumscribing the effects of particular actions to particular situations, and for directing an agent's focus of attention to salient features of a situation	[5, p. 61]
9 Context is a conceptual idea which can only be approximated by models, can be defined and used from different perspectives, is shared knowledge space	[18, p. 13]

8.1.3 Elements of Context

The five essential elements, (1) circumstances, (2) factors, (3) conditions, (4) values, and (5) patterns, used in our description of context can be grouped under the broad headings of abstraction and culture.

1. Abstraction: The removal, in thought, of some characteristics or features or properties of an object or a system that are not relevant to the aspects of its behavior under study [27, p. 6].
2. Culture: refer to systems of shared ideas, to the conceptual designs, the shared systems of meanings that underlie the ways people live [15, p. 139].

Based on these definitions of context, Table 8.3 is a simplified characterization of context that includes five primary elements drawn from Adams and Meyers [3].

Table 8.3 Contextual elements

	Abstraction	Culture
Elements	1. *Circumstances* Particulars of the situation that define the state of affairs 2. *Factors* Specific characteristics or variables that affect the situation 3. *Conditions* The prevailing state of the situation that influences outcomes	1. *Values* General beliefs for which the systems stakeholders have an emotional investment 2. *Patterns* A perceived structure, operation, or behavior that is recurring

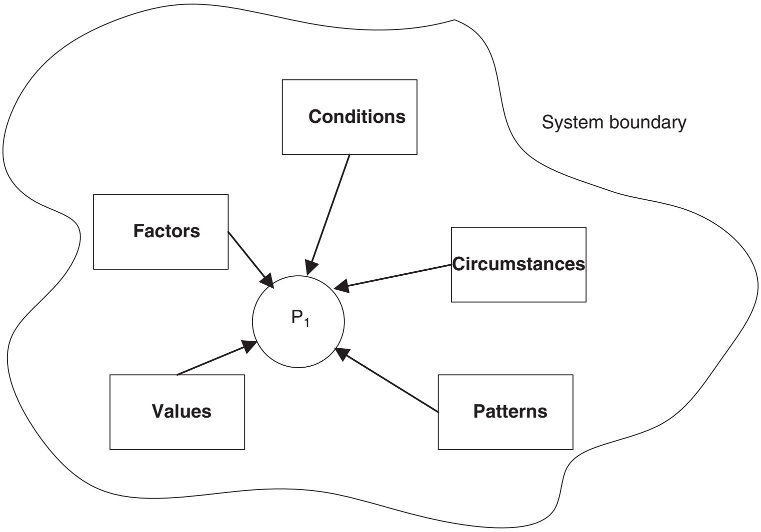


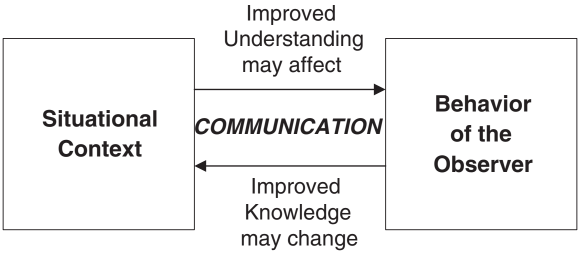
Fig. 8.2 Contextual elements acting on a problem

Examples of how each contextual element contributes to problem context are:

1. Circumstances: Decisions are bound by fixed parameters. An example could be the requirement to comply with an existing law or regulation.
2. Factors: A variable has a specific value that cannot be changed. For instance, a fixed budget.
3. Conditions: A state exists during a specific period of time and as a result may directly influence outputs or outcomes. An example is the threat of a terrorist attack.
4. Value: A strongly held belief. For instance, workers will not be required to work more than 40 h per week.
5. Patterns: A recurring behavior that is generally accepted. An example could be that artisans are allowed to make modifications to the established system design without having to consult the designers.

These five contextual elements can be viewed as nodes acting on our problem in Fig. 8.2.

Fig. 8.3 Situational context and observer behavior



It is important to note that the contextual elements depicted in Fig. 8.2 are within the problem system's boundary. Because they reside within the system boundary they can be controlled and manipulated, whereas elements outside of the system boundary merely act upon the problem.

Because context can be a combination of a tacit or explicit, formal or informal construct, we believe that it must be meaningfully defined when addressing complex systems messes and their constituent problems. Making context both explicit and formal enables knowledge to be shared with others as part of the process required to achieve a mutually agreeable perspective.

8.1.4 Temporal Aspects of Context

Because context is infinite in that it is generated from an infinite number of perspectives, it is problematic to try to understand, know, or manage everything that surrounds a particular situation, person, place, or object. Therefore, we must purposefully limit the information by creating a subset of the information in the context. By limiting the problem space we are controlling what we choose to use to understand the problem and what we are to do next [4].

Context has an important temporal element. Context is not static, but dynamic, changing over time. Change is a function of both external and internal interactions. Communication, which includes improved explanations with respect to the context and the subsequent behaviors of the observers that gain this improved understanding, is a constant cycle of interaction. Figure 8.3 depicts this interaction and supports Mittal's and Paris' [24] notion that "in order to be able to build systems that take into account the context, it is necessary to identify how context constrains behavior and how context in turn is changed by action" (p. 492).

The main point being made by Mittal and Paris [24] is that communication serves as the link between the context of the situation and the observer, and that this is a continuous process.

The idea that both context and the degree of ambiguity change over time is an important one [18]. If problem planning remains rigid and fixed, then (1) there is decreased ambiguity based upon improved understanding and (2) changes occurring in the context surrounding the problem may fail to be incorporated into plans associated with problem resolution.

8.1.5 Data, Information, Knowledge, and Context

In Chap. 1 we introduced the concept of observation and proposed that the term data would be used for observations already interpreted in some way. Because human observation involves interpretation, data may contain bias. Knowing this, we will further propose that data are symbols that represent properties of objects, events and their environments.

Most data is of limited value until it is processed into a useable form. Processing data into a useable form requires human intervention, most often accomplished with the use of an information system. The output of this process is *information*. Information is contained in descriptions, answers to questions that begin with such words as who, what, where, when, and how many. These functional operations are performed on data and transform it into information. It is important to note that the difference between data and information is functional, not structural [1]. Data is transformed into information in the following ways [9]:

- Contextualized: we know for what purpose the data was gathered
- Categorized: we know the units of analysis or key components of the data
- Calculated: the data may have been analyzed mathematically or statistically
- Corrected: errors may have been removed from the data
- Condensed: the data may have been summarized in a more concise form (p. 4).

Like data, information has little utility without additional processing. Processing information into useful elements is a higher-order process that requires a purposeful human intervention.

> Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms. [9, p. 5]

Because knowledge is know-how, a human cognitive process is required to transform information into knowledge, which may serve as the basis for decisions. Information is transformed into knowledge much like data was transformed into information [9]:

- Comparison: how does information about this situation compare to other situations we have known?
- Consequences: what implications does the information have for decisions and actions?
- Connections: how does this bit of knowledge relate to others?
- Conversation: what do other people think about this information? (p. 6)

The basic relationship between data, information, knowledge, decisions, and metrics is depicted in Fig. 8.4.

At this point we must remind ourselves that information is subject to the aphorism known as *Finagle's Laws on Information* [14, 25, 26] where: (1) The

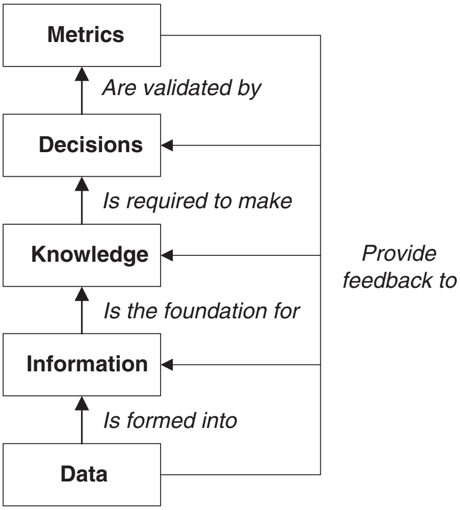


Fig. 8.4 Relationship between data, information, knowledge, decisions and metrics

information you have is not what you want; (2) the information you want is not what you need; (3) the information you need is not what you can obtain; and (4) the information you can get costs more than you want to pay. In order to adequately address Finagle's Laws on Information the systems practitioner should ensure that sufficient redundancy in data and information exists such that triangulation is possible in all data and information processing processes associated with the development of context.

Context has a major role in the information transformation process. Context is the wrapper that must be supplied, most often as explanations, as an integral part of the process in which information is transformed into knowledge. Human intervention is essential in this process because "an explanation always takes place relative to a space of alternatives that require different explanations according to current context" [5]. Because context is dynamic (i.e., the situational information is changing over time), it can only be represented *a posteriori*.

Figure 8.5 shows how context is an essential element in the information transformation process. As a final note on this process, the reader is encouraged to contemplate the explicit positioning of metrics in both Figs. 8.4 and 8.5. This incorporates the feedback principle [31], ensuring that decisions are reviewed through appropriate metrics, which provides insight about the knowledge-based decision. These metrics are identified, in part, from the goals established while answering the *what* question in Chap. 6.

8.1.6 Extracting Procedural Context

So, faced with infinite context that is constantly changing, how does a systems practitioner establish the context for a mess and its constituent problems? The

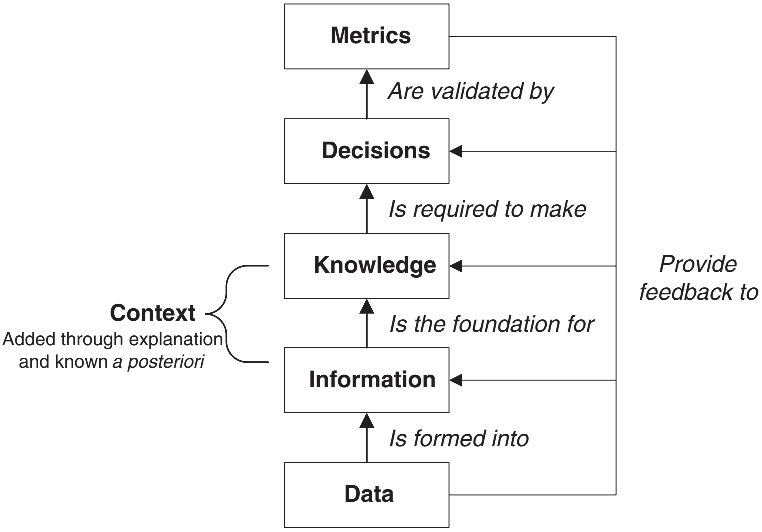


Fig. 8.5 Context as an element of the information transformation process

process through which relevant context is extracted is labeled *proceduralized context* and defined as:

> That part of the contextual knowledge that is invoked, structured and situated according to a given focus and which is common to the various people involved in decision making. [6, p. 233]

It is important to note that each of the contextual elements presented in Table 8.3 are influential in the development of the unique explanations present in each of the contextual knowledge situations. It is the totality of these elements that will both constrain and enable analysis of the problem. Proceduralized context accounts for the contextual knowledge present in each situation associated with the problem. Figure 8.6 is a depiction of proceduralized context.

Armed with an understanding of our context, the section that follows will address how a problem‘s boundaries, which set it apart from its surroundings, provide formal lines of demarcation between the defined mess and its associated problems with what we will define as the environment.

8.2 Boundaries and the Environment

While we’ve discussed the first element of the *where* question, context, this question also has a second element, boundaries. This element addresses the boundaries that separate messes and problems from their environment.

As we improve our understanding of complex systems messes and their constituent problems, we recognize that the issues associated with boundaries—the representations we use to demark a problem from its environment, require additional

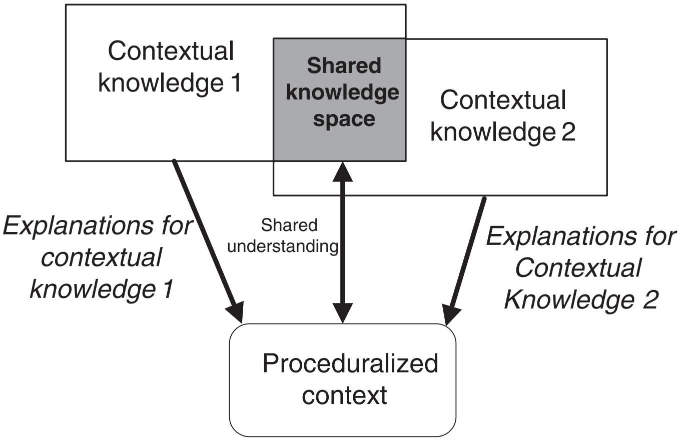


Fig. 8.6 Proceduralized context, adapted from a figure in Brézillon and Pomerol [6, p. 11]

understanding. It is no longer adequate to construct a demarcation line around a problem arbitrarily and to have confidence that the boundary is properly placed. Complex messes and problems are not easily bounded by the surrounding environment. Modern complex systems problems require finesse in the determination and establishment of boundaries. This section will provide definitions for both boundary and environment, discuss the significance of proper boundaries, provide a classification for boundaries, and propose a framework for boundary development.

8.2.1 Definitions for Boundary and Environment

Before we can discuss the characteristics associated with the establishment of a boundary between a problem system and its environment, we must create some relatively precise definitions for the primary terms we will use—boundary and environment.

Boundary is a term that has wide use in a variety of applications. However, when used by systems practitioners, it has a more precise definition that conveys specific meaning.

> Boundary: In the formal system model the area within which the decision-taking process of the system has power to make things happen, or prevent them from happening. More generally, a boundary is a distinction made by an observer which marks the difference between an entity he takes to be a system and its environment. [7, p. 312]

Interestingly, the above definition uses the term environment as part of the definition. Environment is defined as:

> a set of elements and their relevant properties, which elements are not part of the system, but a change in any of which can cause or produce a change in the state of the system. [2, p. 19]

Armed with relatively precise definitions for boundary and environment, the concepts related to the establishment of a boundary, which separates a problem system from its environment, may now be explored.[1]

8.2.2 The Significance of Boundary Establishment

The establishment of a boundary is a fundamental undertaking that has significant ramifications for all aspects of problem discovery and subsequent solution alternatives. Murray Gell-Mann, the 1967 Nobel Laureate in Physics, comments that "As always, determining the boundaries of the problem is a principal issue in problem formulation" [12]. Establishment of a problem boundary defines the limits of the knowledge that may be used during problem analysis. Not only does the establishment of the boundary set limits on knowledge, but it defines those people and organizations (the *Who* stakeholders from Chap. 5) involved in the generation of the knowledge. By establishing a boundary, the systems practitioner has limited the perspectives and world views that can be brought to bear in support of problem analysis and resolution.

With acceptance that no system can be completely known (i.e., the contextual axiom‘s principle of darkness) and with acknowledgement that no single perspective or view of a system can provide complete knowledge of the system (i.e., the contextual axiom's principle of complementarity), the systems practitioner embraces the fact that setting boundaries is not only fundamental, but critical to the successful understanding and subsequent dissolution, resolution, or solution [2] of a systems problem.

C. West Churchman [1913–2004], a leader in the systems movement, understood that boundaries are purely personal and group constructs that serve to define the limits for what is included during problem understanding and subsequent dissolution, resolution, or solution.

> The reason why the nature of the decision maker and the system boundaries are correlative problems is easy to see. We say that the environment of a system consists of those aspects of the natural world which influence the effectiveness of a system relative to the client, but which the decision maker cannot change. The resources, on the other hand, also influence the effectiveness, and can be changed by the decision maker. [8, p. B44]

In summary, problem boundaries are artificial, arbitrary, representations (i.e., personal and group constructs), established to purposefully limit (which often has deleterious effects) knowledge associated with the problem. The section that follows will discuss how boundaries may be classified.

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[1] It is important to note that there are additional ideas about systems boundaries that exist beyond the scope of this book. Readers interested in advanced topics on system boundaries should consider both *structural coupling* [17] and *autopoiesis* [19].

8.2.3 Boundary Classification

Because problem boundaries are established based on a perceived personal or group reality, they should be established purposefully. Sufficiency requires that boundary conditions be classified using three characteristics: (1) temporal aspects; (2) the range of stakeholders included; and (3) ideas related to the scope of the dissolution, resolution, or solution endeavors [21, 22].

1. *Temporal Characteristic*: In order to construct a sufficient boundary condition, the aspect of time must be included. Inclusion of a time boundary ensures that the problem is viewed from a similar perspective or world view by all of the problem's stakeholders. This is often termed a *time horizon* and is an essential characteristic of any problem system's boundary definition.
2. *Scope Characteristic*: A sufficient boundary condition must include the notion of scope—what is to be included as part of the effort to understand the problem and any subsequent dissolution, resolution, or solution endeavors. This should include (a) what range of stakeholders are to be included, (b) the resources available for the effort, and (c) a generalized notion of what aspects of the problem are to be included as part of the endeavor.
3. *Value Characteristic*: A sufficient value characteristic should contain formal definitions that address the participant's expected values. These values should encompass the general beliefs for which the systems stakeholders have an emotional investment.

Armed with definitions both for boundary and environment and understanding both the significance and the characteristics associated with the process of constructing a sufficient boundary, we have some ideas essential to problem bounding. The next section will provide a framework that may be used to ensure that the essential elements are included as integral elements of a coherent approach to context definition and problem bounding.

8.3 Framework for Addressing *Where* in Messes and Problems

We first begin by addressing context. Context is an inherent part of both a problem and its attendant solution.

> Neither problems nor solutions can be entertained free of context. A phenomenon that can be a problem in one context may not be one in another. Likewise, a solution that may prove effective in a given context may not work in another. [13, p. 116]

Thus, it is important to think of each of the five elements of context discussed in Sect. 8.1.3, namely (1) circumstances, (2) factors, (3) conditions, (4) values, and (5) patterns, as they pertain to a given problem and its attendant solution. Each will affect our problem, as depicted in Fig. 8.2 and should be considered with

Table 8.4 Ulrich's framework of twelve critically-heuristic boundary categories [30]

Boundary category	Boundary issue	Participant category
Client	Sources of motivation	Those involved
Purpose		
Measure of improvement		
Decision-maker	Sources of power	
Resources		
Decision environment		
Professional	Sources of knowledge	
Expertise		
Guarantee		
Witness	Sources of legitimation	Those affected
Emancipation		
Worldview		

respect to its temporal concerns as it relates to data, information, knowledge, decisions, and metrics. Further, each will affect the understanding and establishment of our boundary.

Ulrich [29] proposes that boundary judgments and value judgments are linked and that the boundaries adopted for the problem will be a direct function of the value judgments of participants. His answer is to construct practical guidelines that will permit participants to engage in meaningful dialogue where boundaries may be developed based on critical reflection. Ulrich's boundary critique, which he labels *Critical Systems Heuristics* (CSH), is a systemic effort of handling boundary judgments critically by viewing the boundary issues within specific categories.

> The boundary categories are arranged in four groups of three categories each. The first category of each group refers to a social role (rather than an individual person) who is or should be involved in defining the system of concern. For instance, in the first group, this is the "client" – the group of those who benefit or who ought to benefit. The second category addresses role specific concerns that are or should be included. Again taking the example of the first group, this is the client's "purpose" – the interests or concerns that are motivating a proposal. The third category relates to key problems that are crucial for understanding the previous two boundary judgements [sic]. [30, p. 258]

Table 8.4 presents Ulrich's framework. The first column has the social role and the associated role concerns. The second column addresses the underlying boundary issues that are to be addressed. The third column categorizes the participants as either involved or affected.

A useful feature of CSH is a checklist of twelve boundary questions that are used to evaluate heuristically what the problem system *is* and what it *ought* to be.

> For systematic boundary critique, each question needs to be answered both in the "is" and in the "ought" mode. Differences between "is" and "ought" answers point to unresolved boundary issues. There are no definitive answers, in that boundary judgements [sic] may always be reconsidered. By means of systematic alteration of boundary judgements [sic], it is possible to unfold the partiality (selectivity) of an assumed system of concern from multiple perspectives, so that both its empirical content (assumptions of fact) and its normative content (value assumptions) can be identified and can be evaluated without any illusion of objectivity. [30, p. 259]

Table 8.5 Ulrich's checklist of critically heuristic boundary questions [30, p. 259]

Boundary issue	Boundary question
Sources of motivation	1. Who is (ought to be) the **client**? That is, whose interests are (should be) served? 2. What is (ought to be) the purpose? That is, what are (should be) the consequences? 3. What is (ought to be) the measure of improvement? That is, how can (should) we determine that the consequences, taken together, constitute an improvement?
Sources of power	4. Who is (ought to be) the decision-maker? That is, who is (should be) in a position to change the measure of improvement? 5. What resources are (ought to be) controlled by the decision-maker? That is, what conditions of success can (should) those involved control? 6. What conditions are (ought to be) part of the decision environment? That is, what conditions can (should) the decision-maker not control (e.g. from the viewpoint of those not involved)?
Sources of knowledge	7. Who is (ought to be) considered a professional? That is, who is (should be) involved as an expert, e.g. as a researcher, planner or consultant? 8. What expertise is (ought to be) consulted? That is, what counts (should count) as relevant knowledge? 9. What or who is (ought to be) assumed to be the guarantor of success? That is, where do (should) those involved seek some guarantee that improvement will be achieved—for example, consensus among experts, the involvement of stakeholders, the experience and intuition of those involved, political support?
Sources of legitimation	10. Who is (ought to be) witness to the interests of those affected but not involved? That is, who is (should be) treated as a legitimate stakeholder, and who argues (should argue) the case of those stakeholders who cannot speak for themselves, including future generations and nonhuman nature? 11. What secures (ought to secure) the emancipation of those affected from the premises and promises of those involved? That is, where does (should) legitimacy lie? 12. What worldview is (ought to be) determining? That is, what different visions of "improvement" are (should be) considered, and how are they (should they be) reconciled?

Table 8.5 presents Ulrich's checklist of critically heuristic boundary questions for each of the categories specified in Table 8.4.

It is important to note that by using Ulrich's systemic guide for boundary critique, problem boundaries that were previously viewed as artificial and arbitrary representations are now exposed and challenged within a formal framework. Use of a formal framework for the critique permits participation and ownership by all problem stakeholders, and formulates the problem boundary using both *is* (i.e., descriptive) and *ought* (i.e., normative) modes. We propose that systems practitioners should adopt and utilize Ulrich's checklist of critically heuristic boundary questions in Table 8.5 as a means for operationalizing a formal process when identifying problem boundaries.

Table 8.6 Implications of *where* perspective on other perspectives

Perspective	Implications
Who (stakeholders)	Addressing the where question helps us to ensure that the stakeholders are in agreement with the context and boundaries associated with the mess and problems
What (outcomes, outputs)	Having a clear understanding of the context and boundaries for the mess and problems ensures that we can successfully address the desired outputs or outcomes
Why (motivation)	Establishment of relevant context and clearly defined boundaries ensures that the motivations of the stakeholders are synchronized with the scope of the mess and problems
How (mechanisms)	Understanding the context and boundaries allows the proper mechanisms to be employed to increase understanding of the mess and problems
When (temporal considerations)	Establishment of relevant context and clearly defined boundaries ensures that temporal aspects related to the mess and problems are adequately addressed

In summary, the establishment of problem boundaries requires a thorough understanding of both the significance of, and the characteristics associated with, the boundaries between a problem and its environment. This knowledge must be supported by a formal framework in which boundary knowledge is operationalized in a formal process where problem boundaries are proposed, critiqued, and accepted.

8.4 Summary and Implications for Systemic Thinking

This Chapter has provided a foundation for understanding the *where* in a mess or problem. The importance of *context*—the circumstances, factors, conditions, values and patterns that surround messes and problems—was presented. The importance of problem *boundaries*—the representations we use that provide lines of demarcation between messes and problems and the surrounding environment—was also presented. A framework for defining relevant context and operationalizing the process of developing sufficient problem boundaries was developed.

Table 8.6 shows the implications of the *where* question on each of the other systemic thinking perspectives.

After reading this chapter, the reader should:

1. Understand the five unique elements of context;
2. Be able to explain the relationship between data, information, and knowledge;
3. Recognize the importance of establishing a boundary between a system and its environment;
4. Be able to apply articulate how the environment and a boundary are essential elements of the problem; and
5. Be capable of applying a checklist of critical heuristic boundary questions as a framework for establishing a systems boundary.

The Chapter that follows will address the *how* question, where the identification and application of resources required to address messes and their constituent problems are discussed.

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Chapter 9
The *How* of Systemic Thinking

Abstract The previous Chapters in this Section have addressed the *who*, the *what*, the *why*, and the *where* questions associated with messes and their constituent problems. This Chapter will address the *how* question. When we refer to *how* we are interested in the means used in the attainment of specific, purposeful goals. The means are the mechanisms utilized in moving from the current problem state toward a new desired state where the goals and associated objectives have been satisfied. Mechanisms produce the effects that, when taken in concert, move a mess from the current state to the desired state. The sections that follow will focus on nine elemental mechanisms that serve as the means of *how*. The first section will reveal the mechanisms of *how*, the second section will examine the abstract mechanism of *method*, and the third section will provide a framework that may be used when understanding messes and their constituent problems.

9.1 Mechanisms

When we speak of mechanism, we are using the term to describe *the means by which a desired effect or purpose is accomplished*. These mechanisms are the means which transform existing states into desired states. The mechanisms do not act alone, but in concert, to affect the movement from current to desired state. The nine unique mechanisms may be classified in three categories: (1) abstract mechanisms; (2) physical mechanisms; and (3) human mechanisms. The schema for mechanism classification is depicted in Fig. 9.1.

The schema in Fig. 9.1 presents nine (9) unique mechanisms based on how these mechanisms are envisioned and utilized as the means for moving from a current state to a new desired state. The sections that follow will briefly describe each of these mechanisms.

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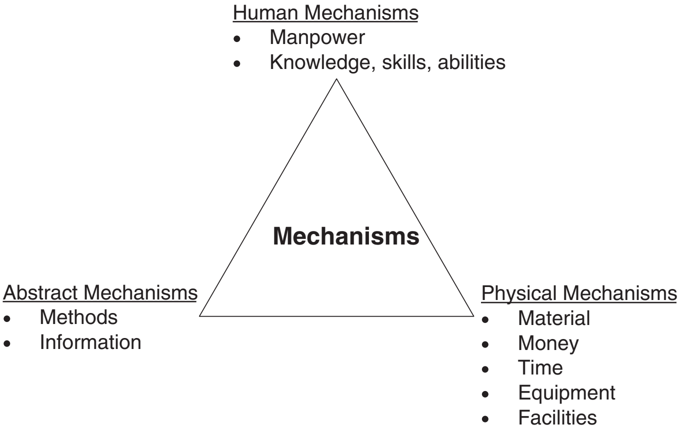

Fig. 9.1 Schema for mechanism classification

9.1.1 Physical Classification for Mechanisms

The mechanisms that are classified as physical are relatively easy to understand. Material, money, time, equipment, and facilities are measurable mechanisms that may be used as means to accomplish objectives.

1. *Material* are items that are consumed in the production of an output or outcome. Materials are often referred to as raw materials since they are the substances from which products are made. An example of a material is uranium-dioxide which is the material from which nuclear pellets for fuel rods are manufactured.
2. *Money* is the medium of exchange used to pay for the exchange of products and services. Money is used as a means pay for products and services used to accomplish objectives. An example of money is the paycheck offered to employees for the hours they work.
3. *Time* is a measure of the duration of events and the intervals between them. Time is fundamental to understanding the movement between the current state and the desired state. All actions taking place between these states are evaluated using time, which serves as a universal measurement. An example of time is the specific period allocated for the accomplishment of a task. Finishing prior to the specified time period is an early finish, a coveted state. Finishing after the specified time period is a late finish, an undesirable state.
4. *Equipment* are movable objects used to create products and services in the production of an output or outcome. An example of equipment would be an ambulance which can be moved to a location where emergency medical services are required.
5. *Facilities* are immovable objects (i.e., they are not moveable in a short-term time bound) used to create products and services in the production of an output or

outcome. An example of a facility is a hospital which exists to provide medical services, but cannot be relocated within a short-term time bound.

The application of physical mechanisms in support of outputs and outcomes is a straightforward concept to understand. Physical mechanisms are an easily measureable and quantifiable means through which functions and processes are delivered to produce desired outputs and outcomes.

9.1.2 Human Classification for Mechanisms

The mechanisms that are classified as human, much like physical mechanisms, are also relatively straightforward. Manpower and knowledge are the attributes of human capital that are used to create outputs and outcomes.

1. *Manpower* is the term used to specify the application of human capital required to accomplish a specific process or function in support of a desired output or outcome. Manpower is usually focused on the quantity of human capital required, which does not address the knowledge, skills, or abilities of the human capital.
2. *Knowledge* as a mechanism, consists of knowledge (with a small k), skills, and abilities (KSA), which are the unique list of qualifications and attributes required to successfully accomplish a process or function in support of a desired output or outcome. Table 9.1 provides formal definitions for these terms.

Table 9.1 demonstrates how knowledge, skills, and abilities can be assessed, measured, or observed as part of the process of ensuring that qualified human capital are provided to perform functions in support of desired outputs and outcomes.

We will propose a new term, *knowledge worker*, which is:

> A human being that possesses the required knowledge, skills, and abilities to perform a specific function in support of a desired output or outcome in the achievement of a purposeful objective or goal.

Once again, the application of human mechanisms is a straightforward concept to understand. Knowledge workers, in sufficient quantities, are required to successfully accomplish functions and processes required to deliver desired outputs and outcomes. It is the knowledge workers that add value to the process of delivering services or producing products, by transforming information into knowledge. At this point, it is important to note that knowledge, skills, and abilities (KSAs) are not static mechanisms. The environment within which the knowledge workers exist should be one where KSAs are acquired, refreshed, expanded, and validated. Because KSAs are such important mechanisms of *how*, the process in which capital K **K**nowledge (which for this discussion we will say encompasses knowledge, skills and abilities) is created, acquired, articulated, and applied, a review of personal and organizational knowledge is required.

Table 9.1 Descriptions of knowledge, skills, and abilities

Term	Description
Knowledge	Knowledge refers to organized factual assertions and procedures that, if applied, makes adequate performance of a task possible [7, 70] Knowledge can be assessed through formal examination [23]
Skills	Skill refers to the proficient manual, verbal or mental manipulation of tools, techniques and methods [7] Skills can be readily measured by a performance test where quantity and quality of performance are tested, usually within an established time limit [23]
Abilities	Ability refers to the power to perform an observable activity at the present time [7, 53] Abilities can be observed and measured through behaviors that are similar to those required in a given role. Abilities are realized aptitudes. Aptitudes are only the potential for performing a behavior [23]

9.1.2.1 Personal Knowledge

Michael Polanyi [1891–1976], was a medical doctor, renowned physical chemist, and philosopher who proposed an individual theory of knowledge he labeled *Personal Knowledge* [50, 51]. Polyani's theory was revolutionary. He advocated the reversal of the established view that knowledge is discovered through the separation of the observer from the subject being studied and that the process is a neutral one in which empirical data are collected and conclusions are drawn. Polyani's notion of Personal Knowledge is one where true discovery is guided by the passionate dedication and intellectual stimulation of the inquiring mind of an individual investigator. Polyani's [50] theory of knowledge claims that humans experience the world by integrating their subsidiary awareness into a focal awareness in what he labeled *tacit knowledge*.

> For just as, owing to the ultimately tacit nature of all our knowledge, we remain ever unable to say all that we know, so also, in view of the tacit character of meaning, we can never quite know what is implied in what we say. (p. 95)

Polyani believed that both tacit and explicit knowledge co-exist along a continuum, and that language was a relevant component of the explicit, as depicted in Fig. 9.2.

At each end of the continuum are tacit and explicit knowledge. Tacit knowledge is contained within physical experiences, intuition or implicit rules of thumb, while explicit knowledge is that which can be spoken, formulated through language, or presented graphically. Polyani's Personal Knowledge is categorized as a 1st generation model of knowledge generation.

9.1.2.2 Organizational Knowledge

The paradigm shift started by Polyani was expanded from the concept of individual or personal knowledge to the realm of organizational knowledge. Organizational knowledge, as a process, is defined as:

> Organizational knowledge creation is the process of making available and amplifying knowledge created by individuals as well as crystallizing and connecting it to an organization's knowledge system. In other words, what individuals come to know in their (work-) life benefits their colleagues and, eventually, the larger organization. [47, p. 1179]

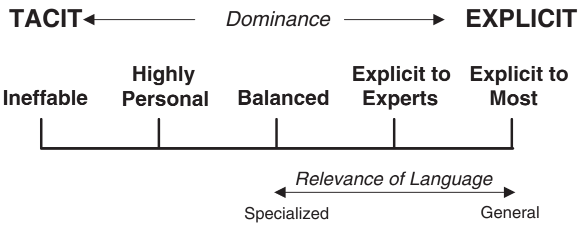

Fig. 9.2 The tacit-explicit continuum of knowledge, adapted from a figure in [22, p. 177]

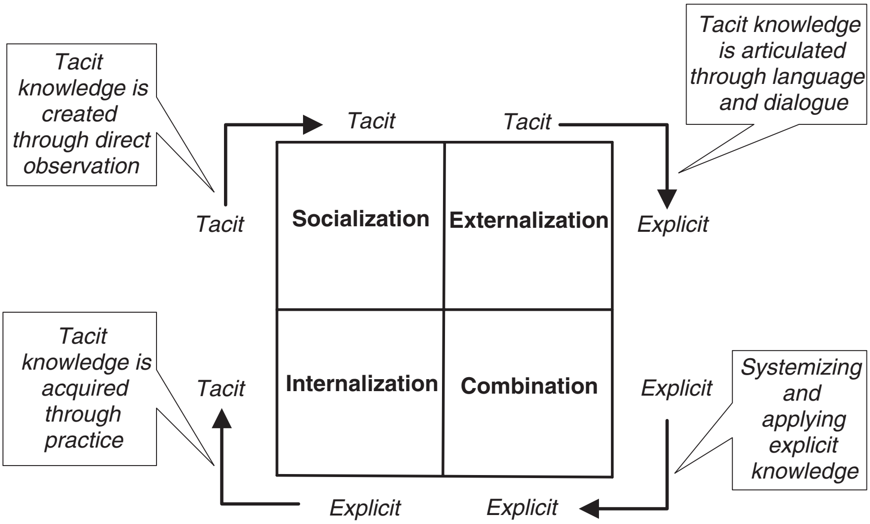

Fig. 9.3 Four-node SECI model of knowledge creation

The dominant theory of organizational knowledge [22] is a knowledge conversion process of Socialization, Externalization, Combination, and Internalization or SECI [43–46]. The four-node SECI model where interactions with the external environment reformulate and expand knowledge through the conversion process (i.e., tacit to explicit knowledge) is depicted in Fig. 9.3.

A description of each of the processes in the four nodes of the SECI Model of knowledge creation are presented in Table 9.2.

In summary, knowledge has both personal and organizational dimensions. However, when we are thinking systemically about situations of messes and problems, we are most interested in organizational knowledge. Organizations must ensure that they have methods and processes in place that ensure knowledge workers are able to create, acquire, articulate, and apply knowledge in support of the organization, its mission, goals, and objectives. The SECI Model is categorized as a 2nd generation model of knowledge generation.

Table 9.2 Process description for the SECI model of knowledge creation

SECI node	Description of process
Socialization	"The process of converting new tacit knowledge through shared experiences in day-to-day social interaction. Since tacit knowledge is difficult to formalize and often time and space-specific, tacit knowledge can be acquired only through shared direct experience, such as spending time together or living in the same environment, typically a traditional apprenticeship where apprentices learn the tacit knowledge needed in their craft through hands-on experiences" [46, p. 4]
Externalization	"Tacit knowledge is made explicit so that it can be shared by others to become the basis of new knowledge such as concepts, images, and written documents. During the externalization stage, individuals use their discursive consciousness and try to rationalize and articulate the world that surrounds them. Here, dialogue is an effective method to articulate one's tacit knowledge and share the articulated knowledge with others" [46, p. 5]
Combination	"The new explicit knowledge is then disseminated among the members of the organization. Creative use of computerized communication networks and large-scale databases can facilitate this mode of knowledge conversion. The combination mode of knowledge conversion can also include the 'breakdown' of concepts. Breaking down a concept, such as a corporate vision, into operationalized business or product concepts also creates systemic, explicit knowledge" [46, p. 5]
Internalization	"This stage can be understood as praxis, where knowledge is applied and used in practical situations and becomes the base for new routines. Thus, explicit knowledge, such as product concepts or manufacturing procedures, has to be actualized through action, practice, and reflection so that it can really become knowledge of one's own" [46, p. 5]

9.1.3 Abstract Classification of Mechanisms

The mechanisms that are classified as abstract, unlike the physical and human classifications, are not as easy to understand. Information and methods, both abstract characteristics, are mechanisms that are essential in creating outputs and outcomes.

1. *Information* is the building block of knowledge. As we described in Chap. 8, most data is of limited value until it is processed into a useable form. Once processed into a useable form data becomes information. Information is the building block of knowledge (refer to Fig. 8.4 for a depiction). Without information, the knowledge workers described in the previous section would have nothing with which to work. Relevant and timely information, and a contingent of knowledge workers, is what gives one organization a competitive advantage over another, and separates a viable organization [5] from one which faces extinction. The ability to acquire knowledge is an essential mechanism. Without information, the development of proper perspectives in support of both relevant context and sufficient boundary conditions, cannot occur.

2. *Methods* are the "systematic procedure, technique, or mode of inquiry employed by or proper to a particular discipline or art" [42, p. 781]. Methods, like the access to relevant and timely information, also contribute to an organization's competitive advantage. Methods ensure replicable processes, act as a precursor to quality, and serve as the basis for evaluation of performance.

Because methods are such an important mechanism in systemic thinking, the invocation and implementation of adequate methods for problem solving will serve as the focus for the rest of this chapter.

9.2 Methods as Mechanisms for Messes and Constituent Problems

Conducting a review of this one important abstract mechanism of *how* is a non-trivial task. In general, there are as many unique methods for addressing situations that involve messes and problems as there are messes and problems. Our task is not to select one all-encompassing method for approaching problems and messes, but to provide an approach for matching the mess-problem system with an approach that is capable of shifting the mess-problem system from a problem-state to a new, more desirable state.

Movement from an undesirable state to a new, desirable state requires us to make sense of the situation with which we are faced. Sensemaking is the formal process by which humans give meaning to experience when attempting to understand real-world situations and any associated data and information.

9.2.1 Sensemaking

Sensemaking has been defined by a number of practitioners. Some relevant definitions, arranged chronologically, are presented in Table 9.3.

From these definitions we can clearly see that sensemaking has, at its core, a structured approach to understanding. Sensemaking has become an accepted practice in a number of programs, with practical applications in:

- The studies of organizations [74, 75].
- The fields of communication and library and information science [12–14].
- The design of interactive systems with the computer-human interaction (CHI) community [55].
- Naturalistic decision-making [32].
- Military decision making process [35].
- A generalized method for inquiry in complex systems [34, 66, 67].

Table 9.3 Definitions for sensemaking

Definition	Source
"A label for a coherent set of concepts and methods used in a now 8-year programmatic effort to study how people construct sense of their worlds and, in particular, how they construct information needs and uses for information in the process of sense-making"	[12, p. 3]
"The basic idea of sensemaking is that reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs"	[73, p. 635]
"The making of sense"	[74, p. 4]
"Sensemaking involves turning circumstances into a situation that is comprehended explicitly in words and that serves as a springboard into action"	[75, p. 409]
"A motivated, continuous effort to understand connections (which can be among people, places and events) in order to anticipate their trajectories and act effectively"	[31, p. 71]
"Sensemaking, a term introduced by Karl Weick, refers to how we structure the unknown so as to be able to act in it. Sensemaking involves coming up with a plausible understanding—a map—of a shifting world; testing this map with others through data collection, action, and conversation; and then refining, or abandoning, the map depending on how credible it is"	[3, p. 3]

The next section will review how sensemaking may be applied as a generalized method for inquiry in situations such as our messes and related problems.

9.2.2 Pragmatic Intersection of Knowledge and Information

Because sensemaking is a structured approach to understanding based on both knowledge and information, we will approach its application in a pragmatic manner. Donald Rumsfeld, a former Naval aviator, member of the House of Representatives, White House chief-of-staff and Secretary of Defense described his view of the various states of knowledge in response to a question during a post-Iraq War press conference, stating:

> Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones [54].

Rumsfeld was quite right in his characterization of the four states of knowledge and the intersection between an observer's knowledge state and the state of information in the real-world. These intersections, along with some associated phraseology, are depicted in Fig. 9.4.

Armed with this pragmatic view of sensemaking we are prepared to review a 3rd generation framework for knowledge generation.

Fig. 9.4 Information and knowledge domain

		Real-World Information State	
		Known	Unknown
Observer's Knowledge State	Known	***Known, known*** *"Things we know we know"*	***Known, unknown*** *"We know there are some things we do not know"*
	Unknown	***Unknown, known*** *"The information is out there, but we don't know we need it"*	***Unknown, unknown*** *"We don't know what we don't know"*

9.2.3 Framework for Sensemaking

A particularly useful sensemaking framework has been developed to improve understanding based upon the degree of order present in systems. The framework is entitled *Cynefin* and is a 3rd generation model of knowledge generation, following Polanyi's 1st generation concept of Personal Knowledge and Nonaka's 2nd generation SECI Model. "Cynefin (pronounced cun-ev-vin) is a Welsh word with no direct equivalent in English. As a noun it is translated as *habitat*, as an adjective *acquainted* or *familiar*…" [65, p. 236].

The Cynefin framework is organized around five domains that exist along a continuum from order to un-order. The area between the zones is purposefully *fuzzy* [76], as these are areas of instability where systems are transitioning between domains states—in what are termed transition zones. The Cynefin framework, with the four knowledge state descriptions from Fig. 9.4, is depicted in Fig. 9.5.

Using the construct in Fig. 9.5, there are unique causal relationships and approaches to be used when dealing with situations in each domain of the Cynefin framework.

1. *Simple*—in this domain the relationship between cause and effect is obvious. The approach for dealing with this domain is to sense, categorize, and respond.
2. *Complicated*—in this domain the relationship between cause and effect requires analysis or some other form of investigation. The approach is to sense, analyze, and respond.
3. *Complex*—in this domain the relationship between cause and effect can only be perceived in retrospect, but not in advance. The approach is to probe, sense and respond.

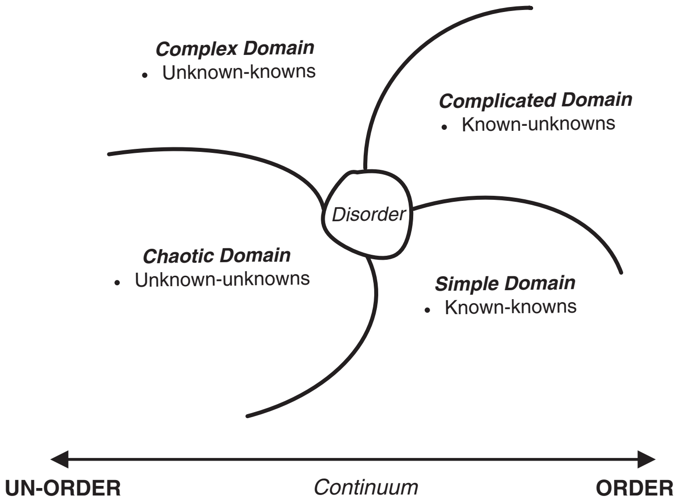

Fig. 9.5 Cynefin (kun-ev'in) framework for complexity

4. *Chaotic*—in this domain there is no relationship between cause and effect at the systems level. The approach is to act, sense, and respond.
5. *Disorder*—this is the domain where neither the state of not knowing what type of causality exists, in which state people will revert to their own comfort zone in making a decision. It exists in the grey space between the other four domains.

Kurtz and Snowden [34] describe the framework's domains:

> The framework actually has two large domains, each with two smaller domains inside. In the right-side domain of order, the most important boundary for sense-making is that between what we can use immediately (what is known) and what we need to spend time and energy finding out about (what is knowable). In the left-side domain of unorder, distinctions of knowability are less important than distinctions of interaction; that is, distinctions between what we can pattern (what is complex) and what we need to stabilize in order for patterns to emerge (what is chaotic). (p. 470)

The principal relationships and examples of appropriate actions (i.e., sense—categorize—respond) that may be invoked in each of the domains is presented in Fig. 9.6. It is important to note that we use *simple* and *complicated* where Kurtz and Snowden [34] use *known* and *knowable*. We do this to consistently apply terms for complexity (i.e., simple, complicated, complex, and chaotic) we have adopted in this book.

The placement of the 5th domain, disorder, is purposeful. By being in the middle of the model, each of the other four states are on the boundary of disorder, which is representative of real-world conditions.

> The very nature of the fifth context—disorder—makes it particularly difficult to recognize when one is in it. Here, multiple perspectives jostle for prominence, factional leaders

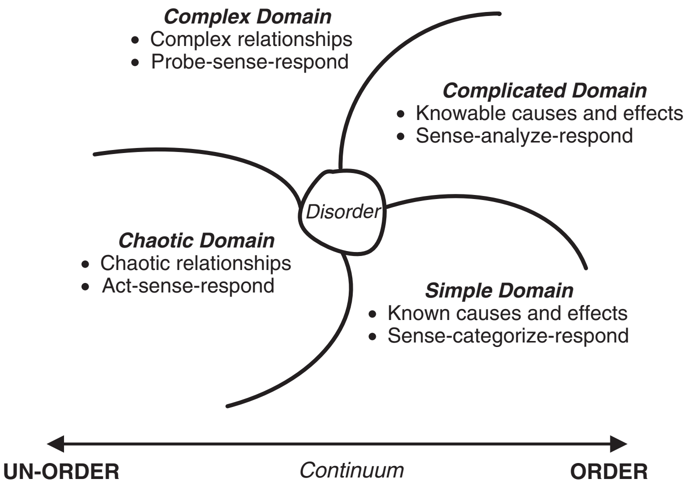

Fig. 9.6 Cynefin domains, relationships, and approaches

> argue with one another, and cacophony rules. The way out of this realm is to break down the situation into constituent parts and assign each to one of the other four realms [67].

Movement between domains, or boundary shifting, is an important element in the Cynefin framework. As a problem‘s degree of order changes, there is a need to shift to a new domain, and its associated modes of understanding and interpretation.

> Boundaries are possibly the most important elements, in sense-making, because they represent differences among or transitions between the patterns we create in the world that we perceive [34, p. 474].

Precisely because messes (our complex problems) may shift between domains, we must invoke the principle of relaxation time which states "system stability is possible only if the system's equilibrium state is shorter than the mean time between disturbance" [1, p. 134]. Armed with this knowledge the systems practitioner understands the requirements for stability as a precursor to analysis and the need to avoid interfering with messes during periods of instability.

Kurtz and Snowden [34] recommend the use of metaphors when describing boundaries. For instance:

> *The* **shallow river** *can be crossed by anyone at any place, and thus control over crossing is difficult to achieve. However, it is easy to tell when one has crossed it (or when others have) because one's feet get wet.*
>
> *The* **deep chasm** *can be crossed only at bridges, which can be built, demolished, and controlled at will. It is not easy to tell when one has crossed the boundary, but such a marker is not required because only some are allowed through.*
>
> *The* **high plateau** *is the boundary with the most potential danger, because you may not be aware that you have crossed the boundary until it is too late and you drop off the other side*. (p. 474)

Table 9.4 Boundary shifts within the Cynefin model [34]

Label	Domain movements	Description
1. Incremental improvement	• Complicated to simple • Simple to complicated	Movement from the knowable to the known and back, repeatedly
2. Exploration	• Complicated to complex	Movement from the knowable to the complex, selectively
3. Exploitation	• Complex to complicated	Movement from the complex to the knowable, selectively
4. Divergence-convergence	• Complex to chaotic to complex	Movement from the complex to the chaotic and back, repeatedly
5. Imposition	• Chaotic to simple	Movement from the chaotic to the known, forcefully
6. Asymmetric collapse	• Simple to chaotic	Movement from the known to the chaotic, disastrously
7. Swarming	• Chaotic to complex to complicated	Movement from the chaotic to the complex, to the knowable; first, in an emergent manner and then, selectively
8. Liberation	• Simple to complex to complicated	Movement from the known to the complex to the knowable, periodically
9. Entrainment making	• Complicated to disorder to chaotic to complex	Movement from the knowable to the chaotic to the complex, periodically
10. Immunization	• Simple to chaotic	Movement from the known to the chaotic, temporarily

There are ten recognizable patterns of movement across the boundaries of the Cynefin model which are described in Table 9.4.

The ten boundary shifts between domains are depicted in Fig. 9.7.

The Cynefin framework provides a depiction that the systems practitioner may use to carefully view problematic situations and purposefully shift the problem to a more manageable situation. By doing this the practitioner is shifting knowledge flows to where appropriate models of decision making may be utilized.

> The purpose of the Cynefin model is to enable sense making by increasing the awareness of borders and triggering with a border transition a different model of decision making, leadership or community. Cynefin argues strongly against single or idealized models, instead focusing on diversity as the key to adaptability. The law of requisite variety is well understood in ecology; if the diversity of species falls below a certain level then the ecology stagnates and dies. Excessive focus on core competence, a single model of community of practice or a common investment appraisal process are all examples of ways in which organizations can destroy requisite variety [66, p. 107].

By increasing information flow and associated knowledge during the transition between and among domains, both connectivity and variety increase, which serve

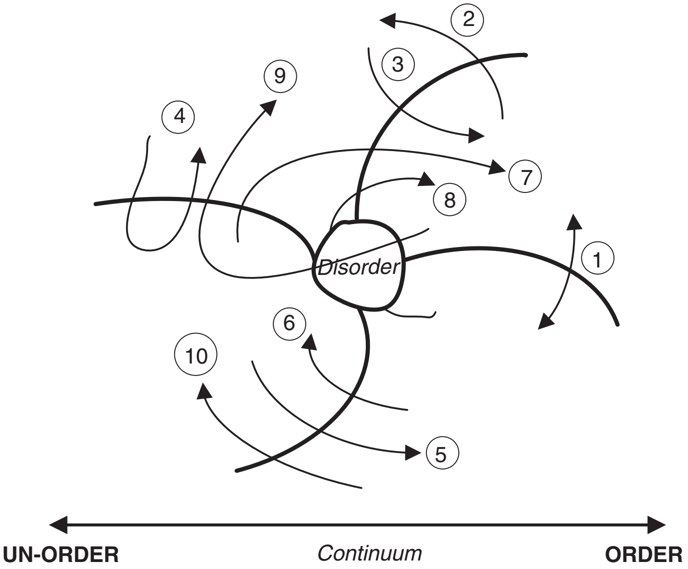

Fig. 9.7 Boundary shifting within the Cynefin framework

to break down existing patterns and create the conditions where new patterns will emerge. Both the connectivity of our problem, as a proxy for the principle of communication [59,60] and the variety, informed by the principle of requisite variety [4], inform the understanding of our mess.

In summary, knowledge of the types of complexity and how to address them is essential when working with complex systems. The Cynefin framework provides a means for understanding how to approach and deal with complex systems based upon their level of complexity.

9.3 Cynefin and Decision Analysis

The Cynefin framework can be coupled with a number of science-based decision analysis methods to provide specific approaches for dealing with complex situations. The four sections that follow will: (1) provide a review of decision science and how the four sub-disciplines of decision analysis are aligned ontologically and epistemologically; (2) provide the structure for the four sub-disciplines of decision analysis; (3) a short introductory description of ten science-based decision analysis techniques appropriate for use with complex systems situations; and (4) depict how the ten science-based decision analysis techniques can be used in conjunction with the Cynefin framework in an effort to increase understanding about problems and messes.

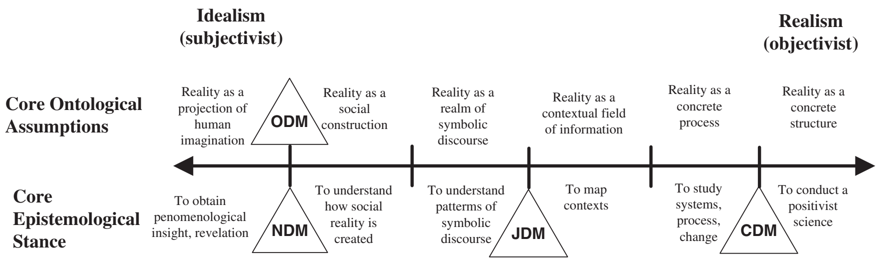

Fig. 9.8 Ontological assumptions and epistemological stances of decision analysis sub-disciplines

9.3.1 Decision Science

The ontological and epistemological constructs for decision science may be shown as a continuum between *idealism* or the subjective school and *realism* or the objective school. In the decision analysis discipline there are four sub-disciplines which span this continuum and are easily positioned on this continuum. The formal, empiricist school of decision analysis, labeled Classical Decision Making (CDM) is positioned at the realism end of the continuum with the objectivist school. Recognizing that decision making is inherently flawed due to human error, the Judgment and Decision Making (JDM) school of decision analysis shifts to the left on the continuum and falls within the rationalist school of thought. The Naturalistic (NDM) and Organizational Decision Making (ODM) schools of decision making belong to the naturalistic paradigm [36] and are placed farther left on the continuum. The placement, with respect to their ontological assumptions and epistemological stances, of the four sub-disciplines of decision analysis is depicted in Fig. 9.8.

9.3.2 Sub-disciplines of Decision Analysis

Decision analysis is a discipline with four recognized sub-disciplines. The four disciplines, their focus, and associated scholarly journals are:

1. *Classical Decision Making (CDM)*: Focuses on the development and study of operational decision-making methods. The primary scholarly publication is the journal Decision Analysis [ISSN 1545-8490].
2. *Naturalistic Decision Making (NDM)*: Emphasizes psychological approaches and methods in decision processes. While somewhat ethnographic in nature, it is based on careful descriptions of how experts actually make choices in complex, real-world situations. The primary scholarly publication is the *Journal of Behavioral Decision Making* [ISSN 0894-3257].
3. *Organization Decision Making (ODM)*: Focuses on decision making as an element of organizational behavior, specifically decision making behaviors in

Table 9.5 Science-based decision analysis techniques for use with Cynefin framework

Sub-discipline	Decision technique	References
Classical decision making (CDM)	1. Utility theory	[29]
	2. Aleatory uncertainty quantification	[24, 48]
	3. Expert judgment elicitation	[10, 11, 15, 33, 58, 76]
Naturalistic decision making (NDM)	4. Strategies for addressing uncertainty	[37, 38]
	5. Situation awareness	[16, 18–21]
	6. Recognition primed decision	[30, 56, 72]
	7. Dynamic model of situated cognition	[41, 61]
Organizational decision making (ODM)	8. Economic theory of the firm	[8, 39, 62, 63]
Judgment and decision making (JDM)	9. Bounded rationality	[25, 26]
	10. Prospect theory	[28]
	11. Heuristics and Bias	[27, 68, 69]

individuals when acting as a member of an organization. The primary scholarly publications are the journals *Organization Science* [ISSN 1047-7039] and *Management Science* [ISSN 0025-1909].

4. *Judgment and Decision Making (JDM)*: Emphasizes normative, descriptive, and prescriptive theories of human judgments and decisions. The primary scholarly publication is the *Judgment and Decision Making* [ISSN 1930-2975].

Table 9.5 is a list of eleven (11) science-based techniques and references from the four decision analysis sub-disciplines that we believe can be used in conjunction with the Cynefin framework.

The section that follows will provide an introductory overview of the decision analysis techniques presented in Table 9.5.

9.3.3 Science-Based Decision Analysis Techniques

Knowledge from each of the sub-disciplines is contained in a number of methodological constructs or techniques. The subsections that follow will provide a brief, high-level description of each of the eleven (11) science-based decision analysis techniques we believe can be used in conjunction with the Cynefin framework.

9.3.3.1 Utility Theory

Subjective expected utility theory is the most general and popular description of rational choice. The notion of *utility* was formalized by von Neumann and Morgenstern [71] who developed four axioms of rationality such that any decision maker satisfying these axioms can construct a utility function. Savage [57] extended this concept of utility to include subjective evaluations of utility to reflect personal preferences and subjective probabilities. Keeney [29] introduced additive (and multiplicative) utility function models.

9.3.3.2 Aleatory Uncertainty Quantification

Complicating the analysis of complex systems is the presence of uncertainty, typically separated into aleatory uncertainty and epistemic uncertainty (see e.g., [24]. "Aleatory uncertainty is also referred to as variability, irreducible uncertainty, inherent uncertainty, stochastic uncertainty, and uncertainty due to chance" [48], pp. 10–12). It comes from the variables that are known to exist in a system (but that have some level of random behavior associated with them that can be expressed by probability distributions). These types of uncertainties are present in any system due to the inherent variability of the natural world. In dealing with both aleatory and epistemic uncertainty, epistemic uncertainty can be reduced with increased information, but aleatory uncertainty is a function of the problem itself.

9.3.3.3 Expert Judgment Elicitation

"Epistemic uncertainty is also referred to as reducible uncertainty, subjective uncertainty, and uncertainty due to lack of knowledge" [48], pp. 10–12). It comes from uknown unknowns, from a lack of knowledge of the system under study. Traditionally, uncertainty has been handled with probability theory, but recent developments maintain that representing all uncertainty information in the same manner is inappropriate and, in order to be analyzed appropriately, several experts believe that aleatory and epistemic uncertainty should be addressed separately (e.g., [2, 9, 49, 52]. Modern approaches to deal with epistemic uncertainty include fuzzy sets [33, 76], Dempster-Shafer theory [10, 11, 58], and possibility theory [15]. Decision makers often solicit subject matter expert opinion to provide estimates on uncertain parameters using these approaches.

9.3.3.4 Strategies for Addressing Uncertainty

Uncertainty is a major road block that delays or blocks action in decision making. It is a state of indecision caused by incomplete information, inadequate understanding, and undifferentiated alternatives [38]. The four sources of uncertainty are characterized as being caused by [40]:

1. Missing information
2. Unreliable information
3. Ambiguous or conflicting information
4. Complex information

The ability to decrease uncertainty in complex situations is desirable. Techniques focused on decreasing uncertainty improve the decision making process. This technique differs from aleatory uncertainty and expert judgment elicitation in that it focuses on the reduction of uncertainty, rather than on characterizing or understanding uncertainty, as the other two techniques do.

9.3.4 Situation Awareness

Situation awareness (SA) is defined simply as “knowing what is going on around you” [21, p. 2]. SA has wide applicability in a variety of domains. A more specific definition for SA is:

> … the perception of the elements in the environment with a volume of time and space, the comprehension of their meaning and the project of their status in the near future. [17, p. 99]

The goal of situation awareness is to develop a formal model of one’s world such that an individual can understand how information and actions can lead to the realization or failure to achieve purposeful goals and objectives. Helping individuals develop a formal model of situation awareness that includes perception, comprehension, and projection will permit them to make improved decisions based on the real-world context surrounding the mess they are facing.

9.3.4.1 Recognition-Primed Decision

The Recognition-Primed Decision (RPD) model describes how people use their experience in the form of a number of patterns or repertoire [30]. The patterns are used to describe the primary causal factors present in a situation. In using RPD, the decision maker generates a possible course of action, compares it to the constraints imposed by the situation, and selects the first course of action that is not rejected. The limitations of the RPD model are centered around the need for extensive experience and training for decision-makers. Training is required to ensure that they correctly recognize the salient features of a problem situation and model solutions, thereby avoiding the problems associated with failing to recognize and properly model during unusual or misidentified situations.

Computational models for RPD have been proposed and show merit for inclusion in solutions using the RPD model [72].

9.3.4.2 Dynamic Model of Situated Cognition

The Dynamic Model of Situated Cognition (DMSC) captures both the human and technological components of complex systems in a single model that depicts how human decision making is influenced by a variety of agents [41, 61].

The DMSC is able to extend traditional Naturalistic Decision Making (NDM) concepts to include a view of the technological portion of a complex system in which dynamic, real-time decisions are being made. The DMSC is described in Chap. 1 and depicted in Fig. 1.4.

9.3.4.3 Economic Theory of the Firm

Nobel Laureate Herb Simon's [1916–2001] classic work *Administrative Behavior* [64] focused on the decision-making behaviors within organizations. Simon explains how internal administrative processes within an organization directly influence the decisions made by its organizational members (i.e., the individuals). It is these processes that ensure consistent, rational decision making in support of the mission, vision, goals, and objectives of the organization.

March and Simon [39] consider some softer aspects of organizational behavior in their work and include the motivational aspects of human behavior. Cyert and March [8] asserted that organizations (i.e., the firm) cannot be treated as a single monolithic entity. Firms, as organizational constructs of individuals, have a wide variety of goals and objectives. This variety is a cause of conflict and a rational construct of the firm's behavior is best represented as a weighted outcome of the conflicting goals and objectives.

Finally, Simon's concept of bounded rationality [62, 63] serves as a mechanism to limit conflict within the firm. Bounded rationality refers to strategies that are not strictly rational, but would be rational if not for factors unrelated to decision consequence (such as alternative order). Brown and Sim [6] elaborate on Simon's bounded rationality:

> One of the key principles from Simon's [62] bounded rationality model is that, rather than formulating and solving complicated optimization problems, real-world agents often can choose the first available actions, which ensure that certain aspiration levels will be achieved. In other words, given the computational difficulties in the rational model paradigm, a more sensible (and descriptively accurate) approach may in fact be to view profit not as an objective to be maximized, but rather as a constraint relative to some given aspiration level (p. 71).

The inclusion of the satisficing principle [62, 63] in any real-world, dynamic, decision process, ensures that the process explicitly accounts for situations whereby one chooses an option that is, while perhaps not the best, good enough.

9.3.4.4 Bounded Rationality

Amos Tversky [1937–1996] and Nobel Laureate Daniel Kahneman continued Simon's work on bounded rationality. Their research focused on the development of a map of bounded rationality, a map which studied the range of systematic biases that separate the beliefs and associated choices people make compared to optimal beliefs and choices presumed in rational-agent models. Kahneman [25, 26] explains the heuristics that people use and the biases to which they are prone in judging under uncertainty. Kahneman finds that most judgments and choices are made intuitively and that intuition and perception are governed by similar rules.

9.3.4.5 Prospect Theory

Kahneman and Tversky [28] proposed prospect theory as a descriptive theory of decision making. Prospect theory assumes that individuals adapt on the fly and make decisions according to the status quo, in comparison to traditional Expected Utility Theory, which assumes that decision makers frame decisions in terms of final consequences. Prospect theory demonstrates that individuals treat gains and losses differently, namely that they base their decisions on being risk averse for gains and risk seeking for losses.

9.3.4.6 Heuristics and Biases

Given the complex nature of complex systems, there is significant potential for cognitive overload. Tversky and Kahneman [69] have shown that people making judgments under uncertainty "… rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations. In general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors" (p. 1124). Tversky and Kahneman [68] also identified human limitations when processing statistical information and dealing with small sample sizes. Some heuristics and biases were discussed in Chap. 1.

Kahneman's latest popular work, *Thinking, Fast and Slow* [27], focuses on thinking as an element of decision making. Kahneman points out that most people have two modes or *systems* of thought: (1) System 1 is fast, instinctive and emotional; and (2) System 2 is slower, more deliberative, and more logical. He uses his notion of heuristics to relate *fast, System 1* thinking to the heuristics or existing patterns of thoughts and experiences humans collect rather than creating new patterns for each new experience.

The next section will depict how the science-based decision analysis techniques can be used in conjunction with the Cynefin framework.

9.4 Framework for Addressing *How* in Messes and Problems

The 3rd generation knowledge generation model represented by Cynefin is a framework for improved understanding in complex systems. In our case the unique construction of Cynefin through its causal relationships and associated decision models (i.e., sense, categorize, probe, analyze, act, and respond) may be related to each of the ten science-based decision analysis techniques. Table 9.6 shows how the five Cynefin domains, the causal relations, decision models, and the eleven (11) science-based decision analysis techniques are related.

Table 9.6 Cynefin elements and science-based decision analysis techniques

Cynefin domain	Causal relations	Decision model	Science-based decision techniques
Simple	Cause and effect is obvious	• Sense • Categorize • Respond	1. Utility theory 7. Dynamic model of situated cognition
Complicated	Cause and effect requires analysis	• Sense • Analyze • Respond	6. Recognition primed decision 8. Economic theory of the firm 9. Bounded rationality
Complex	Cause and effect can only be perceived in retrospect	• Probe • Sense • Respond	2. Aleatory uncertainty quantification 5. Situation awareness 10. Prospect theory
Chaotic	No relationship between cause and effect at the systems level	• Act • Sense • Respond	3. Expert judgment elicitation 4. Strategies for addressing uncertainty
Disorder	Unknown	• Comfort zone decision-making	11. Heuristics and Biases

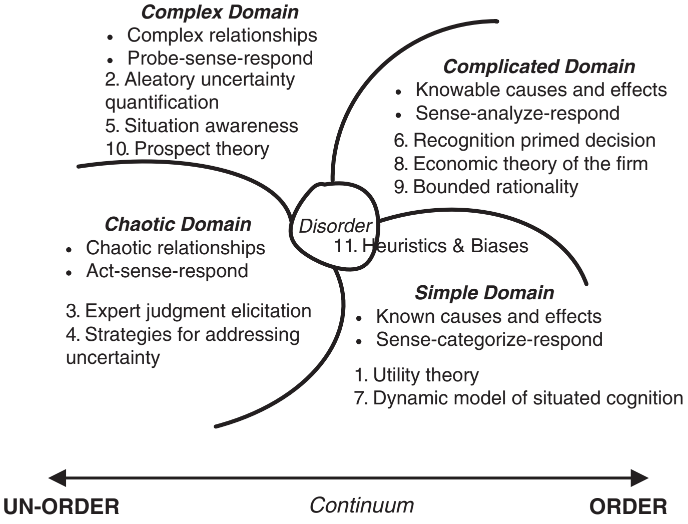

Fig. 9.9 Cynefin framework with elements and science-based decision techniques

Each of the characteristics in Table 9.6 are included on the Cynefin framework and presented in Fig. 9.9 to provide context for the relevant techniques. This Figure may be used by practitioners who are looking for techniques with which to improve their understanding of a complex system or a situation such as a mess and its constituent problems.

Table 9.7 Implications of *how* perspective on other perspectives

Perspective	Implications
Who (stakeholders)	Addressing the *how* question helps us to ensure that the stakeholders have the understanding required to use the methods required to address the mess and problems
What (outcomes, outputs)	Having a clear understanding of the methods required to address the mess and problems ensures that the desired outputs or outcomes may be met
Why (motivation)	Decisions related to the required method may be directly related to the motivations of the stakeholders who will deal with the mess and problems
Where (contextual and boundary considerations)	The methods selected to deal with the mess and problems must be able to handle to relevant context and systems boundaries
When (temporal considerations)	Establishment of appropriate methods must fit within the temporal aspects related to the mess and problems

9.5 Summary and Implications for Systemic Thinking

This chapter addressed the *how* question as it relates to the attainment of specific, purposeful goals. Moving our mess from a current state toward a desired state is achieved through mechanisms. Nine physical, human, and abstract mechanisms were identified and each was discussed. In order to adequately treat a mess and its associated problems sufficient mechanisms must be present. By invoking the redundancy principle from the operational axiom a systems practitioner ensures the purposeful duplication of critical mechanisms in order to improve the reliability of the proposed intervention. Given their non-intuitive nature and importance in achieving increased understanding, specific focus was placed on the discussion of abstract mechanisms, namely methods and information. Regarding methods, sensemaking was discussed as an approach by which to achieve increased understanding. Specifically, the Cynefin framework was addressed, and it was analyzed as it pertained to specific decision analysis techniques and their intersection with Cynefin's domains. This resulted in the development of a framework for analysis of the *how* question for our systemic thinking endeavor.

Table 9.7 shows the implications of the *how* question on each of the other systemic thinking perspectives.

After reading this chapter, the reader should:

1. Understand the nine mechanism types and three broad categories into which these mechanisms fall;
2. Describe the five complexity domains within which messes and problems exist;

3. Be able to relate the complexity domains with appropriate decision analysis techniques;
4. Be capable of identifying an appropriate decision analysis technique for a mess or problem based on its complexity.

The chapter that follows will address the *when* question, where the temporal aspects related to messes and their constituent problems are discussed.

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Chapter 10
The *When* of Systemic Thinking

Abstract The *when* question of systemic thinking attempts to determine the appropriate time for interacting with our mess in an effort to increase our understanding about it. Recalling the TAO of systemic thinking, we must think before we act on (and observe) our mess. The understanding gained from our thinking informs when (and if) we decide to intervene in our mess. In order to discern the appropriate time for action, we explore two criteria of our messes, its *maturity* and its *stability*. These two criteria will first be explored by investigating life cycles and their relevance to the maturity of our mess. We will then explore the phenomena of evolution, both as it pertains to biological systems and to purposeful systems. Then, we will discuss entropy as it relates to evolution. Finally, we develop a framework to address the *when* as it applies to any efforts at intervention in our mess.

10.1 Life Cycles and Maturity

There are many similarities between biological systems and purposeful systems, but perhaps none is more fundamental than the basic life cycle each follows. Although there are more complex models for both in the biological and systems literature, we can summarize biological systems as comprising a "birth-growth-aging and death life cycle" [31, p. 7]. Blanchard [5] discusses a purposeful system's life cycle, saying it:

> …includes the entire spectrum of activity for a given system, commencing with the identification of need and extending through system design and development, production and/or construction, operational use and sustaining maintenance and support, and system retirement and material disposal. (p. 13)

Succinctly, and in terms analogous to the phases associated with a biological life cycle, we may describe purposeful man-made systems as having a life cycle consisting of a definition (birth), development (growth), use (aging), and retirement (death). A depiction juxtaposing both life cycles is shown in Fig. 10.1.

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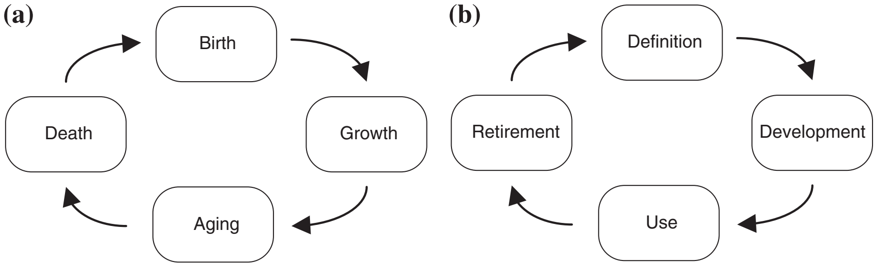


Fig. 10.1 Depiction of biological (**a**) and human-made system (**b**) life cycles

A short description of each stage as it pertains to purposeful man-made systems follows:

- *Definition*: Our system is *born* here. We begin to conceptualize it here by identifying a need that is to met by our system and determining the constraints on our system. As it concerns a mess, definition is an artificial construct. We define the context and environment of our system (see Chap. 8 for further guidance). We define the elements that comprise the mess as a construct of convenience; they likely have no real abstraction at the level we choose the analyze them. A perfect example is the education system in the United States. Our level of abstraction is subjective and purposeful; whether we wish to explore the national education system or the education afforded to the children in our home influences the lens through which we view the problem.
- *Development*: Our system begins to take shape. It matures and *grows* through iterative development and evolution. It may require resources to take a form that is either useful or recognizable to us.
- *Use*: Our system is in use. It requires maintenance and effort to sustain its performance at a level that is acceptable to its users. At this point, consideration and maintenance of our system's entropy (discussed at length in Sect. 10.4) becomes paramount to its continued viability.
- *Retirement*: Our system has fulfilled its intended purpose (and thus it may be retired from service) or surpassed its expected life (and thus it *dies* organically). In the context of a mess, this element is problematic as not all components will have the same time scale or life expectancy. Thus, we may need to invest resources into our mess in an effort to artificially extend its useful life.

The two cycles in Fig. 10.1 show significant similarity between the basic life cycles of biological and purposeful man-made systems. However, when we think about *messes*, which occur as a result of system operation and human involvement and are not purposefully *designed*, the conceptualization of a life cycle becomes a little less clear and orderly. Most notably, the *birth* and *death* of a mess are nebulous constructs. When does a traffic problem in a locality become a mess? When a second mode of transportation (i.e., public transportation), becomes available? When it has to cross traditional jurisdictional boundaries (i.e., city, county, state, or country)? There are certainly several explanations for the birth of said mess that may be reasonable and yet, none

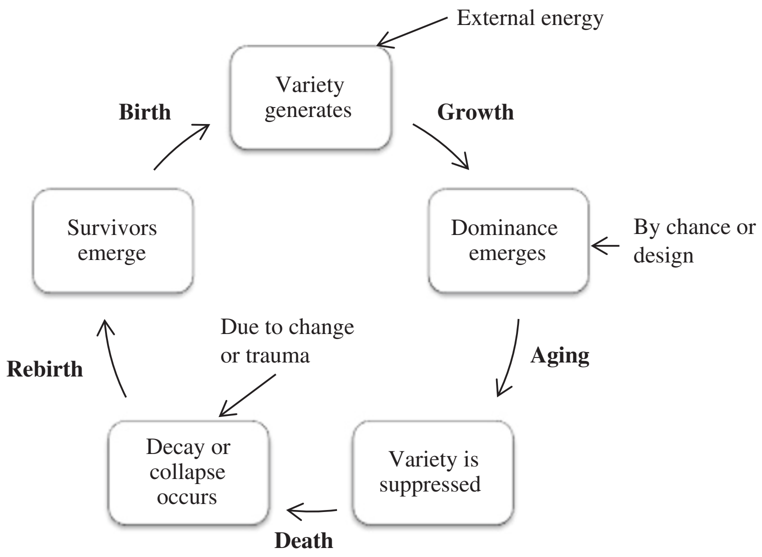


Fig. 10.2 Illustration of cyclic progression, adapted from Fig. 2.9 in Hitchins [21, p. 58]

may be of any value. A more fundamental question may be whether or not the specific birth or death of our mess is a construct that is of any value to its observers. How it came into being (be it by our own purposive behavior or otherwise) and how it will cease to exist (be it by forced retirement, simply run out its expected life, or evolve into an entirely different mess of an unrecognizable nature) is likely of little value. More importantly, it is of interest to us to understand the *life* of our mess and thus, we should primarily focus on the development and use of it, or to use biological terms, its growth and aging. In concerning ourselves with its birth and death, we are likely to get mired in trivialities that are of no value. We must undertake a holistic consideration of the life of our mess. Blanchard [5] agrees, noting:

> The past is replete with examples in which major decisions have been made in the early stages of system acquisition based on the "short term" only. In other words, in the design and development of a new system, the consideration for production/construction and/or maintenance and support of that system was inadequate. These activities were considered later, and, in many instances, the consequences of this "after-the-fact" approach were costly. (pp. 14–15)

Noted systems engineer Derek Hitchins offers a unique, but complementary perspective which may help us. His principle of cyclic progression offers a lens to view our system's development through:

> Interconnected systems driven by an external energy source will tend to a cyclic progression in which system variety is generated, dominance emerges, suppresses the variety, the dominant mode decays or collapses, and survivors emerge to regenerate variety. [20, p. 633]

This principle can be depicted graphically and annotated with the phases of the biological cycle discussed earlier as shown in Fig. 10.2. We can see the cyclic

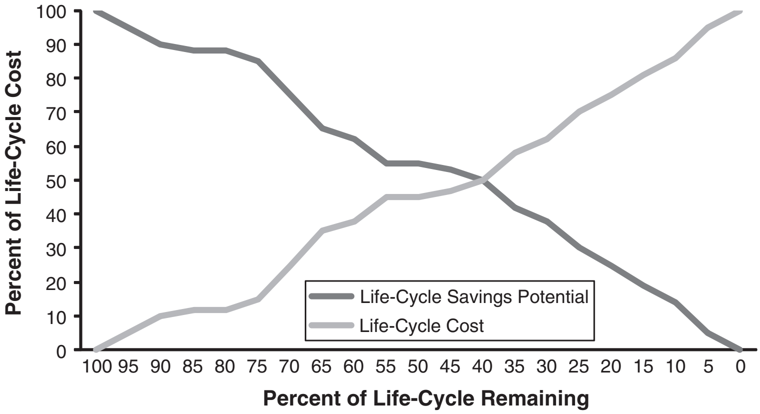


Fig. 10.3 Closed system life-cycle cost and benefit

nature of the life cycle as it is juxtaposed with Hitchins' illustration of cyclic progression.

The question then becomes, at what point in the life of our mess should we intervene? We can look to Fig. 10.3 to give us a clue. All closed systems have a finite life. Without intervention from external sources, our system will cease to exist (more on this and its related element of entropy are found later in this chapter). Thus, as the life of our system progresses, the cumulative costs associated with it increase and the potential for savings decrease. While the exact shapes of the curves shown in Fig. 10.3 vary depending on the circumstances, we know that the total cost is monotonically increasing (i.e., it never goes down), and the savings potential is monotonically decreasing (i.e., it never increases).

Thus, for any given system, every day that passes has the potential to incur more cost for us and present less opportunity for savings. So, should we just invest as early as possible? The answer is not so clear.

To answer this question, we can adapt the notion of a basic cost-benefit analysis (CBA). Traditionally in CBA, alternatives are designed for a system and we trade-off their respective benefits (typically in terms of dollars) with their costs (also typically in dollars) as a ratio expressed in Eq. 10.1.

$$C/B = \frac{Cost}{Benefit} \tag{10.1}$$

The alternative with the lowest *C/B* is chosen as the preferred option to pursue. However, with a mess being so inherently unpredictable, it may not be advantageous for us to use cost and benefit in this sense. More importantly, we may consider the trade-off between cost and benefit as a litmus test of feasibility for considering whether or not to intervene in our mess (and thus, to commit resources). For such an analysis, we can invert Eq. 10.1 and consider the following relationship in Eq. 10.2.

$$[B/C]_{\max} \geq 1 \tag{10.2}$$

Utilizing this inequality, we try to conceptualize if *any* option exists for intervention in our system that provides a larger benefit than its associated cost. This is of course a simplifying assumption in that it typically equates cost in dollars to benefit in dollars, but we can abstract the discussion to any relevant measure of merit.

Let us take a biological example. It would be difficult for a doctor to endorse an urgent heart transplant for a 95-year old patient regardless of the circumstances (i.e., even if death is certain without the operation). The benefit of the operation, may be conceptualized in a number of ways. For instance:

- Five years of additional life or alleviated pain for the patient, can be compared to the cost associated with it, or
- The actual cost of the operation, the expected survival rate of the patient, or the risk of not providing the donor heart to a more viable (and arguably more deserving) patient.

It seems fairly straightforward that the inequality represented by Eq. 10.2 is not met. Complicating this scenario is its likely status as a mess. Maybe the patient would pay cash for the operation alleviating insurance concerns. Alternatively, perhaps there is a clearly more deserving patient (although it may seem abhorrent to some, merit-based rankings of individuals seeking a donor organ can be generated). These and other concerns make this quite a difficult scenario to understand. If we determine that the *B/C* ratio is not sufficient for this alternative, we can conceive of other options. One such alternative is to utilize hospice care for the patient in an effort to allow him to die with dignity. In this case, the cost is minimal (at least from the medical expenditure perspective; the *cost* to the world of losing the individual is another debate entirely, and one we wouldn't dare explore) and the benefit is arguably justified by the cost. Thus, we have found a proposed solution that satisfies Eq. 10.2. In this way, we have satisfied the *maturity* concern associated with the when of systemic thinking. It is in this way that we should think of maturity.

If we take the ratio of the benefit and cost curves in Fig. 10.3 and plot them against the inequality of Eq. 10.2, we can generate the curves shown in Fig. 10.4. This graphic demonstrates that early on in our system development there is a high potential for a high benefit to be realized from intervening in our system, given the significant expected life left in our system. Additionally, early in the development it is cheap to change our system. At some point, when the curves cross, it is no longer advantageous to intervene in our system.

Figure 10.4 must be taken with two caveats as they pertain to a mess:

1. Messes exist in open systems. Open systems interact with their environment. As a result, they are unstable such that Fig. 10.4 can be recalibrated by interjecting resources into the mess. Thus, the B/C curve (and its underlying components of cost and benefit) can be improved or worsened by expending resources in the form of additional mechanisms (the focus of Chap. 9) on the mess. In doing so, we've transitioned our mess, perhaps to a form that is unrecognizable to us (and hopefully to an improved state). Such potential transitions are illustrated in Fig. 10.5.

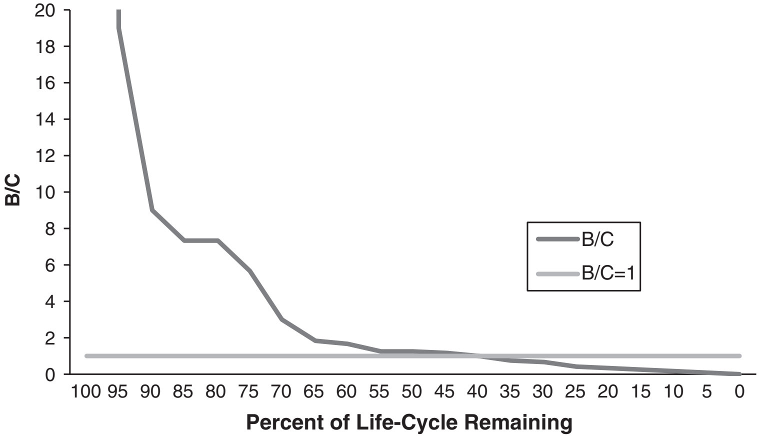


Fig. 10.4 B/C as a function of time

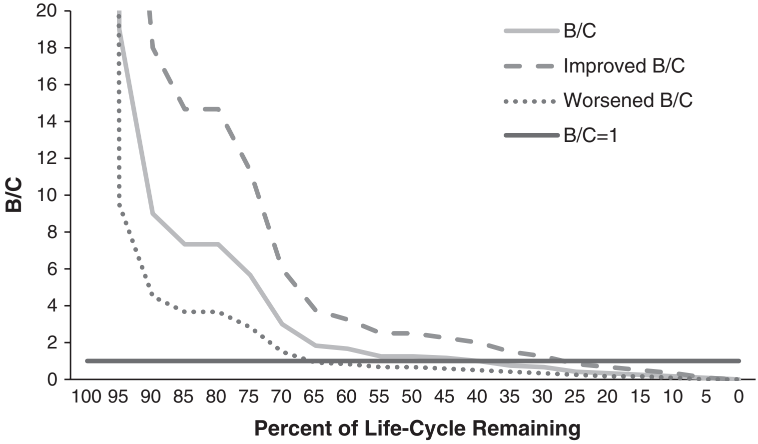


Fig. 10.5 Moving the B/C curve

2. Figure 10.4 illustrates a system, not a mess. Messes are unpredictable. They are likely not to possess a clear cross-over point. Thus, our understanding of the mess is likely to coincide with a range of options, such as those denoted by the improved and worsened curves in Fig. 10.5. This is largely due to the unpredictability of the system and due to the first caveat, i.e., our ability to make adjustments based on our limited understanding.

Thus, the guidance provided in this section is to be taken as a heuristic. The key takeaway of the maturity discussion is for us to consider the relative cost (monetary or otherwise) and expected benefits resulting from increasing our understanding, especially if this increased understanding requires the expenditure of resources, before investing our time, money, and efforts. We must aim for the region above the *breakeven* point for our mess (when $B = C$), but this isn't the only concern. Given the unpredictable nature of our mess, we must also consider its evolution. Sage and Armstrong [31] illustrate the linkage between life-cycle and evolution concerns: "This life-cycle perspective should also be associated with a long-term view toward planning for system evolution, research to bring about any new and emerging technologies needed for this evolution, and a number of activities associated with actual system evolution…" (p. 7). Indeed, the *stability* of our system, a measure equally as important as its *maturity*, must be considered by exploring its evolution and development.

10.2 Evolution

The development and evolution of our mess is continual. Understanding the mechanism of evolution and determining an appropriate time to intervene in our mess is a significant endeavor and yet one we are tasked with. First, we can explore the notion of evolution within biological, or living, systems. Many definitions for evolution exist. Several taken from the biological complexity domain include:

- Biological evolution is the process of gradual (and sometimes rapid) change in biological forms over the history of life [27, p. 72].
- Evolution here is simply robustness to (possibly large) changes on long time scales [10, p. 1666].
- Evolution is the historical process that leads to the formation and change of biological systems [24, p. 880].
- The word evolution comes from the Latin evolvere, "to unfold or unroll"—to reveal or manifest hidden potentialities. Today "evolution" has come to mean, simply, "change." [16, p. 3]

Each of the above definitions connotes change, however, only one, Csete and Doyle's, addresses the purposeful notion of change (they support that evolution exists to maintain system functionality despite uncertainty). As systemic thinkers, we support the notion of purposeful change in systems and we believe the following discussion will bear out a historical belief in this notion as well. Thus, for our purposes we define evolution succinctly as *purposeful change in system structure or behavior*.

Jean-Baptiste Lamarck [1744–1829] developed arguably the most famous pre-Darwin theory of evolution, the idea that living organisms can pass characteristics they acquired throughout their life time on to their offspring. These acquired characteristics, or adaptations, were "changes for the better, or at least, for the more complex“ [27, p. 73].

As Charles Darwin [1809–1882], and others rose to prominence, it was clear that the notion of acquired characteristics in biological systems was false. Darwin's voyages to the Galapagos Islands aboard the H.M.S. *Beagle* survey ship led to his empirical observations about the gradual development and adaptation of finches. His observations led to his belief in the idea of *gradualism*, the notion that small factors, extended over significant time horizons, could have long-reaching effects, and his publication of *The Origin of Species* [12]. Two major premises arose from this work, as summarized by [16]:

> The first is Darwin's theory of **descent with modification**. It holds that all species, living and extinct, have descended, without interruption, from one or a few original forms of life….Darwin's conception of the course of evolution is profoundly different from Lamarck's, in which the concept of common ancestry plays almost no role.
>
> The second theme of The Origin of Species is Darwin's theory of the causal agents of evolutionary change…This theory is a VARIATIONAL THEORY of change, differing profoundly from Lamarck's TRANSFORMATIONAL THEORY, in which individual organisms change. (p. 7)

Mitchell [27] adds one additional point of note regarding Darwin's beliefs:

> Evolutionary change is constant and gradual via the accumulation of small, favorable variations. (p. 79)

This theory was in sharp contrast, at least in the eyes of the early adherents of both, to Gregor Mendel's [1822–1884] *mutation theory*, a theory that stated that variation in organisms was due to mutations in offspring which drive evolution, with natural selection unnecessary to account for origin of species. Mendel's perspective evolved into the Evolutionary Synthesis or Modern Synthesis movement, which provided its own set of principles of evolution. Describing the development of its underlying theory, Futuyma [16] notes:

> Ronald A. Fisher and John B.S. Haldane in England and Sewall Wright in the United States developed a mathematical theory of population genetics, which showed that mutation and natural selection together cause adaptive evolution: mutation is not an alternative to natural selection, but is rather its raw material. (p. 9)

The idea of gradualism was questioned in the 1960s and 1970s, when paleontologists Stephen Jay Gould and Niles Eldridge began to challenge it as "very rare and too slow, in any case, to produce the major events of evolution." [18, p. 115]. Instead, they proposed a theory of *punctuated equilibrium* [13] which instead hypothesized that: "Most evolutionary change, we argued, is concentrated in rapid (often geologically instantaneous) events of speciation in small, peripherally isolated populations (the theory of allopatric speciation)" [18, pp. 116–117].

Despite this challenge, evolutionary synthesis remains crucial to our understanding of evolution today. "The principal claims of the evolutionary synthesis are the foundations of modern evolutionary biology…most evolutionary biologists today accept them as fundamentally valid" [16, pp. 9–10]. While this consensus persists, many questions remain concerning the complexities of modern evolution. The presence of holistic connections in living systems complicates our understanding of biological organisms: "The complexity of living systems is largely due to networks of genes rather than the sum of independent effects of individual genes" [27, p. 275].

At this point, then, most of science believed that evolution alone, in one form or another, was responsible for the complexity inherent in biological systems. Enter theoretical biologist Stuart Kauffman; in studying complex biological systems, Kauffman has developed remarkable theories about evolution and complexity.

Arguably his most fundamental point is that biological complexity does not necessarily arise from a process of natural selection.

> Most biologists, heritors of the Darwinian tradition, suppose that the order of ontogeny is due to the grinding away of a molecular Rube Goldberg machine, slapped together piece by piece by evolution. I present a countering thesis: most of the beautiful order seen in ontogeny is spontaneous, a natural expression of the stunning self-organization that abounds in very complex regulatory networks. We appear to have been profoundly wrong. Order, vast and generative, arises naturally…much of the order in organisms may not be the result of selection at all, but of the spontaneous order of self-organized systems….If this idea is true, then we must rethink evolutionary theory, for the sources of order in the biosphere will now include both selection and self-organization. [25, p. 25]

Further, Kauffman's *fourth law* introduced the notion that "life has an innate tendency to become more complex, which is independent of any tendency of natural selection" [27, p. 286]. Kauffman's book *The Origins of Order* (1993) talks at length about this concept.

Astrophysicist Erich Jantsch [1929–1980] contrasted internal and external self-organizing systems as those that change their internal organization and those that adapt their way of interacting with their environment, respectively. Jantsch [23] discussed three types of internal self-organizing behavior useful to our study:

> mechanistic systems do not change their internal organization;
> adaptive systems adapt to changes in the environment through changes in their internal structure in accordance with preprogrammed information (engineering or genetic templates); and
> inventive (or human action) systems change their structure through internal generation of information (invention) in accordance with their intentions to change the environment (p. 476)

The systems we are concerned with reside in the adaptive or inventive classification. For our purposes, we are concerned with order and stability and what we may learn of purposeful systems by studying biological systems. If we can summarize, we may conceive of two major streams of evolutionary thought: [1] those who believe natural selection is primary, be it via gradual means (e.g., Darwin) or punctuated means (e.g., Gould and Eldredge); and [2] those that believe that self-adaptation and self-organization has arisen via emergent behavior of biological systems (e.g., Kauffman). We may describe evolution by natural selection as being "conceived using data at the macroscopic level" [24, p. 879] and thus as a meta-theory of the development of systems, whereas we may think of self-organization as "essentially present, but..not well controlled" [24, p. 882] and thus, an emergent, inherent property of both the system and its circumstances. It is our belief that these two perspectives may be complementary given their presence on differing levels of logical abstraction, and in fact, both perspectives have implications for how we may seek to understand problems and messes. If we accept the parallelism of biological and purposeful system life cycles, then perhaps, it is not much of a stretch to understand the increasing complexity of both biological and purposeful systems. What drives this increasing complexity? Is it evolution *or* self-organization? We contend that a system that is to maintain its viability [2] must be allowed to evolve *and* self-organize. How do ascertain if our mess has evolved or is evolving; what about self-organizing? More fundamentally perhaps is, does it even matter? The answer, if we are to effect change, is yes. The answer in how to identify the opportunity for this change lies in the concept of entropy, to which we now turn.

10.3 Entropy

How do patterns emerge in systems and in nature? As if appearing to occur by some magical *slight of hand*, structure and patterns emerge in systems without external interference (i.e., they self-organize). This behavior is seemingly illogical, but some investigation will clarify how independent elements arrange themselves in an ordered and purposeful pattern. Understanding this phenomena and its role in systemic thinking requires that we first understand the second law of thermodynamics, which says that entropy (the property of matter that measures the degree of randomization or disorder at the microscopic level) can be produced but never destroyed [29]. The potential energy of our system, which is inversely proportional to its entropy, will decrease without the application of energy to our system. Stated another way, it states that "in a closed system, entropy always increases" [4, p. 144]. But, as Mitchell points out, "nature gives us a singular counterexample: Life…According to our intuitions, over the long history of life, living systems have become vastly more complex and intricate rather than more disordered and entropic" [27, p. 71]. The key is that living systems are *open systems*.

The second law of thermodynamics is true of all *closed systems*, those systems that exchange no materials with their environment. A car's fuel stores its potential energy; without refueling, the car will have a finite driving range. Similarly, our bodies store our potential energy; without consuming calories, will cease to be able to function and eventually we will die. The flow of this energy maintains order and continued existence. There is no such thing as a perpetual motion machine; all systems are less than 100 % efficient and thus, they consume resources, requiring intervention from external entities, to remain viable. Open systems solve this entropy conundrum by exchanging matter with their environment. As a result, they can exhibit the equifinal behavior where "If a steady state is reached in an open system, it is independent of the initial conditions, and determined only by the system parameters, i.e., rates of reaction and transport" [4, p. 142].

If no energy enters or leaves a closed system, the potential energy of the system dissipates with time (i.e., its entropy increases). We can express this notion mathematically. If we designate entropy as S, then the change in entropy of a closed system can be expressed as:

$$\Delta S_C = S_{final} - S_{initial} \geq 0 \tag{10.3}$$

where

ΔS_C	change in closed system entropy
S_{final}	final system entropy
$S_{initial}$	initial system entropy

Open systems behave much differently, owing to their ability to transport matter in and out of the system. Their change in entropy, then, can be denoted as:

$$\Delta S_O = \Delta S_{transport} + \Delta S_{reactions} \tag{10.4}$$

where

ΔS_O	change in open system entropy
$\Delta S_{transport}$	change in entropy transport (either positive or negative) in and out of the system
$\Delta S_{reactions}$	the production of entropy due to internal processes such as chemical reactions, diffusion, heat transport, etc.

The relevance of these two conceptualizations is that open systems can reach the same final state from different initial conditions due to exchanges with the system's environment (i.e., the principle of equifinality). This is directly relevant to us as we assess messes, which are open and involve significant matter (and information) exchange across their system boundaries.

The concept of entropy may be generalized to other contexts. Arguably the most famous beside the thermodynamics perspective, is physicist Ludwig Boltzmann's [1844–1906] statistical entropy [6], which shows the relationship between entropy and the number of ways the atoms or molecules of a thermodynamic system can be arranged. Boltzmann's formula is as follows:

$$S = k_b \text{ In } W \tag{10.5}$$

where S is entropy, as before, k_b is the Boltzmann's constant equal to 1.38×10^{-23} Joules/degrees Kelvin and W is conceptualized as the *thermodynamic probability* of a particular macro-state for some distribution of possible micro-level states of a thermodynamic system.

In a thermodynamic system where each state may have an unequal probability, it is useful to utilize a reformulation of this concept developed by J. Willard Gibbs [1839–1903] in his seminal work [17]:

$$S = k_b \sum_i p_i \text{ In } p_i \tag{10.6}$$

where p_i refers to the probability that a given micro-state can occur. Claude Shannon [1916–2001], the father of Information Theory, adapted these concepts to the analysis of entropy in information, stating:

> That information be measured by entropy is, after all, natural when we remember that information, in communication theory, is associated with the amount of freedom of choice we have in constructing a message. [32, p. 13]

Shannon's conceptualization of information entropy, then, can be defined as:

$$H = -\sum_i p_i \ \log_{\mathrm{b}} \ p_i \tag{10.7}$$

where H is the information entropy, b is the base of the logarithm used (typically taken to be 2 due to the predominant use of binary logic in information theory), and p is the probability associated with each the symbols in each discrete message i. It is worth noting that this formula is maximized when all state probabilities are equal (i.e., for a two state system, $p_1 = p_2 = 1/2$). In this case, the most uncertainty possible is present in the system.

The question is, how is this energy handled by our system, be it information, thermodynamic, or statistical entropy? The short answer lies in the exploration of the concept of self-organization. Self-organization is a well-established phenomena in chemistry, physics, ecology, and socio-biology [28] defined as "the spontaneous reduction of entropy in a dynamic system" [19, p. 155]. Recall our discussion of the second law of thermodynamics stating that entropy can be produced but not destroyed. How, then, is entropy in a system reduced?

Ilya Prigogine [1917–2003] received the 1977 Nobel Prize in Chemistry for his investigation, starting in the 1950s, of the case where self-organizing systems do not reach an equilibrium state. Nicolis and Prigogine [28] were studying structures that they referred to as dissipative; these were structures that exhibited dynamic self-organization. As such, these open systems generated energy, which was dissipated to their environment. Thus, they were able to self-organize (i.e., decrease their entropy) by increasing the disorder (and thus, the entropy) of their environment. This is the key to survival for living systems; they reduce their internal entropy to avoid disorder and chaos prescribed by the second law of thermodynamics (and only true for closed systems). As such, these dissipative systems are able to maintain a dynamic equilibrium [11] by dissipating their energy to the environment in an effort to create a reproducible steady state. This steady state can arise through multiple means, be it by system evolution, manufactured means, or a combination of the two. Examples of these systems range from purposeful systems such as climate control systems (i.e., heaters and air conditioners) to natural systems such as convection, hurricanes, and cyclones, to all living systems.

While these numerous examples illustrate the prevalence of self-organization, they do little to explain how or why self-organization occurs. The varying entropic perspectives of Nicolis, Prigogine, Boltzmann, Gibbs, and Shannon and Weaver are complemented by work in control theory and cybernetics. The term cybernetics was coined by Norbert Wiener in his seminal book whose title defined it as: "the study of control and communication in the animal and the machine" [35]. Heylighen and Joslyn [19], in a discussion of cybernetic control, speak of basins [34] and their relationship to self-organization:

> An attractor y is in general surrounded by a basin B(y): a set of states outside y whose evolution necessarily ends up inside:$\forall\ s \in B(y),\ s \notin y$, n such that$f^n(s) \in y$. In a deterministic system, every state either belongs to an attractor or to a basin. In a stochastic system there is a third category of states that can end up in either of several attractors. Once a system has entered an attractor, it can no longer reach states outside the attractor. This means that our uncertainty (or statistical entropy) H about the system's state has decreased: we now know for sure that it is not in any state that is not part of the attractor. This spontaneous reduction of entropy or, equivalently, increase in order or constraint, can be viewed as a most general model of self-organization. [19, p. 165]

The attractors described by Heylighen and Joslyn [19] will end up in a state of dynamic equilibrium. This arrangement of elements and emergence of order is what W. Ross Ashby [1903–1972] called the principle of *self-organization* [1]. This self-organization results in a lowered entropy for our system as uncertainty has decreased within our system. Heinz von Foerster [1911–2002] devised the principle of *order from noise* [14]. Self-organization can be expedited by the presence of noise; the larger the random perturbations (*noise*) of a system, the more entropy exists in the system and thus, the more quickly it will become ordered.

So what does all of this mean? Our system changes, and maintains stability, as a result of mechanisms involving both evolution and self-organization. The order that emerges (both through evolution on longer time horizons and self-organization on shorter time horizons) is essential for our system to maintain its continued viability. We can enhance this viability through mechanisms such as those described by Stafford Beer [2, 3] in his Viable Systems Model. A self-organizing system achieves this viable equilibrium state by random exploration, with purposeful systems being aided by control mechanisms (recall Checkland's [9] control principle) which reduce the feasible solution space (i.e., the variety) for these systems to explore Ashby [1], von Foerster [14], and von Foerster and Zopf [15] further postulate that this process can be expedited by increasing variation or noise into the system, thereby increasing system entropy and accelerating the systems search's for an equilibrium state. This process is confirmed by Prigogine's theory of dissipative structures who increase their variation (and thus entropy) until it is unsustainable and then dissipate this energy back into the environment.

What does this all mean for the systemic thinker? In theory, it provides a mechanism for determining when to interfere in our system; we should interact with it before its natural tendency to dissipate (or in Hitchins' terms, to decay or collapse) in an effort to expedite its search for equilibrium. In practice, this undertaking is not so straightforward as self-organizing systems, by definition exhibit behavior as described by the principle of homeostasis [8] in an effort to regulate their internal environment. Thus, the most practical approach for us is to identify application points or individual properties where a small change may result in a large, predictable effect. Accordingly, we turn to analysis of an approach which will enable us to determine an appropriate time for intervention in our system.

10.4 The Hierarchy of Complexity

In order to understand when to intervene in a mess, keeping in mind both its maturity and its stability, we must categorize the mess in some capacity. Given that messes and their systems age counterparts are complex, it is perhaps best to classify them according to their complexity. Jackson [22] summarizes the work of Boulding [7] in creating a nine-level hierarchy for real-world complexity, as shown in Table 10.1 and in keeping with the principle of hierarchy [30].

Table 10.1 A summary of Boulding [7] hierarchy of complexity [22, p. S25]

Level	Description	Example
1	Structures and frameworks which exhibit static behavior and are studied by verbal or pictorial description in any discipline	Crystal structures
2	Clockworks which exhibit predetermined motion and are studied by classical natural science	The solar system
3	Control mechanisms which exhibit closed-loop control and are studied by cybernetics	A thermostat
4	Open systems which exhibit structural self-maintenance and are studied by theories of metabolism	A biological cell
5	Lower organisms which have functional parts, exhibit blue-printed growth and reproduction, and are studied by botany	A plant
6	Animals which have a brain to guide behavior, are capable of learning, and are studied by zoology	An elephant
7	People who possess self-consciousness, know that they know, employ symbolic language, and are studied by biology and psychology	Any human being
8	Socio-cultural systems which are typified by the existence of roles, communications and the transmission of values, and are studied by history, sociology, anthropology and behavioral science	A nation
9	Transcendental systems, the home of ‘inescapable unknowables’, and which no scientific discipline can capture	God

Each of these levels is of increasing complexity and each contains emergent properties not found in the levels below. Thus, in seeking to understand a given level, we must also understand those levels beneath it, invoking the principle of recursion [2]. Boulding [7] comments on the maturity of our knowledge about the levels in his hierarchy:

> One advantage of exhibiting a hierarchy of systems in this way is that it gives us some idea of the present gaps in both theoretical and empirical knowledge. Adequate theoretical models extend up to about the fourth level, and not much beyond. Empirical knowledge is deficient at practically all levels. Thus at the level of the static structure, fairly adequate descriptive models are available for geography, chemistry, geology, anatomy, and descriptive social science. Even at this simplest level, however, the problem of the adequate description of complex structures is still far from solved. (p. 205)

Despite our relative naïveté about the higher levels of the hierarchy, Boulding [7] notes that all hope is not lost:

> Nevertheless as we move towards the human and societal level a curious thing happens: the fact that we have, as it were, an inside track, and that we ourselves are the systems which we are studying, enables us to utilize systems which we do not really understand. (pp. 206–207)

Thus, even though we may not *understand* systems at the higher levels of this hierarchy in the theoretical sense, we can work with, utilize, and make sense of them using a sense-making framework. This is absolutely necessary as we attempt to determine when is the appropriate opportunity to intervene in a mess.

10.5 Another View of Sensemaking

Because complexity is such an important characteristic of systems, a number of frameworks have been developed for understanding the relationship between complexity and systems. One such framework is the Cynefin framework presented in Chap. 9.

Another way to look at the Cynefin framework is by the types of systems' connections expected to exist in each of the domains depicted in Fig. 10.6. Kurtz and Snowden [26] discuss these connections:

> On the side of order, connections between a central director and its constituents are strong, often in the form of structures that restrict behavior in some way—for example, procedures, forms, blueprints, expectations, or pheromones. On the side of un-order, central connections are weak, and attempts at control through structure often fail from lack of grasp or visibility. In the complex and knowable domains, connections among constituent components are strong, and stable group patterns can emerge and resist change through repeated interaction, as with chemical messages, acquaintanceship, mutual goals and experiences. The known and chaotic domains share the characteristic that connections among constituent components are weak, and emergent patterns do not form on their own. (p. 470)

It is problematic for us to try to interfere in messes that reside primarily in the un-order domain (complex and chaos), both due to their weak central connections (in our terms, at the mess level) and their unpredictable and unperceivable relationships. It is our goal in these regimes, at best, to shift to an ordered domain. Here we are invoking the principle of relaxation time (see Chap. 4) which sets the requirement for stability as a precursor to analysis and the need to avoid messes during periods of instability. Most importantly, we should concentrate on utilizing our resources to effect changes in the order domain, if possible. Kauffman [25] echoes the difficult in intervening in chaotic systems:

> Deep in the chaotic regime, alteration in the activity of any element in the system unleashes an avalanche of changes, or damage, which propagates throughout most of the system [34]. Such spreading damage is equivalent to the butterfly effect or sensitivity to initial conditions typical of chaotic systems. The butterfly in Rio changes the weather in Chicago. Crosscurrents of such avalanches unleashed from different elements means that behavior is not controllable. Conversely, deep in the ordered regime, alteration at one point in the system only alters the behavior of a few neighboring elements. Signals cannot propagate widely throughout the system. Thus, control of complex behavior cannot be achieved. Just at the boundary between order and chaos, the most complex behavior can be achieved. (p. 302)

An alternative way of conceptualizing conditions for interaction is presented in Fig. 10.7. This figure shows the relationship of entropy and self-organization when compared to each Cynefin domain. As the underlying complexity of a situation increases, its entropy increases. This entropy feeds self-organizing behavior, which makes intervention problematic. Thus, it is advantageous for us to intervene in our system in the less entropic states (and set up conditions for self-organization, such as feedback mechanisms and regulators, in more entropic states).

How, then, should we intervene? This is the focus, in large part, of Chap. 9. *When* should we intervene in our system? For an answer to this question, we develop a framework for intervention in the next section.

Fig. 10.6 Connection strength of Cynefin domains (adapted from Kurtz and Snowden [26, p. 470])

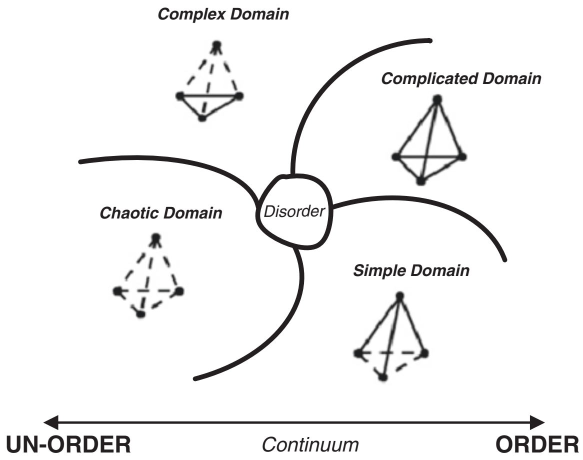
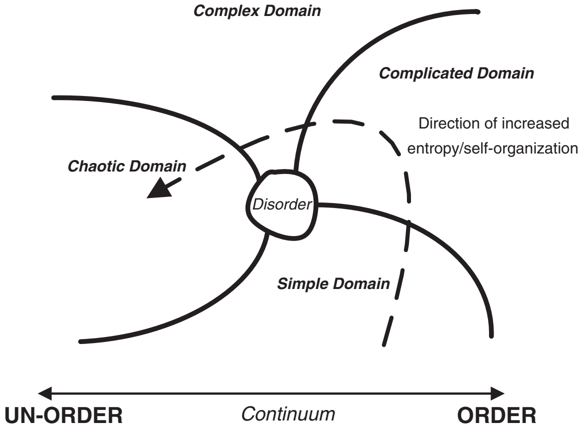


Fig. 10.7 Entropy and self-organization as applied to the cynefin framework



10.6 Framework for Addressing *When* in Messes and Problems

Figure 10.8 shows our proposed seven-element framework for determining if and when we should intervene in our mess in an effort to increase understanding about it. A discussion of the elements follows.

Element 1 urges us to ask, *is our system too mature*? This question arises from the material presented in Sect. 10.2. The key here is asking whether or not our system has sufficient life remaining to warrant us expending resources to intervene in it. If it's too mature, then we move on to Element 2. If not, we move to Element 3.

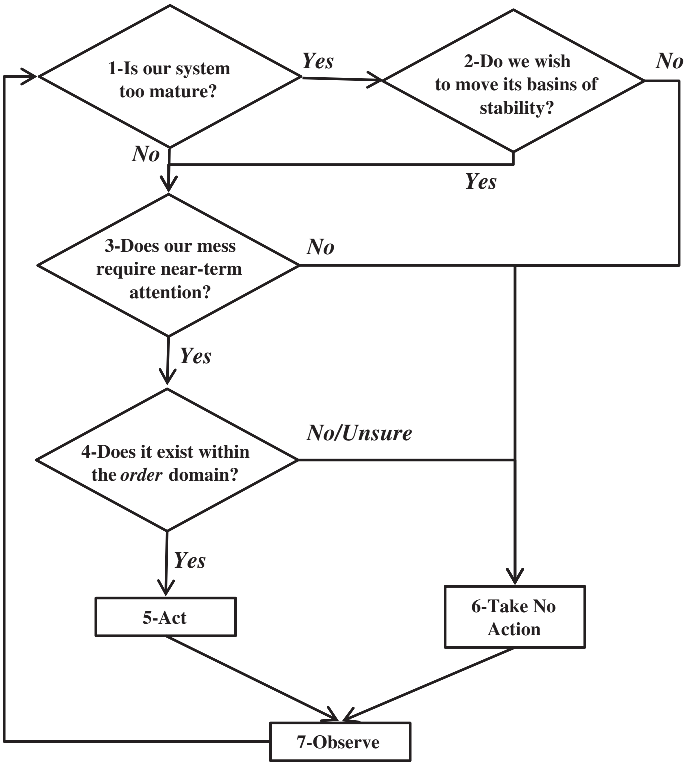


Fig. 10.8 A framework for systemic intervention

Element 2 serves as a follow-up to Element 1. If we have deemed the system too mature under its current configuration, the question we must ask ourselves is, recalling [34], *do we wish to move its basins of stability?* That is, do we wish to shift the system in a manner that perhaps renders it unrecognizable to observers previously familiar with it (see Fig. 10.5 and its shifted C/B curves to conceptualize the potential result of a shift in the system's basins, keeping in mind that intervention in a mess may result in either a positive or negative result). If the answer is no, we move to Element 6. If we do wish to alter it, we move to Element 3.

Element 3 encourages us to ask, *does our mess require near-term attention*? If the answer is no, then we should move to Element 6, take no action. If it does require near-term attention, we should move to Element 4. It should be noted that "near-term" is an intentionally subjective notion. What we intend to convey with this question is for you to think about whether or not your mess should be observed in an attempt to discern its patterns and behaviors before interfering or if it demands action (i.e., a political protest that threatens to unravel and cause unnecessary bloodshed or an unstable thermodynamic system that requires intervention).

Element 4 asks whether or not the mess exists in the order domain. While it is possible that no mess will ever exist here, we may decompose it further and explore its constituent problems. We may explore whether or not any of our problems can be classified under the Cynefin framework as ordered. If any are classified as ordered, they we may be justified to move on to *Element 5*, namely, to act. If not, we are best served moving to Element 6 and taking no action, as self-organization will be the dominant mechanism for change in our mess.

Element 5 represents our decision to act. This action, and its mechanisms, are described in Chap. 9. While we make no prescriptions regarding what action is to be taken, we assert that an individual arriving at this element in the framework is compelled to do *something*. This action is dependent on what effect we are trying to achieve, but failing to act, given the factors that led to this point, is likely to result in a Type V error. After acting, we move to Element 7.

Element 6 represents our decision not to act. If we have arrived here, our system, in its current form, is beyond help, disordered, determined as not needing our immediate attention, or we simply don't wish to try to salvage it. Thus, we choose to not act in order to avoid committing a Type IV error (taking inappropriate action to resolve a problem). This does not mean we are done with our mess; it merely means we will move on to observing without interfering with it. This stage continues to Element 7.

All elements eventually lead to *Element 7*. Element 7 asks us to observe. After acting (or not) based on the factors associated with our mess, we must observe the effects of our decisions. This may include waiting to see if our mess becomes more orderly or attempting to realize the benefits of a programmed intervention in our system. Regardless of why we have arrived here, it is important to observe our system before the framework compels us to return to Element 1 and begin anew.

10.7 Summary and Implications for Systemic Thinking

This chapter discussed the *when* question of systemic thinking. Thinking about this compels us to determine the appropriate time for us to intervene in our system, if ever. In order to develop an approach for determining the appropriate time for intervention in our mess, we developed an approach to assess the *maturity* and *stability* of our mess. The maturity discussion focused on life-cycle concerns and on evaluating the cost-to-benefit ratio of mess intervention, while our stability perspective focused on a discussion of system evolution and self-organization, leading to a method for classifying and understanding our system's state. We then combined these concepts into a 7-element framework to serve as a guide for individuals interested in increasing understanding about their mess. Table 10.2 shows the implications of the when question on each of the other systemic thinking perspectives.

Table 10.2 Implications of *When* perspective on other perspectives

Perspective	Implications
Who (stakeholders)	Stakeholders are the ones who observe our mess, live in it, and interact with it. They have to act when appropriate and abstain from action when appropriate, utilizing the framework proposed in this chapter
What (outputs, outcomes)	In order to achieve the desired outcomes and outputs that we wish, it is necessary for us to have patience in intervening in our system only when appropriate
Why (motivation)	Feedback associated with the motivational element of our mess is crucial in determining when to intervene
Where (contextual and boundary considerations)	Timing of interventions occur in a lock-step fashion with contextual considerations of our system
How (mechanisms)	Even though our timing considerations may suggest an intervention, resource constraints may prevent such an intervention from occurring

After reading this chapter, the reader should:

1. Be able to assess the maturity and stability of a problem; and
2. Understand the appropriateness of intervening in a given mess.

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Chapter 11
Putting it All Together: A Systemic Perspective

Abstract We've come a long way together. Recall Fig. 2.3, which presented a basic illustration of the steps underlying mess decomposition and reconstruction, presented as Fig. 11.1 with additional annotation regarding topics covered since our discussion in Chap. 2. The assumption at this point is that the reader has read through the first ten Chapters of this book and understands how to analyze a singular problem from each of the six perspectives presented in Chaps. 5–10. This analysis alone would be sufficient for a standalone problem. Those interested in understanding messes, however, need to go the extra mile. To this end, this Chapter develops a meta-methodology for understanding messes by discussing the interconnected elements necessary from each perspective to be integrated into a coherent whole for systemic understanding. The primary focus of this chapter is on mess reconstruction. Messes, of course, are a construct of convenience. They are envisioned and constructed in a somewhat arbitrary manner by each of us (as the observer) and yet, in identifying a mess and deconstructing it as we did in Chap. 2, and then analyzing its elements as we did in Chaps. 5–10 (as the systems practitioner), we have placed a responsibility on ourselves to reconstitute these pieces into a coherent whole to allow for systemic understanding of our mess. To start on this journey, we must begin first with mess articulation and problem decomposition. Each perspective is then discussed as it pertains to gained understanding at the mess-level. They are presented as they reside within what we propose as two meta-perspectives, namely *what is* and *what ought-to-be*, or our current and idealized state, respectively, and named after the conventions established by Ulrich [5]. Articulation and reasoning about these two states with respect to our mess provides us with a rational framework for increasing our understanding about it. Finally, this analysis will be explored as it pertains to the act and observe stages of the TAO process. Both the content and the structure in this Chapter are to be taken together as a meta-perspective framework for systemic thinking.

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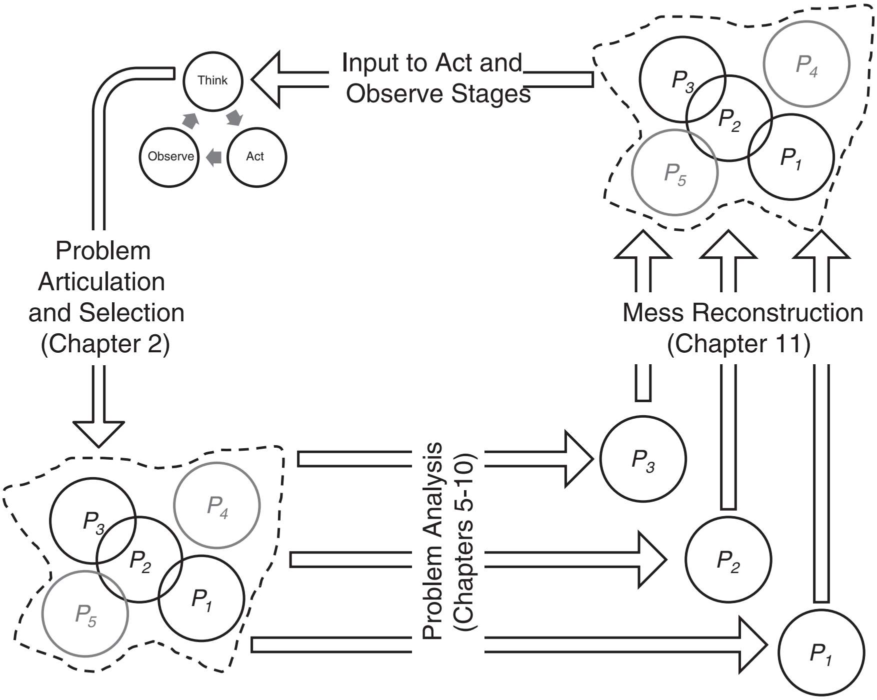


Fig. 11.1 Illustration of mess decomposition and reconstruction (adapted from Fig. 2.3)

11.1 Mess Articulation and Problem Selection

Deciding when we are faced with a mess is akin to U.S. Supreme Court Justice Potter Stewart's [1915–1985] famous description of obscenity, *I know it when I see it*. We usually know a mess when we see one. We discussed in Chap. 2 the characteristics that separate a mess from its constituent problems and so we will not repeat those characteristics here. We will, however, urge individuals at this stage to articulate a narrative for their mess. The narrative should include a simple paragraph to describe the situation you are attempting to understand and then a list of the problems that you've selected (there undoubtedly will be problems you choose, either purposefully or due to the darkness principle, to not explore). This narrative will set the stage for your analysis. Keep in mind the guidelines presented in Chap. 2 for problem formulation so as to avoid the Type III error described in Chap. 1. Armed with this set of constituent problems, you can now set out to analyze each using the methods and perspectives we discussed in Chaps. 5–10. A description of the relevance of each of these perspectives, and they apply to systemic thinking, follows (Fig. 11.1).

11.2 The *Who* Perspective

Recall that the *who* perspective invites us to explore stakeholders and their relationships as they pertain to a particular problem and one another. Completion of the analysis discussed in Chap. 5 leads to an articulation of our stakeholders, and their classification, attitude, strategy, and priority, as they pertain to a given problem. In order to use this information to gain improved understanding about a mess, we must combine it in some fashion. The first step is to generate a global priority for our stakeholders. In order to do so, we must generate a new stakeholder relationship map (recall Fig. 5.9), called a *mess relationship map*, with the following characteristics:

1. The stakeholders present in each problem analysis should be graphed. Since a singular stakeholder may have a differing classification and attitude with respect to many problems, it may be problematic to graph their classification and attitude at the mess level. Instead, we present all stakeholders devoid of classification or attitude, as simple nodes within a mess relationship map.
2. Each problem shall be graphed as a node within the mess relationship map. Connections between it and its related stakeholders (and between problems and one another) shall be captured as arcs.
3. This new map should be used to calculate a global activity and popularity for each stakeholder (and its associated problems). When comparing problems, it may be of use to consider the concepts of activity and popularity as they pertain to each problem; *active* problems are important, whereas non-active are not, while *popular* problems are hard to influence, whereas non-popular ones are not.
4. The popularity and activity of stakeholders should then be used to calculate an engagement priority for each. Deciding on engagement should consider the strategy identified for each with respect to its parent problem (per the guidance given in Chap. 5).

Completion of the mess-level analysis of problems and stakeholders provides us a wealth of information with which to understand our mess. Both the problems as they relate to each other at the mess level and the stakeholders as they relate to each other should be considered. Mess-level stakeholder articulation is demonstrated in Table 11.1. This Table lists each stakeholder, the strategy calculated for each with respect to each problem (P_i denotes the *ith* problem), and its global, mess-level engagement priority. It should be noted that not all stakeholders appear in all problems. Those stakeholders not present in a given problem are denoted as "N/A" in this table.

Stakeholders should be engaged considering both their engagement priority and the agreement of their problem-centric strategies. For example, Table 11.1 shows two different strategies for Stakeholder 1. There are several ways to handle this conflict:

1. We can attempt to isolate our engagement strategies as they pertain to their associated problems, i.e., *involve* Stakeholder 1 in Problem 2 and *collaborate*

Table 11.1 Mess-level stakeholder articulation

Stakeholder	Strategy			Engagement priority
	P_1	P_2	P_3	
Stakeholder 1	N/A	Involve	Collaborate	1
Stakeholder 2	Collaborate	Collaborate	N/A	2
Stakeholder 3	N/A	N/A	Collaborate	3
Stakeholder 4	Defend	Involve	Involve	4
Stakeholder 5	Monitor	N/A	Monitor	5
Stakeholder 6	Monitor	Defend	N/A	6

Table 11.2 Mess-level problem characteristics

Problem	Popularity	Activity	Engagement priority
Problem 1	0.0	1.2	2
Problem 2	1.5	3.0	1
Problem 3	1.7	0.5	3

with Stakeholder 1 in Problem 3. This may be problematic as the practical separation of strategies across problems may prove difficult.

2. We can use an aggressive strategy where we utilize the more intensive strategy for a stakeholder, regardless of which problem it pertains to. This would result in us *involving* Stakeholder 1 as it pertained to both Problems 1 and 2. This is likely to be a worthwhile approach with higher profile (i.e., higher engagement priority) stakeholders as their status in our mess warrants additional attention.
3. Finally, we can use a conservative strategy where we utilize the least intensive strategy for a stakeholder, regardless of which problem it pertains to. This would result in us *collaborating* with Stakeholder 1 as it pertained to both Problems 1 and 2. This is likely to be a worthwhile approach with lower profile stakeholders as their lower engagement priority makes the commitment of substantial engagement resources problematic.

We can also consider our problem interactions at the mess level. Mess-level problem analysis is demonstrated in Table 11.2. This table lists each problem, and its popularity, activity, and engagement priority (calculated using the same heuristic presented in Chap. 5 for stakeholders, that is, sorted in descending order by activity first, and then, if multiple problems share the same activity level, in ascending order by popularity). Investigation of these parameters allows us to gain a holistic understanding of the relative characteristics of our problems. Engagement priority helps us to understand which problem will be the easiest to influence (and provide us the most return as well). This problem priority may also help us resolve conflicts as they arise with mess-level stakeholder analysis, such as the strategies shown in Table 5.1. For example, knowing that Stakeholder 1 is the highest priority stakeholder and he/she is affiliated with Problems 2 and 3, we would work to pursue the strategy associated with Problem 2 first, as it is the higher priority problem.

Armed with a mess-level understanding of our stakeholder and problem engagement priorities, we can turn to the *what* question of mess understanding.

11.3 The *What* Perspective

The *what* perspective forces us to decompose our problem into a number of factors (namely outcomes, outputs, goals, and weights, as discussed in Chap. 6) that provide a richer understanding of what it is we are trying to influence with respect to our problem. As we have discussed at length, however, problems don't exist in an isolated bubble. As such, we must consider the interaction effects of our problem elements on one another. To do so, we must construct a mess-level depiction of our problem and its elements. This depiction should show each problem, its constituent outcomes and outputs, and its weights. If multiple problems share the same outcome-output pairing, then each should be listed as an independent arc with its own weight. This will add to our understanding by showing that multiple problems find a particular pairing important, and in fact, may value it differently through different weights. A depiction of a three problem mess and its respective elements is shown in Fig. 11.2. Note that the values shown on the arcs correspond to the weights.

We can use the network shown in Fig. 11.2 to calculate the activity and popularity of elements in our mess according to Eqs. 5.4 and 5.5, respectively. This analysis should include all elements presented. This will allow us to discern the relative importance of our outcomes, outputs, and problems as they relate to our mess. A notional example of this analysis performed on Fig. 11.2 is shown in Table 11.3. The table shows the problem nodes first, followed by the outcomes, and then the outputs, with each category listed in numerical order.

A qualitative assessment of the results in Table 5.6 provides us a few insights, depending on the element category in question:

- **Problems**: While popularity for all problems in this example is the same (zero), this is not always the case; some problems will have incoming arcs from other problems, indicating the influence of one problem on another. Activity will vary depending on the outgoing number of arcs (defined by the number of outcomes linked to a particular problem). Thus, higher activity problems are linked to more outcomes. While neither inherently good nor bad, higher activity problems may be more difficult to influence as they possess a larger number of outcomes.
- **Outcomes**: For outcomes, popularity is an indicator of the number of problems utilizing a given outcome (as well as the strength of their connection). Higher popularity means it is likely more ubiquitous in our mess. Activity is an indicator of the number (and strength of) connections with outputs. A higher number indicates a more complex outcome, which requires more outputs to evaluate.
- **Outputs**: Activity for all outputs will be the same; it will always be zero as there are no outgoing arcs from outputs. Popularity will provide an indicator of how much outcomes rely on a particular output for evaluation. Thus, a higher popularity means a higher relative importance of a particular outcome.

Assessing our mess from the *what* perspective provides a lens through which we can determine which "buttons" provide the most reach in terms of their ability to influence our mess. Examining popularity and activity for our mess elements (i.e.,

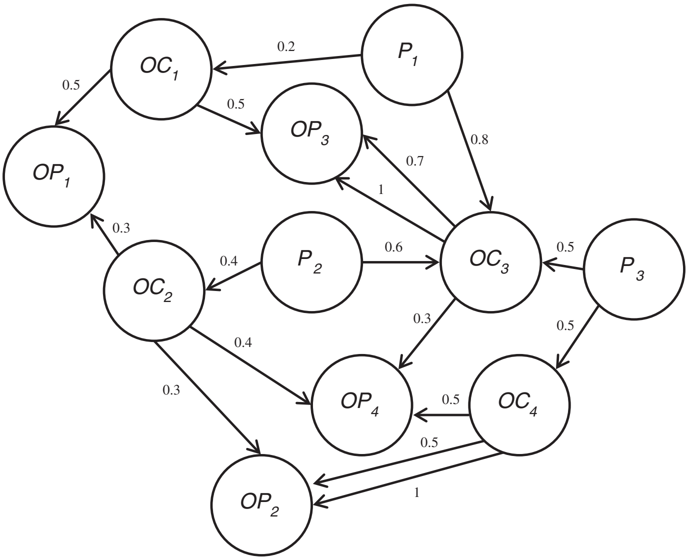


Fig. 11.2 Illustration of mess-level problem characteristics

Table 11.3 Illustrative network characteristics

Node	k_i^{in}	k_i^{out}	s_i^{in}	s_i^{out}	Popularity	Activity
P_1	0	2	0	1	0.0	1.4
P_2	0	2	0	1	0.0	1.4
P_3	0	2	0	1	0.0	1.4
OC_1	2	2	0.2	1.0	0.6	1.4
OC_2	3	3	0.4	1.0	1.1	1.7
OC_3	3	3	1.9	2.0	2.4	2.4
OC_4	3	3	0.5	2.0	1.2	2.4
OP_1	1	0	0.8	0	0.9	0.0
OP_2	3	0	1.8	0	2.3	0.0
OP_3	3	0	2.2	0	2.6	0.0
OP_4	3	0	1.2	0	1.9	0.0

problems, outputs and outcomes) allows us to determine the interrelationship of these components at a mess level. In doing so, we equip ourselves to understand (and influence) our mess systemically.

11.4 The *Why* Perspective

Asking the *why* question as it pertains to our mess is a matter of considering the motivation of those individuals and organizations affiliated with our mess, either willfully or by circumstance of some sort. When we discussed stakeholder analysis and management in Chap. 5, we addressed the importance of identifying

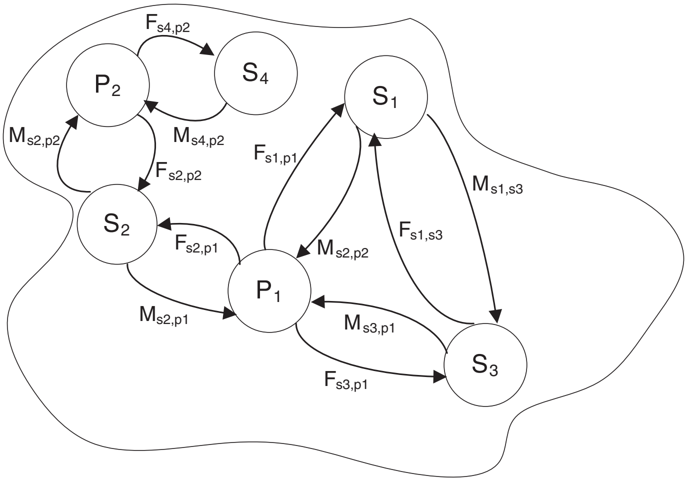


Fig. 11.3 Illustration of mess-level motivation and feedback

the *wants* of our stakeholders as a first pass at understanding their involvement in a problem. Chapter 7 elaborated on this concept at a problem level. At this point, we must construct a graphical representation of our stakeholders, problems, motivations, and feedback. Using this notional stakeholder map similar to the mess relationship map discussed in Sect. 11.3, we can add a motivation and feedback loop to every connection between two stakeholders or between a stakeholder and a problem, in a manner similar to the notional illustration of stakeholder motivation and feedback provided in Fig. 11.3. This deliberate capturing of motivation and feedback affords us a lens through which to monitor the effect of our actions on our stakeholders (and of stakeholders on one another). These feedback mechanisms may be explicit (and dictated by strategies identified in our stakeholder analysis, such as monitor or collaborate) or they may be implicit (such as ensuring communication channels are open in our system to allow for stakeholders to receive feedback on an ad hoc basis). Given our stakeholder priorities, we can prioritize resources associated with feedback (i.e., more important stakeholders will be kept informed in a more regular, more formalized manner, while those warranting little action will be treated as such). Having a systemic perspective of our mess may also allow us to streamline feedback processes, i.e., multiple stakeholders can be kept informed via a singular meeting, provided their motivations are complimentary. This perspective may encourage us to revise the periodicity or method detailed for our stakeholder management plan, as discussed in Chap. 5.

While Fig. 11.3 may serve as a standalone element for analysis and increasing understanding, it may be necessary to integrate this depiction into a singular graphic depicting those elements from the *who, what, and why* elements of systemic thinking. We may call this sum of perspectives the *what is* meta-perspective we alluded to in Sect. 11.1. These three perspectives combined provide us a mess-level understanding of our stakeholders, their interactions, motivations and

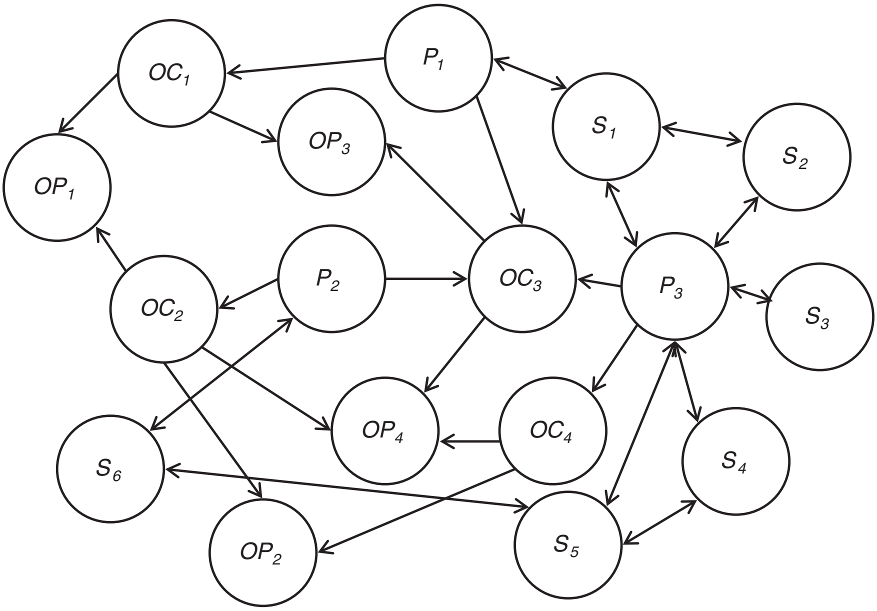


Fig. 11.4 Illustration of "What-Is" meta-perspective

feedback mechanisms, associated problems, and problem element decompositions as they currently exist (at least, as a result of the limited number of perspectives we have available and our limited understanding). This depiction, shown for a notional example in Fig. 11.4, allows us to qualitatively assess the state of our mess and the interrelationships between its elements. No quantitative elements, such as influence magnitude or problem element weights, are present in this depiction. In order to assess where we wish to head, i.e., toward increased understanding of our mess, we must turn to the *what ought-to-be* meta-perspective.

11.5 The *Where* Perspective

The *where* perspective implores us to consider the context and boundary of our mess. Together, these elements provide substantial assistance in guiding us toward increased understanding of our mess, and they begin to lay the groundwork for us to assess desired future states of our mess. We can first use our notion of boundaries to create a mess-level articulation of our boundary in a manner similar to that presented in Table 11.4 and drawn from Ulrich's [1] checklist of critically heuristic boundary questions.

This table serves as a starting point to understand our problem's boundaries and how they might interact with one another. Further, it can serve as a starting point by which we can craft a narrative regarding where we want our mess to *go* (i.e.,

Table 11.4 Critically heuristic boundary issues (based on [1])

	P_1		P_2	
Boundary issue	What is	What ought to be	What is	What ought to be
Sources of motivation				
Sources of power				
Sources of knowledge				
Sources of legitimation				

Table 11.5 Mess-level articulation of contextual elements

Element	P_1	P_2	P_3
Circumstance			
Factor			
Condition			
Value			
Pattern			

where it ought to be), and consider each of its constituent problems and its envisioned state. This envisioned future state can be further enhanced by considering the contextual elements of our problems, namely its circumstances, factors, conditions, values, and patterns, in a manner similar to Table 11.5. It should be noted that both Tables 11.4 and 11.5 rows merely represent category placeholders; that is, circumstances, for example, will likely be many for a given problem and thus, will require multiple rows to be captured appropriately.

The boundary and contextual elements present in Tables 11.4 and 11.5, respectively, can be represented together in a coherent articulation using what is known as a force field diagram. Social psychologist Kurt Lewin [1890–1947] created the theory [2–4] behind the force field diagram, namely that human behavior is caused by forces such as beliefs, cultural norms, and societal pressure, that exist within an individual's life or in society at large. These forces are either supporting the achievement of a goal (known as driving forces) or inhibiting this achievement (known as restraining forces). The force field technique depicts these two opposing force types as vectors (both a magnitude and direction). These forces act on either a current or envisioned state. Thus, both boundary and context elements can be considered in their depiction as shown in Fig. 11.5. Those elements identified as context elements can be captured, as appropriate, as forces, whereas boundary investigation can lead to a description of the problem both in terms of its present state and its idealized state. This articulation is to be undertaken on a per-problem basis.

Once all force-field diagrams have been generated for each of the constituent problems in a mess, we can turn to mess-level understanding. Once mechanism for doing so is to revisit the *what-is* meta-perspective presented in the previous section. In this case, we can use the force-field diagram analysis to revise this perspective. We can add dotted lines to this depiction to represent the idealized state for our system, or as an element of the *what ought-to-be* meta-perspective. While these connections don't exist, they may serve as potential targets for our mechanisms (recall Chap. 9) to be employed in seeking increased understanding about our mess. Figure 11.6 illustrates

Driving Force	***Vector As-Is***	***Vector Ought-To-Be***	***Problem 1***	***Vector Ought-To-Be***	***Vector As-Is***	***Restraining Force***
Driving Force 1	───→	→	*Present State (Idealized State)*	←───	←	Restraining Force 1
Driving Force 2	───→	──→		←──	←	Restraining Force 2
Driving Force 3	→	───→		←───	←──	Restraining Force 3
Driving Force 4	───→	──→		←	←──	Restraining Force 4
Driving Force 5	──→	→		←───	←───	Restraining Force 5

Key: Strong Force ───→ Medium Force ──→ Weak Force →

Fig. 11.5 Illustration of problem force-field diagram

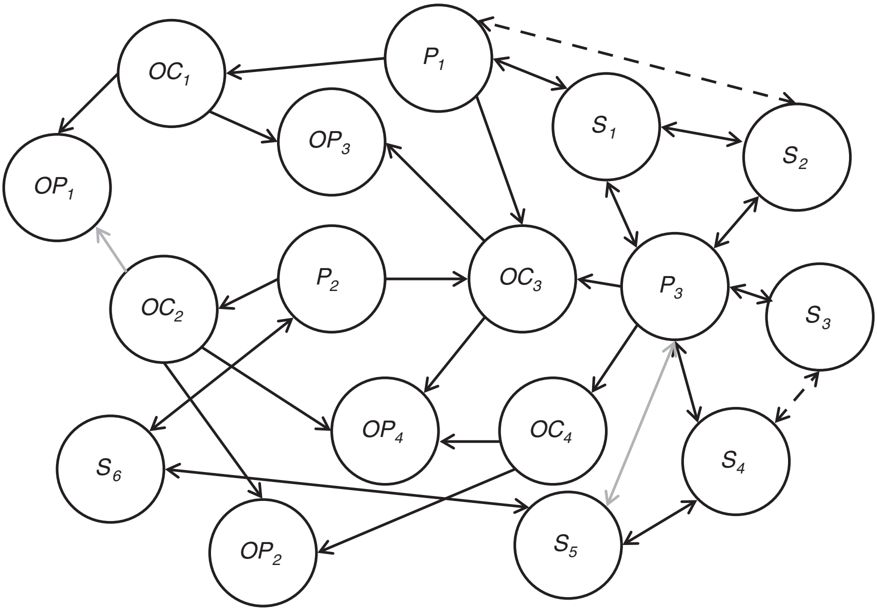


Fig. 11.6 Illustration of "What Ought-To-Be" meta-perspective using context and boundary elements

a revision of Fig. 11.4 to account for idealized state concerns. In this case, we have identified the need for a linkage between stakeholder 2 and problem 1, as well as a need for stakeholders 3 and 4 to communicate. Elements can also be removed as noted as grayed lines (such as the linkage between outcome 2 and output 1 and the linkage between problem 3 and stakeholder 5). These scenarios may represent an outgrowth of our force field analysis, where our envisioned state represents a weaker force than current state, potentially necessitating the removal of a connection in our mess.

Table 11.6 Evaluation of problem intervention suitability

Problem	Strategy	Rationale
P_1	Act	Action is warranted based on maturity, need for near-term attention, and ordered behavior
P_2	Take no action	Problem exists in the unordered domain and, as such, intervention may be problematic
P_3	Take no action	Problem is beyond appropriate level of maturity and we do not wish to move its basins of stability to increase the expected life of its associated problem system

11.6 The *When* Perspective

Continued examination of the *what ought-to-be* meta-perspective leads us to investigate the temporal elements of concern for understanding our mess, namely its stability and maturity. We should follow the framework presented in Chap. 10 for each of our problems, leading to a determination, based on its stability and maturity, as to whether or not it is suitable for mechanism intervention. Each of our problems and their readiness can be contrasted against one another as shown in Table 11.6. It is important to note that this table includes a discussion of the rationale behind the strategy chosen, as this will inform further deliberations regarding mechanism selection.

The results of Table 11.6 can lead to three potential scenarios:

1. All strategies suggest no action be taken. In this case, we should not attempt to intervene in our mess with further understanding of it (in an effort to avoid a Type IV error of the wrong action).
2. All strategies suggest action is to be taken. In this case, we should investigate the mechanisms appropriate for intervention in our mess based on its characteristics and the knowledge we seek to gain. These elements were covered in Chap. 10 and will be revisited as they apply to a mess in the following section. Proper mechanism identification and deployment avoids both the Type IV and Type V errors.
3. There is not universal agreement between problems on whether action is warranted or not. This is likely to be the case in most messes, as various elements within our mess will be of varying stability and maturity. In order to deal with this scenario, further analysis is required to ensure that, in helping to increase our understanding, we do not cause unintended consequences elsewhere within our mess. While this may be unavoidable to some degree, we should take every precaution to avoid obvious conflicts when possible.

If scenario 3 is present, we can reason about our next steps by taking into account the knowledge gained from our *what is* meta-perspective, as well as our analysis of boundary and context. We should investigate the mapping shown in Fig. 11.6 to reason what elements, if possible, can be affected, while also keeping into account the conclusions of our Table 11.6 analysis. Thus, for this example, we should search for elements that are isolated to Problem 1 (and do not include Problems 2 and 3).

Given its status as a mess, this is easier said than done. Outcome 1, however, does fit this criteria. Thus, we should determine whether intervention with respect to this element will be advantageous for our understanding, while also avoiding disruptive effects to Problems 2 and 3, or whether we should forgo any potential negative effects on Problems 2 and 3 and choose a more suitable element for increasing our understanding (stakeholder 1 or outcome 3, for example). Given a (potentially small) list of elements to investigate further, we can now to turn to discussion of those mechanisms that may be employed for increased understanding.

11.7 The *How* Perspective

The final perspective that we need to incorporate is the *how* perspective, which concerns the mechanisms necessary for increasing our understanding. The first step in assessing the how question at the mess-level is to understand what we can understand, if you will. We spoke at length about this in Chap. 9. Depending on the order present in our constituent problems, each may be more or less susceptible to particular mechanisms for understanding. We should categorize each of our problems in a manner consistent with the Cynefin framework presented in Chap. 9 and as shown in Fig. 11.7 for our example mess.

At this point, we can reason further about our mess. In the previous sections, we constructed an *as is* meta-perspective, as well as an understanding of the boundary and context of our mess, and the stability and maturity of it. By the time we've completed these steps at the mess level, we've made a first-order analysis of where we want to head, which problems we wish to intervene into get us there, which are ready for our intervention, and which elements might be the most worthwhile to investigate. Our final perspective allows us to further understand the potential mechanisms we can employ in dealing with our mess. If employed correctly, these mechanisms may serve to fulfill two purposes: (1) to move us toward the achievement of the purposive goals of our system or (2) to gain further understanding about our mess. It is worth noting that these two purposes are not necessarily mutually exclusive.

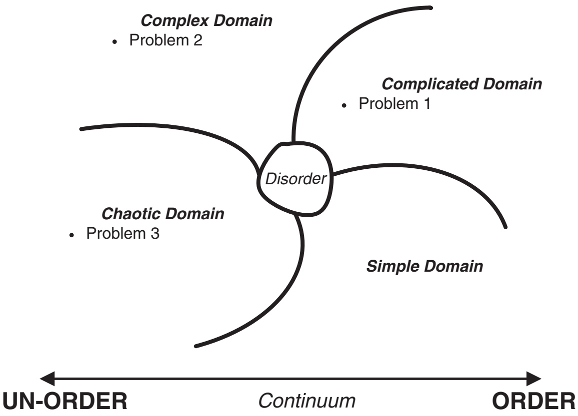
Purpose one is fulfilled primarily by those mechanisms such as manpower, KSA's, material, money, time, equipment, and facilities discussed in Chap. 9. They can help us directly to achieve the purposive goals of our systems, but they also assist indirectly in providing means for increased understanding.

Purpose two is fulfilled primarily by abstract mechanisms such as information and methods. These seek to help us increase our mess understanding by resolving uncertainty, revealing a novel perspective about our mess, or by helping us move from a more un-ordered domain to one that is more understandable. Given the articulation present in Fig. 11.7 for a given problem (and the elements learned in the previous perspectives), we can now identify what method mechanisms (i.e., what techniques, as presented in Table 9.6) will assist us in understanding our mess further or in moving our problems from more un-ordered domains to those that they can.

Table 11.7 Articulation of mechanism deployment

Mechanism category	Mechanism description	What is	What ought-to-be	Intended effect
Money, manpower, KSAs	Deploy novel training program to bring company employees up to speed on new corporate policies	Current workforce is unaware of new policies	Workforce should be familiar with changes	Awareness of workforce, leading to less confusion by employees
Method	Need to decide between competing training programs to select the one with the greatest efficacy	Training decisions are ad hoc	Training decisions are purpose-driven and meaningful	Make better use of resources for training in a constrained budget environment

Fig. 11.7 Notional Cynefin domains and problem matching



We use mechanisms to fulfill both of these purposes and to bridge the gap between the *what is* and the *what ought-to-be* meta-perspectives. This requires us to consider our mess and its stakeholders, problem elements, motivation and feedback, context, boundary, and its stability and maturity. It is advantageous for us to capture the mechanisms, both achievement- and understanding-oriented, in a concise form such as the notional example shown in Table 11.7. In this narrative, it is important to capture the mechanism category, a description of the intended mechanism, contrasting statements of what is and what ought-to-be, and the intended effect (be it to realize the what ought-to-be state or simply to increase understanding).

Once a plan has been made for mechanism deployment and an understanding has been achieved at a sufficient level, we can use this additional insight as input to the act and observe stages of TAO, as discussed earlier in this Chapter and depicted in Fig. 2.3.

11.8 Iteration

Even after we have articulated both our *what is* and *what ought-to-be* meta-perspectives, we aren't really *finished*. To be fair, there is really no *finished* what it comes to a mess. Recall our discussion in Chap. 3 that the goal of our effort is increased understanding. This is a continuous, never-ending process. As we gain more information and increase our understanding, we can make better choices, invest our resources more wisely, ask better questions, use better mechanisms, and truly, think systemically about our mess. This will force us to reassess our choices and assumptions about what we know; it will ask us to refine the perspectives we have of our mess; and it will ask us to do this in spite of the eight factors we talked about back in the preface, namely, (1) intransparency, (2) polytely, (3) complexity, (4) variable connectivity, (5) dynamic developments, (6) time-delayed effects, (7) significant uncertainty, and (8) humans-in-the-loop. Not an easy task, to be sure, but the goal of this book has been to provide a structured framework for doing just that.

11.9 Summary

This chapter introduced two meta-perspectives, the *what is* and the *what ought-to-be* perspectives, in an effort to make sense at the mess level of our problem-level analyses. This guidance provided a framework for systemic understanding of our mess and a general guideline for undertaking a case study of the methodology presented in this book.

As we said early on in this book, everyone's got problems (and messes). How we think about them determines whether or not we'll be successful in understanding and addressing them. It is our hope that we have provided you with a new approach to use when faced with problems and messes that are seemingly intractable, such as the ones we discussed in the preface. Further, it is our hope that you are now able to think systemically about these persistent problems and use the methodology presented in this book to increase your understanding. Good luck!

After reading this chapter (and this book), the reader should:

1. Understand how the elements of our methodology for systemic thinking work together to provide systemic understanding of a mess;
2. Be able to articulate, using our two meta-perspectives, the current and desired states for a mess;
3. Understand what steps are necessary to transition a mess to a more desired state; and
4. Complete the Systemic Thinking Self-Assessment in Appendix A to see if your perspectives have changed since you began reading this book.

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Appendix
Systemic Thinking Self-Assessment

Instructions

Rate the degree of your agreement with the following assertions, on a scale of 1-5, with 1 representing complete disagreement and 5 representing complete agreement. There is no wrong answer here. The purpose of this set of questions is to serve as a self-assessment as to the degree to which you think systemically.

Questions

1. When faced with a complex problem, I have a general idea of how to approach it. ____
2. Understanding a complex problem is more important than solving it. ____
3. Complex problems cannot be optimized. ____
4. Consideration of multiple perspectives adds to, rather than detracts from, a problem analysis effort. ____
5. An appropriate theoretical foundation is essential to any approach to understanding a complex problem. ____
6. Problem stakeholders merit careful consideration and analysis. ____
7. It is necessary to limit the number of measures I consider for a given problem. ____
8. Feedback is essential to maintain stakeholder motivation within a problem. ____
9. It is important to establish a boundary between a system and its environment. ____
10. The underlying complexity of a problem is important in determining how to deal with it. ____
11. There is a wrong time to intervene in a problem. ____
12. Transitioning from a system’s current state to a desired state is neither a trivial nor straightforward endeavor. ____

Total Score ____

P. T. Hester and K. M. Adams, *Systemic Thinking*, Topics in Safety, Risk,
Reliability and Quality 26, DOI: 10.1007/978-3-319-07629-4,

Did I pass?

As you may have deduced, the higher your total score, the more systemic of a thinker you can consider yourself. Each question is addressed in varied capacity throughout the book. There is no optimal, right, or target score. Rather, it is the hope of the authors that your evaluation increases as you progress through the book. We invite you to consider how your score (and your perspective) has changed as you read the book.

Index

P. T. Hester and K. M. Adams, *Systemic Thinking*, Topics in Safety, Risk, Reliability and Quality 26, DOI: 10.1007/978-3-319-07629-4,