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Accounting for Errors when using Systems Approaches

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Abstract

Complex systems problems require the use of a formal philosophical construct and dictate the use of a rigorous systems approach. A systems approach may utilize one of a variety of proven methods, but in each case it involves the imposition of order that ranges from the philosophical to the procedural. Independent of the construct or rigor used to address the complex systems problem is the opportunity to commit a number of errors as part of a systems approach. This paper will discuss six classifications for problem solving errors that may be experienced during the application of a systems approach as part of understanding and treating complex systems problems.

Keywords: systems approaches; errors; error types

1. Introduction

Most complex systems problems can be characterized by (1) uncertainty, (2) complexity, and (3) conflict. Based on this point-of-view, it seems reasonable to assume, for example, that the way in which a complex systems problem is perceived by its solution participants is a major determinant of the degree of uncertainty, complexity, and conflict that each of the solution participants are able to clearly identify as part of the problem context.

Solution participants ensure that the context of the complex systems problem under review includes a definition of human activity in the formulation, analysis, and solution of the problem. This is routinely accomplished through the use of one of a number of systems-based approaches [1-3]. However, none of these systems-based approaches explicitly addresses the errors that may be committed as part of the formulation, analysis, and solution to the problem being addressed by the approach.

Analytical and interpretational errors occur regularly during the formulation, analysis, and solution of systems problems. These errors are committed independent of method (e.g., qualitative or quantitative) and epistemological tradition (i.e., positivist or post-positivist). The errors, of both commission and omission, complicate solutions to these *wicked* problems [4].

We intend to present a typology of six (6) errors derived from the extant literature and use this as a construct, to be included in systems approaches, for avoiding common errors during the formulation, analysis, and solution to *messy* [5] or wicked problems encountered in modern, complex systems.

2. Typology of Errors

There is not general agreement on a single taxonomy for errors in systems approaches. However, our review of the literature on errors has revealed that researchers from four of the 42 internationally agreed upon fields of science

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[6] have conducted inquiry with respect to errors where they have assigned some sort of designation for the error; thus a typology is able to be constructed. Figure 2 includes references from the relevant fields of science.

Table 1. Science Sector and Field of Science that have Conducted Inquiry on Errors

Science Sector	Field of Science	Reference
Social Sciences	Educational Sciences	Betz & Gabriel [7] Kaufman, Dudley-Marling, & Serlin [8] Marascuilo & Levin [9, 10] Onwuegbuzie & Daniel [11] Rosnow & Rosenthal [12, 13]
	Psychology	Games [14] Kaiser [15] Leventhal & Huynh [16] Levin & Marascuilo [17, 18] Meyer [19] Mitroff & Featheringham [20] Mitroff [21]
	Economics and Business	Boal and Meckler [22] Umesh, Peterson, McCann-Nelson & Vaidyanathan [23]
Natural Sciences	Mathematics	Kimball [24] Mosteller [25] Neyman & Pearson [26-28] Tracz, Nelson, Newman & Beltran [29]

From our review of the literature in Table 1 we have constructed a typology of six common errors that we feel systems practitioners will encounter during the formulation, analysis, and solution to complex systems problems.

2.1. Type III Error

We start our description with the Type III error. We know that you will immediately ask, *what happened to the Type I and Type II errors?* We ask you to keep an open mind and it will become obvious why we describe the Type III Error prior to the older and more widely known Type I and Type II errors.

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" [21, p. 15].

Type III errors normally occur during the formulation of systems 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 the solution participants). Failure to reformulate the reported problem is the most common source for a 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:

> *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.'* [20, 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" [24, p. 134].

2.2. Type I and Type II Errors

The extant literature on the Type I and Type II errors also originated in the mathematics (i.e., statistics) field of science with Neyman and Pearson [26-28]. The journals and associated textbooks in the statistics field have consistently classified and reported on these error types. The basis has been on logical considerations in statistical inference; specifically, the traditional non-directional two-sided test. For this test there are only two possible errors: (1) deciding that there is a difference, when, in fact, there is no difference, and (2) deciding that there is no difference, when, in fact there is a difference [15]. These are classified, respectively, as Type I (α) and Type II (β) errors. Table 2 contains a matrix and definitions for the Type I and Type II errors framed in terms of the testing of a null hypothesis, H_0.

Table 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

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 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 actually do have.

Both of these errors typically occur after the complex system problem has been analysed and formulated (and after the practitioners hopefully have avoided committing a Type III error) and the system solution is in the process of being devised.

2.3. 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 our knowledge, the first mention of the Type IV error in the literature was by Marascuilo and Levin [9]. 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.* [17, p. 368]

The primary discussion of Type IV errors has been associated with the interactions in ANOVA models and has dominated most of the scholarly dialogue [8, 12, 13, 23]. However, we have chosen to treat the Type IV (δ) error at a higher level of abstraction. More succinctly, we view the Type IV (δ) error as "the incorrect interpretation of a correctly rejected hypothesis" [9, p. 398].

Boal and Meckler [22] elaborate on the problems caused by a Type IV error as:

> *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.* [22, p. 333]

Thus, even though the problem has been correctly identified, the action identified to resolve the problem is incorrect. Further, there is potential in this situation for the identified problem solution to exacerbate the problem.

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 [30-32].

2.4. Type V Error

The field of cybernetics and the systems *principle of homeostasis* [33] inform systems practitioners 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 be solved 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 [22] 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)*

As with our other examples of errors, this error also has a medical analogy. In this case, a physician commits a Type V error when correctly diagnosing an ailment and failing to take corrective action with respect to the patient's condition on the belief that the ailment will simply go away on its own.

There are many causes for the Type V error. Failure to achieve consensus among relevant stakeholders (e.g., the doctor and the patient do not agree on treatment options) may lead to inaction due to the lack of a singular prevailing option. Additionally, a simple lack of understanding of the root cause of a particular problem may lead to the inability of stakeholders to envision a plausible scenario for solving the problem at hand. Finally, stakeholders may fear worsening the problem by interfering with the underlying system. While this is a valid concern, it is often the case that inaction leads to more dire consequences than action.

2.5. Type VI Error

A Type VI (ζ) error occurs when errors of Types I-V compound to create a larger, more complex problem than originally encountered. Boal and Meckler [22] elaborate on the nature of Type VI errors:

> *When a Type VI error is made, 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.* [22, p. 336]

Complex systems problems that are open to multiple errors are termed *wicked problems* [4] and are in sharp contrast to those denoted as *tame* by Boal and Meckler [22].

It is the Type VI error that we must truly be concerned about. Given that we are already talking about the analysis of complex systems problems, additional complexity introduced by committing a Type VI error, or what we term a system of errors to connote a correlation with Ackoff's characterization of messes (complex systems) as "systems of problems" [34, p. 100], makes the problem intractable and potentially unsolvable.

Continuing with our analogy to medical problems, a Type VI 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).

3. Discussion

We have described six classifications for problem solving errors that may be experienced during the application of a systems approach when understanding and treating complex systems problems. A typology of the six systems errors is presented in Table 3.

Table 3. Typology of Systems Errors

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 (ζ)	An error that results from a combination of the other five error types, often resulting in a more complex problem than initially encountered.	System of Errors

We envision that complex systems problems can be conceived as requiring three consecutive phases: (1) formulation, (2) analysis, and (3) solution. Each of these phases is prone to a different set of errors. Formulation is prone to Type III errors, analysis to Type I or II errors, and solution to Type IV or V errors. In order for a problem to be solved correctly, all of these errors must be avoided.

1. The Type III error must be overcome; that is, the correct problem to be solved must be formulated.
2. Both the Type I and Type II errors must be avoided by observing appropriate statistical practices and making appropriate conclusions based on these practices, during problem analysis.
3. Both the Type IV and Type V errors must be avoided by choosing the appropriate solution for a particular problem, given that the results of a problem demand action.

This series of steps is shown graphically in Figure 1 in a manner adapted from Boal and Meckler [22], but focused on the probabilities associated with particular paths available to the systems analyst. It is worth noting that Type VI errors are represented by the different error combinations presented in Figure 1 (i.e., a Type III error followed by a Type I error). Note that P(α), P(β), P(γ), P(δ), P(ε), and P(ζ) represent the probability of a Type I-VI error, respectively.

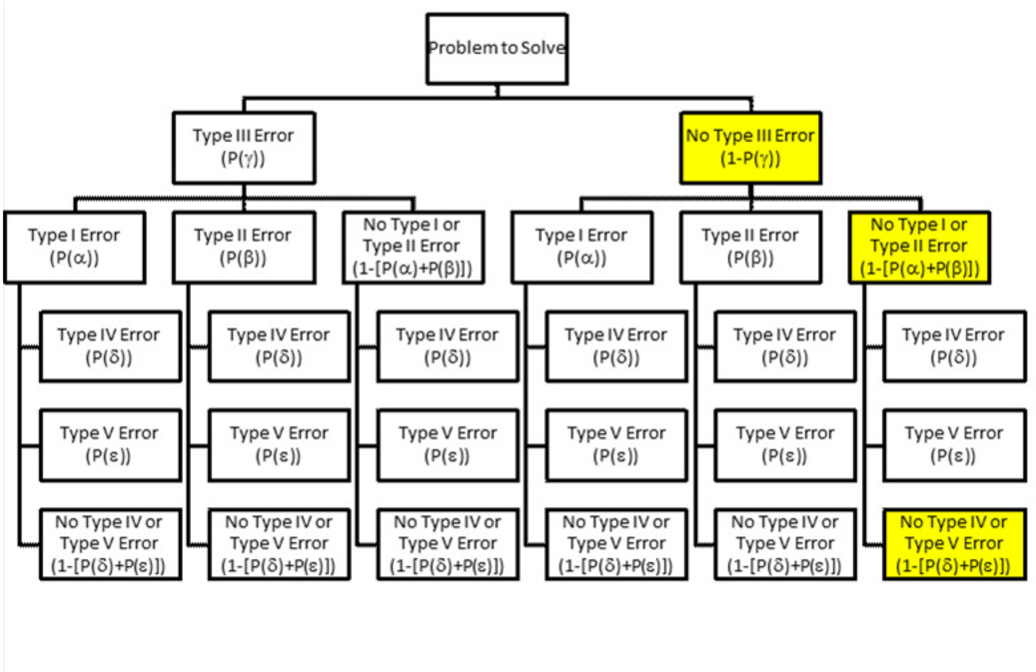

Fig. 1. Tree Depiction of Systems Errors [35, p. 239]

Highlighted in Equation (1) is the only path through which a problem is solved that does not result in an error. This requires that no Type I-V (and by definition, Type VI) errors are committed. We can use this path to calculate the probability of a correctly solved problem as follows:

$$P(correctly\ solved\ problem) = 1 - \left[[1 - P(\gamma)][1 - (P(\alpha) + P(\beta))][1 - (P(\delta) + P(\varepsilon))]\right] \qquad (1)$$

While $P(\alpha)$ and $P(\beta)$ are straightforward quantities identified using statistical procedures, $P(\gamma)$, $P(\delta)$, and $P(\varepsilon)$ may prove to be difficult to estimate. However, this simple equation, understood at a conceptual level, shows that errors in a systems problem are serial; that is, a solution to a particular problem is only as strong as its weakest component, be it problem formulation, analysis, or solution. Any error decreases the overall probability of a correctly solved problem. Multiple errors substantially reduce the likelihood we will solve our problem correctly. Thus, the systems practitioner must be diligent in avoiding all of these error types or risk increasing the likelihood of unsuccessfully solving their problem.

4. Conclusion

It is because complex systems problems are wicked that a formal approach for understanding and treating these problems is required. Based on a long history of formal approaches that address complex systems problems, we have developed a typology for classifying the types of errors that can be expected to be made as part of any approach to dealing with a complex problem and its environment. The developed errors typology is independent of the philosophical construct or procedural rigor used in addressing these complex systems problem. The typology focuses on the opportunity to commit a number of errors as part of any approach.

We have discussed six classifications for problem solving errors that may be experienced during the application of a systems approach and presented a typology of these errors. Our goal has been to make practitioners aware of these errors so that they may avoid them during the formulation, analysis, and solution of a problem. Our typology is based on the literature, but its use in systems approaches is in its embryonic stages and would be well served by feedback and challenge from systems practitioners to test the proposed error typology and its application when using systems approaches for solving complex systems problems.

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