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# Crafting theory to satisfy the requirements of systems science

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ABSTRACT

Just as Lee, Briggs, and Dennis (2014) showed that a rigorous conception of "explanation" leads to requirements for a positivist theory to satisfy, and just as Lee and Hovorka (2015) showed that a rigorous conception of "interpretation" leads to requirements for an interpretive theory to satisfy, we show that a rigorous conception of "systems" leads to certain requirements for a systems theory to satisfy. We apply basics of systems science in general, as well as basics of Luhmann's (Luhmann, 1995; Moeller, 2006) systems perspective in particular. We illustrate these basics with empirical material from a case about the role of information technology in anti-money laundering. The example demonstrates that research in information systems, which has been informed by positivism, interpretivism, and design, can be additionally and beneficially informed by systems science — which, ironically, has been largely absent in information "systems" research.



## 1. Introduction

What is systems science, what are the requirements that systems science imposes on theorizing, and how can research on information systems benefit from and satisfy these requirements? A fundamental premise of this essay is that the academic discipline of information systems, in incorporating the word "systems" in its name (e.g., the Hawaii International Conference on *System* Sciences, Management Information *Systems* Quarterly), needs to take "systems" seriously. Ironically, this academic discipline has not availed itself of the rich intellectual heritage of systems science (of which some notable exceptions include the work of Checkland (2000) and of Alter (2013)). Following not only Lee, Briggs, and Dennis (2014) who examined how to craft theory to satisfy the requirements of explanation, but also Lee and Hovorka (2015) who examined how to craft theory to satisfy the requirements of interpretation, we examine, in this essay, how to craft theory to satisfy the requirements of systems science. However, in our discussion, we will clarify that we shall ground our reflections on systems principles that have their origins in the founders of systems theory (such as Bertalanffy), where such principles are at a higher-level of theoretical abstraction than the specifics of any systems-oriented methodology.

The next and second section of this essay will offer some of the basic, general, and widely agreed-upon features of systems science. The purpose is not to present all features of systems science, but to extract key ideas useful for differentiating systems theorizing from theorizing in positivism, interpretivism, and design so that researchers already familiar with the latter can perceive additional benefits and insights afforded by the former.

The third section will present features of the specific form of systems theorizing advanced by Niklas Luhmann (1927–1998), a scholar whose work has been increasingly felt in the information-systems research community. Luhmann adapted systems theory

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in a way that is readily useful to the large school of behavioral research already ensconced in the information-systems research community.

In the fourth section of the essay, we will abstract, from the preceding discussion on systems science, requirements for systems theorizing to satisfy.

In the fifth section, we will apply these requirements in an empirical case of systems theorizing about the role of information technology in anti-money laundering.

## 2. Some basics of systems science in general

Diverse schools of thought characterize systems science no less than positivist science, interpretive science, and design science.

In this essay, we approach systems science as an empirical science where its object of study is systems in general, rather than systems of specific types, such as social systems, computer systems, and ecological systems (Klir, 2013). Therefore, statements that systems science makes about "systems" would be applicable across systems of specific types. In fact, the vision of the founders of the Society for General Systems Research in 1954 – Bertalanffy (1950), Boulding (1956), Miller (1978) and Rapoport (1950) – was exactly that: the gradual development of a science that would synthesize fundamental principles from different fields. It was the idea of a science that would evolve into a sort of meta-theory through which a diverse array of different phenomena – across different systems – would be described, modeled, and investigated. Hammond (2003), who traced the evolution of systems theory in her work on the history of systems theorizing, called the whole endeavor a *science of synthesis*.

Indicative of the long history of systems science and its relation to information is Leo Szilard's 1929 paper (Szilard, 1964), which exposed the difference between matter/energy and information, and from which the cybernetics paradigm eventually emerged. Also, it is generally acknowledged that Shannon and Weaver's *The Mathematical Theory of Communication* (Shannon & Weaver, 1949) is second only to Norbert Wiener's *Cybernetics* (Wiener, 1948) in establishing concepts for the evolution of systems thinking (including information, communication, and of course, feedback). Thus, the groundwork has already been laid for definitively establishing connections and identifying common core principles between systems science and the study of information systems.

Systems science is also known as "General Systems Theory" (GST). Overlapping versions of GST were rendered by Bertalanffy (1950), Boulding (1956), and others. Boulding emphasizes its generality by describing it as (Boulding, 1956, p. 208) "the skeleton of science in the sense that it aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge."

What, then, is a "system"? According to Bertalanffy (1950, p. 143):

> A system can be defined as a complex of interacting elements $p_1, p_2 \dots p_n$. Interaction means that the elements stand in a certain relation, R, so that their behaviour in R is different from their behavior in an another relation, R′. On the other hand, if the behavior in R and R′ is not different, there is no interaction, and the elements behave independently with respect to the relations R and R′.

As succinct as Bertalanffy's definition might be, it has ramifications of major significance that emerge when made explicit. Hegel, according to Skyttner (2005, pp. 49–50) formulated the following statements concerning the nature of systems.

- The whole is more than the sum of the parts [e.g., Bertalanffy's $p_1, p_2 \dots p_n$].
- The whole defines the nature of the parts.
- The parts cannot be understood by studying the whole.
- The parts are dynamically interrelated or interdependent.

Skyttner, moreover, offers a summary of properties of general systems for which he credits Bertalanffy, Litterer, and others (Skyttner, 2005, p. 53):

- Interrelationship and interdependence of objects and their attributes: unrelated and independent elements can never constitute a system.
- Holism: holistic properties not possible to detect by analysis should be possible to define in the system.
- Goal seeking: systemic interaction must result in some goal or final state to be reached or some equilibrium point being approached.
- Transformation process: all systems, if they are to attain their goal, must transform inputs into outputs. In living systems this transformation is mainly of a cyclical nature.
- Inputs and outputs: in a closed system the inputs are determined once and for all; in an open system additional inputs are admitted from its environment.
- Regulation: the interrelated objects constituting the system must be regulated in some fashion so that its goals can be realized. Regulation implies that necessary deviations will be detected and corrected.
- Hierarchy: systems are generally complex wholes made up of smaller subsystems. This nesting of systems within other systems is what is implied by hierarchy.
- Differentiation: in complex systems, specialized units perform specialized functions. This is a characteristic of all complex systems and may also be called specialization or division of labour.

- Equifinality and multifinality: open systems have equally valid alternative ways of attaining the same objectives from different initial conditions (convergence) or, from a given initial state, obtain different and mutually exclusive, objectives (divergence).

The ramifications in the preceding two lists can all be considered to be detailed restatements or elaborations of Bertalanffy's succinct definition of "system."

Worth emphasizing are systems science's three interrelated features that "the whole is more than the sum of the parts," "the parts are dynamically interrelated or interdependent," and "holistic properties not possible to detect by analysis should be possible to define in the system." These three features have ramifications that serve to distinguish, in two major ways, systems theorizing from positivist theorizing in information systems (IS) research.

The first major way in which systems theorizing is distinguished from positivist IS research is that systems theorizing breaks outside of the boxes-and-arrows depictions to which much positivist IS research is beholden. The latter typically operationalizes theories in the form of multivariate statistical models and visually presents them in the form of boxes-and-arrows diagrams; the boxes denote variables and the arrows denote causal relationships between them, where the arrows may point in only one direction between each pair of variables. Such diagrams are merely visual representations of mathematical equations, where each dependent variable is a box, each independent variable is a box, and an arrow is drawn from an independent variable to a dependent variable where there is a relationship between the two variables. In systems theorizing, however, what positivist IS research considers to be a dependent variable "Y," which is determined by independent variables such as "$X_1$" and "$X_2$," may also act, recursively, to determine "$X_1$" and "$X_2$." In fact, any specified system can acquire information about its own functioning and this can then contribute towards a change of its functioning. Indeed, in systems theory, the very ontology of an "independent" variable is paradoxical! In other words, the unidirectional relationships in positivist IS research gives way to bidirectional or recursive relationships in systems theorizing, which are more realistic but also too mathematically intractable to be incorporated into the multivariate statistical models (typically, regression models and structural equation modeling) used in positivist IS research. Indeed, the infeasibility of modeling, and the resulting absence of, bidirectional or recursive relationships throughout almost all positivist IS research precludes it from qualifying as truly systems research.

The classic form of the technology acceptance model (Davis, Bagozzi, & Warshaw, 1989) provides a good baseline to illustrate what would need to be changed for theorizing to be rendered into systems theorizing. We mention just four key points here. First, in order to collect data on the impacts that the different elements making up a system have on each other, which are impacts over time, the data collection would need to be longitudinal; on this measure alone, the cross-sectional approaches taken in many technology acceptance studies would simply fall short of systems theorizing. Positivist research may, in principle, also be longitudinal, but in the practice of statistical research in information systems, this is more often than not the exception. Second, each pairwise relationship in which one variable influences another (e.g., a person's perceived usefulness of a technology influencing the person's attitude towards using the technology) would also open up the need to examine any interactive effects, including reflexive effects and feedback effects (here, the same person's attitude towards using the technology influencing back the person's perceived usefulness of the technology), which, again, would require longitudinal observation. Third, the level of impact of one element on another (e.g., the effect size, or the numerical estimate of a coefficient of an independent variable's effect on a dependent variable) is not a constant, but can change over time as different elements influence one another. And fourth, each subsystem (represented in a technology acceptance model equation, such as $\text{BI} = \beta_0 + \beta_1 A + \beta_2 U$)[1] can itself change over time (e.g., linear relationships can become nonlinear, new variables can enter an equation, old variables can drop out, interactive or moderating variables can enter), so that the result is a dynamic technology acceptance model.

The second major way in which systems theorizing is distinguished from positivist IS research is that positivist IS research regards alternative ways of explaining the same phenomenon to be competing explanations or competing theories, of which at most one may survive as the right one, whereas systems theorizing (through its feature of equifinality) routinely accepts such alternatives as pathways carved out by different observers (in particular, different observing researchers) that lead to the same result, where typically more than just one of the pathways is regarded as feasible. This idea bypasses the problem-solution duality and focuses more on the description of systems as observer-designated connections between elements and their relations. Systems theorizing recognizes that if a problem "uniquely prescribed its solution, it would evoke its one and only (dis)solution" (Rossbach, 1993).

Reflecting the contrast between positivist IS research and systems theorizing is the difference between analyzing and synthesizing. *To analyze* is to break down an entity down into the parts that make it up, where the goal of the analysis is to understand each part. On the other hand, *to synthesize* is not to break down, but to build up and combine, where the goal of the synthesis is to understand the resulting whole. Positivist IS research is marked by analysis and systems theorizing is marked by synthesis.

Interpretive theorizing would, in principle, appear to be marked by synthesis, just as systems theorizing is. Consider that what Klein & Myers call "the fundamental principle of the hermeneutic circle" (Klein & Myers, 1999, pp. 71–73) explicitly recognizes that the whole (whether the whole of a text or a text analog) is greater than the sum of its parts. This is the recognition that the meaning of a text, as a whole, is not merely the sum total of the meanings of its individual words, but instead is synthesized, even variously by different observers, from the web of relationships among the words. On the other hand, there are few instances of information systems research where, apart from simply being mentioned, the principle of the hermeneutic circle is explicitly operationalized and applied (one instance is found in Sarker and Lee (2002)).

[1] BI is behavioral intention. *A* is attitude towards using the technology. *U* is perceived usefulness of the technology. Each $\beta_i$ is a constant.

However, while interpretive theorizing is closer to systems theorizing than positivism, we need to recognize differences within systems theorizing itself that may assist us further in reflecting on the relationship between interpretivism and systems theory. For example, "while systems thinking is generally associated with the functionalist school of thought, the general-systems group drew from both interpretive and pragmatist traditions" (Hammond, 2003, p. 24). Thus, general systems theory acquires a higher degree of conceptual abstraction and therefore rests above specific epistemologies (and as we point out later on, it is not necessarily incompatible with either the positivist or the interpretive tradition).

Another difference between interpretive theorizing and systems theorizing can be highlighted in the context of how the role of the observer is considered within them. Whereas there are clear parallels in both traditions that recognize the role of the observer, developments in systems theory (with second-order cybernetics) expose another dimension for the role of an observer. While in the interpretive tradition the observer is conceived of as an active agent in the construction and interpretation of meaning, systems theory (in the tradition of second-order cybernetics and Luhmann) sees the observer as a contingent construct itself that can be subsumed into another observation. This opens the possibility of "observing observers" and creates fascinating opportunities that can deepen the interpretive tradition and allow us to develop further observer-relative distinctions through which meaning can be interpreted. An example of this can be found in Luhmann's (2000) book *The Reality of Mass Media* where the role of the observer is observed itself.

## 3. Specifics of Luhmann's instance of systems science

Niklas Luhmann embraced and further developed the basics of systems science, particularly with regard to its application to society. Luhmann's work is complicated and challenging, but he provided the following diagram that usefully and clearly lays out his conceptualization of systems (Luhmann, 1990, p. 9; Moeller, 2006):

We approach this diagram as presenting Luhmann's ontology of systems, where we will devote the most attention to social systems. "Living systems" refer to biological entities. "Psychic systems" refer to the minds of human individuals.

"Social systems" are communication systems, where Luhmann does not define communication simply as human individuals exchanging messages with one another through language, but instead regards communication as a process involving "a unity of announcement (*Mitteilung*), information (*Information*), and understanding (*Verstehen*)" (Moeller, 2006, p. 22), where the translation from German to the English term "announcement" has also instead been "utterance" (Seidl, 2009, p. 28). Notice that this conception of communication recognizes that the understanding developed by a person who is listening (or reading a text) may diverge from what is intended by the person who is speaking (or has authored the text). This conception of communication also recognizes non-verbal communication through interactions as in, for example, first, the economic system, where the interaction (i.e. economic communication) involves the "satisfaction of needs" and the meaning (or what Luhmann calls the "code") is expressed through the unity of the distinction between "payment/non-payment"; second, the legal system, where communication involves the "regulation of conflicts" and the meaning or code is in terms of "legal/illegal"; and third, the political system, where communication involves the "practical application of collectively binding decisions" and the meaning or code is in terms of "government/opposition" (Moeller, 2006, p. 29). In this regard, "codes" are binary distinctions that encapsulate the identity of a core system in society and support communication across all of its subsystems. Furthermore, according to Luhmann's ontology, such core systems (labeled by Luhmann as "function systems") include the aforementioned economic system, legal system, and political system; these are all systems that have been differentiated in society on the basis of unique bottom-to-top inventions, and all of them are supported in their autopoietic re-production by the function of communication. Each is also a communication system.

"Organizations," as another form of social system, also conduct communication, but Luhmann specifically conceptualizes organizations as conducting the communication of decisions, and hence are "systems of decisions" (Moeller, 2006, p. 31).

"Interactions" are yet another form of social system, but are short-lived and "typically operate on a 'face-to-face' level and presuppose physical presence" (Moeller, 2006, p. 30).

Significantly and counter-intuitively, human individuals per se are not constituent parts of Luhmann's social systems. Rather, Luhmann locates actual human individuals in the environment of social systems — in particular, note the placement of "psychic systems" next to, and outside of, social systems in the diagram above. Seidl and Becker describe it in this way (Seidl & Becker, 2009, p. 29): "Luhmann clearly distinguishes between social systems and human beings (psychic systems): social systems reproduce themselves on the basis of communications, and psychic systems on the basis of thoughts. Both systems are operatively closed to each other and can merely cause mutual perturbations in each other."

Luhmann recognizes that human minds, as "psychic systems," can produce announcements/utterances, be the source of information, and develop understanding. Luhmann's systems theory is particularly relevant to those information-systems researchers who subscribe to interpretivism and social theory. First, with regard to interpretivism, Ramage and Shipp point out Luhmann's debt to Husserl (Ramage & Shipp, 2009, p. 13): "The work of the phenomenologist Edmund Husserl was crucial to Luhmann's work, especially the centrality he placed on the concept of meaning — our understanding and interpretation of ideas." Second, with regard to social theory, Luhmann's rendering of a social system with an existence beyond human individuals has its analogues in other social theories. Lee (2004, p. 9) has similarly conceptualized "social" as follows:

> [S]ocial theory is not so much about human individuals as it is about shared, socially constructed institutions that endure even when the individuals who are momentarily present are replaced by new ones. … The things that stay the same, or at least change at a much slower pace than the turnover of people, would be social objects that include the organization's culture, its social structure, its standard operating procedures, many of its business processes, its folklore and its norms for behaviour.

> In this alternative conceptualization, … social theory would more properly be about extra-individual entities such as culture and social structure than directly about individuals.

Lee's conception of the social as being extra-individual, which is a restatement of a foundational concept in sociology, aligns perfectly with Luhmann's conception of what a social system is. Key features of Luhmann's systems theory worth emphasizing are:

- *System/Environment*: For Luhmann, the environment is not a residual category (here system, there environment), but constitutive of the existence of the system. The two are structurally coupled and one cannot exist without the other. The distinction between system/environment (as a unit) is then replicated internally within the system: by way of what Luhmann calls "re-entry," the system copies the distinction into itself (where this is an example of "self-reference," described below). Significantly, from the perspective of any given system (such as the social system), its environment includes other systems with which it interacts.
- *Autopoiesis*: In seeking to describe the self-organizing re-creation of the cell, the biologist Humberto Maturana originally introduced the concept of autopoiesis as a replacement for the concept of circularity. He drew upon Aristotle's distinction between praxis (an actual event that includes its purpose in itself) and poiesis (that which produces something external to itself). Luhmann then generalized Maturana's conception of autopoiesis so that it could be useful for describing self-organization in social systems and other non-biological systems (Maturana & Varela, 1998). Some, but not all, systems exhibit the feature of autopoiesis. "The autopoietic system is one that produces itself. It is perhaps best understood in contrast to an allopoietic system, such as a factory, which takes in materials and uses them to produce something other than itself" (Buchanan, 2010).
- *Communication*: Although communication has already been mentioned, its centrality in the work of Luhmann calls for elaboration. Luhmann considers society as the only closed system, where it is closed by the function of communication. In Luhmann's ontology, human beings are outside of this closed system, which means that, as a result, they cannot communicate; this leads to Luhmann's locution that "only communication can communicate" (Luhmann, 2002, p. 169). This seemingly surprising locution (humans cannot communicate) is purely a definitional issue on Luhmann's part who reserves the term communication for the larger mechanism (utterance/information/understanding) that communication involves. The depiction of communication as autonomous "must be considered as Luhmann's own way of decentering the subject" (Seidl & Becker, 2006, p. 20). This limits the participatory role of people in the working of the mechanism and does not remove human beings from Luhmann's theory altogether (as illustrated previously in Fig. 1, Luhmann includes psychic systems). The significance of this must be stressed: in Luhmann's framework, "what we experience as our own mind operates as an isolated autopoietic system. There is no conscious link between one mind and another. There is no operational unity of more than one mind as a system, and whatever appears as a consensus is the construct of an observer, that is, his own achievement" (Luhmann, 1994, p. 372). Hence, humans may trigger the mechanism of communication, involving announcement/utterance, information, and understanding but Luhmann's definition highlights the asymmetry between communication itself and the cognitive entities that stimulate such communication.
- *Self-reference*: As a unique form of what Luhmann calls "re-entry," self-reference denotes the ability of systems to refer to themselves and their constituent components, as well as the ability to replicate the system/environment distinction internally. Social systems are capable of both self-reference and other-reference (relating and referring to their environment). There are various classifications for self-referential systems (e.g. neutral meaning, biological meaning, second-order cybernetics meaning). Luhmann subscribes to the last where an organization collects information about its own functioning and this in turn can contribute towards a change of its functioning (Geyer, 2002).

By weaving aspects from different strands of systems theory into a systems theory that specifically includes social systems, Luhmann can be said to have elevated systems theory as a tool for the description of complex problems, as well as to have consolidated systems theory. All of the features of systems theory described in the preceding section, "Some Basics of Systems Science in General," are inherited in Luhmann's systems theory.

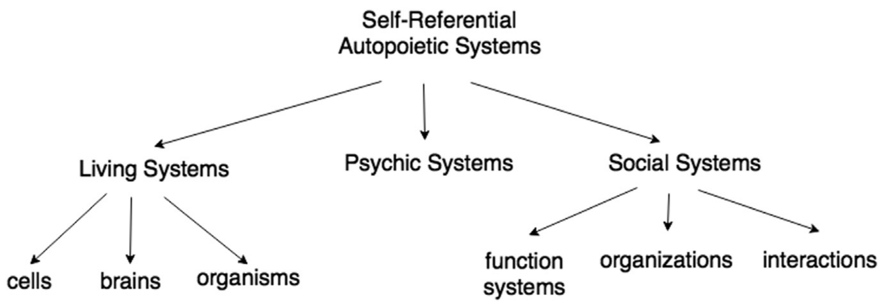


**Fig. 1.** Luhmann's conceptualization of systems.

## 4. A set of requirements for a systems theory to satisfy

Based on our preceding discussion of some basics of systems science in general and Luhmann's systems theory in particular, we offer the following as a set of requirements for a theory to satisfy in order to be considered a systems theory. Given the extensive diversity of systems approaches, the requirements we offer make up but one possible set, where the set is sufficient to be illustrative of systems theorizing. The set consists of three requirements from general systems theory and three requirements from Luhmann's systems theory, where we have selected the latter three so as to be compatible with the former three. In doing so, we also acknowledge that there are differences between systems traditions and that rendering different branches of systems theory through common systemic principles is beyond the scope of the present paper. However, we would like to point out that the requirements we have selected are at a higher-level of theoretical abstraction and largely cut across different systems approaches (e.g. the distinction between system/environment is fundamental to all systems approaches). Thus, we set out to derive three requirements from the earlier discussion on general systems theory (GST) and three requirements from the discussion on Luhmann's systems theory (LST).

### *4.1. GST: requirement to recognize that "the whole is more than the sum of the parts"*

Lee (2010, p. 341) formulates this requirement as follows: "To borrow an analogy from chemistry, the constituent parts of a system are like the reactive elements making up a compound, not the inert elements making up a mixture.…a system is greater than the mere concatenation of its constituent subsystems." A system (like a compound) comes to have properties different from the respective properties of the individual subsystems (or the individual elements) that have reacted to each other in forming it. $H_2O$ can be a liquid even when the H and O forming it are gases. An ERP can be a failure even when the components forming it (including the hardware, software, and networks) are each successful when tested individually.

One way to demonstrate that a systems theory satisfies this requirement is by showing that the same component, when in different combinations with different components with which it interacts, is theorized to manifest different properties. For instance, an ERP consisting of the same configuration of hardware, software, and data structures can be theorized to be a success in one company but a failure in another. The different business context establishes itself as a social *environment* to the technical *system* and in doing so triggers different structural couplings between the same configuration of hardware/software/data and its human-activity context. What we casually call an "information system" is therefore, in this light, an emergent phenomenon.

Another way to demonstrate this is by showing the existence of non-unidirectional relationships between components or variables. This can include bidirectional relationships between pairs of components (i.e., each component in the pair directly impacts the other component) as well as certain mediating relationships in which a variable has an impact on a chain of other variables which, in turn, ultimately has an impact on the original variable itself. The presence of such non-unidirectional relationships also effectively serves to demonstrate not only that the whole is more than the sum of the parts, but also that the parts cannot be understood by studying the whole alone and that the parts are dynamically interrelated or interdependent.

### *4.2. GST: requirement to recognize "goal seeking," which is that "systemic interaction must result in some goal or final state to be reached or some equilibrium point being approached"*

To demonstrate that a systems theory satisfies this requirement involves identifying what constitutes the system's goal, final state, or equilibrium. In biology, for a cell, this could be a homeostatic equilibrium. In economics, for a business firm, this could be the point where marginal cost is equal to average cost. For many systems, the goal could simply be survival.

Another way to demonstrate that a systems theory satisfies this requirement involves, first, identifying the system's components and the relationships among them and, second, showing how they have been structured or programmed so that their interactions overall strive to reach or achieve a goal, final state, or equilibrium. Of course, different observers could simply observe that the system is seeking different goals. In this regard, the requirement to recognize "goal seeking" does not refer to a fixed or deterministic role but to an observer-dependent condition. The role of the observer in this context is primary and supersedes all others. Whenever a property like "goal seeking" is perceived as an objective property of the system, the reader must always consider that objectivity is merely a "state where the observer has been abstracted away" (Angell & Demetis, 2010, p. 114). Luhmann prompts us to "re-introduce the observer" and always reflect on the idea that "whatever is observed is observed by an observer, who cuts up reality in a certain way in order to make it observable" (Luhmann, 1995, p. xxxiv).

### *4.3. GST: requirement to recognize the "transformation process" by which a system "must transform inputs into outputs" in order to attain its goal, and the accompanying "complexity" and "hierarchy" to which the demands of such processing can lead in the system's architecture*

Information systems scholars who have taught coding in one or another third-generation programming language (such as COBOL, C++, Java or PASCAL) are familiar with the "input-process-output" triumvirate, where data are inputted to the "computer program," where the programming steps serve to process the data, and where the results from the processing are then outputted from the program. This is not the general case, but an instantiation, of the transformation process found in any system, where what is inputted, processed or *transformed*, and outputted is not restricted to data. In this analogy, the components and relationships within the program/system can grow in *complexity* as the requirements imposed on what the processing is required to achieve also increases. As the complexity increases, it is addressed by the system's development/evolution/alteration into a set of subprograms/subsystems that, therefore, forms a *hierarchy* of systems and also that, through interactions among themselves, satisfy the requirements imposed on the system as a whole.

To demonstrate that a systems theory satisfies this requirement involves identifying what is being inputted to the system, what the system is transforming, what the system is outputting, and how the system is processing the input into the output.

### *4.4. LST: requirement to recognize "self-reference" and "autopoiesis"*

For a system to be self-referential involves the identification of processes or indeed any other mechanisms through which the system collects information about itself and its own functioning, where this in turn can contribute to a change in its functioning. For a system to be autopoietic involves how the system reproduces itself. In a sense, "self-reference" is the fuel that drives the autopoietic reproduction of systems; self-reference is a more general and abstract concept than that of autopoiesis. The following two additional LST requirements pertain to self-referential, autopoietic systems.

### *4.5. LST: requirement to recognize the "system/environment" distinction and its ramifications*

To satisfy this requirement involves accepting that the environment is not merely external to the system but also constitutive of the system, as well as considering how the environment and system are structurally coupled, how one cannot exist without the other, and how the distinction between the system and the environment is replicated within the system by "re-entry."

### *4.6. LST: requirement to recognize "communication"*

To satisfy this requirement involves showing examples of communication in the form of *announcement/utterance* (Mitteilung), *information* (Information), and *understanding* (Verstehen) where the examples can involve both verbal and nonverbal communication. The understanding held by the person or entity making the *announcement/utterance* (Mitteilung) need not match the *understanding* (Verstehen) developed by the other person or entity. This requirement also requires showing communication mechanisms or channels that exist apart from the human beings (i.e., the psychic system) that use them.

## 5. A set of requirements for a systems theory to satisfy: an illustration with Demetis' case study on anti-money laundering information systems

The study presented by Demetis (2010, p. 341), in which the role of information systems in monitoring Money Laundering (ML) is examined through the case of "Drosia Bank," can help us illustrate the points presented in the previous section. This brief analysis is no substitute for Demetis' own in-depth case study of IS complexity, but it provides a way for us to apply, for purposes of illustration, what systems science is. It is initially important, however, that we lay down the context and some critical terminology.

Financial institutions are compelled by both national and international legislation to monitor customers for potential ML behavior. Banks usually identify such suspicious behavior not only by manual means (e.g. detecting a customer's suspicious physical transaction in a bank branch), but also by using various information systems (in this case, a Case Management System or CMS, a Messaging/Communication System, and a Transaction Monitoring System or TMS). When a ML-alert is raised about a customer (either a technology-generated alert by the TMS or by a member of staff from the branch network of the bank), an analyst investigates the alert further and decides whether it indeed merits suspicion. This judgment is based upon a thorough review of a customer's financial position with the bank and aims at examining the customer's broader transacting behavior. If the customer is considered to be a suspect for ML by the analyst, then the case against the customer is escalated internally and the bank's Money Laundering Reporting Officer (MLRO) is called to make a final decision. The role of the MLRO is critical as he or she is the only authorized individual that sits at board-level and can submit a formal *Suspicious Activity Report* (SAR) to the national Financial Intelligence Unit (FIU) of the country. The FIU makes the final decision on whether to forward the SAR to the prosecution authorities (and the FIU can also request additional information from other local banks, insurance companies, tax-authorities, etc., in support of the investigation). Anti-Money Laundering (AML) investigations can become more complex when multiple jurisdictions are involved. With money launderers attempting to obfuscate the money trail deliberately, the success of the broader AML system has been very limited in securing convictions and recovering assets (Calderoni, 2015).

### *5.1. Requirement to recognize that the "whole is more than the sum of its parts"*

If the three different information systems that were examined in the Drosia Bank case are considered as distinct and independent subsystems (i.e., as "elements" in a "mixture") making up the AML-related IS-infrastructure, then it would not be possible to account for phenomena observed as emerging from the whole or "compound" system that the three individual systems constitute. By considering their interactions, we can appreciate the conditions that emerge when we view the three systems in relation to each other. In one example, suspicious cases are registered in the Case Management System of the AML team where they are assigned a unique code if they originate from a specific branch; this allows for the identification of the branch and the compiling of statistics at the regional level. This also allows one to observe how well the branch identifies possible ML. However, a limitation of the CMS is that it does not account for mergers of branches. Once, when the bank requested a software modification to account for this, the company to which the software development had been outsourced responded that they could not fix this issue without a complete redesign; the bank decided not to pursue this for cost reasons. The consequence was that, after a merger, *no-longer existing branches continued to exist virtually* (Demetis, 2010, pp. 72–73). This quirk in the CMS had an impact on other systems, including the transaction monitoring system (TMS), which then needed to be configured to accommodate "virtual transactions." In other words, the result was that the TMS's own operations then became transformed. Whereas members of staff from the obsolete branches had moved on and had become a part of the internal money laundering reporting structures of other branches, the TMS still attributed their activities to their original branches. Through this, the integrity of the compiled statistics was compromised.

Another example involves staff members in account openings for new customers. In this situation, branch employees would not always check for previous accounts of customers and would assign an *additional* "*unique*" *identification number* for already existing customers. As a result, when a customer was flagged for potential ML by the TMS based on transactions they would be conducting under one Unique ID (e.g. by using a debit card issued under that Unique ID), the suspicious case for that customer was registered in the CMS with the reported Unique ID number on file. But with customers having multiple "Unique IDs" due to human errors from branch-level staff, the investigative process became compromised. ML analysts were complaining that they had no confidence in extracting a customer's overall financial position as they would have to consolidate all transactions corresponding to *all the* "*Unique IDs*" for a single suspect. On a number of occasions, as the usefulness of the Unique-ID system was jeopardized, the AML team was forced to resort to another information system that established communication between the AML group and all the branches of the bank. The AML team would then request all branches to check and verify whether they had accounts in the names of specific suspects. In a limited number of occasions, the customers that were under investigation were tipped off and withdrew all the funds from their accounts.

In both of the above examples, information dependencies required for automated transaction monitoring were compromised. This illustrates the general idea that different information *systems* can "feed off each other." An "isolated" problem in one subsystem becomes an element in a complex nexus of relationships. The collective or "compound" information system, which emerges from these interactions, is furthermore inextricably bound with the social context in which it is embedded. Through the structural couplings of one information system with another, the collective information system represents a "whole that is more than the sum of its parts," in the sense that the "whole" places demands on its subsystems that may result in emergent problems at the level of the whole, but also opportunities that may emerge from the expanding variety of interconnections made possible.

### *5.2. Requirement to recognize "goal seeking"*

In the context of Drosia Bank, if we consider the overall system to be the AML group of the bank, then its goal would be the *identification of suspicious behavior relating to ML*. In order for the system to accomplish this goal (and avoid financial fines and reputational risk), the AML group strove to balance the subsystemic goals that converged into its higher-level (or systems-level) goal-seeking identity. A sample of such subsystemic goals involves, among others: (1) optimizing the capacity of manual ML-analysts to examine individual cases and (2) improving the SQL queries that filter transaction data in order to flag suspicious transactions. In the case of Drosia Bank, 2000 alerts were generated by the software every day, while the ML-analysts only had the capacity to investigate 100 of these alerts manually.

Even though the bank hired more personnel to cope with the volume of technology-generated suspicious alerts and nearly doubled its staff, ML-analysts could only scrutinize approximately 200 cases per day. Despite this increase, the real number of suspicious cases remained very low and only 10 cases per month were deemed to be really worthy of escalation (from a total of 60,000 alerts generated by the software). This brought the True Positive Rate (TPR) of the transaction monitoring system to 0.017%, which was a very disappointing result. With the bank not being able to hire more staff, gradual improvement of this percentage (which increased to about 1–2% for the technology-generated alerts only) reached an equilibrium: the bank continued to experiment with algorithms to detect suspicious behavior and applied a risk-filter that would prioritize the 2000 daily alerts (and allow ML-analysts to focus on the top 200 riskier cases they could handle per day).

This "goal-seeking" optimization was also informed by the bank's participation in an extranet-based forum controlled by the vendor of the TMS; all the banks (globally) that had bought the same TMS would exchange views, techniques and ML typologies for optimization. As Drosia Bank found that the vast majority of banks reported similar – disappointing – TPR percentages, it did not intensify its efforts in further goal-seeking towards TPR-optimization. Of course, changes in the environment (e.g. legislative requirements and FIU demands or new modeling techniques) might prompt the bank to pursue further changes, leading to yet another (dynamic) equilibrium point. Hence, "goal seeking" is a dynamic process that emerges out of the structural coupling of any system with its environment and does not always indicate convergence into a singular goal. If we apply the system/environment distinction internally to any given system then "goal seeking" can also be viewed as a process of internal negotiation within an organizational subsystem (as described above for the AML department of Drosia Bank) and can also incorporate conflicting "goal seeking" perspectives (e.g. how regulatory expectations for continuing improvement in targeting ML might diverge from the bank's decisions to adjust ML profiling based on internal restrictions).

### *5.3. Requirement to recognize the "transformation process" by which a system "must transform inputs into outputs" in order to attain its goal*

In the case of any bank that seeks to optimize the identification of ML suspects, the transformation process can be described in the following sequence: *inputs* come in the form of raw financial transaction data (generated by customers or other parties as they transact with the bank); the *process* occupying the logical space between inputs and outputs is the fundamental identity of the transformation process — in the case of Drosia Bank, it consisted of algorithmic models (e.g., SQL queries) that encapsulated the abstractions of suspicious behavior and were applied to input in the form of raw transaction data, where this included sanction list data (e.g. issued by the EU or the US government) along with names of suspects (mostly terrorist and politically exposed persons) that needed to be checked (Demetis, 2010, pp. 94–95), and general rules that attempted to categorize and spot money laundering behavior; and finally, the application of such algorithmic models to the raw transaction data result in the *outputs* — identification of the potential *suspects for money laundering* that then needed to be checked thoroughly by ML-analysts so that the suspicions could be substantiated.

Of course, we need to recognize that this process is dependent on how the *system* is identified and designated by an *observer*. As any definition of a system is observer-relative, a different observer could identify the whole bank as the system (instead of the AML department in this paragraph). In that case the input would be everything that is described above and the relevant output would be the communication act of SARs to the FIU. Changing observer perspectives not only recognizes that *whatever observed reality we may distill* in the concept of the *system* can be carved out differently (as far as ontology is concerned), but also carries practical significance for the transformation of input into output, by recognizing the transcendence of this process from one identified system to the other. In our case and at the level of the AML department, the transformation process is guided by algorithms that encapsulate ML behavior and transform *raw transactions* into *suspected transactions*. If we switch perspective to the level of the entire bank then the transformation process converts raw transactions into SARs.

### *5.4 & 5.5. Requirements to recognize "self-reference," "autopoiesis" and the "system/environment" distinction*

Where we consider the system to be the bank's AML department, the system/environment distinction manifests itself in two ways. First, there is an internal environment (internal relative to the boundary of the institution of the bank; this would include all other departments *within the bank* excluding AML). Second, there is an external environment that includes everything besides the bank (every other institution in the financial sector, the FIU, the Central Bank, etc.). This means that the primary distinction between system/environment can be replicated both internally and externally. This may appear to complicate matters but the focus remains that the start of systems theoretical analysis is the recognition of the primary distinction between system/environment. It is this fundamental distinction between system/environment that enables a system to acquire self-reference. In turn, self-reference becomes the first expression of *autopoiesis* — with the system organizing itself so that it can (re)create and sustain its own elements and relations. For example, the autopoietic expression of the AML department of Drosia Bank would be based on (re)producing suspicious transactions that may be recognized as money laundering. If the AML department ceases to perform this function, it may threaten the viability of the bank (as the regulator may suspend or revoke the bank's license, or even levy a financial fine like in the case of HSBC that received a $1.8 bn penalty for non-compliance). Thus, the AML department requires raw transactions and behavioral ML-patterns as input so that it can continue to produce *suspicious transactions* (and maintain its *raison d'être*), much like a biological organism requires energy to maintain its existence and remain alive. The AML department maintains and re-establishes itself through that process while the general/abstract concept that describes the reflexive character of such autopoietic reproduction is the concept of *self-reference*: the system refers to itself and its processes in a reflexive way and re-arranges their interconnections (based on internal/external feedback) so that these can continue to maintain the system and its processes.

Every autopoietic system is self-referential and self-reference is the mechanism through which the autopoiesis of a system can be maintained. Even though there are various definitions of self-reference, it is important to re-state that LST is closer to the 2nd-order cybernetics tradition: this implies that the system "collects information about its own functioning, that in turn — can contribute towards a change of its functioning." (Geyer, 2002, p. 1022). In this context, all the subsystems of an autopoietic system contribute to its autopoietic reproduction and fuel its self-reference. In the context of the AML department, there were various ways in which it collected information about (and for) itself. One way involved the "exploitation" of other subsystems within the system of the bank; these subsystems would be perceived by the AML department as environments within the system itself: for example, the AML department would request data from the marketing department in order to use these in the process of profiling ML activities. Another way that the AML department would seek to use information for itself would be through re-purposing information requests that it received from the external environment of the bank — for example, the AML department would carefully reflect on any requests from prosecution authorities and it would seek to glean financial intelligence from them for the purpose of improving its own profiling techniques; it would adjust its SARs reporting processes and change its own functioning after the FIU would reflect on the quality of submitted reports; and it would further attempt to enhance its capacity for analysis and change its profiling algorithms in the face of not only industry feedback, but also online forums where companies that have bought the same ML transaction monitoring software would reflect on its use/improvements/features. Through all of these activities, the AML department would exercise the self-referential character of its operations and support the self-reference of the organization.

### *5.6. Requirement to recognize "communication"*

It is unavoidable that any analysis of the concept of communication will entail paradoxes since all knowledge is founded on a paradox (Angell & Demetis, 2010); also, in the case of communication, a deconstruction may feel strongly coerced as it is usually portrayed at a highly abstract level. Still, the analysis of communication in the form of *announcement/utterance* (Mitteilung), *information* (Information), and *understanding* (Verstehen) is helpful in reflecting on the transformational ontology of whatever is being communicated within a system (or between system/environment). In the case of Drosia Bank, we can take a single financial transaction as an example and consider it as an *announcement* that is initiated by a customer of the bank. This (and every other) announcement contains a variety of further "information elements" that are contingent upon the database structure of the bank (we can think of an organization here as inviting interactions/transactions from its environment). In turn, the transactions initiated by the bank's customers are accompanied by a multitude of information elements that are triggered in each case.

In the context of transacting data, some examples would include: *the value of transaction*, *the method of transaction* (e.g. *ATM*, *bank branch*, *e-banking*), *the location*, *the transacting code* (e.g. *cash*, *card*, etc.), and *about thirty more such elements for every single transaction.* From the utterance, then, of a single financial transaction, which encapsulates all of the above elements, *Information* emerges as the sub-systemic selection of utterance-elements that are relevant for a specific purpose. For instance, the AML department in the bank (as a subsystem of the Drosia Bank system) isolated certain elements that were more relevant for profiling money laundering transactions (e.g. value, location) while it ignored others.

In this process, the AML department could include more *Information* from both different "utterance" occurrences shared by other systems in the environment of the bank (e.g. a tax authority sharing tax statements) and previous unselected utterance-elements from within the bank. *Understanding* then implies a dynamic feedback loop between an observer's cognition and information, similar to what John Dewey has described as a "double movement of reflection" (Dewey, 1933). In this context, *Understanding* becomes a cognitive assessment of *Information* (e.g. by ML-analysts) and the latter's connection with the subsystems' goal-seeking identity. *Understanding*, then, for the AML department, implies an assessment of whether the selected utterance-elements (that its own subsystem perceives as *Information*) could be considered as truly suspicious for ML. Only then would the MLRO engage with the communication-system of "submitting SARs" in order to escalate the suspicion to the FIU. In such an event, the FIU would be forced to consider the MLRO's filed SARs as another *announcement*/*utterance* — the starting point of further communication. We use the expression, "starting point" to indicate a change in the stakeholders participating in communication. A closer approximation *for the concept of communication* would not describe communication as a sequence of distinct entities but as a dynamic and adaptable stream through which different interconnecting elements of a system negotiated (in a self-referential manner) their own interconnections and enabled/disabled information couplings with other elements in their environment. In this context, Luhmann's counterintuitive declaration that it is "only communication that communicates" implies that the structural skeleton of communication that includes the *utterance*, *information* and *understanding* triad (as analyzed above), remains independent of human beings. Of course, different human beings will enable different individual interpretations as distinct cognitive observers but these remain instances of the general system of communication.

## 6. Discussion and conclusion

As mentioned earlier, systems science is not so much an empirical science about phenomena in nature or society as it is an approach that empirical sciences (including IS research) can incorporate. The creation of systems theory itself has involved, among other things, a gradual evolutionary process of incorporating concepts from a multiplicity of scientific fields into a highly abstract lexicon; this convergence towards theoretical abstraction has been a long and bottom-to-top process of synthesis. The goal that systems theory itself has been seeking has been one of reaching the highest levels of abstraction possible. Of course, this was not for the mere sake of abstraction itself, but a reflection of the need to tackle phenomena of greater complexity (e.g. social phenomena).

Furthermore, the benefits that systems theory can provide to the field of information systems are not only restricted to a theoretical level but extend to a practical one as well, particularly when it comes to academia-industry interactions. Systems theory can facilitate communication between academia and industry that is far better than what structuration theory – to bring up just one example – could achieve. The success of Soft Systems Methodology (attributed mainly to Checkland and Scholes (1990) is a testament to the possibility of delivering industry relevance through systems concepts. A reason that systems theory can bring additional value for interactions between academics and practitioners pertains to the following: as the development of systems theory was fuelled by many different disciplines in order to assist the synthesis that it promised, its lexicon evolved to include such inter-disciplinarity. As a result, systems theory can be more easily understood by different fields as it transcends physics, chemistry, computer science, biology, sociology, politics, art, economics, and other disciplines. By lending itself to being stated in lay terms more readily than do other theoretical approaches, systems theory can be communicated back to IS practitioners. That is of particular significance for the IS community within which individuals with different scientific backgrounds find their home for research and/or practice.

Also, in the context of the case discussed in this paper, different aspects of the rich details and reasoning offered by the preceding Drosia Bank illustration can be incorporated in a positivist theory, an interpretive theory, and a design theory. A positivist theory would, however, need to allow the modeling of bidirectional and recursive relationships between variables. This would constitute a bold move for positivist IS research, as it would recognize that an "independent variable" in an IS context is a paradox and that variables cannot be examined as distinct and isolated entities. Hence, some recognition (and integration) of the reflexive interdependencies between variables would be a step forward.

An interpretive theory would need to attend to the differences made by subjective meanings or *verstehen* and recognize that one can take different observing perspectives of different individuals in the organization or any other field setting. Perhaps the most fascinating thread for this is in "observing observers," thereby conducting second-order observations that can allow for more elaborate (and insightful) deconstructions of IS situations. For a clear application of this, the reader is encouraged to look further into Luhmann's (2000) work on *The Reality of the Mass Media*.

Also, a design theory would be required, by the web of relationships among subsystems that are the sine qua non of systems science, to account for the impacts of IT artifacts on social artifacts and other artifacts, for the impacts of the social and other artifacts on the IT artifacts, and all the subsequent second-order, third-order, etc., impacts of these artifacts on each other. The forgoing is at the level of GST. If Luhmann's systems theory or LST is additionally followed, then the positivist, interpretive, or design theory could additionally apply Luhmann-defined concepts and systems insights. A researcher, of course, could choose to follow instead the concepts of another specific systems thinker, such as Checkland (2000) or Alter (2013), or indeed draw from a selected pool of systems concepts that would provide a theoretical platform for reflecting on specific phenomena. We emphasize that what we provide in this paper is not a universal set of systems criteria but just one possible set out of many.

We view the requirements of systems science as not constraining, but liberating the academic discipline of information systems, where systems concepts offer new or additional ways by which IS research can expand its ways of theorizing. Not only would the discipline then truly deserve its name of information *systems*, but it could also offer better theories with which to interpret, explain, and even design information systems.

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