RAPDtT: HOMOMORFISMO OPERACIONAL PARA CAJAS NEGRAS

RAPDtT: OPERATIONAL HOMOMORPHISM FOR BLACK-BOX SYSTEMS

[1]Julio César González Silva,
[2]Raúl Fabián Roldán Nariño

Pontificia Universidad Javeriana

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Resumen

Este estudio muestra cómo el modelo RAPDtT —basado en Recepción (R), Almacenamiento/Buffer (A), Procesamiento (P), Despacho (D) y vectores de transporte internos y externos (t, T)— funciona como un homomorfismo operacional mínimo y suficiente para abrir y formalizar la tradicional caja negra. A partir del registro de entradas y salidas, planteamos la equivalencia operacional Φ(Input) ~== -t-> R -t-> A -t-> P -t-> D -t-> (input). Más que una identidad matemática exacta, esta relación hace explícita la estructura de la función de transferencia del sistema. De este modo, logramos formalizar su arquitectura interna con límites claros, trazabilidad y cierre operacional, lo que facilita el control homeostático mediante retroalimentación negativa.

La minimalidad del modelo se puso a prueba mediante la navaja de Ockham: si se elimina un solo componente, la representación pierde validez frente a los requerimientos del sistema. Al integrar la ontología sistémica de Mario Bunge y la teoría de sistemas dinámicos de W. Ross Ashby, planteamos RAPDtT como una arquitectura estándar provisional para analizar, diseñar y auditar procesos físico-informacionales en sistemas de flujo acotado.

Palabras clave: RAPDtT; caja negra; caja blanca; arquitectura estructural; cibernética de primer orden; logística; trazabilidad.

[1] M.Sc. in Engineering, Universidad Nacional Abierta y a Distancia(UNAD)
ORCID: 0000-0002-3514-1511 / Email: jcgonzalezs0864@gmail.com

[2] Ph.D. in Engineering, Pontificia Universidad Javeriana / ORCID: 0000-0001-6315-999X /
Email: rroldan@javeriana.edu.co

Abstract

This study shows how the RAPDtT model, based on Reception (R), Storage/Buffer (A), Processing (P), Dispatch (D), and internal and external transport vectors (t, T), functions as a minimal and sufficient operational homomorphism for opening and formalizing the traditional black box. Using input and output records, we propose the operational equivalence Φ(Input) ~ == -t-> R -t-> A -t-> P -t-> D -t-> (input). Rather than representing a strict mathematical identity, this relationship makes the structure of the system's transfer function explicit. In doing so, we formalize its internal architecture with clear boundaries, traceability, and operational closure, thereby facilitating homeostatic control through negative feedback.

The minimality of the model was tested using Ockham's razor: removing a single component invalidates the representation under the established requirements. By integrating Mario Bunge's systemic ontology and W. Ross Ashby's dynamic systems theory, we position RAPDtT as a provisional standard architecture for analyzing, designing, and auditing physical-informational processes in bounded-flow systems.

Keywords: *RAPDtT; black box; white box; structural architecture; first-order cybernetics; logistics; traceability.*

Introduction

The notion of a black box, initially developed in electrical engineering and later formalized in cybernetics, has enabled the understanding of complex systems based solely on the observation of their inputs and outputs, without the need to access their internal structure.

Wiener [1] describes the black box as a device that transforms an input signal through an unknown operation Φ to generate an observable response. Ashby [2] extends this idea by noting that multiple internal mechanisms can produce equivalent external behaviors, which is why rigorous observation of the protocol—the chronological sequence of inputs and outputs—constitutes the only legitimate means of inferring regularities.

From a historical perspective, Mindell [3] shows that the black box emerged as a technical solution at Bell Laboratories, where the abstraction of devices in terms of signals made it possible to separate communication, control, and physical mechanisms, giving rise to the language that underpins first-order cybernetics as proposed by Wiener and his colleagues [1].

Within this context, the RAPDtT model is introduced. Initially developed to describe logistics flows, it was later consolidated as an ontological and operational architecture capable of representing any physical or informational flow through six universal operations: Reception (R), Storage/Buffer (A), Processing (P), Dispatch (D), internal transport (t), and external transport (T). Its minimal sequence T-t-R-t-A-t-P-t-D-t-T constitutes a linear causal structure that enables traceability, operational closure, flow continuity, and control through negative feedback, thus fulfilling the principles of first-order cybernetics.

Based on this understanding and drawing on the concepts proposed by Bunge [4], we ultimately advance a canonical definition of RAPDtT following his methodology, which holds that defining a system with scientific and philosophical rigor requires more than mere description; it must be decomposed into its ontological triad of Composition (C), Environment (E), and Structure (S) [4, pp. 30–34].

This work demonstrates that RAPDtT is not merely a descriptive model but a functional structure that opens the black box and explicitly defines its internal architecture through the transfer function Φ, rendering it analogous to a white box. An equivalence is established between the abstract internal apparatus of the black box and the sequential composition of RAPDtT, showing that:

$$\Phi(Input) \sim == -t-> R - t-> A-> t-> P - t-> D - t-> \sim = \\ = (Output) \qquad (1)$$

where the symbols at the endpoints represent the external flow couplings connecting the transfer function to its surrounding environment at both the input and output stages, and ~== denotes a descriptive signal.

This work maintains that RAPDtT is not merely a descriptive model, but a functional structure that enables the black box to be opened and its internal architecture to be made explicit through the transfer function Φ.

Background and related work

The Black Box

A black box is a system whose internal mechanisms remain unknown, inaccessible, or unanalyzed [1], [3], leaving only its inputs and outputs available for observation. Under this framework, the system is modeled using a mapping function Φ, which transforms present and past inputs into an observable response [2], [3], formalized as:

$$Output = \Phi(input) \qquad (2)$$

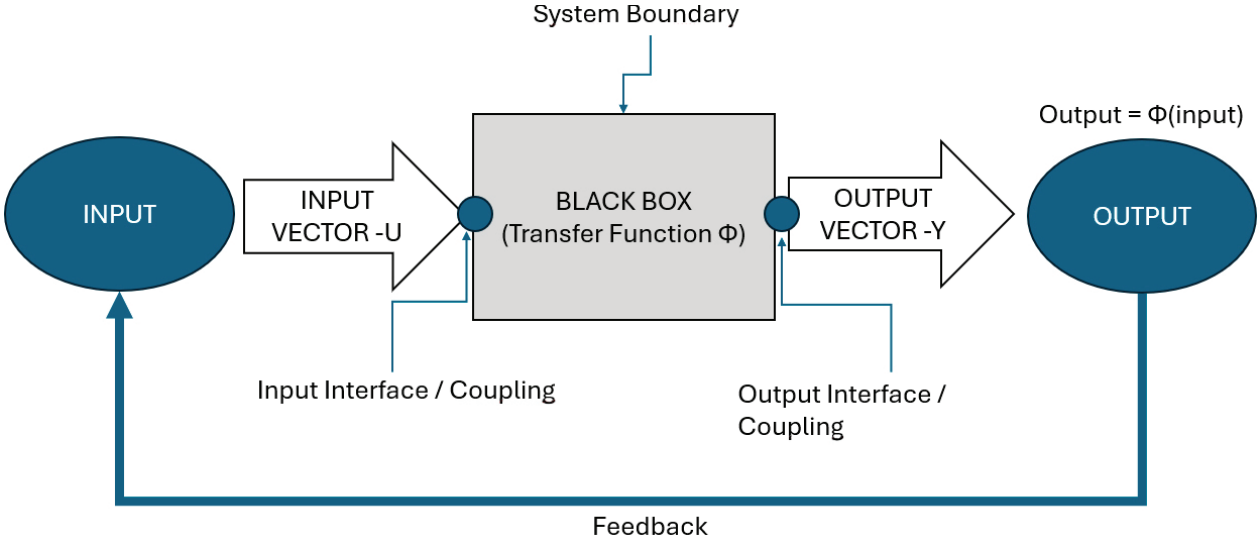
Since the internal mechanisms of a black box cannot be observed, all information is obtained through a protocol, that is, the chronological record of input and output states. Mathematically, this implies that when the system is treated as a black box, Φ is an unknown function.

Ashby notes that the same external behavior—that is, what the box does—can be produced by infinitely many different internal mechanisms.

For Wiener [1], a black box is a device, such as an electrical network with input and output terminals, that performs a specific operation on an input signal to produce a response. The key point for Wiener is that the observer has no information about the internal structure or the components that perform the transformation.

The structure of a system treated as a black box is shown in Fig. 1.

Figure 1. Black-box representation of a system



Source: own elaboration.

Note. The representation identifies the inputs and outputs, the inflow and outflow vectors, the system boundaries, and, under the conditions governing the box, the transfer function that relates input to output through internal processing, represented by the function Φ.

Ashby [2] demonstrated that highly complex systems can be controlled and understood without inspecting their internal structure, provided that their input-output relationships are systematically decoded. Under this cybernetic framework, a complex system is studied as a black box by chronologically logging inputs and outputs to reveal operational regularities.

This protocol yields a behavioral model rather than a structural representation, as distinct internal configurations can produce identical output behaviors, a principle known as homomorphism. Consequently, "memory" is not treated as a physically verifiable property but rather as an artifact of the system's incomplete observability.

Accordingly, understanding and managing real systems involves decoding the transition logic between states by analyzing the system as a black box and observing its responses, without the need to know its internal workings.

The White Box

Wiener [1, p. xli] identifies the white box as the counterpart of the black box, defining it as a system with a known structure designed according to a specific plan to ensure a predetermined relationship between input and output. Unlike a black box, a white box has fully known component interconnections and laws governing its internal operation, enabling observation, description, and control based on the information available for auditing.

Wiener proposes that "white boxes," that is, structures with known configurations representing terms in a mathematical expansion, can be used to model or emulate a black box.

The RAPDtT Model

The RAPDtT model is an operational reference model originally developed by González Silva and Vásquez Bernal as a method for the operational management of logistics flows and processes. It is defined as a logical and sequential arrangement of six basic operations that describe the movement of materials and information: Reception (R), Storage/Buffer (A), Processing (P), Dispatch (D), Internal Transport (t), and External Transport (T).

Its origin lies in the observation of logistics processes, in which González Silva identified the repetitive and orderly sequence of activities that determined the operational characteristics of the processes studied.

Subsequently, building on prior developments, it evolved into a model capable of providing descriptive, sequential, and recursive representations of physical and informational flows, regardless of the context in which they occur [5], [6].

The ontological structure of RAPDtT is defined as a universal and recursive operational architecture that describes the logical sequence of any logistics flow, which must occur in a specific order to maintain traceability. This structure is based on six basic operations: Reception (R), Storage/Buffer (A), Processing (P), Dispatch/Direction (D), Internal Transport (t), and External Transport (T) [5]. Without these basic operations, no formal interconnection between processes would exist, nor could physical and informational flows be maintained [7], [8].

Its essence rests on the following pillars:

Operational Homomorphism: functions as an operational "seed" capable of representing, using the same language, anything from a micro-level task, such as one performed by a machine, to a macrosystem, such as an entire value network [6]. The RAPDtT structure maintains the same form and functional laws regardless of scale, making the model a valid representation of reality.

Flow Determinism: generates a logical sequence of activities that provides makes information flows observable and describable, as specifically studied by González Silva and Vásquez Bernal in the field of manufacturing [9].

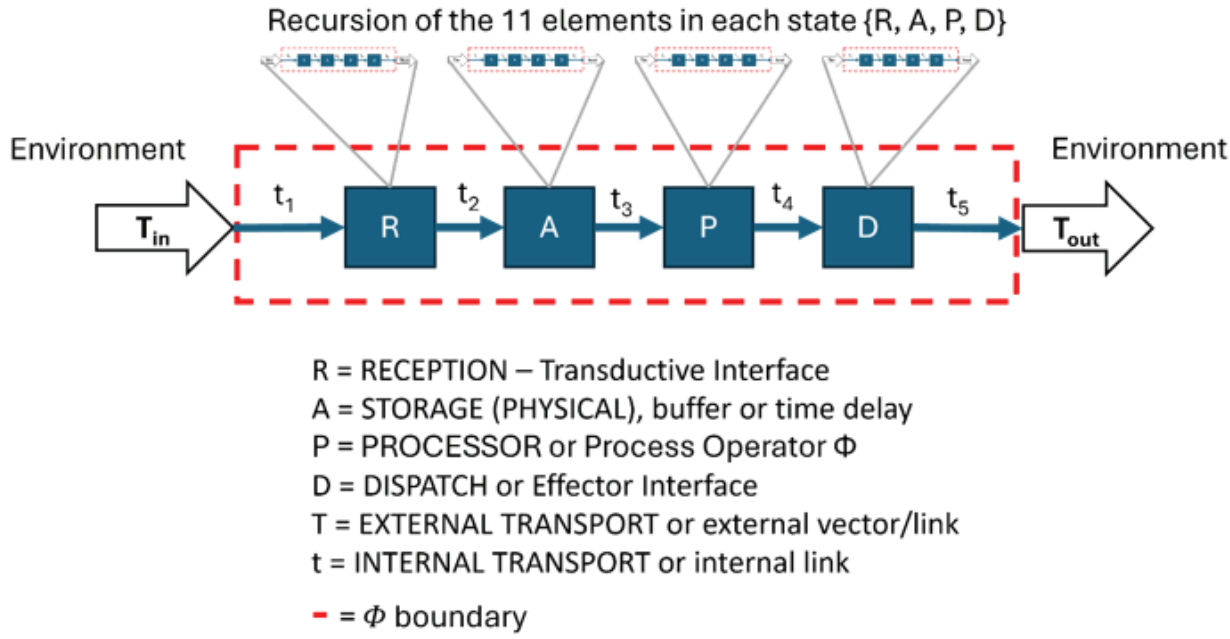
Operational Closure: standardizes the physical handling of materials and the corresponding information flows, enabling tracking and operational control at any organizational scale [7].

Systemic Homeostasis: consistent with first-order cybernetics, its structure enables the establishment of control and negative feedback mechanisms to maintain system balance in the presence of disturbances [6].

Within a first-order cybernetic framework, RAPDtT outlines the following logical sequence,

using transport operations as flow vectors. As shown in Fig. 2, the diagram represents the recursive structure of the model, including its input and output interfaces and the Φ boundary:

Figure 2. Simplified diagram of the RAPDtT model



Source: own elaboration.

Note. The diagram is based on González Silva's RAPDtT model and shows the recursive organization of its operations [5], including the input and output elements and the Φ boundary.

Bunge's Ontological Triad and Complementary Concepts for the Framework

Bunge [4] proposes that every system can be characterized by the triad of Composition (C), Environment (E), and Structure (S). Composition (C) consists of the real entities or components with properties that are part of the system. Environment (E) is defined as everything that is not part of the system but interacts with it. For Bunge, the environment is the set of things that act upon the system or upon which the system acts. Finally, Structure (S) is the set of relationships and links (mechanisms) that hold the components together.

Bunge complements this triad with essential concepts: Systemism [4, p. 70], which views every system as a nested hierarchy of subsystems; Emergentist Materialism [4, p. 176], which holds that function arises from the specific connectivity of components rather than from mystical properties; and Observer Independence [4, p. 208], which maintains that systems and their structures exist regardless of external observation, a principle fundamental to referential architectures.

Additionally, a historical approach supports the claim that the RAPDtT model can account for legacy technical and logistical systems, such as Bowersox's pipeline, machine flow descriptions, or office workflows, including those that predate the model's formalization. This reconstructive capability provides empirical evidence for its ontological definitions, demonstrating that its structure is homomorphic to the actual operation of diverse systems. This reaffirms its validity as a general architecture for transformable systems in which flow is constrained by boundaries and observable traceability.

To connect these ontological structures with operational control, we must consider the evolution of the "black box." Mindell [3] explains that this concept emerged in electrical engineering to describe sealed devices analyzed solely through their inputs and outputs.

Within this technical context, Harold Stephen Black's work on negative feedback in 1927 [3] transformed passive systems into active machines by separating the message from the physical medium. Initially developed as a specific solution for stability, feedback was later generalized during World War II by Nyquist and Bode [2], giving rise to the signal language that underpins cybernetics. Thus, the black box is not merely a theoretical abstraction but the result of a technical evolution at Bell Laboratories that enabled the representation of the world through a common language of signals [3, p. 434].

Validation in Regulated Sectors

The RAPDtT model is grounded in both conceptual formulation and an empirically documented trajectory. Its comparison with the classical logistics pipeline [9] and its use as a macro-micro analytical framework corroborate the stability of the RAPD sequence articulated by the transport vectors t/T.

Its applicability to small enterprises [7] demonstrates its capacity to represent operational environments with low levels of formalization while maintaining flow traceability. This is further reinforced by its application in highly regulated sectors, such as green logistics for bioethanol in Colombia [10]. In that context, RAPDtT was used to structure critical points in supply and production in accordance with environmental regulations and HACCP principles.

Collectively, these precedents provide sufficient historical and empirical support to assert that RAPDtT functions as a referential and recursive flow architecture that can be articulated with the black-box approach and the function Φ as an explicit structural identity. Additionally, RAPDtT was successfully applied in a case study at Pisende S.A.S. [11] in Medellín, Colombia, where the model served as a diagnostic tool for identifying the processes and tasks responsible for Pareto-critical ceramic breakage during the distribution process.

Occam's Razor

The principle of parsimony, or Occam's Razor, proposed by the philosopher William of Ockham [12], serves as a foundational postulate in the configuration of robust structures. This principle states that "entities should not be multiplied beyond necessity" [13], establishing a mandate of intellectual economy that prioritizes simplicity and efficiency in establishing technical validity.

Under this principle, the minimality of an architecture ceases to be an aesthetic choice and becomes part of its ontological essence; a structure is truly powerful not when there is nothing more to add, but when nothing can be removed without compromising its existence. This pursuit of irreducibility is what guarantees the validity of a model in the face of environmental complexity.

Results

RAPDtT and Its Formalization as a Coherent Ontological Body

The sequence depicted in Fig. 2 identifies the Φ boundary but does not explicitly delimit the system boundary required to formalize the processing apparatus that converts input into output. Under this condition, the model's symmetry and operational closure must be reviewed and rigorously evaluated to verify its status as a system descriptor while ensuring compliance with the criteria established by first-order cybernetics. The following section is proposed to fulfill these objectives:

Justification of Symmetry and Operational Closure in the RAPDtT Model

The structure of the model exhibits functional symmetry, beginning and ending with the external transport vector (T) as the interface with the environment, while internal transport (t) acts as the "connecting glue" between states. This architectural choice reflects two fundamental principles of systems engineering:

Transport as a Structural Coupling Vector: in systems theory [1], [2] and logistics process management [14], transport is understood as the mechanism that connects subsystems by moving materials, information,

or energy from one point to another. Therefore, flow cannot originate spontaneously within Reception (R) or terminate within Dispatch (D). By placing a "t" before Reception and after Dispatch, the model ensures the existence of a transmission medium connecting the system boundary with the environment. Without these terminal "t" vectors, the system would become an isolated island, unable to synchronize with external transport (T).

State Continuity (Uninterrupted Flow): in systems theory, state continuity is based on the existence of uninterrupted flows of matter, energy, or information that maintain structural coherence and functional stability. Bertalanffy [15] considered this principle from the outset to ensure that the system preserves its homeostasis, in accordance with first-order cybernetics, through continuous exchanges with the environment.

These considerations establish the criteria for continuous transmission within the model, conditions that inherently support the proposal of RAPDtT as a system descriptor. Therefore, the model must be recognized as a homomorphism suited to this task.

RAPDtT and Systemic Homomorphism with Bunge's Triad (<C, E, S>)

As part of the preceding proposal, RAPDtT is examined by decomposing its structure in terms of Bunge's three pillars: C, E, and S:

Composition (C): defines the entities or components of the system. In RAPDtT, the enabling functions are R, A, P, and D. Bunge requires these components to be real, that is, entities with properties, and in this context, these functions are defined as "ontologically invariant functional stages of the flow."

Environment (E): defines what is not part of the system but interacts with it. Here, the external vectors T are located. For Bunge, the environment comprises all things that act upon the system's components or upon which the components act.

Structure (S): for Bunge, structure is the set of relationships and links (mechanisms) that hold the components together. In RAPDtT, this is represented by the internal vectors t and the invariant, non-commutative sequence T · t · R ·t · A · t · P · t · D · t · T.

In this way, RAPDtT satisfies Bunge's triad, thereby meeting the structural requirements for positing a systemic homomorphism. This validates its necessary ontological condition, enabling an approach to describing the black-box system.

From the Black Box to the White Box with RAPDtT

In this work, Φ represents exclusively the internal transformation apparatus of the black box. Let:

$$\Phi(Input) = (output) \quad (3)$$

The RAPDtT model proposes (RAPD) as the functional stages arranged in a fixed sequential order and coupled by the internal transport vector t, or, expressed as a chronological sequence, -t-> R - t-> A- t-> P- t-> D - t->. External transport (T) functions as the coupling mechanism with the environment (system boundary). Under this formulation, this sequence is proposed as the operational homomorphic equivalent of Φ. For notational clarity, we propose:

$$\Phi(Input) \approx = [-t-> R - t-> A - t-> P - t-> D - t->] \ (input) \quad (4)$$

For the purposes of this work, this correspondence should be understood as structural and operational rather than as a strict functional identity in the mathematical sense.

It is worth noting that the chronological sequence "-t -> R- t-> A—t-> P – t-> D- t->" indicates that what reaches Dispatch (D) has already passed through Processing (P), and so on, thereby enforcing the logical and mandatory sequence that standardizes the model.

In this correspondence, the presence of transport vectors at both boundaries ensures operational closure. This implies the following:

At the input boundary: the system assumes responsibility for the material/information from the moment it crosses the boundary.

At the output boundary: the system does not release the flow until it has been fully transmitted beyond the boundary.

This symmetry, t … t, also enables traceability by ensuring that each state transition is supported by a movement vector, thereby eliminating "blind spots" in which information could be lost between the white box and the environment. This constitutes a crucial mechanism for transforming a black box into a white box.

***Formal Proof: RAPD as the Structure of* Φ**

For a descriptor of Φ to be valid and formally defined, it must map the entity's lifecycle without "blind spots." We propose that RAPD achieves this through the following logical correspondence:

The function Φ cannot operate on what it does not recognize. The reception (R) state formalizes the domain of the function by identifying the flow.

In the sequence Reception (R) → Storage (A), the Storage (A) state serves as the descriptor of the temporal variable in Φ. It represents the value of the variable during the waiting interval in which the transformation has not yet occurred, although the object is already part of the system. This state acknowledges that no transformation in Φ is instantaneous and that flows are not perfectly constant.

The Processing (P) state corresponds to the execution of the transformation law that changes the entity's properties. The transfer function is the mechanism that converts the input into the output to generate a new state, which constitutes the raison d'être of the "black box."

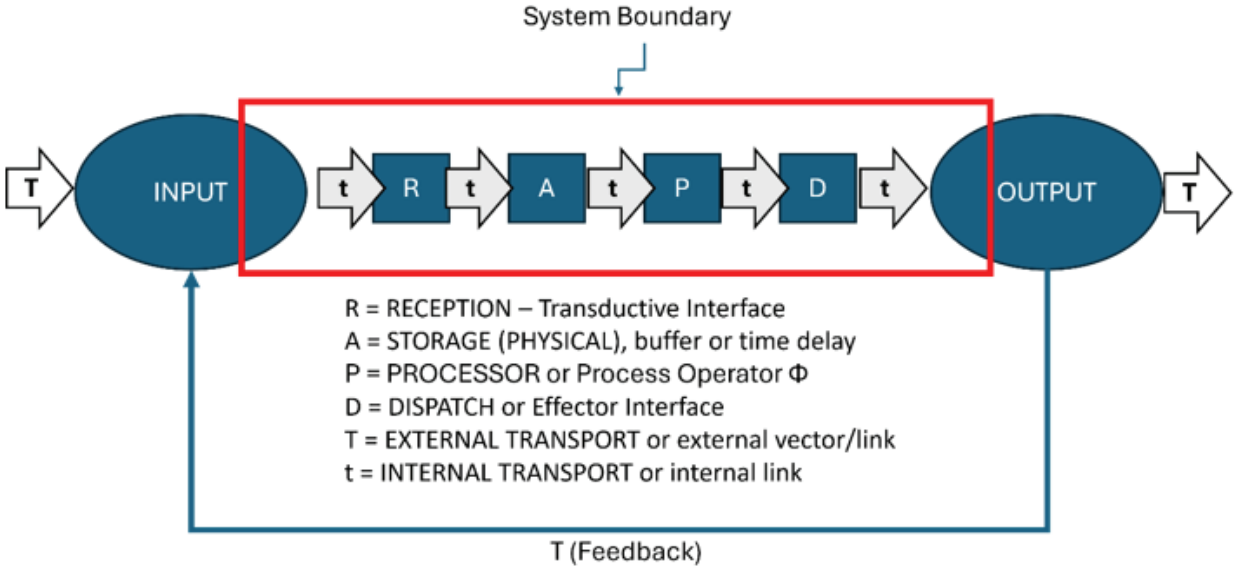
Finally, the Dispatch (D) state represents operational closure. Dispatch (D) marks the moment when the result of Φ exits the system boundary. Without Dispatch (D), the system loses operational closure and structural traceability, as results would accumulate indefinitely without being delivered to the output vector.

Under these considerations, sequence (4) is validated as an operational equivalence, which implies, according to (2), that:

$$-t\rightarrow R-t\rightarrow A-t\rightarrow P-t\rightarrow D-t\rightarrow (input)\sim == output \quad (5)$$

Accordingly, the activities that define the input-output boundaries correspond to the beginning and end of the sequence, which begins and ends with "t." These transport vectors are responsible for receiving flows from or delivering them to the environment. Acting as coupling mechanisms, they handle what external transport brings into or takes out of the system. Reception (R) is the activity that validates the inflow. Under these parameters, the system boundaries and structure can be represented as shown in Fig. 3.

Figure 3. System boundaries and RAPD operational homomorphism



Source: own elaboration.

Note. Fig. 3 makes the system boundary explicit in relation to the RAPDtT representation shown in Fig. 2. The RAPD operations, connected through internal transport as a coupling mechanism, represent Φ as an operational homomorphism of the system's internal operations.

Fig. 3 illustrates the definitive transition from the opacity of the black box to the operational transparency of the RAPDtT model. Under this configuration, RAPD is aligned with the transfer function Φ, establishing its equivalence as an operational homomorphism in terms of a white box.

Under the proposed considerations, RAPD is a valid descriptor of Φ because it encompasses the four structural dimensions required, under the defined assumptions, for any flow: Identity, Time, Change, and Boundary, which, according to Bunge [4], are nonnegotiable foundations. If any dimension is missing, the description of the transformation remains incomplete, resulting in a gray or black box. Adding extra dimensions introduces technical redundancy, thereby violating the principle of minimality.

This reinforces the proposed equivalence by acknowledging that the RAPDtT structure also satisfies the formal conditions of a dynamic system defined by Ashby [2]: a set of invariant functional stages, a transition rule, and external coupling. These constitute logical propositions of necessary dependency for a system to formally exist as a white box, that is, with an explicit and distinguishable internal structure.

Under this formal correspondence, the coupling interface is proposed as {t, T}, the set of invariant functional stages as {R, A, P, D}, and the transition criterion as {t}, reaffirming the equivalence in white-box terms.

The resulting system satisfies the external characteristics of the black box while simultaneously allowing the recognition of a standard internal operational form that exhibits recursiveness, in accordance with Bunge's systemic principles. Each activity of RAPDtT can also be treated as a black box and opened using the same logic, providing further evidence of the model's recursive and fractal properties. This property originally enabled the intuitive scaling from a microtask to a logistics chain and its extrapolation to an entire value network.

Equivalence (4) establishes that the transfer function Φ is not merely an abstraction but a composite architecture. By recognizing that the RAPD core, linked by internal transport (t) and coupled to the environment via external transport (T), adequately describes the internal functioning under the defined structural requirements, the RAPDtT model is established as the key to opening the black box, formally transforming it into an auditable, recursive, and universal operational equivalent of a white box.

RAPDtT and the Minimality Criterion

Having established the proposed operational equivalence between black-box and white-box systems through RAPDtT, it remains necessary to determine whether RAPDtT satisfies the minimality principle as a nonredundant and sufficient descriptor of Φ. To address this question, the principle of parsimony, or Ockham's Razor, is applied.

Proof of Minimality (Ockham's Razor)

To apply Ockham's Razor, also known as the principle of parsimony or the principle of economy, each component must be evaluated according to the criterion of ontological necessity.

If an ontological function or state can be removed without causing the system to collapse, then it is superfluous. If its absence disrupts the flow logic, it is a necessary entity.

This requires examining the RAPDtT architecture function by function to determine whether the architecture $T \cdot t \cdot R \cdot t \cdot A \cdot t \cdot P \cdot t \cdot D \cdot t \cdot T$ constitutes a minimally sufficient set of ontologically invariant functional stages, under specified conditions, for describing the black box. Such an assessment not only confirms operational homomorphism but also establishes RAPDtT as a minimally sufficient structure for describing a flow object and, in this case, the function Φ.

Interface Vectors (T and t)

Ockham's principle demands simplicity, which implies avoiding the multiplication of redundant elements. Therefore, it is necessary to examine each vector individually in terms of its necessity within the sequence:

T (External Transport): represents the Environment (E). If T is removed, the system becomes isolated, and no exchange of energy or matter occurs. Without T, the system is no longer an open system but an inert object. This indicates that T is a necessary interface vector.

t (Internal Transport): represents the Structure (S) and transit time. If t is removed, the ontologically invariant functional stages (R, A, P, D) and their connections to T collapse into one another. The flow element cannot occupy two ontologically invariant

functional stages at the same time without a transition vector. Without t, the flow would amount to teleportation. Therefore, t is an irreducible coupling vector.

Review of Each State under the Principle of Parsimony

To evaluate each state according to the principle of parsimony, negation is applied to each element in sequence ("if not state, then…"), analyzing whether its absence could be compensated for by another:

If R is removed → Loss of Identity: the system no longer recognizes the input, and traceability of origin collapses. This is the point of no return at which the flow enters the system's domain. Under this consideration, R is an irreducible ontological state.

If A is removed → Collapse due to Asynchrony: the system requires infinite synchronization; under any environmental variation (noise), the flow is interrupted due to the lack of a buffer. The concept of latency is essential for achieving homeostasis. Even if the average latency = 0, it must exist. Its removal is not permissible under non-ideal flow conditions and nonzero external perturbations.

If P is removed → Loss of System Function: the system becomes a simple conduit: what enters leaves unchanged. The system ceases to create value and becomes merely a conduit with no real purpose.

If D is removed → Blockage due to Saturation: the flow enters but never exits; the system becomes internally blocked and is unable to deliver results to the environment. Destination traceability is lost, as the object remains "trapped" indefinitely within the system boundary. D is therefore an irreducible closure state.

Under these considerations, RAPDtT is parsimonious because it is strictly sufficient. It represents the point at which the model contains the fewest possible elements without losing its capacity to describe reality. Adding or omitting functional stages would create either redundancy or disconnection.

The combination of the functional stages R, A, P, and D and the vectors T and t constitutes the necessary and sufficient set that makes RAPDtT minimal, not merely as a simple structure but as an irreducible one: removing any single element destroys the architecture's ability to describe reality in an auditable and recursive manner.

This also enables RAPDtT to describe the system according to systemic principles by organizing flows in accordance with Emergentist Materialism [4], whereby flows are organized into physical functional stages whose interactions produce emergent system properties. The function Φ emerges as a property of the RAPD architecture, representing how the components are connected within the black box.

Furthermore, the model satisfies observer independence, since RAPDtT, as a coherent "white-box" ontology, aligns with scientific realism [4], [8], which asserts that systems exist and possess real structural properties regardless of observation.

Discussion

Foundational Axioms

Systemic Existence: an open transforming system exists when it organizes flows that cross a boundary defined by the external vectors T_{in} and T_{out}.

Neutrality and Emergence: the architecture is independent of the nature of the flow (material, informational, energetic, decisional, or symbolic). The system's function Φ emerges from the organization of the flow, not from the nature of the object.

Constructive Recursiveness: the architecture is recursive; each enabling function (R, A, P, D) can itself be structured as a RAPDtT system, preserving the non-commutative sequence at any level of granularity.

The Ontological Triad <C, E, S>

Composition (C): Enabling Functions: the system consists of four functions representing ontological functional stages with structurally distinguishable roles within the observational discretization of the flow:

Reception (R): formalizes entry into the system domain.

Storage (A): preserves the value and integrity of the flow during latency.

Processing (P): executes the transformation of the properties or value of the flow.

Dispatch (D): formalizes the output and transfer of the flow to the environment.

Environment (E): External Vectors (T): coupling with the supersystem occurs exclusively through external

transport vectors (T), which act as boundary transfer interfaces (input/output).

Structure (S): Internal Vectors (t) and Sequence: the system function Φ is an emergent property arising from the articulation of the composition through internal transport vectors (t), which ensure flow continuity between functions. The structure is defined by the non-commutative sequence:

$$T \cdot t \cdot R \cdot t \cdot A \cdot t \cdot P \cdot t \cdot D \cdot t \cdot T \quad (6)$$

Structural Constraint: omitting any component (R, A, P, D, t, T) or altering its order invalidates the representation under the structural requirements defined in this work.

Epistemological Note: this first-order architecture assumes the ontological independence of the system from the observer without denying epistemological mediation in its description. By identifying the internal structure of the function Φ, the model provides an explicit architecture that allows the black box to be reinterpreted as a formalizable operational structure when the defined conditions are met, through a white-box formalization compatible with second-order cybernetics without prescribing internal control mechanisms.

Conclusions

The analysis demonstrates that the RAPDtT model provides an explicit formalization of the underlying operational structure of systems that, within the cybernetic tradition of Norbert Wiener and W. Ross Ashby, can be treated as black boxes.

The operational correspondence between the transfer function Φ and the sequence t–R–t–A–t–P–t–D–t establishes that a system's transformation can be represented through a standard operational structure when conditions of defined boundaries, traceable flow, and controllability are met. Under these assumptions, the black box ceases to be an opaque mechanism and can be formalized as a white-box architecture whose internal operation can be documented, replicated, and audited.

The validity of RAPDtT is not based on a strict mathematical identity but on its empirical development, its coherence with first-order cybernetics, and its ability to explain, through operational homomorphism, the internal dynamics of real logistics and technical systems. This integration of empiricism and formalization allows the model to function simultaneously as a descriptor, an explanatory framework, and a reconstructive tool.

Historical analysis further confirms its capacity for retrospective explanation: the model can be applied to interpret technologies and processes that predate its formulation and to make the structure of their transformations explicit. Consistent with Mario Bunge's systemic realism, this structural stability suggests ontological robustness, demonstrating that the architecture preserves coherence across scales and contexts.

The model's applicability presupposes (i) the availability of an observational protocol for recording inputs and outputs, (ii) the existence of a traceable flow of matter, energy, or information, and (iii) conditions that allow the implementation of negative feedback. In non-observable systems or systems lacking controllable coupling, the model may require extensions or may be limited to partially formalizable components.

Regarding exclusivity, RAPDtT is not asserted to be the only possible homomorphism for formalizing the black box; rather, under the defined structural requirements, it constitutes a minimally sufficient operational core. The current absence of an alternative architecture with lower cardinality that preserves identity, time, change, and boundary provisionally supports its parsimony without precluding the possibility of formal counterexamples.

Overall, RAPDtT can be characterized as an open and recursive operational architecture for transformative systems with bounded flow. Its potential to describe, analyze, and reconstruct complex systems positions it as an integrative tool in systems engineering and control theory, while its validity remains contingent on the structural assumptions established herein.

In summary, the RAPDtT model is presented not as an exhaustive solution but as a proposed approach to the operational syntax of complex systems. Under this premise, the structure serves as a framework that makes the identity of the object and its governed transformation explicit without compromising traceability. This perspective invites future research to explore RAPDtT as a framework for structural transparency, in which systemic management emerges as a logical consequence of its own ontological configuration.

Author contributions

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