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Case Report

Geometric-Physical Coordinate Framework of Phenomena-Time in Open Systems with L-Balance Axis Constraint

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Abstract

Mathematical models used in hydrology, physics, chemistry, and many engineering systems are largely based on empirical or semi-empirical relationships. One fundamental reason for this is that classical coordinate systems—whether Cartesian or relativistic spacetime—are inherently incapable of representing the laws of conservation in open systems. These frameworks describe the instantaneous state of quantities, but do not inherently incorporate the flow, input–output balance, and irreversible nature of processes into their geometric structure. In this paper, a new geometric–physical framework for modeling open systems is introduced, based on a four-dimensional manifold with a structural axis of equilibrium L and the phenomenon–time law. In this framework, the conserved quantities are not simply described by spatiotemporal coordinates, but their evolution path, input flow, and equilibrium state are represented explicitly along the L-axis. Thus, the conservation law is applied directly to the geometry of the system state space, not as an external constraint. The proposed framework separates the dynamics of open systems into three general components: initial irreversible acceptance, two-way equilibrium acceptance, and residual phenomena. The geometric-physical coordinate framework introduces an analytical tool for the geometric representation and structural comparison of the behavior of open systems under known non-equilibrium thermodynamics. Unlike conventional empirical approaches, the present framework allows for the analytical determination of capacities, equilibrium thresholds, and limit behaviors of the system without heavy reliance on experimental calibration. The results show that the phenomenon-time law can be used as a unified geometric foundation for modeling open systems under survival laws and provides a coherent platform for theoretical analysis, dynamic simulation, and interdisciplinary generalization.

Keywords

Open Systems, Phenomenon-Time Law, Input-Output Balance, Irreversibility, System Capacity

1. Introduction

Numerous mathematical models have been developed in chemistry, physics, soil science, and hydrology, most of which rely heavily on empirical data or semi-empirical relationships [1-7]. While these models perform adequately over limited ranges, they generally lack a unified theoretical foundation, which severely restricts their generalizability to natural conditions or different scales. In contrast, models grounded in fundamental theory are rare and often encounter conceptual and practical challenges, including the simultaneous description of dynamics, input–output relationships, and conservation laws in real systems [8-10].

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A fundamental root of these limitations lies in the structure of conventional coordinate systems. Classical coordinate axes, originally designed to describe spatial and temporal states, do not intrinsically provide a basis for the explicit representation of conservation laws. In these frameworks, quantities such as mass or energy are often implicitly assumed, and the roles of input and output flows are ignored. Consequently, even models that appear physically based are, in practice, reduced to empirical forms [11, 13].

Historically, this limitation originates from the formulation of physical space. Since the seventeenth century, with René Descartes' introduction of Cartesian coordinates, space has been represented as a set of independent and orthogonal dimensions. In this framework, each point is specified by three independent components (x,y,z), forming the foundation of analytical geometry and subsequently Newtonian mechanics, where quantities such as position, velocity, momentum, and force are all defined based on these coordinates [13].

In the early twentieth century, Einstein's special theory of relativity transformed this structure by integrating space and time into four-dimensional spacetime. Minkowski's geometric interpretation demonstrated that physical events must be described in four-dimensional space (x,y,z,t), with time playing a structural and fundamental role similar to spatial dimensions [14-16]. The Minkowski metric became the cornerstone of modern physics.

Despite these profound advances, conventional coordinate systems—both Euclidean and relativistic—still share a fundamental limitation: the inability to represent conservation laws and flows of quantities in open systems in an integrated manner. These systems primarily describe instantaneous states, whereas many real-world processes in physics and engineering—such as mass and energy transport, density evolution, or information exchange—are process-oriented and input–output dependent, which cannot be naturally represented in classical coordinates [17].

This limitation is particularly evident in open systems, where mass, energy, or particle numbers continuously enter or leave. In such cases, standard coordinates (x,y,z,t) merely provide descriptive roles and fail to explicitly represent flows, conservation constraints, and the irreversible nature of processes. Phenomena such as sensitivity to initial conditions and Loschmidt's paradox clearly demonstrate that conventional coordinate tools are insufficient for describing these processes [18, 19].

To address these challenges, recent advances in nonequilibrium thermodynamics—including the Conservation–Dissipation Formalism—have attempted to provide structures that simultaneously describe conservation laws, system dynamics, and entropy production [8]. In this context, the framework proposed in this paper introduces a "four-dimensional manifold with an additional geometric constraint" and adds a new structural axis L, enabling simultaneous representation of persistent quantity flows, input–output dependencies, dynamic evolution, and irreversible behavior of open systems in a coherent geometric form.

2. Definitions and Concepts

To clarify the structure of the proposed framework, before the definitions and concepts, the overall workflow of the study is divided into three distinct layers, as shown in Figure 1.

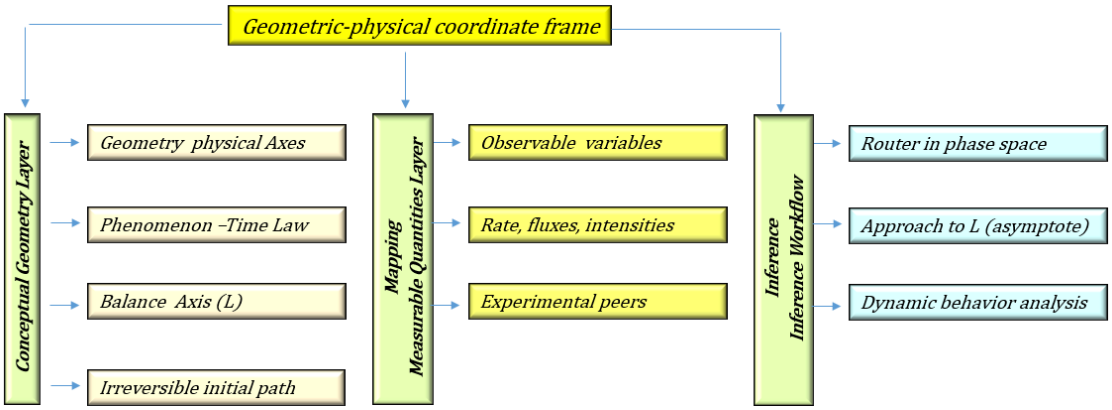

Figure 1. *Schematic diagram of the geometric-physical coordinate frame.*

2.1. Definitions

2.1.1. Phenomenon (P)

Within this framework, a phenomenon (P) is introduced as a symbolic surrogate and a dynamic unit—a modeling variable rather than a fundamental physical entity—that carries an extensive quantity. This quantity may change and redistribute in space, time, and structure, yet its total amount is always governed by a conservation law, such as mass, energy, momentum, or other extensive quantities that play a fundamental role in nonequilibrium thermodynamic equations. This description aligns with contemporary approaches in the physics of open systems, which emphasize the behavior of flows and

exchanges of extensive quantities [8, 11, 12].

Each phenomenon is defined not only at an instantaneous moment but along its entire evolution path, extending across the four-dimensional manifold (x,y,z,t) and along the geometric–structural axis L. This description is consistent with contemporary approaches in open system physics, which emphasize the behavior of flows and the exchange of extensive quantities. In this context, nonequilibrium thermodynamic theories and open system frameworks have found a prominent role [8, 11, 21].

While traditional frameworks primarily focus on "instantaneous" states, contemporary studies indicate that to accurately describe systems, processes must be treated as continuous evolution paths in time and phase space, especially under conditions where entropy and irreversibility play decisive roles [9-11].

Within this framework, the components of a phenomenon are defined as follows:

1) p_{in}: input phenomenon entering the system.
2) p_T: initial uptake; the portion of the phenomenon that enters the system irreversibly and unidirectionally.
3) p_e: equilibrium or secondary uptake; the portion of the phenomenon that occurs after reaching the equilibrium threshold and is associated with reversible behavior.
4) p_r: residual phenomenon; the portion of the output that simultaneously appears with p_e.
5) p_{out}: output phenomenon from the system, including $p_{out}=p_T+p_e+p_r$.
6) p: system uptake or product, defined as $p=p_T+p_e$.
7) $p_{e,max}$: equilibrium uptake capacity.
8) p_{max}: total uptake capacity, defined as $p_{max} + p_{e,max} + p_T$

2.1.2. Time

In this model, time is treated as a measurable geometric dimension represented by the axis t. In regions of uniform flow, the reparameterization $\tau=v_pt$ is employed, functioning analogously to ctctct in special relativity, thereby scaling time consistently with spatial dimensions [15, 17].

The equilibrium threshold time T is defined as the maximum time during which the initial uptake occurs. In other words, the irreversible process takes place over the interval $0 \le t \le T$.

2.1.3. Phenomenon Input Velocity (v_p)

The phenomenon input velocity v_p is a measure representing the change of the phenomenon along the L axis relative to time. In the proposed model, this velocity is assumed constant along the flow path of the phenomenon; that is: $dL/dt=v_p$const.

The constancy of v_p ensures that the input–output ratio along L remains unchanged and that the flux of extensive quantities is modeled uniformly [8, 11]. Given a uniform input flow, the input phenomenon over a time interval ttt is expressed as: $p_{in}=v_pt$.

Examples: Steady gas flow at the input of an ammonia plant, uniform irrigation in a farm, fixed-dose drug administration, batch experiments, and uniform vehicle motion represent cases of constant v_p.

2.1.4. Input–Output Mapping

This mapping defines the functional relationship between the input variations of a phenomenon and the resulting output.Within the L framework, this mapping is defined such that its variation along L is zero: $\partial(p_{out}/p_{in})/\partial L=0$

Hence, the input–output ratio remains constant along L [11, 12]. This constraint cannot merely be applied as an external constraint to a Cartesian coordinate system because, in that case, the conservation law would only be enforced a posteriori after solving the equations. In the present framework, this ratio is inherently incorporated into the coordinate geometry at the state-space level.

Phenomenal Flux

The phenomenal flux represents the movement or transfer of extensive quantities (mass, energy, momentum, etc.) within the spacetime manifold and along L.

This flux comprises reversible, irreversible, and cumulative transfers and is defined based on v_p and the input–output mapping [8, 11]. The L axis represents system equilibrium and conservation laws [21] and satisfies the relation $\partial(\text{Flux})/\partial L=0$.

2.1.5. L Constraint

The L axis is not an independent physical dimension but a geometric constraint applied to the base manifold. This constraint indicates that variations of the phenomenal flux along L are zero:

$$\partial(\text{Flux})/\partial L=0$$

The L-axis represents the geometric application of the conservation laws [11, 12]. It is important to emphasize that the equilibrium axis L is not a direct empirical quantity, but rather a geometric construct obtained from the analysis of the system's trajectory in coordinate space and its asymptotic behavior.

Time Reparameterization τ

In regions of uniform flow, the parameter $\tau=v_pt$ is used for a more geometric representation of the process. This parameter allows coordinated and mappable changes along both time and L [15-17].

2.1.6. Phenomenon–Time

According to the phenomenon–time law [9, 10, 21], any extensive phenomenon can be expressed as:

$$p(t) = \int_0^t v(\tau)d\tau \quad (1)$$

where t is the local or coordinate time, and τ is the intrinsic or proper time.

In the simple case with constant flow characteristics and velocity, the phenomenon–time relationship reduces to: $P = v_p t$

Equilibrium Threshold

The boundary between unidirectional and bidirectional uptake is called the equilibrium threshold, denoted p_T. This corresponds to the amount fully absorbed by the system.

Space as a Phenomenon

In mass–energy systems, space itself is an extensive quantity because it determines the geometric–mass capacity of the flux. Space can be represented as the product of effective flux dimensions or the integral over mass–energy depths. Thus, "space" can also be modeled as a phenomenon [21].

Bending

In open systems, if the output–input ratio is constant and equal to one, the curve is linear. Any reduction or increase in this ratio induces bending of the curve [19, 21].

Hence, the curve curvature directly reflects the dynamics of the phenomenon in time and space and represents the actual output relative to the input or local time.

2.1.7. Principle of Initial Irreversibility

According to the principle of initial irreversibility [9, 10, 19, 21], the beginning of any natural process requires the formation of an initial directed stage in which the evolution of the system follows a linear and asymmetric path with respect to time reversal. This initial directionality, independent of thermodynamic considerations, is considered the structural origin of the irreversibility of the process in its later stages.

The principle of initial irreversibility has two important differences from the law of thermodynamics: 1) it is independent of the unidirectional direction of change, and the direction of change can lead to a decrease or an increase in entropy; 2) it emphasizes the linearity of the process at the beginning of any natural interaction.

2.2. Conceptualization

2.2.1. Mass and Energy Processes in Open Systems

The phenomenon–time framework presented in this study is based on the assumption that system dynamics can be described by tracking the evolution paths of extensive quantities and how they are absorbed over time and space.

The goal of this framework is not to derive closed forms for all existing empirical relationships but to demonstrate that the general structure of these relationships—regardless of domain-specific details—can be mapped onto a unified phenomenon–time pattern.

To illustrate the proposed framework, two classical examples of open systems are considered: rainfall–runoff and energy–motion. These examples reveal the general pattern of extensive phenomenon behavior.

(i). Rainfall–Runoff

When precipitation begins over dry soil, the hydrological response can be divided into three distinct stages. In the first stage ($0 \le t \le T$), all rainfall input is used for surface absorption, vegetation wetting, and storage in microtopography, with no runoff formation. This stage is inherently irreversible, and the entire input is stored as the initial uptake p_T in the system. As time progresses, absorption capacity decreases, and part of the input becomes runoff, such that equilibrium uptake (p_e) and residual output (p_r) appear simultaneously ($p_r \leftrightarrow p_e$).

This behavior leads to a concave curve with a decreasing slope. Ultimately, under uniform precipitation and asymptotic conditions ($t \to \infty$), the total soil uptake capacity $p_{maxp\_}\{\rm max\}pmax$ is reached, and nearly all input converts to runoff. This pattern aligns with the general structure of phenomenon–time and phenomenon–phenomenon behavior in open systems [4-6, 17, 18].

Equation 2 describes the two-stage process of natural phenomena in an open system:

$$p_{in}(t) = v_p t = \begin{cases} p_T, & 0 \le t \le T \\ p_T, p_r, p_e, & T < t < \infty \\ p_r, & t = \infty \end{cases} \quad (2)$$

(ii). Energy and Motion of a Body

For a body subjected to a constant force, the system's dynamic response can similarly be divided into three stages. In the initial interval ($0 \le t \le T$), all input energy is used to overcome static friction and stored as the initial uptake in the body–surface system. Once motion begins, the input energy is distributed between kinetic friction (p_e-) and the kinetic energy of the body (p_r-). At long times under a constant force, the system reaches uniform motion, and the input energy effectively converts into kinetic energy. This structure precisely follows the "initial uptake → equilibrium uptake ⇌ residual phenomenon" pattern and is consistent with experimentally observed behaviors in mechanical and thermodynamic systems [9-11, 13, 14].

The described pattern is observed not only in rainfall–runoff and mechanical motion but also in adsorption processes, chemical reaction kinetics, water infiltration in soil, biological growth curves, and learning curves. Empirical and analytical studies have demonstrated that these processes share a common general form [15-20].

Figure 2 shows the general shape representation of the phenomenon-phenomenon curves (A) and phenomenon-time curves (B) based on experimental data and analytical models reported in [1, 2, 7, 13-19, 21, 22].

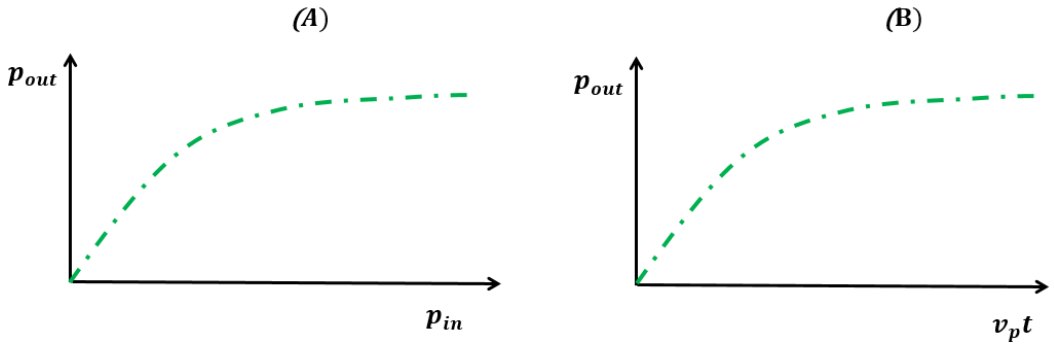

Figure 2. *General form of phenomenon–phenomenon curves (A) and phenomenon–time curves (B) based on experimental results.The limitations of two-dimensional and three-dimensional Cartesian plots in representing extensive processes have previously been highlighted within the frameworks of non-equilibrium thermodynamics and open systems [8, 11-14].*

2.2.2. Limitations of Traditional Coordinate Axes

Loss of the true spacetime substrate

In the Cartesian framework, the precise value of $p_{in}=v_p t$ is inherently undefined. In these plots, the time axis is merely horizontal, providing no information about the flow path, input velocity v_p, or the geometric–physical space. Consequently, the velocity vector is effectively removed from the model, and the system's dynamic behavior is incompletely represented.Even in cases where the input is implicitly considered in models, it lacks a defined geometric location and a traceable evolution path; as a result, explicit and continuous enforcement of the conservation law along the process is impossible.

Inability to apply the conservation law

In both three- and four-dimensional coordinate systems, even if one assumes that the conservation law holds in an open-system format, $\partial p_{in} = \partial p_r + \partial p$

the positions of outputs cannot be identified, the initial slope (dynamic initial condition) is not visible, and there is no equilibrium point or input–output reference to apply the conservation principle.

Consequently, models derived from such plots are typically empirical, trial-and-error, non-generalizable, and inconsistent with conservation laws.

Fundamental Corrections

Recent studies have shown that to properly model persistent phenomena, providing a comparable mathematical model that is capable of simulating natural data, five fundamental modifications are needed [20, 21]:

1) Apply conservation laws in an open-system format (mass conservation is usually shown in a closed-system form).
2) Employ the phenomenon–time law, analogous to the relation L=ct in relativity.
3) Apply the principle of irreversibility.
4) Design experiments based on the phenomenon–time framework.
5) Modify traditional coordinate systems and introduce a new geometric–physical coordinate system.
6) Based on previous studies [17-21], coordinate system modification is more fundamental than the other five items. The proposed coordinate system is introduced below.

2.2.3. Four-Dimensional System with L-Equilibrium Constraint

In this study, a four-dimensional coordinate system is proposed in which the L equilibrium axis plays a key role. According to this framework, the output vector p_{out} is the sum of three spatial components p_x, p_y, and p_z, and the input vector p_{in} defined according to the phenomenon–time law [8-14, 21] as $pin=v_p t$.

In the open system, the L axis is introduced as the conservation or equilibrium axis, dividing the coordinate plane into two symmetric regions: the first region represents the input values, and the second corresponds to the outputs.

This axis contains all points where the conservation law of the phenomenon holds and, in addition to maintaining input–output equilibrium, defines the dynamic boundary between output components p_T, p_e, and p_r (Figure 2).

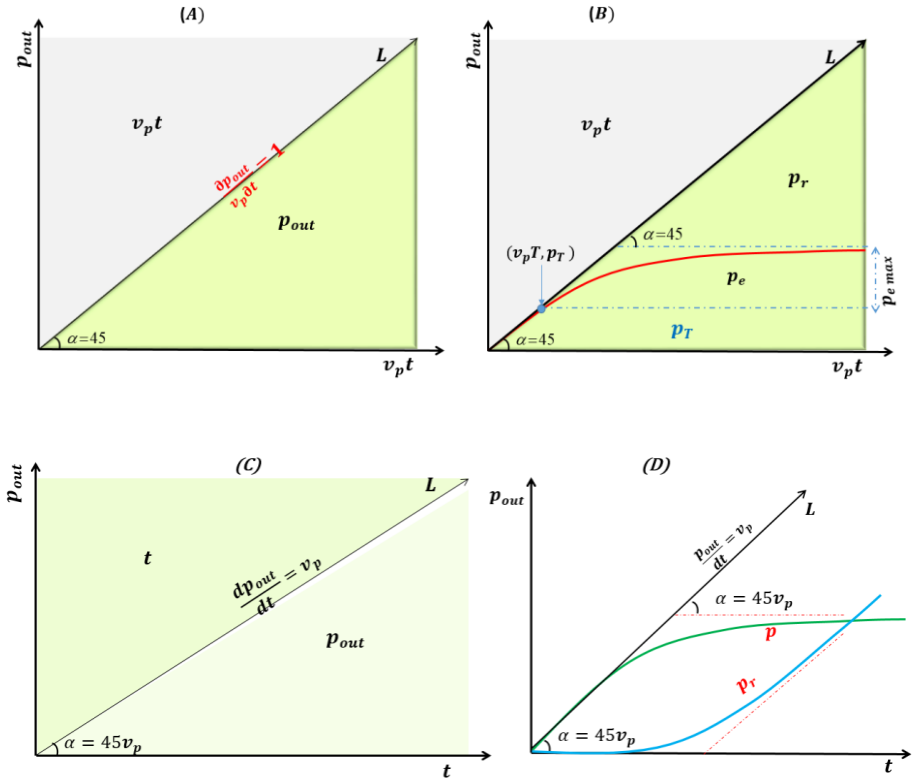

Figure 3. *General form of the conceptual model of equilibrium processes based on the law of conservation of mass in the new coordinate system A) the equilibrium axis L and B) the position of the input, output, irreversible, equilibrium and residual quantities in the open system based on the phenomenon of time based on C) the horizontal axis in terms of time and D) the output curve p and p_r on the horizontal axis in terms of time [8-14, 21].*

It is necessary to emphasize that the angle shown in this figure has a geometric-descriptive meaning and is used to show the application of the input-output equilibrium constraint in the coordinate space.

In Figure 3, the units of measurement are shown in terms of the quantity being measured, for example, if the phenomenon is a mass quantity, the horizontal axis can be (seconds) (milligrams per second) and the vertical axis is shown in milligrams. But the L axis borrows its unit from the input and output quantities. Since the L axis is the balance axis, it is usually equal to 1, unless the horizontal axis is measured in time, in which case the balance axis unit is the same as the initial input velocity v_p. In this case, the L axis will rotate by $\alpha=45v_p$ depending on the value of v_p.

L-axis angle and its role in irreversibility analysis

The L axis is typically drawn at a 45° angle relative to the input and output axes. This geometry has two key effects in analyzing extensive and irreversible processes:

1) Transforming the principle of irreversibility into an exact mathematical form: When input and output belong to the same type of quantity (e.g., mass–mass or energy–energy), the 45° angle ensures that the L-axis scales for input and output are identical. This condition allows the initiation point of the bidirectional process and the equilibrium threshold p_T to be geometrically and unambiguously determined.
2) Initial tangency of experimental curves: Many empirical curves of extensive processes converge toward the L-axis (the L-axis is tangent to the curve's starting point). Therefore, assuming the terminal portion of the process curve is parallel to the horizontal axis, analytical expressions for the curve can be derived. Even when input is expressed as a function of time t, the L-axis, with an adjusted angle based on v_p, can accurately model the starting point and initial path of the experimental curve.
3) This framework systematically enables the extension of irreversibility analysis and curve geometry to systems with heterogeneous quantities while maintaining mathematical accuracy and clarity for homogeneous cases.

Phenomenon–time mapping: From the L-axis geometry, the following relationship holds for any value of x:

Reminder: because the angle between the line L and the horizontal axis (A) is 45 degrees, it is proved that for each value of: $\frac{dx}{dL} = \frac{dx}{dA}$

This relationship provides the basis for mapping between the time and phenomenon axes, allowing simultaneous dynamic analysis in both frameworks.

2.2.4. Mathematical Formulation of the Phenomenon–Time Model

To derive the mathematical model from the conceptual

curve of Figure 2, the conservation law of the phenomenon is first written:

$$\partial p_{in} = \partial p_r + \partial p \quad (3)$$

But secondary acceptance is equal to:

$$p = p_e + p_T \quad (4)$$

Also, according to the law of time phenomena, $p_{in}=v_p t$ Therefore: Equation 4 can be written as a time phenomenon to model the reversible part as Equation (5).

And after moving the parameters in Equation (4), Equation (5) is obtained.

$$\frac{dp_r}{dp_{in}} + \frac{dp_e}{dp_{in}} = 1 \quad (5)$$

To solve Equation (5), it is sufficient to use the following two assumptions based on the conceptual model in Figure 2.

$$\frac{dp_r}{dp_{in}} = \frac{p_e}{p_{e\ max}} \quad (6)$$

$$\frac{dp_e}{dp_{in}} = \frac{k_{sh}}{K_{sh}+p_{in}} \quad (7)$$

The constant k_{sh} is the transition characteristic.

To test hypotheses 6 and 7, since the curve is a gradual change, it is sufficient to examine the time t for the two limits $t\to 0$ and $t\to\infty$. In this case, both sides of the equation are equal. In this case, by integrating equations (6) and (7) into equation (5), the time phenomenon equation (8) is obtained for the equilibrium part of the process.

$$p_e = p_{e,max}\frac{(p_{in}-p_T)}{K_{sh}+(p_{in}-p_T)} \quad (8)$$

But using Equation (4), Equation (8) can be written as Equation (9), which is called the general equation of the phenomenon.

$$p = p_T + p_{e,max}\frac{(p_{in}-p_T)}{K_{sh}+(p_{in}-p_T)} \quad (9)$$

Equation (9) can be converted to Equation (10) based on the law of time phenomena.

$$p = p_T + p_{e,max}\frac{(v_p t-p_T)}{K_{sh}+(v_p t-p_T)} \quad (10)$$

Equation (10) is called the universal principle equation of saturation dynamics.

Equation (10) is called the phenomenon–phenomenon equation, representing a static slice of the dynamic model (Equation (9)).

Equations (9) and (10) are expressed in terms of system acceptance. When expressed in terms of residual values, using Equation (3), one obtains:

$$p_{in} = p_r + p$$

or

$$p_r = p_{in} - p \quad (11)$$

Substituting Equation (9) into Equation (11) gives the residual phenomenon:

$$p_r = p_{in} - [p_T + p_{e,max}\frac{(v_p t-p_T)}{K_{sh}+(v_p t-p_T)} \quad (12)$$

Equation (12) describes the residual phenomenon for a continuous and unlimited input flow. Studies have shown [20] that for an unlimited input p_{in}, this equation corresponds exactly to the runoff equation in hydrology (see Table 2).

If the input p_{in} is a finite source N_0, then replacing p_r with N(t)) yields:

$$N(t) = N_0 - [p_T + p_{e,max}\frac{(v_p t-p_T)}{K_{sh}+(v_p t-p_T)} \quad (13)$$

Equation (13) corresponds to the decay equation in chemical kinetics, also referred to in literature as the reactant depletion curve [20].

In many processes, p_T is negligible; thus, Equation (13) simplifies to:

$$N(t) = N_0 - p_{e,max}\frac{(v_p t)}{K_{sh}+(v_p t)} \quad (14)$$

Equation (14) represents the half-life equation (see Table 2), where N_0 is the total initial quantity and N(t) is the remaining quantity at time t.

3. Discussion

3.1. Geometric–Physical Framework and the L-Equilibrium Axis

The proposed framework is based on a four-dimensional manifold with the L-axis and the phenomenon–time law. Unlike classical Cartesian or Minkowski spacetime systems, this framework does not merely capture the instantaneous states of quantities; it models the evolution paths, fluxes, and input–output equilibrium of extensive quantities in open systems. The L-axis, as a geometric–structural constraint, aligns the input and output paths within a unified substrate and preserves the flow ratio:

$$\left(\frac{\partial p_{out}}{\partial p_{in}}\right)/\partial L = 0$$

It is important to emphasize that the ℓ axis of equilibrium

should not be confused with conventional non-Cartesian coordinates or metric-based structures. The role of L is to define a geometric constraint on the path of open systems, not to reformulate physical space in the classical sense.

3.2. Emergence of Diverse Empirical Structures from a Single Principle

The results indicate that many empirical equations across different fields—from hydrology and surface chemistry to reaction kinetics and substance half-life—follow a phenomenon–time structure. This structure consists of three components:

1) Primary irreversible acceptance (p_T)
2) Secondary equilibrium acceptance (p_e)
3) Uniform phenomenon flux ($p_{in}=v_pt$)

The combination of these components generates the general shape of empirical curves without requiring case-specific assumptions or fit-dependent parameters.

The application of this framework across different domains is summarized in Table 1.

Table 1. *Introduction of equilibrium dynamical models in different scientific fields based on the general phenomenon–time model [20, 21].*

Dynamic model of the phenomenon		$p = p_T + p_{emax}\frac{p_l}{K_{sh}+p_l} * OR$ $p = p_T + p_{emax}\frac{v_p t_l}{K_{sh}+v_p t_l}$ **	
Scientific field		**model**	**References**
Hydrodynamic infiltration(Law of Conservation of Spacetime)		$I = AWT + PAW\frac{h_l}{K_{sh}+h_l}$	[18]
Hydrology	Retemtion	$S = \mathrm{I} + F_{max}\frac{P_{al}}{K_{sh}+P_{al}}$	[17]
	Runoff	$Q = P_a - (\mathrm{I} + F_{max}\frac{P_{al}}{K_{sh}+P_{al}})$	[17]
Surface chemistry	Adsorbtion	$q = q_T + q_{emax}\frac{C_l}{K_{sh}+C_l}$	[20, 23]
	Desorption	$C_r = C_0 - (q_T + q_{emax}\frac{C}{K_{sh}+C})$	[23]
Chemical kinetics	product	$x_p = c_T + x_{pemax}\frac{C_l}{K_{sh}+C_l}$	[20]
	reactant	$x_r = C_0 - (c_T + x_{pemax}\frac{C_l}{K_{sh}+C_l})$	[20]
Motion and energy		$e_\mu = e_{\mu sT} + e_{\mu kmax}\frac{E_l}{K_{sh}+E_l}$	[20]
Hydrodynamic infiltration		$I = AWT + PAW\frac{v_0 t_l}{K_{sh}+v_0 t_l}$	[21]
Hydrology(Rainfall–Runoff)		$S = I + F_{max}\frac{v_0 t_{al}}{K_{sh}+v_0 t_{al}}$	[17]
Surface chemistry		$q = q_T + q_{emax}\frac{v_0 t_l}{K_{sh}+v_0 t_l}$	[21]
Chemical kinetics (product)		$x_p = c_T + x_{pemax}\frac{v_0 t_l}{K_{sh}+v_0 t_l}$	[20]
Motion and energy		$e_\mu = e_{\mu sT} + e_{\mu kmax}\frac{v_0 t_l}{K_{sh}+v_0 t_l}$	[20]
finite-state flow		$x_{tr} = C_0 - (c_T + x_{pmax}\frac{v_0 t}{K_{sh}+v_0 t})$	[20]
Half-life equation		$N = N_0 - N_{pe,max}\frac{v_0 t}{K_{sh}+v_0 t}$	[20]

* Dynamic phenomenon model ($p_l = p - p_T$) ** Dynamic phenomenon time model($v_p t_l = v_p t - p_T$), $v_p \equiv v_0$

Table 2. List of abbreviations

Title	Parameter	Title	Parameter
Friction energy loss threshold movement (Joules)	$e_{\mu kmax}$	Residual substance (mg/liter)	x_{tr}
Maximum kinetic energy dissipated by friction (Joules)	τ	Maximum product substance (mg/liter)	x_p
Time Reparameterization	v_p	Energy input to the system	E_{in}
Fixed initial speed (Phenomenon)	k_{sh}	speed	v
Transition characteristic	N_0	length (in geometric space)	L
All matter at time zero	$N(t)$	Time(mine)	t
Amount of remaining material versus time	B	Amount of adsorption (mg / L)	q*
Product concentration in chemistry	C	Maximum chemical absorption at the equilibrium threshold (mg/L)	q_T
Initial concentration (unlimited flow)	C_e	Absorbent equilibrium capacity (mg / L)	q_{emax}
Adsorption equilibrium concentration (mg / L)	C_0	speed of light	c
Initial concentration (limited source)	S	Adsorbent capacity (mg / L)*	$q_{max} = q_{emax} + q_T$
Total Retention(mm)	Q	Characteristic time	T
Runoff depth	P	Special conversion rate	r
rainfall(mm)	h_r	Residual energy (potential)	U
Residual water (equilibrium)	ρ	Product energy (kinetic)	K
Volumetric mass	I	Residual energy (kinetic)	e_e
Infiltration depth(cm)	V	Wasted energy (friction)	e_μ
Volume	R_e	Plant available water	PAW
Retention Equilibrium	PWP	Equilibrium threshold Phenomenon	p_T
Permanent wilting point	AWT	Maximum equilibrium Phenomenon	p_{emax}
Accessible water threshold	p_r	$p - p_T$	p_l
Residual phenomenon	p	Fixed initial speed (controlled)	v_0
Phenomenon	$e_{\mu kmax}$	Residual substance (mg/liter)	x_{tr}

* Here we have written the capacities in mg/L. This is for simplicity. In any case, it can always be converted to mg/g.

The phenomenon–time equations (9) and phenomenon–phenomenon 10 are derived precisely from this general structure and show that seemingly separate models in different domains are all versions of the same basic dynamics. This is in complete agreement with the experimental findings reported in [16-21], where the general model $p = p_T + p_{emax}\frac{p_l}{K_{sh}+p_l}$ OR $p = p_T + p_{emax}\frac{v_p t_l}{K_{sh}+v_p t_l}$ has been confirmed in domains such as rainfall-runoff, water infiltration, surface adsorption, chemical kinetics, and friction-motion.

3.3. Limitations of Existing Models and Advantages of the Proposed Framework

Systematic literature review reveals common conceptual limitations in classical models—e.g., SCS–CN in hydrology, soil–water interaction, surface chemistry, reaction kinetics, and energy–motion dynamics:

1) *Lack of explicit input flux definition:* The fundamental parameter $p_{in}=v_p t$ is either neglected or only implicitly

considered. Input evolution paths are generally undefined, and conservation laws are not explicitly enforced.
2) *Incomplete modeling of irreversibility and equilibrium threshold:* The initial irreversible stage p_T, clearly observed in experimental data, is often overlooked or substituted by empirical parameters.
3) *Limited predictive capability for system capacity:* The maximum system capacity $p_{max}=p_T+p_{e,max}$ typically requires heavy calibration and is poorly generalizable.
4) *Non-differentiability and unstable simulation:* Empirical models are often non-differentiable, preventing precise dynamic simulation.

The proposed framework addresses these limitations using three fundamental principles:
1) The phenomenon–time law to define the input flux substrate
2) Incorporation of the primary irreversibility principle as a general component
3) The L-axis geometric constraint to represent input–output equilibrium and the onset of the equilibrium regime

Thus, the phenomenon–time equation is not an empirical approximation but a natural consequence of the combination of conservation laws, manifold geometry, and general behavior of open systems.

3.4. Formalism Consistency Across Scientific Domains

The phenomenon–time and phenomenon–phenomenon equations are not restricted to physics or engineering. Empirical evidence shows the same structural form emerging in biological, geological, and informational systems. This broad applicability indicates that the base dynamics "primary acceptance + equilibrium acceptance" is a general feature of open systems under conservation laws, independent of the specific scientific domain. Parameter mapping requires domain-specific interpretation, but the underlying mathematical structure remains consistent.

3.5. System Capacity Interpretation and Scientific Implications

A key implication of the phenomenon–time framework is the ability to extract intrinsic system capacities—including p_T, $p_{e,max}$ and p_{max}—from the geometric structure of the L-axis. These capacities are intrinsic geometric–physical quantities derived from the conservation law and flux structure rather than empirical parameters. This is particularly advantageous in low-data or scale-invariant scenarios, providing robust predictive capability beyond conventional empirical models.

4. Conclusions

This study introduces a new geometric–physical coordinate system for modeling open systems, in which conservation laws are intrinsically applied via the L-equilibrium axis. Key findings are:
1) *Redefinition of evolution paths and fluxes:* The L-axis allows simultaneous representation of instantaneous states and input–output trajectories of extensive quantities, preserving flow ratios and separating irreversible (p_T) and equilibrium (pe) stages.
2) *Unified formalism across scientific domains:* Phenomenon–time and phenomenon–phenomenon equations describe diverse processes—from hydrology and chemical kinetics to energy–motion dynamics—within a single mathematical structure. This demonstrates that the "primary acceptance + equilibrium acceptance" dynamics is a general property of open systems under conservation laws.
3) *Resolution of classical model limitations:* The framework analytically models input flux, irreversibility, and final system capacity, without relying on empirical approximations or heavy calibration.
4) *Intrinsic system capacity characterization:* Maximum system capacity ($p_{max} = p_T + p_{e,max}$) is defined as a geometric–physical quantity, emerging from flux structure and conservation laws rather than empirical fitting.
5) *Differentiability and simulation capability:* The framework supports precise mathematical analysis and dynamic simulation, allowing extraction of system quantities throughout the process without scale limitations.

Future research directions include:
1) Investigating non-uniform inputs and variable boundary conditions
2) Extending the framework to relativistic regimes for high-speed systems
3) Explicit integration with non-equilibrium thermodynamics and free energy definitions
4) Application to complex networks and multi-quantity systems
5) Derivation of Lagrangian or Hamiltonian formulations for phenomenon–time dynamics and analysis of energy–momentum conservation and equilibrium

Author Contributions

Shayan Shamohammadi is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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