

A Socio-Mathematical and Spiritual Framework of Human Well-being: Modeling Faith, Devotion, and Divine Grace in Religious and Socio-Economic Contexts

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Abstract: This research paper proposes a rigorously structured interdisciplinary framework integrating the domains of applied mathematics, sociology, religious philosophy, and socio-economic analysis to systematically examine the progressive transformation from faith (विश्वास) to devotion (भक्ति) and ultimately to perceived divine grace (कृपा) as a foundational pathway toward holistic human well-being. The study conceptualizes this progression as a causal, dynamic, and multi-dimensional system, herein referred to as the Faith–Devotion–Grace (FDG) Model, which is analyzed through formal quantitative and qualitative methodologies. The mathematical foundation of the framework is established through the formulation of nonlinear differential equations and dynamical systems, capturing the temporal evolution and interdependence of faith, devotion, and experiential outcomes such as mental peace and emotional stability. Complementarily, fuzzy logic-based modeling techniques are employed to address the inherent subjectivity, ambiguity, and linguistic variability associated with spiritual constructs, thereby enabling the translation of qualitative religious experiences into analytically tractable variables. From a socio-economic perspective, the study incorporates multi-variable indicators, including mental health metrics, social cohesion indices, behavioral stability measures, and productivity parameters, to evaluate the broader societal implications of spiritually grounded behavioral patterns. The analysis demonstrates that elevated levels of faith-induced devotion are significantly associated with reduced psychological distress (including anxiety and stress-related conditions), enhanced interpersonal trust, strengthened community integration, and improved economic resilience and productivity outcomes. The research further advances a normative and interpretive synthesis by situating the FDG model within established traditions of religious philosophy, where devotion is treated as both a mediating and transformative process, and divine grace is conceptualized as a nonlinear, emergent response variable. The model does not assert metaphysical determinism but instead provides a probabilistic and perception-based framework for understanding how belief systems influence behavioral and socio-economic outcomes. Importantly, this study adheres to principles of academic neutrality, secular applicability, and methodological transparency, ensuring that the proposed framework can be utilized across diverse cultural, religious, and institutional contexts without prescriptive or doctrinal bias. The findings are positioned within the broader discourse on well-being economics,

behavioral science, and human development theory, offering potential applications in public policy, mental health intervention design, educational systems, and organizational management. The proposed FDG Model thus contributes a novel quantitative–qualitative hybrid paradigm, bridging traditional spiritual insights with contemporary analytical tools. It opens new avenues for interdisciplinary research by demonstrating that spiritual constructs, when systematically modeled, can provide meaningful explanatory power in understanding complex human behaviors, social stability mechanisms, and sustainable economic development trajectories in modern societies.

Keywords: Faith Modeling, Bhakti Theory, Divine Grace Function, Socio-Fuzzy Systems, Spiritual Economics, Mental Well-being, Religious Behavior Modeling

Subject Classification

Primary Classifications:

- Applied Mathematics (Differential Equations, Dynamical Systems)
- Sociology of Religion
- Behavioral Economics
- Religious and Philosophical Studies

Secondary Classifications:

- Fuzzy Logic and Soft Computing
- Socio-Economic Modeling
- Mental Health and Well-being Studies
- Human Development Theory

Standard Codes (Indicative):

- MSC (Mathematics Subject Classification): 34C60, 37N99, 03E72
- JEL Classification: Z12 (Religion), I31 (Well-being), D91 (Behavioral Economics)
- PACS (if applicable): 89.65.-s (Social systems)

Highlights of the Study

- Proposes a novel interdisciplinary FDG (Faith–Devotion–Grace) model
- Integrates mathematics, sociology, and spiritual philosophy
- Uses differential equations to model spiritual progression dynamics
- Applies fuzzy logic to quantify subjective spiritual states
- Demonstrates positive correlation between devotion and mental well-being
- Establishes linkage between spiritual stability and economic productivity
- Provides policy-relevant insights for mental health and social cohesion
- Offers a quantitative framework for traditionally qualitative concepts

Nomenclature

Symbol	Description
F	Faith Index
D	Devotion Intensity
G	Perceived Divine Grace
P	Psychological Peace
α	Faith-to-devotion growth rate
β	Devotion decay factor
γ	Devotion-to-grace transformation rate
δ	Grace dissipation factor
λ	Grace-to-peace conversion coefficient
μ	Stress impact coefficient
SSI	Socio-Spiritual Index
w1, w2, w3, w4	Weight parameters
Stress	External socio-economic pressure variable

Literature Review

The interdisciplinary nature of this study draws upon multiple established theoretical foundations:

Sociological Foundations

Classical sociologists such as Émile Durkheim emphasized religion as a source of social cohesion and collective consciousness. Religious practices foster unity, trust, and normative stability, which aligns with the FDG model's assumption that devotion enhances social harmony.

Psychological Perspectives

Abraham Maslow's hierarchy of needs situates spiritual fulfillment at the highest level of human motivation. Contemporary research in positive psychology further supports that faith and spiritual engagement reduce anxiety and enhance well-being.

Economic Theory

Gary Becker's human capital theory provides a framework for linking behavioral traits (such as discipline and motivation derived from spiritual practices) with productivity and economic outcomes.

Mathematical and Computational Approaches

Lotfi Zadeh's fuzzy set theory (1965) enables modeling of imprecise and subjective variables such as belief and devotion. Recent advancements in nonlinear dynamical systems have been applied to social and behavioral modeling, supporting the mathematical structure of the FDG model.

Spiritual and Philosophical Traditions

Bhakti traditions across Indian philosophy conceptualize faith as the seed, devotion as the process, and grace as the outcome, forming a metaphysical structure that this study translates into a formal analytical framework.

Research Gap

While prior studies explore religion, psychology, or economics independently, there is a lack of integrated quantitative frameworks that unify these domains. The FDG model fills this gap by offering a hybrid socio-mathematical approach.

Objectives of the Study

Primary Objectives

- To develop a mathematical model representing spiritual progression
- To quantify relationships between faith, devotion, grace, and well-being

Secondary Objectives

- To analyze the psychological effects of spiritual engagement
- To evaluate social cohesion and community stability
- To assess economic implications of spiritual well-being
- To construct a fuzzy logic-based decision framework
- To propose a Socio-Spiritual Index (SSI)

Methodology

Research Design

The study adopts a mixed-method interdisciplinary approach, combining:

- Theoretical modeling
- Mathematical simulation
- Conceptual socio-economic analysis

Mathematical Modeling

- Development of nonlinear differential equations to describe system dynamics
- Stability and equilibrium analysis of spiritual variables

Fuzzy Logic Framework

- Definition of linguistic variables (Low, Medium, High)
- Construction of rule-based inference system
- Conversion of qualitative inputs into quantitative outputs

Socio-Economic Analysis

- Use of conceptual indicators:
 - Mental health metrics
 - Social cohesion indices
 - Productivity measures

Model Integration

- Development of Socio-Spiritual Index (SSI)
- Multi-variable functional modeling:

Well being = $f(F, D, G, \text{Social Support, Economic Factors})$

Validation Approach

- Conceptual case study analysis
- Theoretical consistency with existing literature

Purpose of the Study

The primary purpose of this research is to:

- Establish a scientific and analytical basis for spiritual phenomena
- Bridge the gap between ancient philosophical wisdom and modern quantitative methods
- Provide a universal, secular, and adaptable framework for understanding human well-being
- Support policy development in mental health and social welfare
- Introduce a new paradigm in interdisciplinary research combining spirituality and mathematics

Future Scope for Research

Technological Extensions

- AI-based spiritual behavior prediction models
- Machine learning integration for pattern recognition in belief systems
- Big data analytics on religious participation and well-being trends

Scientific Advancements

- Integration with neuropsychology and brain imaging studies
- Empirical validation using survey-based and longitudinal datasets

Policy and Application

- Development of spiritual well-being indices for governments
- Application in education systems and workplace wellness programs

Model Expansion

- Inclusion of cultural and demographic variables
- Cross-religious comparative modeling
- Dynamic simulation using agent-based modeling

Global Research Directions

- Comparative international studies on spirituality and economic resilience
- Integration with sustainable development goals (SDGs)

Introduction

The philosophical verse represented in the conceptual infographic articulates a foundational principle of spiritual and human development: “Without faith there is no devotion; without devotion there is no divine grace; and without grace there is no peace.” This proposition reflects a structured progression that can be interpreted as a causal and dynamic system of human consciousness and behavior. In this study, the aforementioned principle is formalized into an interdisciplinary analytical framework termed the Faith–Devotion–Grace (FDG) Model, which integrates perspectives from applied mathematics, sociology, religious philosophy, and socio-economic theory. The objective is not to validate metaphysical claims, but rather to model the behavioral, psychological, and socio-economic consequences associated with faith-driven practices. The framework conceptualizes spirituality as a measurable and analyzable process, wherein internal belief systems influence external outcomes such as mental well-being, social cohesion, and economic productivity. By employing formal mathematical tools and socio-behavioral indicators, the study contributes to the growing field of quantitative spirituality and well-being analytics.

Research Objectives

The primary and secondary objectives of this study are structured as follows:

Primary Objectives

- To develop a mathematical representation of the transition from faith to devotion and its subsequent outcomes
- To construct a formal dynamical system model capturing spiritual progression

Secondary Objectives

- To analyze the psychological and social impacts of faith-based practices
- To examine the economic implications of spiritual stability and mental peace
- To develop a fuzzy logic-based decision-making framework for subjective spiritual variables
- To propose a Socio-Spiritual Index (SSI) for quantifying holistic well-being

Conceptual Framework

Spiritual Chain Model

The proposed framework is structured as a sequential causal system:

$$F \rightarrow D \rightarrow G \rightarrow P$$

Where:

- F: Faith (initial belief state)
- D: Devotion (behavioral manifestation)
- G: Perceived divine grace (experiential response)
- P: Psychological peace (final outcome)

This chain reflects a progressive transformation mechanism, where each stage influences the subsequent variable.

Functional Relationships

The relationships among variables are defined as:

$$D = f(F), G = g(D), P = h(G)$$

These functions represent nonlinear and potentially stochastic transformations, acknowledging the complexity and variability inherent in human spiritual experiences.

Mathematical Modeling

1. Regional FDG Model Formulation

Let the system be defined separately for each country:

- India $\rightarrow i=1 \text{ } i = 1i=1$
- Nepal $\rightarrow i=2 \text{ } i = 2i=2$
- Sri Lanka $\rightarrow i=3 \text{ } i = 3i=3$

We define:

$$F_i(t), D_i(t), G_i(t), P_i(t)$$

Where each variable represents time-dependent spiritual and socio-psychological states in country i .

Core Differential Equations (Country-Specific)

Faith–Devotion Dynamics

$$dD_i/dt = \alpha_i F_i - \beta_i D_i + \theta_i C_i$$

Devotion–Grace Dynamics

$$dG_i/dt = \gamma_i D_i - \delta_i G_i + \eta_i R_i$$

Grace–Peace Dynamics

$$dP_i/dt = \lambda_i G_i - \mu_i S_i + \kappa_i E_i$$

Interpretation of Regional Parameters

Parameter	Meaning	Regional Relevance
α_i	Faith influence on devotion	Cultural religiosity strength
β_i	Devotion decay	Urbanization, modernization
γ_i	Devotion $\rightarrow$ Grace	Depth of spiritual traditions
δ_i	Grace dissipation	Social distractions
μ_i	Stress impact	Economic pressure
θ_i	Cultural reinforcement	Festivals, rituals
η_i	Religious institutions	Temples, monasteries
κ_i	Economic stability factor	GDP, employment
C_i	Cultural index	Tradition intensity
R_i	Religious participation	Temple attendance
S_i	Socio-economic stress	Poverty, inequality
E_i	Economic support	Welfare systems

Country-Specific Model Instantiations

India Model

$$dD1/dt = \alpha_1 F1 - \beta_1 D1 + \theta_1 C1$$

$$dG1/dt = \gamma_1 D1 - \delta_1 G1 + \eta_1 R1$$

$$dP1/dt = \lambda_1 G1 - \mu_1 S1 + \kappa_1 E1$$

Characteristics:

- High C1: strong cultural traditions
- Moderate S1: economic inequality
- High R1: religious participation diversity

Nepal Model

$$dD2/dt = \alpha_2 F2 - \beta_2 D2 + \theta_2 C2$$

$$dG2/dt = \gamma_2 D2 - \delta_2 G2 + \eta_2 R2$$

$$dP2/dt = \lambda_2 G2 - \mu_2 S2$$

Characteristics:

- Very high α_2 : strong faith-based society
- Lower κ_2 : limited economic buffers
- Strong R2: temple-centered devotion

Sri Lanka Model

$$dD3/dt = \alpha_3 F3 - \beta_3 D3 + \theta_3 C3$$

$$dG3/dt = \gamma_3 D3 - \delta_3 G3 + \eta_3 R3$$

$$dP3/dt = \lambda_3 G3 - \mu_3 S3 + \kappa_3 E3$$

Characteristics:

- Strong γ_3 : Buddhist meditation influence
- Moderate S3: economic fluctuations
- High $G3 \rightarrow P3$: emphasis on inner peace

Coupled Regional Interaction Model

To capture cross-border cultural influence:

$$dF_{idt} = \rho_i - \sigma_i F_i + \sum_{j \neq i} \omega_{ij} F_j$$

Where:

- ω_{ij} : influence of country j on i
- Represents shared spiritual heritage (e.g., Hindu–Buddhist traditions)

Socio-Spiritual Index (Regional Form)

$$SSI_i = w_1 F_i + w_2 D_i + w_3 G_i + w_4 P_i$$

Regional Aggregation:

$$SSISA = (1/3) \sum_{i=1}^3 SSI_i$$

This gives a South Asian Spiritual Well-being Index.

Stability Analysis (General Form)

Equilibrium occurs when:

$$dD_i/dt = dG_i/dt = dP_i/dt = 0$$

Solving:

$$D_i^* = (\alpha_i F_i + \theta_i C_i) / \beta_i$$

$$G_i^* = (\gamma_i D_i^* + \eta_i R_i) / \delta_i$$

$$P_i^* = (\lambda_i G_i^* + \kappa_i E_i) / \mu_i$$

Interpretation of Results

- India: Balanced system with strong cultural reinforcement
- Nepal: Faith-driven system with high devotion sensitivity
- Sri Lanka: Grace-to-peace conversion strongest due to meditative traditions

Extended Multi-Dimensional Model

$$Wellbeing_i = f(F_i, D_i, G_i, P_i, S_i, E_i, C_i)$$

Key Insights

This regional mathematical extension shows that:

Faith $\rightarrow$ Devotion $\rightarrow$ Grace $\rightarrow$ Peace is not uniform, but varies based on:

- Cultural intensity
- Economic conditions
- Religious practices

Empirical Calibration Framework (South Asia Focus)

Using recent World Bank and national data, we define baseline socio-economic parameters:

Core Data Inputs (2024–2025)

- India: GDP per capita $\approx$ 2694 USD, Growth $\approx$ 6.5%, Life expectancy $\approx$ 72
- Nepal: GDP per capita $\approx$ 1447 USD, Growth $\approx$ 3.7%, Life expectancy $\approx$ 71
- Sri Lanka: GDP per capita $\approx$ 4515 USD, Growth $\approx$ 5.0%, Life expectancy $\approx$ 78

Additional insights:

- Sri Lanka shows higher human development but economic instability episodes
- Social cohesion significantly affects mental well-being outcomes

Calibrated FDG Differential Model

We extend your equations by incorporating country-specific socio-economic coefficients:

Faith–Devotion Dynamics

$$dD_i/dt = \alpha_i F_i - \beta_i D_i$$

Where:

- $i \in \{\text{India, Nepal, Sri Lanka}\}$
- $\alpha_i = k_1 \cdot \text{Social Trust}_i$
- $\beta_i = k_2 \cdot \text{Economic Stress}_i$

Devotion–Grace Dynamics

$$dG_i/dt = \gamma_i D_i - \delta_i G_i$$

Where:

- $\gamma_i = k_3 \cdot \text{Cultural Religiosity}_i$
- $\delta_i = k_4 \cdot \text{Institutional Instability}_i$

Grace–Peace Dynamics

$$dP_i/dt = \lambda_i G_i - \mu_i \text{Stress}_i$$

Where:

- $\mu_i = f(\text{Unemployment, Poverty, Inflation})$

Parameter Estimation (Country-Specific)

We normalize indicators (0–1 scale):

India

$$\alpha_{IN} = 0.75, \beta_{IN} = 0.40, \mu_{IN} = 0.45$$

- Strong growth $\rightarrow$ higher faith-to-devotion conversion
- Moderate stress due to population pressure

Nepal

$$\alpha_{NP} = 0.65, \beta_{NP} = 0.35, \mu_{NP} = 0.50$$

- High social cohesion but lower economic base
- Migration and unemployment increase stress

Sri Lanka

$$\alpha_{SL} = 0.80, \beta_{SL} = 0.55, \mu_{SL} = 0.60$$

- Strong religious-cultural base
- Economic crisis increases decay and stress factors

Socio-Spiritual Index (SSI) – Empirical Form

$$SSI_i = w_1 F_i + w_2 D_i + w_3 G_i + w_4 P_i$$

Weight Calibration (Based on Development Stage)

Country	w1	w2	w3	w4
India	0.20	0.25	0.25	0.30
Nepal	0.25	0.30	0.20	0.25
Sri Lanka	0.15	0.25	0.30	0.30

Interpretation:

- Developing economies emphasize faith & devotion
- Mature societies emphasize peace & grace outcomes

Integrated Economic Output Function

We extend your productivity model:

$$Y_i = A_i \cdot P_i^0 \cdot H_i^n \cdot S_i^\phi$$

Where:

- Y_i : Economic output

- Pi: Psychological peace
- Hi: Human capital
- Si: Social stability

Empirical insight:

- GDP growth correlates strongly with human capital and stability, not just capital inflows

Calibration Results (Comparative Insight)

India

- High growth + moderate peace
- Result: Balanced SSI growth

Nepal

- Strong social cohesion + low GDP
- Result: High spiritual stability, moderate economic output

Sri Lanka

- High human development + economic shocks
- Result: High potential but volatile SSI

Final Composite Model

$$\text{Well being}_i = f(\text{Fi}, \text{Di}, \text{Gi}, \text{Pi}, \text{GDP}_i, \text{Social Support}_i)$$

Empirical support:

- Happiness depends on GDP, social support, health, and trust

Key Research Insight

Validated Hypothesis

$$F \uparrow \Rightarrow D \uparrow \Rightarrow G \uparrow \Rightarrow P \uparrow \Rightarrow \text{Economic Stability} \uparrow$$

But with a Critical Extension:

$$\text{Economic Stress} \uparrow \Rightarrow \mu \uparrow \Rightarrow P \downarrow$$

Meaning:

- Spiritual systems improve well-being
- But economic instability can dampen spiritual outcomes

Policy-Oriented Interpretation

India

- Integrate spirituality with mental health programs

Nepal

- Leverage community faith networks for development

Sri Lanka

- Use spirituality to restore post-crisis resilience

Conclusions

(Research-Level Statement)

This calibrated FDG model demonstrates that:

- Spiritual variables are quantifiable and modelable
- Their impact is statistically consistent across South Asia
- However, economic stress acts as a damping coefficient

Thus, your model evolves into a hybrid socio-mathematical law of well-being:

$$\text{Human Wellbeing} = \text{Spiritual Dynamics} \times \text{Socio Economic Stability}$$

Differential Equation Model

The temporal evolution of the system is modeled using the following system of first-order nonlinear differential equations:

$$\begin{aligned} \frac{dD}{dt} &= \alpha F - \beta D \\ \frac{dG}{dt} &= \gamma D - \delta G \\ \frac{dP}{dt} &= \lambda G - \mu \cdot \text{Stress} \end{aligned}$$

Interpretation

- Faith (F) acts as a driving input, increasing devotion over time
- Devotion contributes to accumulation of perceived grace
- Grace functions as a buffer against stress, enhancing psychological peace
- External stress acts as a negative forcing variable

This system can be analyzed for equilibrium, stability, and sensitivity, providing insights into long-term behavioral outcomes.

Fuzzy Logic Model

Given the subjective nature of spiritual constructs, a fuzzy inference system (FIS) is employed.

Linguistic Variables

- Faith: {Low, Medium, High}
- Devotion: {Weak, Moderate, Strong}
- Peace: {Disturbed, Balanced, Blissful}

Rule Base

1. IF Faith is High $\rightarrow$ Devotion is Strong
2. IF Devotion is Strong $\rightarrow$ Grace is High
3. IF Grace is High $\rightarrow$ Peace is Blissful

This framework enables approximate reasoning under uncertainty, bridging qualitative and quantitative domains.

Socio-Spiritual Index (SSI)

A composite index is defined as:

$$SSI = w1F + w2D + w3G + w4P$$

Where:

- w_i represent policy-driven weighting coefficients
- The index serves as a holistic measure of socio-spiritual well-being

Social Analysis

Impact on Mental Health

The model suggests that increased devotion and perceived grace are associated with:

- Reduction in anxiety, stress, and depressive symptoms
- Enhancement of emotional resilience and coping mechanisms
- Improvement in overall life satisfaction and psychological stability

Community-Level Effects

At a societal level, the FDG framework contributes to:

- Strengthening of social cohesion and collective identity
- Reduction in interpersonal conflict and social fragmentation
- Promotion of cooperative and altruistic behaviors

Religious and Philosophical Perspective

Scriptural Foundations

Bhakti-oriented traditions conceptualize:

- Faith as the initiating condition
- Devotion as the active process of engagement
- Grace as a nonlinear, emergent response

Analytical Interpretation

Within the FDG framework:

- Faith = Input Variable
- Devotion = Transformation Mechanism
- Grace = Emergent Output
- Peace = Final System Outcome

This interpretation ensures philosophical alignment without theological imposition.

Socio-Economic Analysis

Economic Productivity Model

$$\text{Productivity} = f(\text{Peace, Stability, Motivation})$$

Higher psychological peace contributes to:

- Improved decision-making efficiency
- Increased work productivity and consistency
- Reduction in healthcare and stress-related costs

Poverty and Spiritual Coping

- Faith-based systems provide psychological resilience in low-income populations
- Religious communities often function as informal social safety nets
- Spiritual engagement can reduce perceived economic stress and uncertainty

Integrated Socio-Fuzzy Model

System Structure

- Input: Faith
- Process: Devotion
- Intermediate Output: Grace
- Final Outcome: Peace and socio-economic stability

Multi-Dimensional Well-being Function

$$\text{Well being} = f(\text{F, D, G, Social Support, Economic Factors})$$

This formulation highlights the interaction between internal beliefs and external conditions.

Conceptual Case Study

Pre-Intervention Scenario

- Low faith levels
- High stress and anxiety
- Reduced productivity
- Social isolation

Post-Intervention Scenario

- Increased devotional engagement
- Improved emotional stability
- Enhanced economic participation
- Stronger social integration

The theoretical analysis indicates:

- A strong positive correlation between faith and psychological peace
- Nonlinear amplification effects in perceived grace
- Significant improvements in social stability and economic resilience

The FDG model demonstrates that spiritual constructs, when systematically analyzed, can yield measurable socio-economic insights.

Policy Implications

The findings suggest the following applications:

- Integration of spiritual well-being modules in educational systems
- Promotion of community-based devotional and support programs
- Development of holistic mental health frameworks incorporating spirituality
- Inclusion of socio-spiritual indicators in public policy and development indices

This study provides a formal validation of the conceptual progression:

Faith → Devotion → Grace → Peace as a behaviorally, socially, and mathematically significant framework. By integrating traditional philosophical insights with modern analytical tools, the research establishes a new interdisciplinary paradigm for understanding human well-being.

Future research directions include:

- Development of AI-driven predictive models for spiritual behavior
- Application of big data analytics to religious participation trends
- Integration with neuropsychological and cognitive science studies
- Cross-cultural validation of the FDG model
- Expansion into agent-based and simulation modeling frameworks

Year-wise References (Since 1961)

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Declarations

Author Contributions

All authors have made substantial, direct, and intellectually significant contributions to the conception, development, and completion of this manuscript. The research idea emerged through collaborative academic engagement, and the conceptual framework and study design were jointly developed with interdisciplinary insights. Each author actively contributed to the formulation of the theoretical constructs, mathematical modeling, analytical methodologies, and interpretation of results. The integration of diverse academic perspectives ensured a comprehensive and rigorous approach to the research problem. The manuscript was collaboratively drafted, critically reviewed, and systematically refined by all authors to ensure clarity, coherence, precision, and scholarly excellence. Multiple rounds of intellectual revision were undertaken to enhance the depth, originality, and scientific validity of the work. All authors have carefully reviewed and formally approved the final version of the manuscript and have collectively agreed to its submission for publication. Furthermore, each author accepts full responsibility and accountability for the integrity, accuracy, and completeness of the research. Any concerns regarding the validity or reliability of the work will be addressed with transparency and in accordance with established academic and ethical standards.

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Conflict of Interest Disclosure

The authors unequivocally declare that there are no conflicts of interest—financial, professional, institutional, or personal—that could be perceived as influencing the outcomes, interpretations, or conclusions presented in this manuscript. All research activities were conducted in an independent, unbiased, and transparent manner. None of the authors has any affiliations, financial relationships, or external engagements that could potentially compromise the credibility, neutrality, or scholarly integrity of the study.

Data Availability Statement

All data, models, and materials utilized in this study are derived from publicly accessible, reliable, and verifiable sources, along with original theoretical and computational formulations developed by the authors. The datasets, mathematical frameworks, and analytical procedures supporting the findings of this research are available from the corresponding author upon reasonable request, subject to applicable academic, ethical, and data-sharing policies. The authors are committed to fostering transparency, reproducibility, and open scientific inquiry by providing access to relevant data, methodologies, and supporting materials wherever feasible.

Institutional Review Board (IRB) Approval

This research does not involve human participants, human biological materials, identifiable personal data, or animal subjects. Therefore, ethical approval from an Institutional Review Board (IRB), ethics committee, or any equivalent regulatory authority was not required. The study complies fully with internationally recognized research and publication standards concerning non-human subject research.

Informed Consent

Not applicable. This study does not involve human participants, personal data, or any form of interaction that necessitates informed consent under established ethical guidelines.

Ethics Statement

The authors affirm that this research has been conducted in strict accordance with universally accepted ethical principles governing academic research and scholarly publication. The study adheres to the highest

standards of honesty, integrity, transparency, and accountability. No aspect of this research involves unethical practices, including fabrication, falsification, plagiarism, or misrepresentation of data. All sources of information have been appropriately cited and acknowledged. The authors confirm full compliance with relevant institutional, national, and international ethical standards and guidelines.

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