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The Overlap Is Not the Bond: A Set-Theoretic and Probabilistic Framework for Marriage, Family Structure, and Divorce

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ABSTRACT

This article develops a theoretical and conceptual mathematical framework for representing marriage, family structure, and divorce. The framework combines set-theoretic representation, normalized similarity measures, active-bond dynamics, probability trees, and ideas from complex systems. Each person is modeled as a time-dependent attribute structure embedded in a universal attribute space. The central modeling assumption is a non-identity principle: within a sufficiently rich description, two distinct persons are represented by non-identical identity structures. Interpersonal closeness is therefore not defined by complete equality, but by normalized overlap measures such as the Jaccard index and, in a more general formulation, by weighted or fuzzy similarity measures. Marriage is modeled not merely as the intersection of two person-sets, but as an active marital-bond structure supported by shared values, emotional attachment, cooperation, legal or symbolic commitment, residence, children, shared responsibilities, and common goals. Love is represented as a time-dependent reinforcement variable that may increase, decrease, stabilize, or recover according to interaction history, conflict, repair capacity, and deliberate maintenance. Because relationship outcomes are high-dimensional, context-sensitive, and path-dependent, the article does not propose a universal deterministic equation for marriage or divorce. Instead, it formulates a probability-tree representation in which branch probabilities may depend on personality, culture, socioeconomic pressure, family interference, previous reactions, and timing. Divorce is defined as the collapse of the active marital-bond measure rather than the disappearance of all shared attributes. The framework is extended to nuclear and extended family structures and is connected to family systems theory, mathematical sociology, agent-based modeling, and complex-systems reasoning. The numerical examples and Monte Carlo simulation included in the article are illustrative and are not presented as empirical divorce predictions. No empirical validation is reported in the present paper. Rather, the model is proposed as a formal theoretical scaffold designed for near-future empirical testing, in which the marital-bond measure and probability-tree branch probabilities may be operationalized, estimated, and evaluated using longitudinal couple data.

Keywords: set theory; marriage; family systems; divorce; probability tree; path-dependence; complex systems; active marital bond; Jaccard similarity; theoretical model.

INTRODUCTION

Human relationships are often described through the language of closeness, distance, overlap, boundary, attachment, separation, and shared life. These terms are usually qualitative, but they also suggest a natural formal interpretation. One may represent a person, within a specified model, as an evolving structure of attributes, including memories, beliefs, habits, personality traits, biological characteristics, social roles, relationships, cultural background, and personal history. When two persons form a marriage or long-term partnership, some parts of their lives become shared: values, routines, responsibilities, memories, emotional attachment, legal or symbolic commitments, children, residence, and common goals. At the same time, each person retains individual boundaries and non-shared identity. The motivating observation of this article is the following:

Within a sufficiently rich description of identity, two distinct persons may become deeply connected, but they should not be modeled as having completely identical identity structures. Complete identity would eliminate the distinction between the two persons as separate objects of description.

This observation is not proposed as an empirical discovery, but as a modeling principle. It suggests that marriage should not be idealized as the perfect merging of two persons into one undifferentiated object. A stable and healthy relationship may involve a large and meaningful shared region, but it also requires boundaries, difference, and the persistence of individual identity. The purpose of this paper is to develop this idea into a formal conceptual framework for representing marriage, family structure, and divorce.

The proposed framework uses four complementary mathematical languages:

i. set-theoretic and similarity-based representations to describe persons, shared attributes, and relational overlap;

ii. explicit modeling postulates to state the assumptions on which the framework depends;

iii. probability trees to represent uncertainty, sequence, conditional outcomes, and path-dependent relationship processes;

iv. complex-systems reasoning to interpret feedback, sensitivity to initial conditions, nonlinearity, and population-level rather than deterministic individual prediction.

The article is not intended to replace psychological, sociological, legal, cultural, or therapeutic accounts of marriage and divorce. It also does not claim to provide an empirically validated prediction model. Rather, it offers a formal theoretical language for organizing relationship dynamics and for distinguishing between general personal overlap and the active marital bond. The framework is designed so that, in near-future empirical work, its variables may be connected to relationship-quality scales, surveys, simulations, and longitudinal couple data.

RELATION TO EXISTING WORK AND NOVEL CONTRIBUTION

Mathematical and computational approaches to social relations have a substantial history. Marriage markets, divorce dynamics, family systems, and social networks have been studied through mathematical sociology, stochastic processes, network theory, dynamical systems, and agent-based modeling. Agent-based models, for example, can represent individuals as interacting agents with attributes, preferences, constraints, and changing states, and they have been widely used in social simulation and complex-systems research (Epstein & Axtell, 1996; Jarynowski & Nyczka, 2018; Laubenbacher et al., 2008; Schelling, 1971). Family systems theory and marital-satisfaction research have also emphasized interaction patterns, feedback, communication, adaptation, dyadic adjustment, and negative interaction patterns associated with marital instability and dissolution (Bowen, 1978; Gottman, 1992, 1999; Gottman & Levenson, 1992, 2000; Spanier, 1976). In addition, dynamic mathematical models of marital interaction have shown that relationship processes can be represented through nonlinear and qualitative dynamical systems (Cook et al., 1995).

The present paper does not claim to introduce set theory, Venn-style representation, probability trees, family systems theory, or marital psychology as new fields. Its contribution is instead integrative and conceptual. It proposes a formal language in which several relationship concepts can be represented within a single mathematical framework. The proposed contribution is organized around the following elements:

a) a non-identity modeling postulate stating that, within a sufficiently rich description, distinct persons should not be represented as identical identity structures;
b) a distinction between general personal overlap, represented by shared attributes, and the active marital-bond structure that sustains the marriage as a functioning relationship;
c) a probabilistic tree representation for conditional, sequence-dependent, and history-dependent relationship outcomes;
d) an extension from the marital dyad to nuclear-family and extended-family structures, including supportive and disruptive external influences;
e) a pathway for future empirical operationalization through relationship-quality indicators, psychological scales, sociological measures, simulations, and longitudinal couple data.

This framing is intended to clarify the epistemic status of the article. The framework is not presented as a completed predictive theory or as an empirically validated model of divorce. Rather, it is a theoretical scaffold for organizing assumptions, defining relational quantities, generating testable hypotheses, and preparing the model for near-future empirical calibration and evaluation.

MATHEMATICAL PRELIMINARIES

Let U denote an attribute space containing the attributes considered relevant to human identity and social relations within a specified model. The space U is not assumed to be metaphysically absolute or complete in a practical empirical sense. Rather, it depends on the purpose of the study, the level of description, and the available data. Attributes may include psychological traits, values, memories, biological characteristics, social roles, language, culture, education, religious beliefs, family ties, legal states, economic variables, and behavioral patterns.

Definition 1 (Person-set). *In the simplest binary formulation, a person P at time t is represented by a non-empty time-dependent set*

$$P(t) \subseteq U, \qquad P(t) \neq \varnothing \tag{1}$$

The elements of $P(t)$ represent the attributes, memories, roles, relationships, and characteristics included in the model at time t.

Remark 1 (Model dependence). *The representation $P(t) \subseteq U$ should not be interpreted as the complete reality of a person. It is a model-dependent representation. If U is too coarse or incomplete, different persons may appear artificially similar or even identical within the model. The non-identity principle introduced below is therefore intended for sufficiently rich descriptions of identity.*

Definition 2 (Complement and boundary). *The complement of $P(t)$ relative to U is*

$$P^c(t) = U \setminus P(t) \tag{2}$$

The complement represents what is outside the modeled identity of the person. In this limited formal sense, it may be interpreted as a mathematical representation of boundary.

Definition 3 (Overlap and normalized similarity). *For two persons $A(t)$ and $B(t)$, their raw modeled overlap is*

$$A(t) \cap B(t) \tag{3}$$

When the sets are finite, a useful normalized similarity measure is the Jaccard index:

$$\mathcal{J}(A,B;t) = \frac{|A(t)\cap B(t)|}{|A(t)\cup B(t)|} \tag{4}$$

where $0 \leq \mathcal{J}(A,B;t) \leq 1$, provided $A(t) \cup B(t) \neq \varnothing$.

The Jaccard index avoids a difficulty that can arise in a simple set-theoretic formulation. It is not sufficient to claim that $A(t) \cap B(t) \neq A(t)$ for all distinct persons, because if $A(t) \subset B(t)$, then $A(t) \cap B(t) = A(t)$ while $A(t) \neq B(t)$.
A normalized similarity measure provides a more careful way to express the intended idea: two distinct persons may share many attributes, but, within a sufficiently rich identity description, they are not represented as completely identical.

Definition 4 (Weighted or fuzzy person-structure). *For a more general representation, a person P may be modeled by a time-dependent membership or salience function*

$$p_P(a,t): U \to [0,1] \tag{5}$$

where $p_P(a,t)$ denotes the degree, strength, salience, or relevance of attribute $a \in U$ for person P at time t.

In this formulation, the binary set model is a special case in which $p_P(a,t) \in \{0,1\}$. The weighted or fuzzy version is more appropriate for many human attributes, because variables such as trust, cultural identity, religious commitment, emotional attachment, resentment, financial stress, or family influence are usually matters of degree rather than simple presence or absence. For two weighted person-structures A and B, a weighted Jaccard-type similarity may be defined as:

$$\mathcal{J}_w(A,B;t) = \frac{\sum_{a\in U} \min\{p_A(a,t), p_B(a,t)\}}{\sum_{a\in U} \max\{p_A(a,t), p_B(a,t)\}} \tag{6}$$

provided the denominator is nonzero. This measure satisfies

$$0 \leq \mathcal{J}_w(A,B;t) \leq 1 \tag{7}$$

It reduces to the ordinary Jaccard index when all membership values are binary.

POSTULATES OF THE MODEL

The assumptions below are called postulates rather than axioms because they are modeling assumptions for a human system, not universal mathematical truths independent of interpretation.

Postulate 1 (Personhood as modeled attribute set). *Every living person in the model is represented by a unique non-empty time-dependent set $P(t) \subseteq U$.*

Postulate 2 (Non-identity of distinct persons). *For two distinct persons A and B,*

$$A(t) \neq B(t) \tag{8}$$

for any complete description of their identity at time t. In normalized form,

$$\mathcal{J}(A,B;t) < 1 \tag{9}$$

This does not mean that $A(t) \cap B(t)$ is always small. It means only that complete identity is excluded for distinct persons.

Postulate 3 (Temporal change). *For most nonzero time intervals*

$$\Delta t,\ P(t+\Delta t) \neq P(t) \tag{10}$$

A person is therefore modeled dynamically, not as a fixed object.

Postulate 4 (Marriage as active bond). *A marriage between two persons H and W is represented by an active marital-bond set*

$$\mathcal{M}_{HW}(t) \subseteq H(t) \cap W(t) \tag{11}$$

where $\mathcal{M}_{HW}(t)$ includes active shared elements such as emotional attachment, cooperation, legal or symbolic *commitment, shared residence, common goals, mutual responsibilities, sexual or romantic intimacy when applicable, shared children, shared rituals, and joint decision-making.*

Remark 2. *This distinction is important. The general intersection $H(t) \cap W(t)$ may remain non-empty even after divorce because the former spouses may still share memories, children, language, culture, legal history, or social networks. Therefore, divorce should not be defined as $H(t) \cap W(t) = \varnothing$ in general. It is more accurate to define divorce as the collapse of the active marital-bond set.*

Postulate 5 (Emotional distance). *The emotional or relational distance between H and W is inversely related to the strength of their active marital bond. A simple conceptual representation is*

$$d_{HW}(t) = \frac{1}{\varepsilon + \mu(\mathcal{M}_{HW}(t))}, \qquad \varepsilon > 0 \tag{12}$$

where μ is a nonnegative measure of marital-bond strength. The small constant ε prevents division by zero.

Postulate 6 (Love as a dynamic reinforcement parameter). *Let $L_{HW}(t)$ denote the emotional bonding intensity between H and W. The evolution of $L_{HW}(t)$ is not assumed to be universally decreasing. Instead,*

$$\frac{dL_{HW}}{dt} = R_{HW}(t) - D_{HW}(t) \tag{13}$$

where $R_{HW}(t)$ represents reinforcement factors such as care, communication, trust, forgiveness, shared meaning, and constructive problem-solving, while $D_{HW}(t)$ represents decay factors such as neglect, contempt, betrayal, chronic conflict, addiction, external stress, or emotional withdrawal.

Postulate 7 (Context-dependence of parameters). *Let $X_i(t)$ denote a relationship-relevant parameter, such as culture, money, family interference, health, children, religion, addiction, education, age difference, migration, or social crisis. Its effect on the marital bond is context-dependent:*

$$\frac{\partial \mu(\mathcal{M}_{HW})}{\partial X_i} \tag{14}$$

may be positive, negative, or approximately neutral depending on the couple, history, culture, and timing.

DEFINITIONS

Definition 5 (Active marital-bond measure). *The scalar*

$$\mu(\mathcal{M}_{HW}, t) \geq 0 \tag{15}$$

denotes the modeled strength of the active marital bond between partners H and W at time t. In the simplest set-theoretic formulation, μ may be interpreted as a nonnegative measure of the active marital-bond set $\mathcal{M}_{HW}(t)$. In a weighted or fuzzy formulation, it may be defined as a weighted aggregate of active relational components, for example

$$\mu(\mathcal{M}_{HW}, t) = \textstyle\sum_{a \in U_M} \omega_a \, m_{HW}(a, t) \tag{16}$$

where $U_M \subseteq U$ is the marital-bond attribute domain, $m_{HW}(a,t) \in [0,1]$ denotes the current strength or activation of marital-bond component a, $\omega_a \geq 0$ is its theoretical weight, and

$$\textstyle\sum_{a \in U_M} \omega_a = 1 \tag{17}$$

In the present theoretical paper, the weights ω_a are not empirically estimated. They are introduced as placeholders for future calibration and testing.

Definition 6 (Critical bond threshold). *A critical threshold $\theta_{HW} > 0$ is a couple-specific or context-specific boundary below which the active marital bond is modeled as unstable:*

$$\mu(\mathcal{M}_{HW}, t) < \theta_{HW} \tag{18}$$

The threshold may vary across couples, cultures, legal systems, religious contexts, socioeconomic conditions, and historical periods. Therefore, θ_{HW} should not be interpreted as a universal constant.

Definition 7 (Marital dissolution or divorce). *Marital dissolution is modeled as the functional collapse of the active marital-bond measure. In an ideal limiting formulation, this may be written as*

$$\lim_{t \to t_d} \mu(\mathcal{M}_{HW}, t) = 0 \tag{19}$$

where t_d denotes the time of dissolution. More generally, dissolution may occur when the active bond remains below the critical threshold for a sufficiently long period:

$$\mu(\mathcal{M}_{HW}, t) < \theta_{HW} \qquad \text{for } t \in [t_d - \Delta, t_d] \tag{20}$$

where $\Delta > 0$ represents a context-dependent duration of instability. This formulation allows for the possibility that some residual emotional, legal, parental, historical, or social connection remains after divorce. Thus, marital dissolution does not require

$$H(t_d) \cap W(t_d) = \varnothing \tag{21}$$

Definition 8 (Relationship state vector). *The relationship state may be represented by a time-dependent vector*

$$\boldsymbol{X}_{HW}(t) = \begin{pmatrix} L_{HW}, Q_{HW}, T_{HW}, C_{HW}^{\text{com}}, G_{HW}, R_{HW}^{\text{rep}}, N_{HW}^{\text{conf}}, \\ F_{HW}^{\text{fin}}, I_{HW}^{\text{fam}}, C_{HW}^{\text{cult}}, K_{HW}, S_{HW}, A_{HW}, \Delta age_{HW}, \ldots \end{pmatrix}(t) \tag{22}$$

where L_{HW} denotes emotional bonding or love, Q_{HW} relationship quality, T_{HW} trust, C_{HW}^{com} communication quality, G_{HW} shared goals, R_{HW}^{rep} repair capacity, N_{HW}^{conf} negative conflict, F_{HW}^{fin} financial condition or pressure, I_{HW}^{fam} family interference or support, C_{HW}^{cult} cultural difference or compatibility, K_{HW} children-related factors, S_{HW} social environment, A_{HW} addiction or harmful dependency factors, and Δage_{HW} age difference. The vector is not intended to be exhaustive; it identifies relationship-relevant variables that may be expanded, removed, or redefined depending on the theoretical or empirical context.

WHY A SINGLE DETERMINISTIC EQUATION IS INSUFFICIENT

A tempting approach is to represent marital-bond strength by a single deterministic equation, for example

$$\mu(\mathcal{M}_{HW}, t) = f\left(L_{HW}(t), F_{HW}^{\text{fin}}(t), I_{HW}^{\text{fam}}(t), C_{HW}^{\text{cult}}(t), S_{HW}(t), K_{HW}(t), \ldots\right) \qquad (23)$$

Such an expression may be useful as a local approximation if the variables, measurement procedures, population, and time scale are clearly specified. However, it would be misleading to interpret one context-free function f as a universal equation for marriage, stability, or divorce.

Human relationships are difficult to represent by a single universal deterministic equation for at least four reasons. First, the state space is high-dimensional. Each partner is affected by many personal, relational, biological, social, cultural, economic, and historical variables. In abstract form, a person may be represented as an evolving state

$$P(t) = \Phi_P(x_1(t), x_2(t), \ldots, x_n(t), t) \qquad (24)$$

where the variables $x_i(t)$ may themselves change over time and interact with one another.

Second, the same parameter may have different signs or magnitudes in different contexts. For example, children may strengthen one marriage by increasing shared meaning and responsibility, while increasing stress in another. Financial pressure may produce solidarity in one couple and blame, avoidance, or conflict in another. Third, sequence and timing matter: an early event may change the interpretation of later events, and a later stressor may have different effects depending on the accumulated history of previous reactions. Fourth, measurement is imperfect. Variables such as love, trust, respect, resentment, repair capacity, and family interference are not directly observable physical quantities; they require operational definitions, measurement instruments, and interpretation.

Therefore, the present paper does not propose a universal deterministic equation for marriage or divorce. Instead, it treats marital dynamics as a context-dependent, partially observable, and path-dependent process. The probability-tree representation introduced below is intended to accommodate uncertainty, conditional dependence, timing, sequence, and accumulated history. Deterministic relations may still appear as components of the model, but they are embedded within a broader probabilistic and dynamic framework.

PROBABILITY-TREE FRAMEWORK

Structure

A probability tree begins with an initial marital state and branches according to events, parameters, reactions, and subsequent states. The root represents the beginning of marriage or an initial observation state. Branches represent activated relationship-relevant events, such as financial pressure, illness, children-related stress, relocation, cultural conflict, family interference, addiction, or major life transitions. Sub-branches represent responses to these events, such as constructive, destructive, avoidant, neutral, or mixed reactions. Leaves represent possible outcomes, including strengthened marriage, stable marriage, chronic crisis, separation, reconciliation, or divorce.

In the present theoretical framework, the probability tree is not interpreted as a fully estimated empirical model. Rather, it is a formal representation of conditional dependence, timing, sequence, and accumulated relational history.

Figure 1. Probability-tree framework for marital outcomes

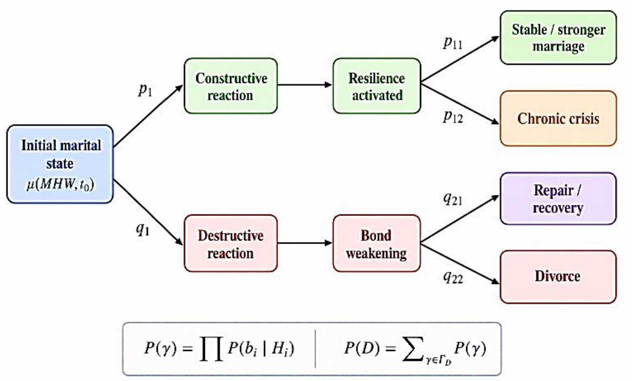

Figure 1: Illustrative probability-tree framework for marital outcomes. The root represents an initial marital state with active-marital-bond strength $\mu(M_{HW}, t_0)$. Branches represent constructive or destructive reactions, and later branches lead to possible states such as resilience activation, chronic crisis, repair or recovery, and divorce. The formulas below summarize path probability and total divorce probability in the probability-tree representation.

Path probabilities

Let γ be a path through the tree consisting of branch events $b_1, b_2, \ldots, b_n$. The probability of the path is

$$\mathbb{P}(\gamma) = \prod_{i=1}^{n} \mathbb{P}\left(b_i \mid \mathcal{H}_i\right) \qquad (25)$$

where $\mathcal{H}_i$ is the history available before branch b_i. This history may include previous events, previous reactions, current marital-bond strength, emotional bond, social conditions, personality variables, family context, and the timing of earlier stressors. If Γ_D is the set of all paths ending in divorce or marital dissolution, then the total probability of divorce is

$$\mathbb{P}(D) = \sum_{\gamma \in \Gamma_D} \mathbb{P}(\gamma) \tag{26}$$

Similarly, if Γ_S is the set of paths ending in stable marriage, then

$$\mathbb{P}(S) = \sum_{\gamma \in \Gamma_S} \mathbb{P}(\gamma) \tag{27}$$

These expressions are formal identities within the tree representation. In empirical applications, the branch probabilities would need to be estimated from data rather than assigned hypothetically.

Illustrative example

Consider three relationship-relevant stressors: financial crisis F, family interference I, and cultural difference C. The same unordered set of stressors,

$$\{F, I, C\} \tag{28}$$

may generate different outcomes depending on the order in which the stressors occur and the reactions generated at each stage.

- Sequence 1: $F \rightarrow I \rightarrow C$. Financial stress may produce blame or withdrawal; family interference may arrive after the active bond has already weakened; cultural difference may then be interpreted negatively. In this path, the marital bond may collapse.
- Sequence 2: $C \rightarrow F \rightarrow I$. Cultural difference may first be interpreted as learning and mutual growth; financial stress may be handled through teamwork; family interference may be resisted constructively. In this path, the marital bond may survive or grow.

These examples are not empirical claims. They illustrate how the proposed framework represents the possibility that sequence and reaction history alter relational outcomes.

Worked numerical example

The following example is hypothetical and is included only to show how the framework can be used. It is not an empirical estimate of any real population. Let F denote financial crisis, I family interference, and C cultural difference. Suppose a negative reaction is denoted by N and a constructive reaction by P. Consider two selected divorce-leading paths with conditional branch probabilities. For Sequence 1, $F \rightarrow I \rightarrow C$, assume

$$\mathbb{P}(N_F \mid F)\& = 0.70 \tag{29}$$

$$\mathbb{P}(N_I \mid N_F, F)\& = 0.75 \tag{30}$$

$$\mathbb{P}(D \mid N_F, N_I, C)\& = 0.80 \tag{31}$$

The probability of this selected divorce-leading path is therefore

$$\mathbb{P}(\gamma_D^{(1)}) = 0.70 \times 0.75 \times 0.80 = 0.42 \tag{32}$$

For Sequence 2, $C \rightarrow F \rightarrow I$, assume

$$\mathbb{P}(P_C \mid C)\& = 0.65 \tag{33}$$

$$\mathbb{P}(P_F \mid P_C, F)\& = 0.60 \tag{34}$$

$$\mathbb{P}(D \mid P_C, P_F, I)\& = 0.25 \tag{35}$$

Then the probability of this selected path is

$$\mathbb{P}(\gamma_D^{(2)}) = 0.65 \times 0.60 \times 0.25 = 0.0975 \tag{36}$$

These quantities are path probabilities, not total divorce probabilities for the two sequences. The total divorce probability for a sequence would require summing over all divorce-ending paths:

$$\mathbb{P}(D \mid F \rightarrow I \rightarrow C) = \sum_{\gamma \in \Gamma_{D(F \rightarrow I \rightarrow C)}} \mathrm{P}(\gamma) \tag{37}$$

and similarly for other event orders. The numerical values above are illustrative only, but the calculation shows how empirical branch probabilities could later be estimated from longitudinal data.

Illustrative computational simulation

To illustrate the computational form of the probability-tree framework, a small Monte Carlo simulation was implemented in Python. The simulation uses three relationship-relevant parameters: financial crisis F, family interference I, and cultural difference C. Each simulated couple begins with an initial active marital-bond strength $\mu(\mathcal{M}_{HW}, t_0)$ and an initial resilience level. At each event, the couple reacts constructively, neutrally, or destructively. Constructive reactions increase bond strength and resilience, while destructive reactions reduce them. Reaction probabilities depend on current bond strength, resilience, event type, event order, and previous history.

The simulation is intentionally illustrative. The numerical parameters are hypothetical and should not be interpreted as empirical divorce rates. Moreover, because the reaction rules explicitly include sequence and history dependence, the simulation does not independently validate the path-dependence principle. Its purpose is narrower: to demonstrate how the proposed probability-tree framework can be implemented computationally and how sequence-dependent outcomes can arise under the stated assumptions.

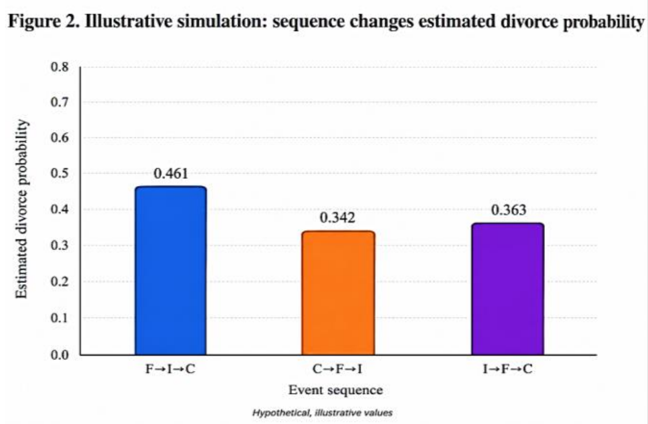

Figure 2: Illustrative simulation showing that the same three stressors $\{F, I, C\}$ can produce different estimated divorce probabilities depending on sequence. The numerical values are hypothetical and are included only to illustrate the computational logic of the framework; they should not be interpreted as empirical divorce rates.

Table 1: Illustrative simulation results for three event sequences.

Sequence	Mean final bond strength	Standard deviation	Estimated divorce probability
$F \to I \to C$	0.383	0.324	0.461
$C \to F \to I$	0.478	0.323	0.342
$I \to F \to C$	0.442	0.307	0.363

In this illustrative run, the sequence $F \to I \to C$ produces the highest estimated divorce probability, while $C \to F \to I$ produces the lowest. These results should not be interpreted as empirical evidence about real marriages. They show only that, within the assumptions of the simulation, outcome probabilities may differ when the same stressors occur in different orders. This is consistent with the broader path-dependence principle developed in the framework.

PATH-DEPENDENCE PRINCIPLE

Proposition 1 (Path-dependence under history-dependent transitions). *Suppose that relationship states evolve through a sequence of events $e_1, e_2, \dots, e_n$, and that the state update after event e_i depends not only on the event itself but also on the previous relationship state and accumulated history. That is,*

$$\boldsymbol{X}_{HW}(t_i) = T_{e_i}(\boldsymbol{X}_{HW}(t_{i-1}), \mathcal{H}_{i-1}) + \eta_i \quad (38)$$

where $\boldsymbol{X}_{HW}(t_i)$ is the relationship state after event e_i, T_{e_i} is an event-specific transition rule, $\mathcal{H}_{i-1}$ is the history before event e_i, and η_i is a stochastic or unmodeled perturbation term. Then the final outcome may depend on the sequence, timing, and reaction history, not only on the unordered set of events.
Proof sketch.

Let two relationships experience the same unordered set of events,

$$\{F, I, C\},$$

where F denotes financial crisis, I denotes family interference, and C denotes cultural difference. Consider two different event orders:

$$F \to I \to C$$

and

$$C \to F \to I.$$

Because the transition rule T_{e_i} depends on the previous state and accumulated history, the state before the second event in the first sequence need not equal the state before the second event in the second sequence. Thus,

$$T_I(T_F(\boldsymbol{X}_0, \mathcal{H}_0), \mathcal{H}_1)$$

need not equal

$$T_F(T_C(\boldsymbol{X}_0, \mathcal{H}_0), \mathcal{H}_1').$$

Consequently, the final states generated by the two event orders may differ even though the unordered set of events is the same. Therefore, within a history-dependent transition framework, relationship outcome cannot generally be represented as a function only of the unordered set of active parameters. It may also depend on sequence, timing, and accumulated reaction history.

Remark 3. *This proposition is a formal modeling statement, not an empirically validated law. It shows that path-dependence follows once relationship transitions are allowed to depend on prior states and accumulated history. Whether a specific form of path-dependence holds in real marital data remains an empirical question for future testing.*

VENN REPRESENTATION OF MARITAL STAGES

Figure 3 provides a schematic Venn-style representation of the model. The diagrams are not intended as exact measurements of identity, love, compatibility, or marital stability. They are visual tools for communicating two ideas: first, that partners may share a region of modeled attributes; and second, that the active marital bond may expand, weaken, or collapse over time. In the strict formulation of the model, the active marital-bond structure satisfies

$$\mathcal{M}_{HW}(t) \subseteq H(t) \cap W(t) \quad (39)$$

rather than being identical to the entire overlap. Thus, the shaded or central region in a Venn-style diagram should be understood as a simplified visual representation of the active bond, not as a complete mathematical measurement. In the weighted or fuzzy formulation, the diagram is even more schematic, because bond components may vary by degree rather than by binary inclusion.

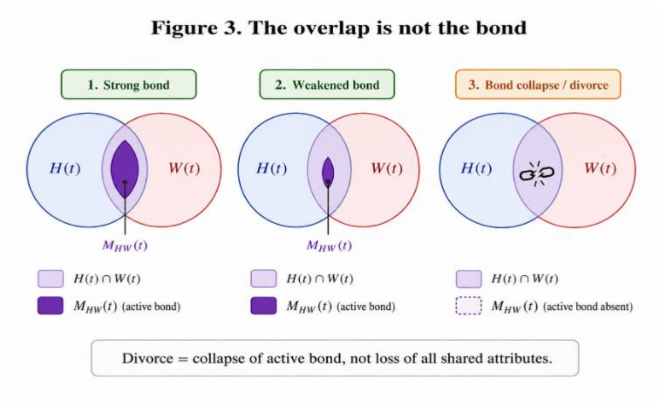

Figure 3: Conceptual distinction between general interpersonal overlap and the active marital bond. The left and right circles represent the partner identity sets $H(t)$ and $W(t)$, and the light central region represents the broader overlap $H(t) \cap W(t)$. The darker inner region represents the active marital bond $M_{HW}(t)$. The figure illustrates three stages: a strong bond, a weakened bond, and bond collapse or divorce. Even when some shared attributes remain, divorce is modeled as the collapse of the active bond rather than the disappearance of all overlap.

EXTENSION TO NUCLEAR AND EXTENDED FAMILIES

Nuclear family

A family should not be represented only as the intersection of all members' attributes. Such an intersection may be too small and may fail to capture the relational structure of the family. A stronger formulation treats the nuclear family as a structured relational system. Let the nuclear family be represented as

$$\mathcal{F}_N(t) = (V_N(t), E_N(t), \mathcal{A}_N(t)) \quad (40)$$

where,

$$V_N(t) = \{H, W, C_1, \ldots, C_n\} \quad (41)$$

is the set of family members, $E_N(t)$ is the set of relational bonds among them, and $\mathcal{A}_N(t)$ is the set of shared family attributes, such as home, routines, family name, economic resources, rituals, obligations, responsibilities, and memories. This formulation allows the family to be represented not merely as a common overlap, but as a network of persons, relationships, and shared attributes.

Children

A child should not be modeled as merely a subset of the parents' union. Such a representation would overemphasize parental inheritance and underrepresent biological variation, social environment, education, peers, culture, personal experience, and individual agency. A more appropriate theoretical representation is

$$C_i(t) \subseteq H(t) \cup W(t) \cup \mathcal{E}_i(t) \quad (42)$$

where $\mathcal{E}_i(t)$ denotes the child's broader developmental environment. This includes, for example, education, peers, culture, biological variation, social experience, media exposure, community context, and personal history. The formulation preserves the idea that parents contribute to the child's identity while avoiding genetic, psychological, and sociological oversimplification.
In a weighted or fuzzy formulation, the child's attribute structure may be represented by

$$p_{C_i}(a,t) = \Psi_i(p_H(a,t), p_W(a,t), e_i(a,t), \zeta_i(a,t)) \quad (43)$$

where $p_H(a,t)$ and $p_W(a,t)$ represent parental attribute functions, $e_i(a,t)$ represents environmental contribution, and $\zeta_i(a,t)$ represents individual variation or unmodeled influences. This equation is not intended as a genetic or psychological law; it is a schematic representation of multiple sources of child development.

Extended family and external influence

Let $G(t)$ represent extended family members such as grandparents, uncles, aunts, cousins, and in-laws. The extended family may support, weaken, or have no significant effect on the active marital bond. To avoid differentiating with respect to a person as if the person were a numerical variable, define an influence variable

$$I_g(t) \in [-1,1] \quad (44)$$

for each external family actor or subsystem $g \in G(t) \setminus V_N(t)$. Positive values of $I_g(t)$ represent supportive influence, negative values represent harmful interference, and values near zero represent negligible or neutral influence. Family influence may then be represented by the condition

$$\exists g \in G(t) \setminus V_N(t) \quad \text{such that} \quad \frac{\partial \mu(\mathcal{M}_{HW}, t)}{\partial I_g(t)} \neq 0 \quad (45)$$

provided that μ is modeled as a differentiable function of influence variables. More generally, without assuming differentiability, one may write

$$\Delta_g \mu(\mathcal{M}_{HW}, t) \neq 0 \quad (46)$$

where $\Delta_g \mu$ denotes the change in marital-bond strength associated with the influence of actor or subsystem g.
The sign and magnitude of the effect are context-dependent. An extended family may provide childcare, financial support, emotional support, cultural continuity, and practical wisdom. It may also create pressure, control, boundary violations, loyalty conflicts, or chronic marital conflict. Therefore, extended-family influence should not be classified as

inherently positive or negative; its effect depends on the couple, culture, timing, boundaries, and previous relationship history.

COMPLEX-SYSTEMS INTERPRETATION AND PHYSICAL ANALOGIES

The proposed framework has methodological connections with complex-systems thinking because a marriage or long-term partnership may be represented as a high-dimensional, dynamic, partially observable, and context-dependent relational system. Some concepts from physics and complex systems are useful as analogies for organizing thought about marital dynamics. These analogies are not intended to imply that human beings are particles or that marriages obey mechanical laws. **Table 2** summarizes several useful analogies.

Table 2: Methodological analogies between complex-systems concepts and the proposed marital-dynamics framework.

Physics or systems concept	**Analogy in the relationship model**
State space	Relationship state vector $\boldsymbol{X}_{HW}(t)$ containing emotional, communicative, social, economic, cultural, and family-related variables
Path-sum intuition	Sum over possible relationship paths $\sum_{\gamma} \mathbb{P}(\gamma)$ in the probability-tree representation
Statistical mechanics	Emphasis on population-level regularities and probabilistic tendencies rather than exact deterministic prediction of an individual marriage
Sensitivity to initial conditions	Small early differences in communication, trust, repair, or conflict may contribute to large later differences in relationship trajectory
Stability landscape	Possible relational basins or regimes such as flourishing, stable functioning, chronic crisis, separation, reconciliation, or divorce
Feedback loops	Positive reinforcement cycles, repair processes, negative escalation cycles, and self-reinforcing patterns of avoidance or conflict
Path-dependence	Later relational states depend on earlier events, reactions, timing, and accumulated history

The analogy should not be exaggerated. The framework does not claim that marital relations are physical systems in the strict sense, nor that concepts such as energy landscapes or path sums have literal physical meaning in this context. Their value is methodological and heuristic: they encourage dynamic, probabilistic, nonlinear, and history-sensitive thinking about relationship processes.

FUTURE EMPIRICAL OPERATIONALIZATION AND TESTING

A central limitation of the present framework is that the marital-bond measure $\mu(\mathcal{M}_{HW}, t)$ remains theoretical unless it is linked to measurable indicators. No empirical validation is reported in the present paper. The purpose of this section is therefore not to claim predictive validity, but to show how the proposed framework may be operationalized and tested in near-future empirical research.

Future empirical work could operationalize marital-bond strength through validated relationship scales, structured questionnaires, behavioral indicators, and longitudinal couple outcomes. For example, the Dyadic Adjustment Scale measures aspects of relationship quality such as agreement, cohesion, satisfaction, and affective expression (Spanier, 1976). Gottman and Levenson's work on marital dissolution emphasizes interaction patterns, negative affect, physiology, and later relationship outcomes (Gottman & Levenson, 1992, 2000); however, prediction claims should be treated cautiously and validated with independent samples (Heyman, 2001).

Table 3: Possible future operationalization of the marital-bond measure. These indicators are examples and require empirical validation before predictive use.

Model component	**Possible empirical indicator**	**Expected relation to $\mu(\mathcal{M}_{HW}, t)$**
Q_{HW} relationship quality	Dyadic adjustment, satisfaction, cohesion	Positive
T_{HW} trust	Trust and perceived reliability items	Positive
C_{HW}^{com} communication	Constructive communication, listening, repair attempts	Positive
G_{HW} shared goals	Agreement about future, family, finance, values	Positive
R_{HW}^{rep} repair capacity	Ability to recover after conflict	Positive
N_{HW}^{conf} negative conflict	Criticism, contempt, defensiveness, stonewalling	Negative
I_{HW}^{fam} harmful interference	External pressure from family or social environment	Usually negative, context-dependent

A possible future empirical approximation is

$$\hat{\mu}(\mathcal{M}_{HW},t) = w_1 Q_{HW}(t) + w_2 T_{HW}(t) + w_3 C_{HW}^{\mathrm{com}}(t) + w_4 G_{HW}(t) + w_5 R_{HW}^{\mathrm{rep}}(t) - w_6 N_{HW}^{\mathrm{conf}}(t) - w_7 I_{HW}^{\mathrm{fam}}(t) \tag{47}$$

where the variables represent relationship quality, trust, communication, shared goals, repair capacity, negative conflict, and harmful family interference, respectively. The coefficients w_i would need to be estimated empirically and may differ across populations, cultures, legal contexts, and time periods. Therefore, this equation is not proposed as a universal law. It is a schematic example of how the theoretical construct $\mu(\mathcal{M}_{HW},t)$ could be translated into a measurable index.

A near-future pilot study could test this structure using longitudinal couple data. At baseline, partners would complete measures of relationship quality, trust, communication, shared goals, repair capacity, negative conflict, family interference, and relevant stressors. Follow-up observations after several months or one year could measure relationship satisfaction, instability, separation intention, reconciliation, or divorce. The main empirical question would be whether lower values of $\hat{\mu}(\mathcal{M}_{HW},t)$ predict later instability, and whether sequence-dependent stressor histories improve prediction beyond static variable lists. In such a study, probability-tree branch probabilities could be estimated from observed frequencies. For example,

$$\widehat{\mathbb{P}}(N_F \mid F) = \frac{\text{number of couples showing a negative reaction after financial crisis}}{\text{number of couples experiencing financial crisis}} \tag{48}$$

and

$$\widehat{\mathbb{P}}(D \mid N_F, N_I, C) = \frac{\text{number of couples dissolving after the sequence } (N_F,N_I,C)}{\text{number of couples observed with the sequence } (N_F,N_I,C)} \tag{49}$$

These estimates would allow the probability-tree model to move from a theoretical representation to an empirically calibrated model.

Predictive testing should use out-of-sample evaluation, cross-validation, or independent samples to reduce overfitting. For example, a future study could compare a static-variable model,

$$Y = \beta_0 + \beta_1 F + \beta_2 I + \beta_3 C + \epsilon \tag{50}$$

with a sequence-sensitive model,

$$Y = \beta_0 + \beta_1 F + \beta_2 I + \beta_3 C + \beta_4 \mathrm{Seq}(F,I,C) + \epsilon \tag{51}$$

where Y represents a later relationship outcome. If the sequence-sensitive model improves prediction on held-out data, this would provide empirical support for the path-dependence component of the framework.

TESTABLE HYPOTHESES

Although the present article is theoretical and does not report empirical validation, the framework becomes scientifically useful when it generates hypotheses that can be examined in future studies. The following hypotheses are examples that could be tested using longitudinal couple data, structured surveys, behavioral observations, or calibrated simulations.

- H1 Couples with higher repair capacity $R_{HW}^{\mathrm{rep}}(t)$ will show a lower probability of active-bond collapse after external stress, controlling for initial relationship satisfaction or baseline marital-bond strength.
- H2 The same unordered set of stressors will predict different outcomes when their temporal sequence differs. Therefore, sequence and timing variables should improve prediction beyond static variable lists.
- H3 Harmful family interference $I_{HW}^{\mathrm{fam}}(t)$ will have a stronger negative effect when the active marital-bond measure $\mu(\mathcal{M}_{HW},t)$ is already below, or near, the critical threshold θ_{HW}.
- H4 Positive reinforcement $R_{HW}(t)$ will moderate the effect of negative conflict $N_{HW}^{\mathrm{conf}}(t)$, reducing the probability that conflict leads to active-bond collapse or marital dissolution.
- H5 General interpersonal similarity, measured by $\mathcal{J}(H,W;t)$ or $\mathcal{J}_w(H,W;t)$, will not by itself be sufficient to predict marital stability. The active marital-bond measure $\mu(\mathcal{M}_{HW},t)$ should explain additional variance beyond general attribute similarity.
- H6 Couples with similar initial values of $\mu(\mathcal{M}_{HW},t_0)$ may follow different trajectories if their early reaction histories differ, supporting the framework's emphasis on path-dependence.
- H7 The predictive effect of external stressors, such as financial pressure or family interference, will be moderated by repair capacity, trust, and communication quality.

These hypotheses help distinguish the framework from a purely metaphorical representation. They show how the theoretical structure can be converted into empirical tests, simulations, or statistical models. At the present stage, however, they should be interpreted as proposed hypotheses for future research rather than as established empirical findings.

LIMITATIONS

This framework has several important limitations.

1. The framework remains theoretical and conceptual. No empirical validation is reported in the present article. The numerical example, simulation, and operationalization table are included only to illustrate

how the framework could be developed, calibrated, and tested in future research.

2. The model should not be interpreted as a divorce-prediction instrument. It does not predict individual marriages with certainty, nor does it claim to determine whether a particular couple will remain married, separate, reconcile, or divorce.
3. The marital-bond measure $\mu(\mathcal{M}_{HW}, t)$ requires empirical operationalization before predictive use. Its components, weights, thresholds, and measurement procedures must be estimated and validated using appropriate data.
4. The framework depends on the choice of attribute space U. If U is incomplete, too coarse, or culturally biased, the resulting person-sets, similarities, and marital-bond measures may be misleading.
5. Cultural, legal, religious, economic, and historical meanings of marriage vary widely. Therefore, the model should not be assumed to have identical interpretation across societies without cultural adaptation and validation.
6. The current formulation is written mainly for a two-person marital dyad. Although extensions to other family structures are possible, they require additional definitions and should not be assumed to follow automatically from the dyadic case.
7. The probability-tree model may become very large when many parameters, reactions, and time points are included. Practical use would require simplification, estimation strategies, or computational methods such as simulation, pruning, Bayesian modeling, or agent-based modeling.
8. The physical and complex-systems analogies are heuristic. They are intended to encourage dynamic and probabilistic thinking, not to imply that human beings are particles or that marriages obey literal physical laws.
9. The illustrative simulation encodes path-dependence in its assumptions. Therefore, it demonstrates computational implement ability, but it does not independently prove that the same path-dependence exists in real marital data.
10. Future empirical testing will require longitudinal couple data, independent validation samples, transparent measurement procedures, and comparison with existing psychological and sociological models.

FUTURE RESEARCH

Future research can develop the framework in several directions. The most immediate next step is empirical calibration and testing. The present paper does not report empirical validation, but the framework has been formulated so that its main constructs can be operationalized in near-future studies.

I. Collect longitudinal couple data to estimate the components of the active marital-bond measure $\mu(\mathcal{M}_{HW}, t)$ and to evaluate whether $\hat{\mu}(\mathcal{M}_{HW}, t)$ predicts later relationship satisfaction, instability, separation intention, reconciliation, or divorce.

II. Estimate conditional branch probabilities in the probability-tree model from observed event–reaction–outcome sequences. For example, future data could be used to estimate probabilities such as $\mathbb{P}(N_F \mid F)$, $\mathbb{P}(N_I \mid N_F, F)$, and $\mathbb{P}(D \mid N_F, N_I, C)$.

III. Compare the proposed marital-bond measure with existing marital-satisfaction, dyadic-adjustment, relationship-quality, and divorce-risk measures in order to determine whether the framework explains additional variance beyond established instruments.

IV. Test whether sequence, timing, and accumulated reaction history improve prediction beyond static variable lists. This should be evaluated using cross-validation, held-out samples, or independent replication samples to reduce overfitting.

V. Build agent-based simulations in which individuals possess evolving attribute structures, weighted similarities, changing relational bonds, and context-dependent reactions to stressors.

VI. Develop culturally adaptive versions of the model by studying how legal systems, religion, social norms, extended-family involvement, economic pressure, gender roles, and migration affect the interpretation of marital-bond variables.

VII. Extend the framework beyond two-person marital dyads to other relational structures, including parent–child relations, extended families, friendships, business partnerships, academic collaborations, and social networks.

VIII. Investigate whether the critical threshold θ_{HW} is best modeled as couple-specific, culture-specific, or dynamically changing over time.

IX. Examine whether weighted or fuzzy-set representations provide better empirical fit than binary set representations of personal attributes and relational overlap.

X. Develop ethical guidelines for any future predictive use of the framework, especially if the model is applied to sensitive relationship decisions, counseling contexts, or family-policy research.

The near-future empirical goal is not to prove a universal mathematical law of marriage or divorce, but to evaluate whether the proposed constructs especially active marital-bond strength, repair capacity, family influence, and sequence-dependent stressor histories provide useful explanatory or predictive information when tested against real longitudinal data.

CONCLUSION

This article has proposed a theoretical set-theoretic and probabilistic framework for representing marriage, family structure, and divorce. The central modeling idea is that two persons can become deeply connected without becoming identical. Their shared life is represented not as the complete merging of two identities, but as an active marital-bond structure embedded within a broader region of personal overlap. Love, trust, communication, repair capacity, culture, finance, children, extended family, and social environment are treated as dynamic, context-dependent, and potentially path-dependent components of the relationship state.

The framework avoids two oversimplifications. First, it does not define divorce as the disappearance of all shared attributes. Former spouses may continue to share memories, children, legal history, language, social networks, or cultural background.

Divorce is therefore better represented as the functional collapse of the active marital-bond measure rather than as the emptying of the total personal intersection. Second, the framework avoids the mathematically weak claim that $A(t) \cap B(t) \neq A(t)$ for all distinct persons.

Instead, it uses normalized similarity measures, such as the Jaccard index and its weighted extension, to represent interpersonal similarity while preserving the non-identity of distinct persons within a sufficiently rich description.

Probability trees are used to represent uncertainty, conditional dependence, sequence, timing, and accumulated history. The worked numerical example and illustrative Monte Carlo simulation demonstrate how the framework can be implemented computationally, but they are not empirical evidence and should not be interpreted as real divorce predictions. Their purpose is to clarify the internal logic of the proposed model and to show how path-dependent assumptions can be represented formally.

The article does not claim to provide a final predictive theory of marriage or divorce. Its contribution is a formal conceptual scaffold for organizing assumptions, defining relational quantities, generating hypotheses, and preparing the model for near-future empirical testing. Future work should operationalize the active marital-bond measure, estimate probability-tree branch probabilities, and evaluate the model using longitudinal couple data and independent validation samples.

In this sense, the proposed framework suggests that the mathematics of relationship life is not the mathematics of perfect certainty or complete identity. It is a mathematics of overlap and boundary, reinforcement and decay, probability and uncertainty, sequence and history, stability and change.

A GLOSSARY OF SYMBOLS

Symbol	Meaning
U	Attribute space used in the model; not assumed to be metaphysically complete or universal in practice
U_M	Marital-bond attribute domain, containing active relational components relevant to $\mathcal{M}_{HW}$
$P(t)$	Binary person-set representing modeled attributes of person P at time t
$p_P(a,t)$	Weighted or fuzzy membership/salience function for attribute a of person P at time t
$P^c(t)$	Complement of person-set $P(t)$ relative to U
$H(t)$	Person-set of partners H at time t
$W(t)$	Person-set of partners W at time t
$H(t) \cap W(t)$	General modeled personal overlap between partners H and W
$\mathcal{M}_{HW}(t)$	Active marital-bond set or structure between partners H and W
$m_{HW}(a,t)$	Strength or activation of marital-bond component a at time t
$\mu(\mathcal{M}_{HW},t)$	Modeled strength or measure of the active marital bond at time t
$\hat{\mu}(\mathcal{M}_{HW},t)$	Empirical or estimated approximation of the active marital-bond measure
ω_a	Theoretical or empirically estimated weight assigned to marital-bond component a
$\mathcal{J}(A,B;t)$	Jaccard similarity of binary person-sets $A(t)$ and $B(t)$ at time t
$\mathcal{J}_w(A,B;t)$	Weighted Jaccard-type similarity of weighted person-structures A and B at time t
$d_{HW}(t)$	Conceptual emotional or relational distance between partners H and W
$L_{HW}(t)$	Love or emotional bonding intensity between partners H and W at time t
$R_{HW}(t)$	Reinforcement term for love or relational bond

$D_{HW}(t)$	Decay or damage term for love or relational bond
$X_i(t)$	Relationship-relevant parameter at time t
$\boldsymbol{X}_{HW}(t)$	Relationship state vector for partners H and W at time t
θ_{HW}	Critical active-bond threshold for instability or dissolution
t_d	Time of divorce or marital dissolution
Δ	Duration over which the active marital bond remains below a critical threshold
γ	Path in the probability-tree representation
$\mathbb{P}(\gamma)$	Probability of a path γ
Γ_D	Set of all paths leading to divorce or marital dissolution
Γ_S	Set of all paths leading to stable marriage
$\mathcal{H}_i$	History available before branch event b_i
$\mathcal{H}(t)$	Accumulated relationship history up to time t
T_{e_i}	Event-specific transition rule after event e_i
η_i	Stochastic or unmodeled perturbation term in the transition equation
$\mathcal{F}_N(t)$	Nuclear-family relational system at time t
$V_N(t)$	Set of nuclear-family members
$E_N(t)$	Set of relational bonds among nuclear-family members
$\mathcal{A}_N(t)$	Set of shared nuclear-family attributes
$C_i(t)$	Person-set or attribute structure of child i at time t
$\mathcal{E}_i(t)$	Developmental environment of child C_i at time t
$G(t)$	Extended-family set
g	Extended-family actor or subsystem
$I_g(t)$	Influence variable associated with extended-family actor or subsystem g
$\Delta_g\mu(\mathcal{M}_{HW},t)$	Change in active marital-bond strength associated with the influence of g
Q_{HW}	Relationship quality indicator
T_{HW}	Trust indicator
C_{HW}^{com}	Communication-quality indicator
G_{HW}	Shared-goals indicator
R_{HW}^{rep}	Repair-capacity indicator
N_{HW}^{conf}	Negative-conflict indicator
F_{HW}^{fin}	Financial condition or financial-pressure indicator
I_{HW}^{fam}	Family-interference or family-support indicator
C_{HW}^{cult}	Cultural-difference or cultural-compatibility indicator
K_{HW}	Children-related factor
S_{HW}	Social-environment factor
A_{HW}	Addiction or harmful dependency factor
Δage_{HW}	Age difference between partners

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