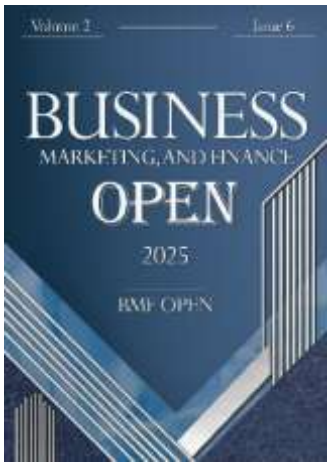
Designing a Mathematical Model of Brand Heritage in the Banking Industry: A Case Study of Bank Melli Iran

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Abstract: Brand heritage is a strategic asset of well-established brands that can influence customer behavior and the continuity of their relationships with an organization by fostering authenticity, trust, nostalgia, and attachment. This study aims to develop a mathematical model based on agent-based simulation of brand heritage in the banking industry, with Bank Melli Iran serving as the case study. In terms of purpose, the study is applied, while methodologically it adopts a developmental–analytical approach based on an integrated framework combining mathematical modeling and agent-based simulation. In the first stage, the key components of brand heritage and the factors influencing customer behavior were identified through theoretical studies and expert judgment, and the relationships among the variables were subsequently specified. A mathematical model was then developed by incorporating variables such as perceived brand heritage, authenticity, nostalgia, trust, brand image, attachment, satisfaction, service quality, digital experience, word-of-mouth communication, and customer loyalty. The model was implemented in a simulation environment using the NetLogo software. In the agent-based model, customers were represented as heterogeneous agents, while employees and competitors were incorporated as environmental factors influencing the decision-making context. The simulation results indicated that brand heritage has positive effects on customer perceptions of authenticity, trust, nostalgia, and attachment, and that a substantial proportion of its effect on loyalty is transmitted through these mediating mechanisms. Furthermore, digital experience and service quality play important roles in transforming the historical equity of a brand into sustainable customer loyalty. Scenario analysis demonstrated that an integrated strategy combining brand heritage, digital transformation, employee empowerment, and customer experience management outperformed individual strategies in enhancing trust and loyalty and improving customer retention.

Keywords: Brand Heritage; Agent-Based Simulation; Mathematical Modeling; Customer Loyalty; Bank Melli Iran.

1. Introduction

In contemporary service markets, brand value is increasingly shaped not only by current functional performance but also by the meanings, memories, associations, and historical experiences accumulated around an organization over time. This consideration is particularly important for long-established institutions whose identity has been formed through decades of interaction with customers, communities, employees, and broader social systems. Within this context, brand heritage has emerged as a strategic marketing construct describing the capacity of an organization's past—its longevity, historical continuity, core values, symbols, traditions, achievements, and accumulated experiences—to create meaningful value in the present and guide its future positioning. Rather than

representing age alone, brand heritage reflects the interpretation and strategic activation of organizational history in ways that reinforce identity, credibility, and differentiation. Early research established brand heritage as an important driver of marketing performance because organizations capable of connecting their historical identity with contemporary stakeholder expectations may possess distinctive resources that are difficult for competitors to imitate [1]. Subsequent scholarship has increasingly demonstrated that the value of heritage depends on how consumers interpret historical continuity and how those interpretations are translated into psychological and behavioral responses.

The significance of brand heritage is especially pronounced in industries characterized by perceived risk, uncertainty, and long-term relational exchanges. Banking is a particularly relevant setting because customers entrust financial institutions with resources, personal information, transactions, savings, and long-term financial decisions. In such an environment, organizational longevity and continuity can operate as informational signals of stability, reliability, institutional experience, and resilience. A bank with an established historical presence can potentially leverage this accumulated legacy to distinguish itself from newer competitors; however, the existence of history does not automatically create heritage value. Heritage must first be recognized, interpreted, and experienced by customers. Research conceptualizing brand heritage as a temporal perception emphasizes that consumers do not simply respond to objective brand age; instead, they form subjective judgments about the meaningful continuity between a brand's past, present, and anticipated future [2]. Consequently, understanding heritage requires attention to both organizational characteristics and consumer-level processes through which historical resources become psychologically and behaviorally consequential.

One of the central mechanisms through which brand heritage can produce favorable consumer responses is perceived brand authenticity. Consumers frequently use historical continuity, consistency of values, recognizable symbols, and continuity of organizational identity as cues for judging whether a brand is genuine, credible, and true to its professed character. Experimental evidence indicates that emphasizing heritage can enhance consumer responses when historical elements create meaningful perceptions about the brand rather than simply communicating chronological age [3]. Research on corporate heritage brands similarly shows that authenticity depends on how consumers interpret signs, narratives, identity claims, and historical associations surrounding the organization [4]. More recent evidence reinforces this pathway by demonstrating that brand heritage and nostalgia can contribute substantially to perceived brand authenticity, which can subsequently generate consumer engagement and psychological ownership [5]. In banking, this mechanism is particularly salient because authenticity may reduce perceived uncertainty by communicating continuity between institutional claims, historical conduct, and current customer experience.

Another major psychological consequence of heritage is nostalgia. Heritage brands can activate personal memories, collective memories, intergenerational experiences, and emotional associations with earlier periods of customers' lives or with the history of the wider community. Nostalgia therefore transforms historical information into an emotionally meaningful consumer experience. Historical narratives, symbols, traditional branch identities, longstanding social roles, and family experiences with a financial institution may connect customers to a bank through memories that extend beyond functional evaluations of financial products. Research indicates that perceived brand heritage can generate emotional responses that strengthen customers' relationships with established brands, while the effectiveness of heritage depends partly on product category and the meanings consumers assign to longevity [6]. Brand narratives provide an especially important vehicle in this process because stories about origins, accomplishments, traditions, and continuity can organize historical information into

memorable and identity-relevant meanings [7]. Thus, nostalgia should be understood not as a decorative consequence of historical marketing but as an affective mechanism through which heritage may contribute to attachment, identification, and continued relationships.

Brand heritage may also influence customer behavior by supporting trust. In financial services, trust represents a critical relational resource because customers frequently evaluate outcomes that are difficult to verify immediately and must depend on the competence, integrity, stability, and consistency of the service provider. A credible heritage can reduce perceived uncertainty by signaling organizational endurance and accumulated experience. Empirical research in service contexts has demonstrated that brand heritage can affect behavioral intentions through relational mechanisms such as brand trust and loyalty [8]. From a signaling perspective, heritage-related indicators—including longevity, established traditions, historical performance, recognized symbols, and continuity of values—may serve as signals that customers use when direct information about future service performance is incomplete. Research applying signaling theory to time-honoured brands suggests that heritage-related attributes can communicate quality and credibility and thereby influence consumer evaluations and behavioral responses [9]. In banking, where customers continuously assess security, continuity, responsiveness, and institutional reliability, these signaling functions may be particularly important.

Despite these potential advantages, heritage should not be treated as an inherently positive or self-sustaining resource. A long history can create value only when consumers perceive it as relevant to contemporary expectations. Heritage brands therefore face a strategic tension between continuity and adaptation. Excessive reliance on the past may produce perceptions of obsolescence, while radical modernization may weaken the historical continuity that makes the brand distinctive. Research examining the relationship between heritage and innovation demonstrates that these elements need not be mutually exclusive. Instead, heritage and innovation can function complementarily when contemporary offerings preserve the symbolic authenticity and identity of the established brand [10]. Similarly, research comparing revitalization and retro-branding strategies indicates that the effectiveness of heritage activation depends on how organizations integrate elements of the past with contemporary value creation and consumer expectations [11]. These findings are highly relevant to banking, where heritage institutions must increasingly combine historical credibility with mobile banking, digital platforms, remote services, technological innovation, and rapidly changing expectations regarding convenience and personalization.

The challenge of balancing past and present is becoming even more significant as customer populations become increasingly heterogeneous. Older customers may associate heritage with familiarity, accumulated experience, and long-term institutional relationships, whereas younger and digitally oriented customers may assign greater importance to technological quality, accessibility, speed, personalization, and user experience. Heritage effects therefore cannot be assumed to be homogeneous across all consumers. Recent research shows that perceived heritage can influence purchase behavior through emotional resonance and self-brand identification, indicating that the psychological impact of heritage depends on how consumers connect organizational history with their own self-concept and emotional experience [12]. Such findings reinforce the need to move beyond treating the customer population as a single homogeneous unit. In a banking environment, differences in age, relationship duration, digital literacy, heritage sensitivity, service preferences, risk aversion, and social influence may produce substantially different responses to the same heritage strategy.

The literature has therefore progressively shifted from viewing brand heritage primarily as organizational age or historical background toward a multidimensional and dynamic phenomenon involving authenticity, identity, narratives, innovation, nostalgia, engagement, and consumer interpretation. Systematic reviews confirm this

development while also identifying substantial methodological gaps. A recent synthesis of the literature demonstrates that research on brand heritage has investigated outcomes such as authenticity, engagement, perceived value, consumer attitudes, and behavioral intentions, yet remains dominated by conventional survey designs, experiments, and relatively static causal models [13]. Another systematic review conceptualizes heritage as a dynamic process through which meanings from the past are encoded organizationally, communicated symbolically, interpreted by consumers, and reconstructed in contemporary contexts [14]. This dynamic conception suggests that heritage is continuously reproduced rather than simply inherited. Consequently, the outcomes of heritage management can change as customer experiences, communication patterns, technologies, organizational practices, and competitive environments evolve.

An additional conceptual complication concerns the distinction between inherited and strategically constructed heritage. Organizations do not merely preserve an objective historical record; they select, interpret, narrate, and sometimes reconstruct elements of the past for present strategic purposes. The notion of invented corporate heritage illustrates that heritage can emerge through deliberate organizational processes of selecting and institutionalizing historical narratives, even where a straightforward inherited tradition is absent [15]. This perspective emphasizes the managerial character of heritage construction and raises important questions regarding credibility and consistency. Heritage claims are likely to generate value only when customers perceive alignment between historical narratives and contemporary organizational conduct. Accordingly, current service quality, employee behavior, digital performance, and customer experience may either confirm heritage claims or create inconsistency between historical identity and present-day reality.

The growing complexity of these relationships highlights an important limitation of traditional statistical approaches. Regression analysis and structural equation modeling can effectively estimate relationships among variables, test theoretical pathways, and identify direct and indirect effects, but they commonly represent relationships in an aggregated and relatively static manner. They are less suited to representing repeated interactions among heterogeneous customers, adaptive learning, social network influence, word-of-mouth diffusion, competitive responses, threshold effects, feedback loops, and emergent population-level patterns. In markets where individual customers repeatedly update their attitudes on the basis of service encounters, digital experiences, social information, organizational communication, and competitor attractiveness, macro-level loyalty and retention are generated through many interacting micro-level processes. Therefore, a methodological framework capable of representing heterogeneity, interaction, adaptation, and temporal evolution is required.

Agent-based modeling (ABM) provides such a framework by representing a system as a population of autonomous and potentially heterogeneous agents whose behavior is governed by defined rules and whose interactions can produce emergent aggregate outcomes. ABM has been increasingly employed in economic and market research because it allows researchers to move beyond representative-agent assumptions and simulate systems involving nonlinear relationships, bounded rationality, interaction networks, adaptation, and feedback. Reviews of agent-based modeling in economic markets emphasize its capacity to capture heterogeneous agents, out-of-equilibrium behavior, emergent phenomena, and complex interaction structures while providing a computational environment for testing alternative scenarios [16]. Within financial-market research, ABM similarly provides a framework for linking individual-level behavioral rules to aggregate market dynamics, although careful attention must be paid to model validation, parameter calibration, interaction topology, and behavioral assumptions [17]. These methodological characteristics correspond closely to the theoretical requirements of brand heritage research in dynamic service settings.

Consumer decision making is also particularly compatible with an agent-based perspective because actual consumers rarely behave as perfectly rational optimizers. Their choices depend on limited information, habits, preferences, social influence, previous experiences, perceived risk, and heterogeneous decision thresholds. Agent-based models incorporating bounded rationality demonstrate how consumer choices can be generated from individualized decision rules and how heterogeneous responses may collectively shape market outcomes [18]. Similarly, computational models of consumer choice have been used to evaluate how marketing variables such as pricing and advertising interact with individual behavior and market dynamics [19]. The same logic can be extended to brand heritage: customers can differ in their sensitivity to historical continuity, nostalgia, digital service quality, trust, competitor attractiveness, or peer opinions, and these differences can be explicitly represented rather than averaged away.

Agent-based modeling is also valuable because brand-related behavior evolves through diffusion and social interaction. Customers exchange opinions, recommendations, dissatisfaction, and narratives within social networks, and these interactions can alter other customers' perceptions of an organization. Research on agent-based modeling of market diffusion demonstrates that ABM is particularly suitable for examining how individual-level adoption and communication behaviors produce aggregate diffusion patterns, while simultaneously emphasizing the need for empirical calibration and transparent behavioral assumptions [20]. For heritage brands, this means that positive or negative word-of-mouth may reinforce or weaken perceived heritage, authenticity, trust, and loyalty over time. A heritage strategy that appears effective under a static average-response model may generate substantially different outcomes when customer heterogeneity, network effects, competitive alternatives, and cumulative experiences are introduced.

These theoretical and methodological considerations are particularly relevant to Bank Melli Iran, where historical continuity and institutional legacy coexist with pressures generated by digital transformation, evolving customer expectations, competitive banking alternatives, and generational change. The study underlying the present article conceptualizes customers as heterogeneous agents and incorporates employees, branches, competitors, service quality, digital experience, social influence, and word-of-mouth within a dynamic simulation framework. Its proposed mathematical structure treats perceived heritage, authenticity, nostalgia, trust, attachment, satisfaction, loyalty, and switching behavior as interconnected state variables that evolve over time rather than as isolated static outcomes. This structure is consistent with the contemporary view that effective heritage management requires both preservation of historically meaningful identity and continuous adaptation to current service expectations.

Accordingly, the principal research gap concerns the absence of an integrated dynamic framework capable of explaining how brand heritage operates through heterogeneous customer perceptions and repeated interactions while simultaneously accounting for authenticity, nostalgia, trust, attachment, service quality, digital experience, word-of-mouth, employee-mediated heritage transmission, and competitive pressure. Existing research has provided substantial evidence regarding individual relationships among these constructs, yet it has offered comparatively limited understanding of how they interact cumulatively over time and how managerial interventions may generate different system-level outcomes. By combining empirically grounded relationships with mathematical formulation and agent-based simulation, brand heritage can be conceptualized not merely as an antecedent in a linear causal model but as an evolving strategic resource whose consequences emerge from interactions among customers, employees, organizational policies, technologies, and competitors. Such an approach also permits counterfactual and "what-if" scenario analysis, allowing managers to examine the potential

consequences of alternative heritage communication, digital innovation, employee development, customer experience, and competitive strategies before their implementation.

Therefore, the aim of this study is to design and validate an integrated mathematical agent-based simulation model of brand heritage in the banking industry, using Bank Melli Iran as a case study, in order to explain the dynamic effects of perceived brand heritage, authenticity, nostalgia, trust, attachment, service quality, digital experience, satisfaction, social interaction, and competitive conditions on customer loyalty and retention.

2. Methods and Materials

The research is applied-developmental in terms of objective and exploratory-mixed and model-oriented in terms of nature. The applied aspect of the research is because the final output can serve as a decision-support tool for evaluating brand heritage, customer experience, brand modernization, and customer retention policies at Bank Melli Iran. The developmental aspect relates to designing a new computational framework for converting the brand heritage construct into a set of state variables, update rules, and agent behaviors. In the qualitative section, documentary analysis and semi-structured interviews with experts are employed; in the quantitative section, relationships among constructs are estimated using survey data and statistical methods; and in the simulation section, the agent-based model is executed with a discrete-time step approach.

The research population is defined in two sections. The expert population includes managers and senior experts at Bank Melli Iran in the fields of marketing, brand, public relations, customer experience, digital banking, branches, and planning, along with faculty members and specialists in marketing and agent-based simulation. For the qualitative section, purposive and snowball sampling was used until theoretical saturation was reached, with approximately 15 to 25 experts examined. For fuzzy Delphi, a panel of 20 to 30 people was used. The customer population includes all individual customers of Bank Melli Iran, with multi-stage stratified sampling considering age, relationship history, type of service usage (in-person or digital), and geographic region.

Agent-Based Model Design Logic

The designed model is a multi-agent system with discrete time $t = 0, 1, ..., T$. In each period, customers receive an experience from the bank, obtain information and attitudes from their social network, update their perception of heritage and current bank performance, and then decide whether to stay, increase engagement, recommend the bank, or migrate to a competitor. Employees and branches serve as intermediaries for transmitting heritage and experience; the bank determines marketing, digital, and heritage policies; and competitors create alternative attractiveness for customers.

Table 1: Types of Research Agents in Banking Industry Brand Heritage

Agent	Main Characteristics	State Variables	Decision/Behavior	Model Output
Customer	Age, generation, relationship history, heritage sensitivity, digital literacy, risk aversion	Perceived heritage, trust, authenticity, nostalgia, attachment, satisfaction, loyalty	Stay, increase usage, recommend, migrate	Customer lifetime value, loyalty, customer share
Employee/Branch	Interaction quality, brand knowledge, brand commitment, digital capability	Service quality, heritage transmission intensity, brand narrative	Service delivery, explanation/narration, problem-solving	Customer experience, trust
Bank Melli	Brand budget, digital quality, heritage policy, innovation, branch network	Heritage strength, reputation, experience quality	Investment and policy-making	Customer retention, brand value
Competitor Bank	Quality, innovation, price/fee, brand attractiveness	Alternative attractiveness	Competition for customer attraction	Migration rate

Sets, Indicators, and Parameters

The main sets and indicators of the model are defined as follows:

-I = {1, ..., N}: Set of customers; i is the customer index

-J = {1, ..., M}: Set of branches/employees or touchpoints

-K = {1, ..., K}: Set of competitor banks

-t = {0, ..., T}: Simulation time periods

-N_i: Set of social neighbors of customer i in the communication network

Customer State Variables

Table 2: Customer State Variables

Symbol	Definition	Range
$PH_{i,t}$	Perceived brand heritage of customer i at time t	[0,1]
$TR_{i,t}$	Trust in the bank	[0,1]
$AU_{i,t}$	Perceived brand authenticity	[0,1]
$NO_{i,t}$	Nostalgia/memory bond	[0,1]
$BI_{i,t}$	Brand image	[0,1]
$AT_{i,t}$	Attachment to brand	[0,1]
$SA_{i,t}$	Satisfaction	[0,1]
$LO_{i,t}$	Loyalty	[0,1]
$DX_{i,t}$	Digital experience	[0,1]
$SQ_{i,t}$	Perceived service quality	[0,1]
$WOM_{i,t}$	Tendency toward word-of-mouth	[-1,1]
$SW_{i,t}$	Probability of migration to competitor	[0,1]

Bank-Level Variables

-BH_t: Brand heritage stock or strength at time t

-DI_t: Level of digital banking innovation and quality

-HC_t: Intensity of brand heritage communication and narrative

-ES_t: Quality of employee and branch interaction

-REP_t: Public reputation of the bank

-$COMP_t$: Average attractiveness of competitors in the market

Mathematical Model of Brand Heritage Dynamics

In this research, brand heritage is modeled as a dynamic stock. This stock is fed by historical capital and stability of core values, but can be weakened by the effect of poor current performance or lack of alignment with new customer expectations.

$$BH_{t+1} = \text{clip}[BH_t + \alpha_1 HP_t + \alpha_2 CV_t + \alpha_3 REP_t + \alpha_4 HC_t - \alpha_5 NE_t - \alpha_6 CR_t, 0, 1] \quad (1)$$

In equation (1), HP represents credible performance history, CV represents stability of core values, REP represents reputation, HC represents heritage communication, NE represents negative experience, and CR represents the intensity of crisis or damaging event to brand credibility. The clip function keeps the value within the range of zero to one.

Customer Perceived Heritage Equation

$$PH_{i,t+1} = (1-\lambda_i)PH_{i,t} + \lambda_i[\beta_1 BH_t + \beta_2 NO_{i,t} + \beta_3 ES_t + \beta_4 HC_t + \beta_5 SN_{i,t}] \quad (2)$$

λ_i is the customer's learning/attitude adjustment rate. $SN_{i,t}$ indicates the social network effect on the customer. In this structure, perceived heritage is formed from the combination of the bank's actual heritage strength, customer memory and nostalgia, interaction experience with employees, historical communication of the bank, and others' opinions.

Social Network Effect and Word-of-Mouth

$SN_{i,t} = \Sigma_{j \in N_i} w_{ij} \cdot WOM_{j,t} / \Sigma_{j \in N_i} w_{ij}$ (3)

$WOM_{i,t+1} = clip[\theta_1 SA_{i,t} + \theta_2 LO_{i,t} + \theta_3 PH_{i,t} - \theta_4 NE_{i,t}, -1, 1]$ (4)

The weight w_{ij} represents the intensity of the social relationship between two customers. This mechanism enables the spread of positive or negative attitudes toward the bank at the network level.

Authenticity and Nostalgia Model

$AU_{i,t+1} = clip[\gamma_1 PH_{i,t} + \gamma_2 CON_t + \gamma_3 SQ_{i,t} + \gamma_4 DI_t - \gamma_5 INC_t, 0, 1]$ (5)

$NO_{i,t+1} = clip[(1-\varrho_i) NO_{i,t} + \varrho_i(\delta_1 PH_{i,t} + \delta_2 MEM_i + \delta_3 FAM_i), 0, 1]$ (6)

CON represents the consistency and continuity of brand identity, and INC represents perceived inconsistency between historical claims and current performance. MEM indicates individual memory, and FAM indicates family/generational transmission of bank experience.

Customer Trust Model

$TR_{i,t+1} = clip[(1-\eta) TR_{i,t} + \eta(\varphi_1 AU_{i,t} + \varphi_2 SQ_{i,t} + \varphi_3 DX_{i,t} + \varphi_4 PH_{i,t} - \varphi_5 RISK_{i,t}), 0, 1]$ (7)

Trust is strengthened by authenticity, service quality, digital experience, and perceived heritage, and decreases with risk experience, errors, insecurity, or dissatisfaction.

Brand Image and Attachment Model

$BI_{i,t+1} = clip[\psi_1 PH_{i,t} + \psi_2 TR_{i,t} + \psi_3 SQ_{i,t} + \psi_4 DX_{i,t} + \psi_5 REP_t, 0, 1]$ (8)

$AT_{i,t+1} = clip[\omega_1 TR_{i,t} + \omega_2 NO_{i,t} + \omega_3 BI_{i,t} + \omega_4 ID_{i,t}, 0, 1]$ (9)

$ID_{i,t}$ represents the customer's identity alignment with the bank. Brand heritage is expected to have different effect intensities across different customer generations.

Satisfaction and Loyalty Model

$SA_{i,t+1} = clip[\kappa_1 SQ_{i,t} + \kappa_2 DX_{i,t} + \kappa_3 TR_{i,t} - \kappa_4 GAP_{i,t}, 0, 1]$ (10)

$LO_{i,t+1} = clip[\mu_1 LO_{i,t} + \mu_2 TR_{i,t} + \mu_3 AT_{i,t} + \mu_4 SA_{i,t} + \mu_5 PH_{i,t} - \mu_6 CA_{i,t}, 0, 1]$ (11)

GAP represents the gap between expectation and performance, and CA represents the attractiveness of competitor alternatives for the customer. The presence of the term $\mu_1 LO_{i,t}$ introduces the effect of relationship inertia and loyalty memory into the model.

Competitor Attractiveness and Migration Model

$CA_{i,t} = \nu_1 Qc_t + \nu_2 Dc_t + \nu_3 Pc_t + \nu_4 BRc_t - \nu_5 SC_i$ (12)

$Z_{i,t} = a_0 + a_1 CA_{i,t} - a_2 LO_{i,t} - a_3 TR_{i,t} - a_4 PH_{i,t} - a_5 AT_{i,t} + a_6 NE_{i,t}$ (13)

$SW_{i,t} = 1 / (1 + \exp(-Z_{i,t}))$ (14)

Qc, Dc, Pc, and BRc represent competitor's quality, digital capability, economic attractiveness, and brand strength, respectively. SC is the customer's switching cost. The logit equation keeps migration probability between zero and one.

Customer Decision Rule

$Stay_{i,t} = 1$ if $SW_{i,t} < \tau_i$; otherwise 0 (15)

τ_i is the individual migration threshold and is considered different for different customers. This heterogeneity can be generated from beta distribution, truncated normal distribution, or empirical distribution estimated from survey data.

Employee Role Model in Brand Heritage Transmission

$HT_{j,t} = \xi_1 BK_j + \xi_2 BC_j + \xi_3 SQ_j + \xi_4 ST_j$ (16)

$ES_t = (1/M) \Sigma_j HT_{j,t}$ (17)

BK represents employee knowledge of the bank's history and identity, BC represents behavioral commitment to the brand, SQ represents service quality, and ST represents narrative ability and brand meaning transmission. Thus, employees act as heritage carriers in the model.

Bank Management Objective Function

Although ABM is not inherently an optimization model, a complementary objective function can be defined for managerial use to compare different policies based on simulation output:

$Max\ J = \Sigma_t [w_1 \cdot BH_t + w_2 \cdot LoyalRate_t + w_3 \cdot Retention_t + w_4 \cdot AvgTrust_t + w_5 \cdot CLV_t - w_6 \cdot C_t]$ (18)

C_t represents the total costs of heritage, marketing, employee training, and digital enhancement policies. Weights w are determined based on AHP/BWM or expert opinion.

Macro Output Indicators of the Model

-Average perceived heritage: $AvgPH_t = (1/N)\Sigma_i PH_{i,t}$

-Average trust: $AvgTR_t = (1/N)\Sigma_i TR_{i,t}$

-Loyalty rate: $LoyalRate_t$ = number of customers with LO ≥ 0.70 / N

-Customer retention rate: $Retention_t$ = 1 − number of migrants / N

-Positive word-of-mouth rate

-Share of different generations among loyal customers

-Customer lifetime value and revenue from retained customers

-Composite banking brand heritage index

Banking Brand Heritage Composite Index

$BHI_t = q_1 BH_t + q_2 AvgPH_t + q_3 AvgAU_t + q_4 AvgTR_t + q_5 AvgNO_t + q_6 AvgAT_t$ (19)

Weights q can be extracted using BWM, AHP, or entropy method, and their sum equals one.

Agent Initialization

At the beginning of the simulation, demographic and behavioral variables of each customer are entered into the model from empirical distributions. Age and relationship history come from actual data, attitudinal variables from questionnaire score distributions, and social network structure from small-world, scale-free, or calibrated networks based on customer interaction data. To avoid artificial results, initial parameters are extracted from real data as much as possible, with expert opinion or scenario ranges used only where data is lacking.

Parameter Calibration

Coefficients β, γ, φ, ψ, ω, κ, and μ are extracted from calculating relationships among constructs in customer data. Dynamic parameters such as learning rate, forgetting rate, migration threshold, and network effect intensity were adjusted through calibration based on minimizing the distance between model output and actual bank indicators.

$\theta^* = \text{argmin}\theta\ \Sigma_r v_r [Y_r(real) - Y_r(sim, \theta)]^2$ (20)

In this equation, θ is the parameter vector, and Y is the set of target indicators such as retention rate, loyalty, digital service usage, or migration.

Table 3: Research Scenarios

Code	Scenario	Description
S0	Baseline scenario	Continuation of the bank's existing conditions without new intervention.
S1	Heritage narrative strengthening	Increasing historical communication, symbols, national role, and brand stories.
S2	Heritage + Digital	Strengthening heritage along with improving application quality, remote services, and innovation.
S3	Heritage-oriented employee training	Increasing employee knowledge and ability to transfer heritage in branches.
S4	Trust crisis	Simulation of a negative shock in reputation or service quality.
S5	Competitive pressure	Increasing brand attractiveness and digital capability of competitor banks.
S6	Young generation	Increasing the share of new generation customers with lower sensitivity to age and higher sensitivity to digital experience.
S7	Integrated strategy	Combination of heritage, digital innovation, employee training, and customer experience management.

3. Findings and Results

In the fuzzy Delphi stage, the perspectives of 30 experts in banking, brand, and marketing were collected and analyzed. Results indicated that all identified dimensions, with scores above the acceptance threshold of 0.7, possessed sufficient consensus and importance for inclusion in the final model. Among the examined dimensions, historical continuity, brand authenticity, and continuity of core values received the highest expert agreement, indicating the special importance of brand age and history, preservation of authentic and distinguishing characteristics, and continuity of fundamental values in shaping and perceiving brand heritage. Accordingly, while confirming the content validity of the model dimensions, the Delphi results provided a suitable basis for entering selected variables into the stage of mathematical relationship formulation and agent-based simulation. Table (4) presents the results of the fuzzy Delphi analysis.

Table 4: Results of Fuzzy Delphi Analysis in Selecting Brand Heritage Dimensions in the Banking Industry

Dimension	First Round	Second Round	Change
Historical continuity	0.89	0.93	0.04
Core values continuity	0.86	0.91	0.05
Heritage symbols	0.81	0.88	0.07
National/social role memory	0.84	0.90	0.06
Brand authenticity	0.88	0.92	0.04
Intergenerational memory	0.78	0.86	0.08
Heritage transmission by employees	0.76	0.85	0.09
Heritage compatibility with digital modernization	0.83	0.90	0.07

The increase in scores for all components from the first to the second round indicates convergence of expert perspectives. The high score for heritage compatibility with digital modernization also shows that brand heritage creates value when aligned with contemporary customer experience.

Hypothesis Testing Using Structural Equation Modeling

After determining the measurement models in order to evaluate the conceptual model of the study, ensure the presence or absence of causal relationships among the research variables, and assess the goodness of fit between the observed data and the conceptual model, the research hypotheses were also tested using Structural Equation Modeling (SEM). The results of the hypothesis testing are presented in the following figure.

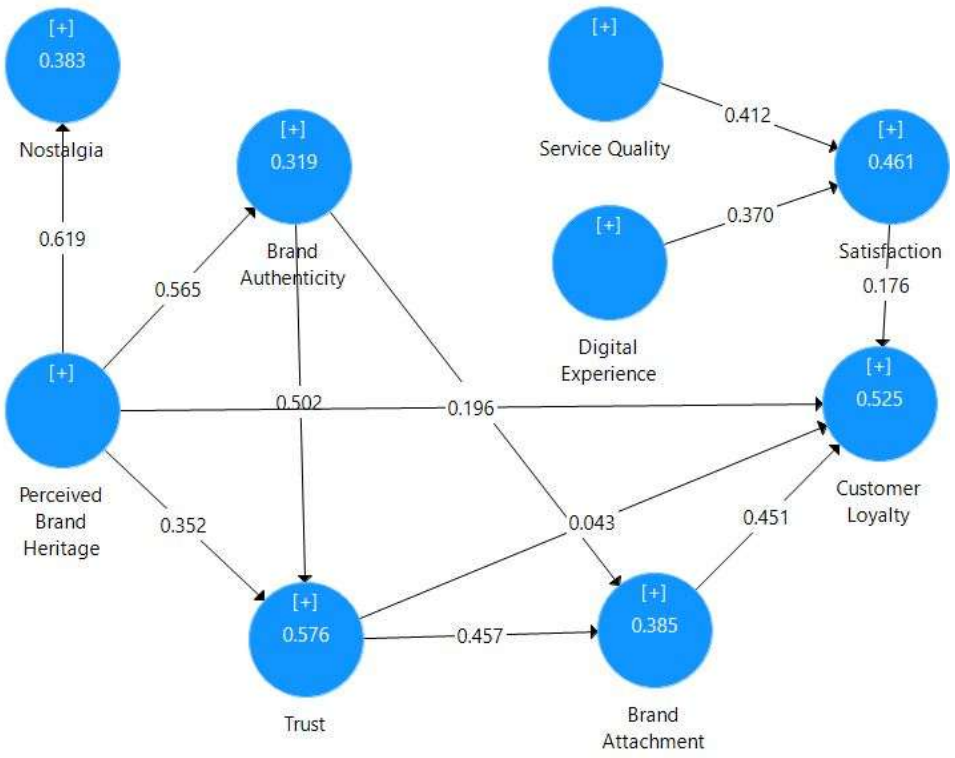


Figure 1. Overall Measurement Model and Hypothesis Testing Results in the Standardized Mode

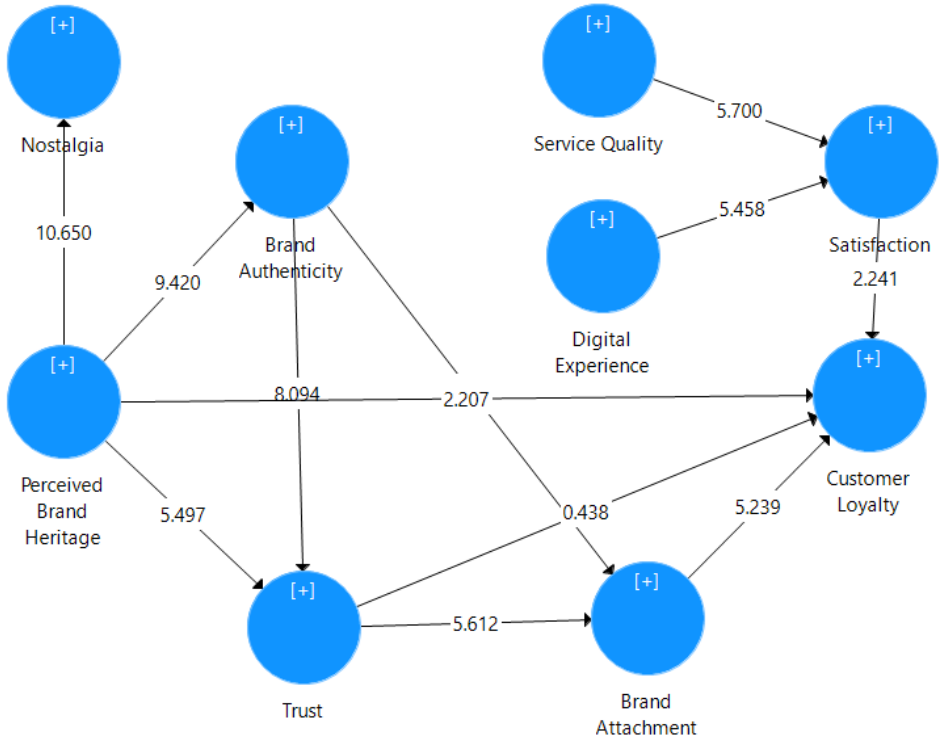


Figure 2. Overall Measurement Model and Hypothesis Testing Results in the Significance Mode

To assess reliability, Cronbach's alpha and Composite Reliability (CR) were used. Convergent validity was employed to assess validity, while the Goodness-of-Fit (GOF) index was used to evaluate the overall fit of the model.

Table 5. Reliability and Validity of the Outer Models

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Brand Attachment	0.796	0.733	0.828	0.617
Brand Authenticity	0.789	0.794	0.877	0.704
Customer Loyalty	0.757	0.699	0.814	0.597
Digital Experience	0.720	0.638	0.797	0.569
Nostalgia	0.771	0.785	0.866	0.684
Perceived Brand Heritage	0.802	0.804	0.884	0.718
Satisfaction	0.735	0.767	0.848	0.652
Service Quality	0.760	0.804	0.860	0.672
Trust	0.792	0.809	0.878	0.706

The results indicate that all constructs demonstrate acceptable to high levels of internal consistency and convergent validity. Cronbach's Alpha values range from 0.720 to 0.802, while rho_A values range from 0.638 to 0.809. The Composite Reliability values are between 0.797 and 0.884, indicating satisfactory reliability across all constructs. In particular, Perceived Brand Heritage (0.802), Trust (0.792), Brand Attachment (0.796), and Brand Authenticity (0.789) show strong internal consistency. Although the rho_A value for Digital Experience is relatively lower (0.638), its Composite Reliability of 0.797 remains acceptable, indicating that the construct still demonstrates adequate reliability.

The results also provide evidence of satisfactory convergent validity because the AVE values range from 0.569 to 0.718, exceeding the commonly accepted minimum threshold of 0.50 for all constructs. The highest AVE values are observed for Perceived Brand Heritage (0.718), Trust (0.706), and Brand Authenticity (0.704), indicating that these constructs explain a substantial proportion of the variance in their respective indicators. Overall, the findings confirm that Brand Attachment, Brand Authenticity, Customer Loyalty, Digital Experience, Nostalgia, Perceived Brand Heritage, Satisfaction, Service Quality, and Trust all possess adequate measurement quality, allowing the constructs to be reliably used in the subsequent structural model analysis.

The following table summarizes the significance coefficients and the results of the proposed research hypotheses.

Table 6: Hypothesis Testing Results

Hypotheses	Standardized Coefficient (β)	t-value	Significance	Result
Perceived brand heritage has a positive and significant effect on perceived brand authenticity.	0.56	9.42	Significant	Confirmed
Perceived brand heritage has a positive and significant effect on customer nostalgia.	0.61	10.65	Significant	Confirmed
Perceived brand heritage has a positive and significant effect on customer trust.	0.35	5.49	Significant	Confirmed
Perceived brand authenticity has a positive and significant effect on customer trust.	0.50	8.09	Significant	Confirmed
Customer trust has a positive and significant effect on brand attachment.	0.45	5.61	Significant	Confirmed
Service quality has a positive and significant effect on customer satisfaction.	0.41	5.70	Significant	Confirmed
Digital experience has a positive and significant effect on customer satisfaction.	0.37	5.45	Significant	Confirmed
Customer satisfaction has a positive and significant effect on customer loyalty.	0.17	2.24	Significant	Confirmed
Customer trust has a positive and significant effect on customer loyalty.	0.04	0.43	Not significant	Rejected

Brand attachment has a positive and significant effect on customer loyalty.	0.45	5.23	Significant	Confirmed
Perceived brand heritage has a positive and significant effect on customer loyalty.	0.19	2.20	Significant	Confirmed

Interpretation of Hypothesis 1

The first hypothesis examined whether perceived brand heritage has a positive and significant effect on perceived brand authenticity. The results show a standardized path coefficient of $\beta = 0.56$ and a t-value of 9.42, indicating a strong positive and statistically significant relationship. Therefore, the hypothesis is confirmed. The finding suggests that when customers perceive a bank as possessing a strong historical legacy, continuity, distinctive values, symbols, and established traditions, they are more likely to perceive the brand as genuine and authentic. The relatively high coefficient indicates that perceived brand heritage is an important determinant of brand authenticity. This result is also consistent with the theoretical structure of the research model, in which authenticity represents one of the principal mechanisms through which historical heritage is translated into favorable customer perceptions.

Interpretation of Hypothesis 2

The second hypothesis assessed the positive and significant effect of perceived brand heritage on customer nostalgia. The results indicate a standardized coefficient of $\beta = 0.61$ and a t-value of 10.65, demonstrating a strong and statistically significant positive relationship. Accordingly, the hypothesis is confirmed. This finding indicates that stronger perceptions of brand heritage are associated with stronger nostalgic feelings among customers. Historical continuity, memories, long-term presence, traditional symbols, and accumulated experiences can stimulate emotional connections with the past and strengthen customers' nostalgic responses toward the bank. Among the examined relationships, this pathway has the highest standardized coefficient, demonstrating the particularly important role of perceived brand heritage in generating customer nostalgia.

Interpretation of Hypothesis 3

The third hypothesis examined whether perceived brand heritage positively and significantly influences customer trust. The estimated standardized coefficient is $\beta = 0.35$, with a t-value of 5.49, confirming that the relationship is positive and statistically significant. Therefore, the hypothesis is confirmed. The result suggests that customers who perceive a stronger and more credible heritage in the bank are more likely to develop trust toward it. Historical continuity and accumulated organizational experience can function as signals of stability, reliability, and institutional credibility. Although the magnitude of this relationship is lower than the direct effects of heritage on authenticity and nostalgia, the result demonstrates that brand heritage independently contributes to the development of customer trust.

Interpretation of Hypothesis 4

The fourth hypothesis investigated the effect of perceived brand authenticity on customer trust. The results show a standardized coefficient of $\beta = 0.50$ and a t-value of 8.09, indicating a substantial positive and statistically significant relationship. Consequently, the hypothesis is confirmed. The finding demonstrates that customers who perceive the bank as authentic are more likely to trust it. Authenticity can reduce perceived uncertainty by creating the impression that the brand's values, communications, and behavior are genuine and consistent. The relatively high coefficient further indicates that authenticity is an important mechanism for converting the historical heritage of the brand into customer trust.

Interpretation of Hypothesis 5

The fifth hypothesis examined the positive effect of customer trust on brand attachment. The results indicate a standardized coefficient of $\beta = 0.45$ and a t-value of 5.61, demonstrating a positive and statistically significant relationship. Thus, the hypothesis is confirmed. This finding indicates that when customers trust the bank, they are more likely to develop a stronger emotional and psychological attachment to the brand. Trust provides a foundation for maintaining a stable relationship with the organization and can facilitate deeper emotional connections. The magnitude of the coefficient suggests that customer trust is an important antecedent of brand attachment within the proposed model.

Interpretation of Hypothesis 6

The sixth hypothesis evaluated whether service quality has a positive and significant effect on customer satisfaction. The results reveal a standardized coefficient of $\beta = 0.41$ and a t-value of 5.70, demonstrating a positive and statistically significant relationship. Therefore, the hypothesis is confirmed. The result indicates that improvements in the quality, reliability, responsiveness, and overall performance of banking services are associated with higher levels of customer satisfaction. This finding highlights that historical brand heritage alone is not sufficient to generate favorable customer outcomes; rather, the heritage of the bank must be supported by effective and satisfactory service delivery. The coefficient also indicates that service quality represents an important determinant of satisfaction in the proposed framework.

Interpretation of Hypothesis 7

The seventh hypothesis investigated the effect of digital experience on customer satisfaction. The results show a standardized coefficient of $\beta = 0.37$ and a t-value of 5.45, indicating a positive and statistically significant relationship. Hence, the hypothesis is confirmed. The finding demonstrates that a more favorable digital experience is associated with greater customer satisfaction. In the contemporary banking environment, customers increasingly interact with banks through digital platforms, applications, and electronic services. Therefore, the ability to combine historical brand heritage with efficient and user-friendly digital experiences can contribute significantly to maintaining customer satisfaction. The positive coefficient confirms the importance of digital experience within the proposed model.

Interpretation of Hypothesis 8

The eighth hypothesis examined whether customer satisfaction has a positive and significant effect on customer loyalty. The results indicate a standardized coefficient of $\beta = 0.17$ and a t-value of 2.24. Since the relationship is statistically significant and positive, the hypothesis is confirmed. The finding suggests that satisfied customers are more likely to maintain their relationship with the bank and demonstrate greater loyalty. However, compared with several other significant relationships in the model, the relatively small coefficient indicates that satisfaction alone has a comparatively modest direct contribution to loyalty. This suggests that customer loyalty is a multidimensional outcome influenced not only by satisfaction but also by deeper psychological factors such as brand attachment and perceived heritage.

Interpretation of Hypothesis 9

The ninth hypothesis examined whether customer trust has a positive and significant effect on customer loyalty. The standardized coefficient is $\beta = 0.04$, while the t-value is 0.43. The very small coefficient and low t-value indicate that the relationship is not statistically significant. Therefore, the hypothesis is rejected. The finding suggests that although trust is important for developing other psychological responses, such as brand attachment, its direct effect on customer loyalty is not sufficiently strong in the estimated model. In other words, customer trust may contribute to loyalty indirectly through other variables rather than functioning as a direct determinant of loyal behavior. This

result highlights the importance of considering the mediating pathways within the proposed brand heritage model rather than assuming that trust automatically leads directly to loyalty.

Interpretation of Hypothesis 10

The tenth hypothesis assessed the positive and significant effect of brand attachment on customer loyalty. The results show a standardized coefficient of $\beta = 0.45$ and a t-value of 5.23, demonstrating a strong positive and statistically significant relationship. Consequently, the hypothesis is confirmed. The finding indicates that customers who develop a stronger emotional and psychological attachment to the bank are considerably more likely to remain loyal. Compared with customer satisfaction and trust, brand attachment has a substantially stronger direct coefficient, suggesting that emotional bonds constitute an important mechanism for transforming favorable customer perceptions into sustained loyalty. Thus, strengthening customers' psychological connection with the brand can play an important role in customer retention and long-term relationship continuity.

Interpretation of Hypothesis 11

The eleventh hypothesis examined whether perceived brand heritage has a positive and significant direct effect on customer loyalty. The results demonstrate a standardized coefficient of $\beta = 0.19$ and a t-value of 2.20, indicating a positive and statistically significant relationship. Therefore, the hypothesis is confirmed. The finding shows that perceived brand heritage contributes directly to customer loyalty, although the magnitude of this direct relationship is relatively modest compared with its effects on authenticity and nostalgia. This supports the broader model in which brand heritage influences loyalty through several psychological mechanisms while also retaining a direct effect. The result therefore indicates that heritage should not be treated merely as an indirect antecedent of loyalty; it also has an independent direct contribution to customers' willingness to maintain their relationship with the bank.

Customer Characteristics

Table (7) shows the characteristics of the target customers examined in this research.

Table 7: Characteristics of Studied Customers

Variable	Category	Frequency	Percentage
Gender	Male	255	51.0
Gender	Female	245	49.0
Age group	30-39	174	34.8
Age group	40-49	130	26.0
Age group	50 and above	106	21.2
Age group	Less than 30	90	18.0
Relationship history	8-15 years	160	32.0
Relationship history	More than 15 years	144	28.8
Relationship history	3-7 years	119	23.8
Relationship history	Less than 3 years	77	15.4
Main channel	Mobile/Internet	209	41.8
Main channel	Hybrid	183	36.6
Main channel	Branch	108	21.6

Customers were purposefully selected to cover different generations and users of both in-person and digital channels. This diversity is important for agent-based modeling because the effect of heritage is not uniform across all customers.

Table (8) presents the results of descriptive analysis of the research constructs.

Table 8: Descriptive Analysis Results of Research Constructs

Construct	Mean	Standard Deviation	First Quartile	Third Quartile
Perceived brand heritage	4.063	0.604	3.641	4.508
Brand authenticity	3.925	0.614	3.512	4.351
Nostalgia	3.755	0.780	3.218	4.312
Brand trust	4.103	0.600	3.744	4.581
Brand image	3.929	0.658	3.479	4.426
Attachment	3.707	0.679	3.282	4.174
Satisfaction	3.796	0.653	3.362	4.275
Loyalty	3.932	0.677	3.490	4.473
Digital experience	3.563	0.749	3.035	4.141
Service quality	3.884	0.631	3.448	4.347

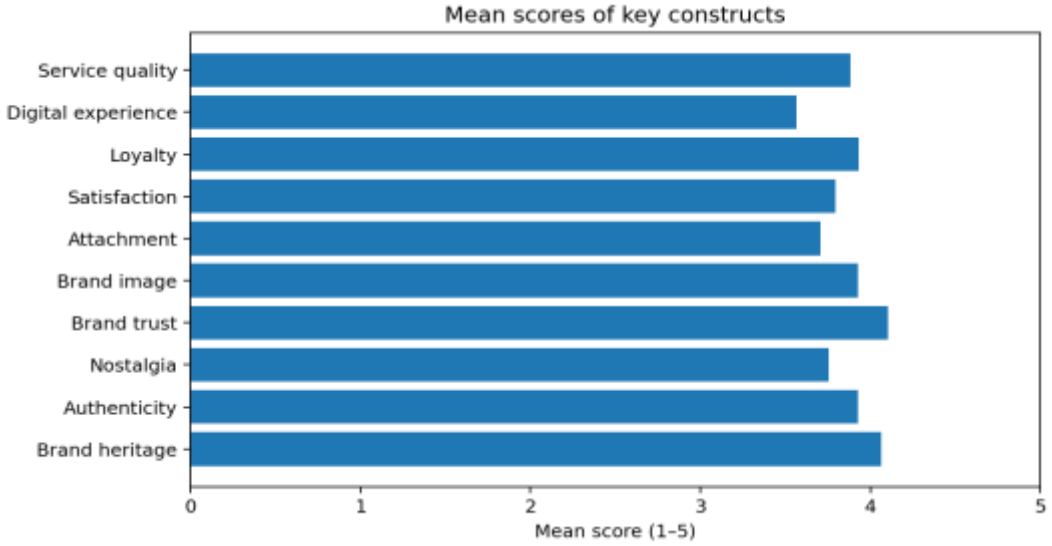


Figure 3: Mean of Main Model Constructs

As shown in Figure (3), the highest mean belongs to trust, followed by perceived brand heritage. Digital experience has the lowest mean. This gap indicates that the bank's historical advantage, without improving digital experience, may not fully translate into loyalty among new generations.

Table (9) presents the reliability assessment results of the brand heritage measurement model in the banking industry.

Table 9: Validity and Reliability Assessment Results of Brand Heritage Measurement Model

Construct	Cronbach's Alpha	CR	AVE	√AVE
PH	0.91	0.93	0.69	0.84
AU	0.88	0.91	0.67	0.82
NO	0.86	0.90	0.65	0.80
TR	0.92	0.94	0.72	0.86
BI	0.89	0.92	0.68	0.83
AT	0.87	0.91	0.66	0.81
SA	0.90	0.93	0.70	0.84
LO	0.93	0.95	0.74	0.87
DX	0.88	0.92	0.69	0.82
SQ	0.91	0.94	0.71	0.85

All Cronbach's alpha and composite reliability values exceed 0.70, and AVE values exceed 0.50. Therefore, reliability and convergent validity of the constructs are satisfactory.

Table (10) presents the path analysis results of the designed model, including beta coefficients and test results.

Table 10: Path Analysis Results of the Mathematical Model

Path	β	t	p	Result
PH → AU	0.570	8.940	0.000	Confirmed
PH → NO	0.460	7.210	0.000	Confirmed
PH → TR	0.310	5.620	0.000	Confirmed
AU → TR	0.290	4.980	0.000	Confirmed
TR → AT	0.380	6.140	0.000	Confirmed
NO → AT	0.270	4.710	0.000	Confirmed
SQ → SA	0.440	8.110	0.000	Confirmed
DX → SA	0.260	4.830	0.000	Confirmed
SA → LO	0.320	5.720	0.000	Confirmed
TR → LO	0.280	5.060	0.000	Confirmed
AT → LO	0.240	4.290	0.000	Confirmed
PH → LO	0.140	2.770	0.006	Confirmed

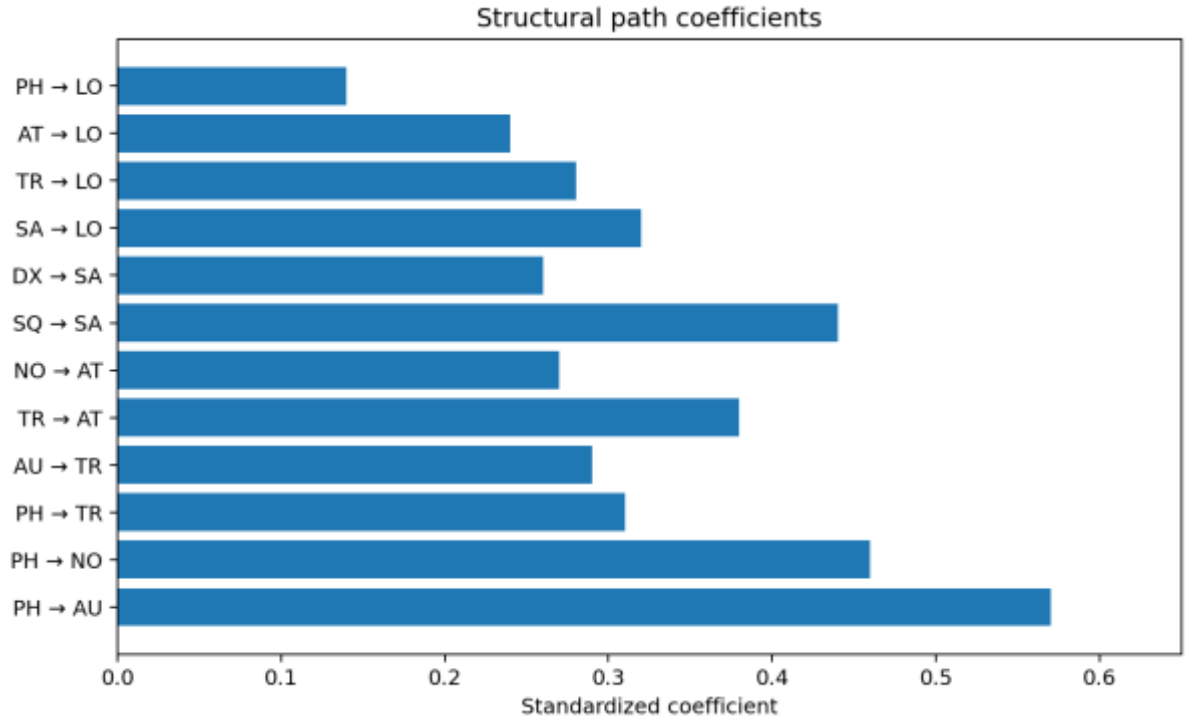


Figure 4: Standard Coefficients of Structural Model Paths

The strongest pathway is the effect of brand heritage on perceived authenticity with β=0.57. The direct effect of heritage on loyalty is present but weaker. Therefore, the major portion of heritage's effect is transmitted through mediating pathways of authenticity, trust, nostalgia, and attachment. This analysis demonstrates that if multiple separate behavioral rules are defined in agent-based modeling, it leads to the conclusion that heritage should not be reduced to a simple loyalty function.

Table (11) presents the results of the coefficient of determination (R^2) analysis for the research variables.

Table 11: Coefficient of Determination Analysis for Endogenous Variables

Endogenous Variable	R^2
Authenticity	0.42
Nostalgia	0.31
Trust	0.56

Attachment	0.49
Satisfaction	0.51
Loyalty	0.68

The R^2 for loyalty equals 0.68, meaning trust, attachment, satisfaction, and brand heritage collectively have high explanatory power for loyal behavior.

In the calculated model, 10,000 customer agents, 250 employee or touchpoint agents, and 6 competitor banks were defined. The time horizon was 60 months with a simulation step of one month. Each scenario was run 100 times with different random seeds. Structural model coefficients were used as starting points for calibration, followed by adjustment of learning rate, WOM intensity, migration threshold, and competitor effect.

In the baseline scenario, the existing status of Bank Melli Iran was simulated without any intervention or new policy in brand heritage strengthening, to determine the natural behavior and baseline trend of model variables over time. In this scenario, the main characteristics of brand heritage—historical continuity, authenticity, and core values continuity—were maintained at current levels, with interactions among customers, employees, and competitors according to baseline model conditions.

Table (12) presents the results of the baseline scenario.

Table 12: Baseline Scenario Results

Month	Heritage Index	Trust	Loyalty Rate	Retention Rate
0.000	0.720	0.750	0.610	0.900
6.000	0.724	0.752	0.613	0.902
12.000	0.729	0.754	0.617	0.904
18.000	0.735	0.756	0.621	0.905
24.000	0.739	0.758	0.625	0.907
30.000	0.742	0.759	0.629	0.909
36.000	0.746	0.760	0.632	0.910
42.000	0.750	0.762	0.636	0.912
48.000	0.753	0.763	0.639	0.913
54.000	0.756	0.764	0.642	0.914
60.000	0.759	0.765	0.645	0.916

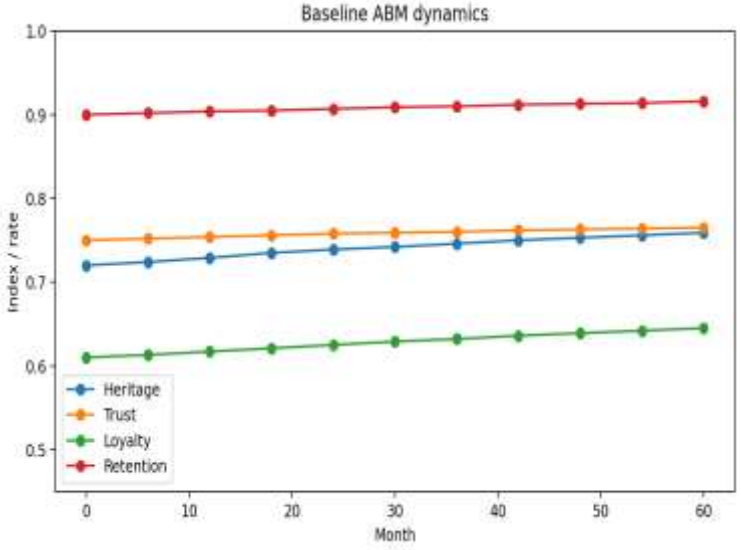


Figure 5: Dynamics of Main Model Indicators in Baseline Scenario over 60 Months

The 60-month simulation results showed that the brand heritage perception index increased from 0.720 to 0.759, customer trust from 0.750 to 0.765, loyalty from 0.610 to 0.645, and customer retention rate from 0.900 to 0.916. This finding indicates that even in the absence of intervention policies, the bank's brand heritage can gradually contribute to maintaining trust, loyalty, and continuity of customer relationships. At the same time, the baseline scenario served as a comparison benchmark for evaluating the effectiveness of other policy scenarios.

Scenario S7 the integrated strategy of heritage, digital experience, employee empowerment, and customer experience management—produced the best results, with loyalty reaching 0.801 and customer retention reaching 0.962. In contrast, trust crisis caused the most severe decline, demonstrating that age and heritage are not absolute shields against negative experiences.

Scenario S2 also showed that combining heritage and digital is stronger than historical narrative alone. The managerial implication is that Bank Melli must prove its history through contemporary experience—meaning security, speed, ease, and digital innovation must align with the historical promise of trust and credibility. Table (13) compares the eight examined scenarios and the extent of change in loyalty, customer retention, trust loyalty, and heritage.

Table 13: Comparison of Different Scenarios in Preserving Brand Value in the Banking Industry

Scenario	Heritage	Trust	Loyalty	Customer Retention	Loyalty Change (%)
S0 Baseline	0.759	0.765	0.645	0.916	0.000
S1 Heritage narrative	0.824	0.792	0.691	0.929	4.600
S2 Heritage + Digital	0.846	0.821	0.744	0.947	9.900
S3 Employee transmission	0.813	0.804	0.712	0.936	6.700
S4 Trust crisis	0.643	0.612	0.501	0.841	-14.400
S5 Competitive pressure	0.748	0.741	0.566	0.872	-7.900
S6 Young generation dominance	0.731	0.752	0.604	0.894	-4.100
S7 Integrated strategy	0.881	0.858	0.801	0.962	15.600

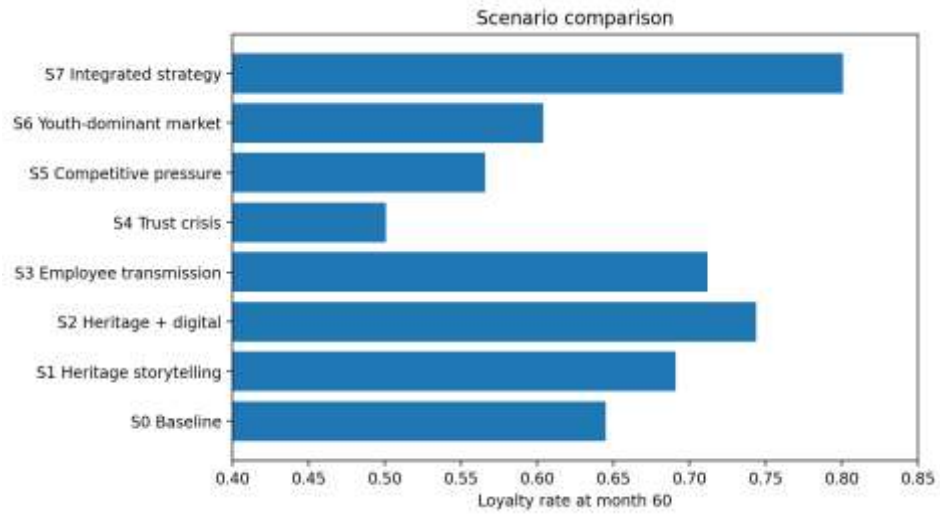


Figure 6: Comparison of Loyalty Rates at Month 60

With increasing age, sensitivity to heritage and nostalgia increases. In contrast, sensitivity to digital experience is higher among younger groups. This result demonstrates one of the strengths of agent-based modeling, as average-based models typically conceal these behavioral differences.

Table (14) shows generational heterogeneity in sensitivity to heritage, nostalgia, and digital experience.

Table 14: Generational Heterogeneity in Sensitivity to Heritage, Nostalgia, and Digital Experience

Age Group	Heritage Sensitivity	Nostalgia	Digital Sensitivity
<30	0.62	0.49	0.78
30-39	0.70	0.60	0.72
40-49	0.78	0.71	0.64
50+	0.86	0.82	0.51

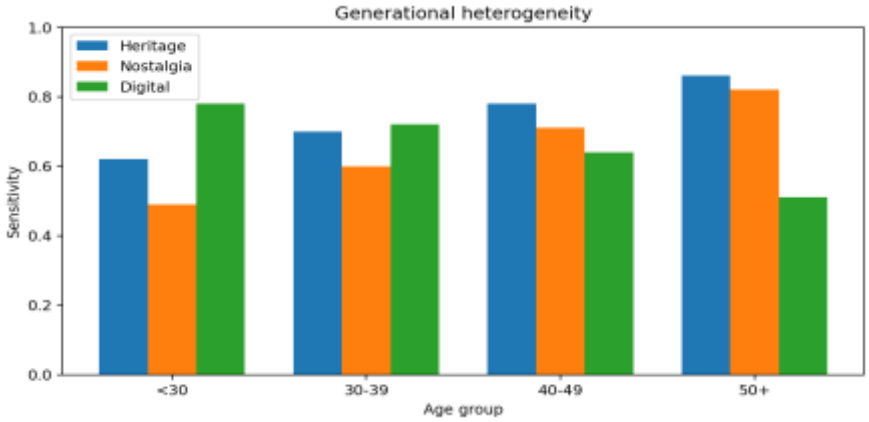


Figure 7: Generational Heterogeneity in Sensitivity to Heritage, Nostalgia, and Digital Experience

The highest sensitivity pertains to the heritage-trust pathway, followed by trust-loyalty. Digital experience and WOM intensity occupy subsequent ranks. Therefore, to convert heritage into economic outcomes, trust strengthening must be the central focus of brand policy. Competitor attractiveness also shows high sensitivity. This finding indicates that heritage value is relative—customers do not evaluate the bank in a vacuum, but rather compare the historical advantage with competitors' quality, innovation, and value proposition.

Table 16: Sensitivity Analysis Results of Heritage-Trust and Trust-Loyalty Model

Parameter	Sensitivity Index
Heritage-Trust weight	0.42
Trust-Loyalty weight	0.37
Digital experience	0.35
WOM effect	0.31
Competitor attractiveness	0.29
Learning rate	0.24
Employee transmission	0.22
Nostalgia weight	0.18

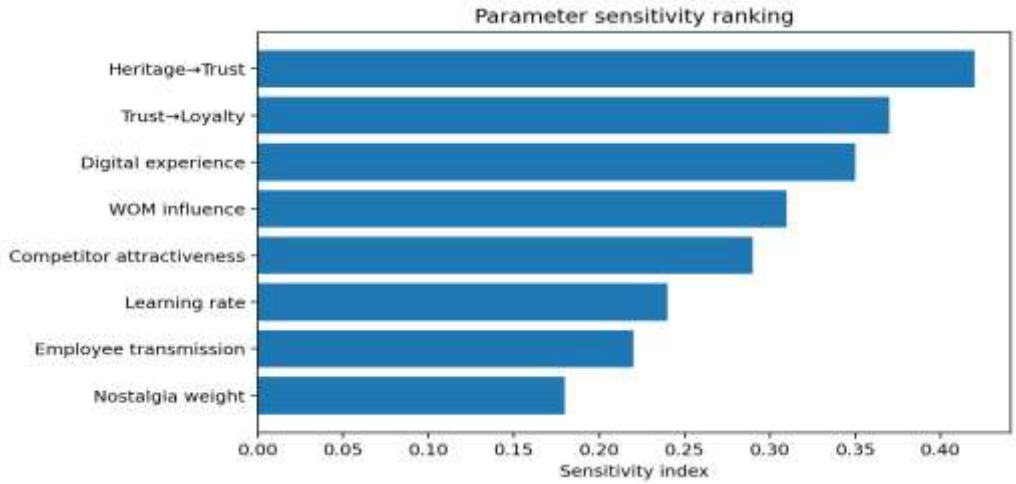


Figure 8: Ranking of Sensitive Model Parameters

In the simulation, WOM is the mechanism for spreading attitudes among customers. Customers with high satisfaction and loyalty can transmit positive heritage perceptions to network neighbors. Conversely, in crisis conditions, dissatisfied customers with high network centrality can accelerate trust erosion. Therefore, WOM management and identification of influential customers are part of brand heritage management policy.

The model must demonstrate logical behavior under extreme conditions: severe trust decline should increase migration; high heritage without service quality should not produce maximum loyalty; and simultaneous increase of heritage, digital quality, and trust should raise retention rate. The model reproduced these behavioral directions. In the real version, it is recommended to keep part of the real time series for out-of-sample validation and report MAE, RMSE, and MAPE criteria.

Results indicate that the agent-based brand heritage model consists of four layers: historical capital and bank policy; customer perception and memory; psychological constructs including authenticity, trust, nostalgia, and attachment; and market behavior including loyalty, WOM, retention, or migration. The dynamics of these layers in the social network, under the influence of digital experience and competition, create heterogeneous and nonlinear effects. Therefore, brand heritage becomes a sustainable advantage when the brand's past is perceived as credible, current performance confirms the historical promise, and the contemporary experience aligns with competitive standards.

4. Discussion and Conclusion

The present study developed and evaluated a mathematical agent-based simulation model of brand heritage in the banking industry, using Bank Melli Iran as the empirical context. The findings collectively demonstrate that brand heritage functions as a dynamic strategic resource rather than merely as an accumulated historical attribute. Expert assessment showed strong consensus regarding the importance of historical continuity, continuity of core values, brand authenticity, heritage symbols, national and social role memory, intergenerational memory, employee-mediated heritage transmission, and compatibility between heritage and digital modernization. In the second Delphi round, historical continuity received the highest score of 0.93, followed by brand authenticity at 0.92, continuity of core values at 0.91, and compatibility with digital modernization at 0.90. These findings support the broader conceptualization of brand heritage as a multidimensional phenomenon in which organizational history becomes strategically meaningful when it remains connected to current identity, customer experience, and future development. Wiedmann et al. similarly identified heritage as an important performance-related resource capable of differentiating established brands and contributing to favorable stakeholder perceptions [1]. More recent systematic syntheses likewise indicate that the concept has evolved beyond mere brand longevity toward authenticity, identity, consumer experience, innovation, and the strategic transmission of historical meaning [13, 14].

The structural analysis further showed that perceived brand heritage had its strongest effect on perceived brand authenticity ($\beta = 0.570$, $t = 8.940$), followed by nostalgia ($\beta = 0.460$, $t = 7.210$) and trust ($\beta = 0.310$, $t = 5.620$). Authenticity also positively affected trust ($\beta = 0.290$, $t = 4.980$), while trust positively influenced attachment ($\beta = 0.380$, $t = 6.140$), and nostalgia positively influenced attachment ($\beta = 0.270$, $t = 4.710$). The direct effect of perceived brand heritage on loyalty was significant but substantially smaller ($\beta = 0.140$, $p = 0.006$) than its effects on authenticity and nostalgia, indicating that much of the influence of heritage on loyalty is transmitted through psychological and relational mechanisms. The model explained 42% of the variance in authenticity, 31% in nostalgia, 56% in trust, 49% in attachment, 51% in satisfaction, and 68% in loyalty. This pattern strongly supports

the proposition that heritage is not simply a direct predictor of behavioral loyalty. Rather, historical meaning must first be translated into perceptions of genuineness, reliability, emotional continuity, and psychological connection before it produces durable behavioral consequences.

The particularly strong heritage–authenticity relationship is consistent with previous brand heritage research. Heritage provides consumers with evidence of continuity, endurance, and consistency between a brand's claimed identity and its historical conduct. Rose et al. showed that emphasizing brand heritage can positively affect consumer responses when historical cues increase the meaningfulness and credibility of the brand [3]. Rindell and Pinto Santos similarly demonstrated that consumers construct authenticity through the interpretation of historical signs, brand meanings, memories, and expectations of continuity [4]. Kumar and Kaushal further found that brand heritage and nostalgia contribute to perceived brand authenticity, which subsequently strengthens consumer engagement and psychological ownership [5]. The present findings extend these studies to a banking context and suggest that, for a long-established financial institution, historical continuity can function as evidence that the institution is genuine and consistent rather than merely old. This distinction is important because heritage only becomes valuable when customers perceive continuity between historical identity and present organizational behavior.

The positive effect of perceived brand heritage on nostalgia provides further evidence that the value of heritage is partly affective. Longstanding banks may become embedded in personal, family, and collective memories, particularly among customers who have maintained relationships with the institution across extended periods. The agent-based findings showed that sensitivity to heritage and nostalgia increased with age: heritage sensitivity rose from 0.62 among customers younger than 30 to 0.86 among those aged 50 and above, while nostalgia sensitivity increased from 0.49 to 0.82 across the same groups. By contrast, digital sensitivity declined from 0.78 among customers younger than 30 to 0.51 among those aged 50 and above. These findings align with the view that heritage is experienced temporally and depends upon consumers' subjective relationships with the past [2]. They are also consistent with Pecot et al., who showed that the positive evaluation of brand longevity depends on contextual and category-related factors rather than longevity being universally advantageous [6]. Brand narratives may further intensify these processes by organizing the past into emotionally meaningful stories that support identification and attachment [7].

The results concerning trust are particularly significant for banking. Perceived heritage directly strengthened trust, while authenticity additionally contributed to trust, indicating that customers do not interpret heritage only as historical symbolism; they may also use it as a signal of institutional stability, credibility, and reliability. Song and Kim's signaling perspective similarly suggests that heritage-related cues can reduce uncertainty by communicating quality, continuity, and credibility [9]. Zeren and Kara also found that brand heritage can influence behavioral intentions in service settings through trust and loyalty-related mechanisms [8]. In the present model, the heritage–trust pathway was the most sensitive model parameter, with a sensitivity value of 0.42, followed by the trust–loyalty pathway at 0.37. Digital experience, word-of-mouth influence, competitor attractiveness, learning rate, employee transmission, and nostalgia followed in descending order. Thus, trust appears to operate as a crucial conversion mechanism through which historical equity becomes economically and behaviorally meaningful.

The results also demonstrated that service quality and digital experience cannot be separated from heritage management. Service quality had a positive effect on satisfaction ($\beta = 0.440$, $t = 8.110$), while digital experience also increased satisfaction ($\beta = 0.260$, $t = 4.830$). Satisfaction subsequently increased loyalty ($\beta = 0.320$, $t = 5.720$), while trust ($\beta = 0.280$) and attachment ($\beta = 0.240$) also contributed positively to loyalty in the calibrated structural model.

These findings suggest that historical credibility alone cannot compensate for weak contemporary performance. This conclusion is consistent with Xu et al., who demonstrated that heritage and innovation can work together rather than representing opposing strategic orientations [10]. Chen and Chou similarly showed that effective heritage revitalization depends on blending historical identity with contemporary value and consumer relevance [11]. Consequently, a heritage bank must continually validate its historical promise through current service delivery, technological capability, responsiveness, and user experience.

The importance of combining heritage with contemporary experience became particularly clear in the simulation scenarios. Under baseline conditions, the heritage index increased from 0.720 to 0.759 across the 60-month simulation, trust increased from 0.750 to 0.765, loyalty from 0.610 to 0.645, and retention from 0.900 to 0.916. However, heritage narrative reinforcement alone raised loyalty only to 0.691 and retention to 0.929, whereas combining heritage with digital enhancement increased loyalty to 0.744 and retention to 0.947. Employee-based heritage transmission also produced improvements, with loyalty reaching 0.712 and retention 0.936. The integrated strategy, combining heritage, digital innovation, employee empowerment, and customer experience management, produced the strongest simulated outcomes, with heritage reaching 0.881, trust 0.858, loyalty 0.801, and retention 0.962. In contrast, a trust crisis reduced loyalty to 0.501 and retention to 0.841, while intensified competitive pressure reduced loyalty to 0.566 and retention to 0.872. These results indicate that heritage produces the greatest value when embedded within an integrated contemporary strategy rather than treated as a stand-alone communication resource.

The superiority of the integrated scenario is theoretically meaningful because heritage management requires consistency among historical claims, organizational behavior, technology, and service encounters. A brand may communicate an impressive history, but if the current customer experience contradicts that history, the heritage signal may lose credibility. This interpretation is consistent with Liu et al., who showed that heritage influences customer behavior through emotional resonance and self-brand identification even within contemporary digital environments [12]. It also corresponds with Castillo-Villar's conceptualization of heritage as a dynamic meaning-transfer process rather than a fixed organizational possession [14]. From this perspective, Bank Melli Iran's heritage is continuously reconstructed through each interaction with mobile applications, branches, employees, service processes, social communication, and competitive alternatives. Heritage therefore survives not because it belongs to the past, but because the present repeatedly confirms its meaning.

The negative trust-crisis scenario is equally important. The substantial deterioration in loyalty and retention under this condition demonstrates that longevity does not immunize an organization against contemporary failures. Historical reputation may create a reservoir of goodwill, but severe negative experiences can weaken trust and accelerate customer migration. The simulation further showed that word-of-mouth functions as a diffusion mechanism through which favorable or unfavorable attitudes spread among customers; particularly influential dissatisfied customers may accelerate trust erosion during crises. This outcome is compatible with the logic of agent-based consumer modeling, in which macro-level market outcomes emerge through repeated interactions among heterogeneous individuals rather than through isolated individual decisions. Tsiatsios et al. emphasize that consumer choice is shaped by bounded rationality and heterogeneous behavioral rules [18], while Kot demonstrates the usefulness of agent-based approaches for examining how consumer-level decisions interact with marketing conditions to create aggregate outcomes [19]. Rand and Stummer similarly show that agent-based models are particularly useful for studying diffusion processes, social interaction, and heterogeneous adoption behavior [20].

The generational results further reinforce the methodological value of the agent-based approach. Younger customers displayed stronger sensitivity to digital experience and comparatively lower sensitivity to historical heritage, whereas older customers exhibited the opposite pattern. Such heterogeneity would be partly obscured in models based solely on sample averages. This finding also helps explain why the young-generation-dominance scenario produced weaker outcomes than the baseline, with heritage declining to 0.731, loyalty to 0.604, and retention to 0.894. Heritage must therefore be translated differently across customer segments. Younger consumers may respond less strongly to institutional age alone but may attach meaning to heritage when it is expressed through innovation, security, ease of use, and contemporary digital interfaces. This complements Liu et al.'s finding that heritage can operate through emotional resonance and self-brand identification [12] and supports the broader argument that heritage must remain relevant to the identity and expectations of current consumers.

Methodologically, the findings support the use of agent-based modeling for extending conventional brand heritage research. The model represented 10,000 customer agents, 250 employee or touchpoint agents, six competitor banks, a 60-month horizon, and repeated simulations with different random seeds. Such a structure makes it possible to study customer heterogeneity, repeated adaptation, social network influence, competitor attractiveness, employee-mediated heritage transmission, and emergent loyalty patterns simultaneously. This advantage aligns with Jamali and Lazarova-Molnar, who emphasize the capacity of agent-based modeling to represent heterogeneous actors, nonlinear interaction, adaptation, and emergent economic behavior [16]. Choi and Choi similarly argue that agent-based models are valuable for connecting micro-level heterogeneous behavior to aggregate system outcomes, while stressing the importance of behavioral specification, calibration, interaction structures, and validation [17]. The present study therefore contributes not only substantively to brand heritage research but also methodologically by showing how a construct typically analyzed through static surveys can be translated into dynamic behavioral rules and simulated across time.

Finally, the findings indicate that brand heritage should be conceptualized as a renewable rather than exhaustible strategic resource. The historical foundations of a long-established bank provide an initial stock of symbolic and relational capital, but its value depends upon continuous confirmation through authenticity, trust, service quality, digital capability, employee behavior, and competitive relevance. This interpretation corresponds with Brunninge's argument that corporate heritage can be actively constructed and strategically reproduced rather than simply inherited [15]. It also aligns with the systematic evidence that brand heritage scholarship increasingly emphasizes the relationship between the past and future rather than preservation of the past in isolation [13, 14]. Overall, the present study demonstrates that Bank Melli Iran's historical capital can support loyalty and retention, but the strongest outcomes emerge when history, trust, technological modernization, employee behavior, and customer experience operate as an integrated system.

The study has several limitations that should be considered when interpreting its findings. First, the empirical context was limited to Bank Melli Iran, and the historical, organizational, competitive, and customer characteristics of this institution may differ from those of private banks, newly established banks, digital banks, and financial institutions in other countries. Second, although the model incorporated heterogeneous customers, social interaction, employees, competitors, and several behavioral variables, no simulation can capture every determinant of actual customer decision making. Variables such as macroeconomic shocks, regulatory changes, major cybersecurity incidents, pricing policies, individual financial conditions, and broader cultural changes may alter the dynamics of loyalty and migration. Third, some dynamic model parameters necessarily depended on calibration and expert judgment where direct longitudinal data were unavailable. Fourth, the simulation represents

behavioral processes through formalized rules, meaning that deviations from those rules in real customer behavior may produce different long-term patterns. Finally, although repeated simulations and extreme-condition checks supported the logical behavior of the model, stronger external validation against independent longitudinal banking data would increase confidence in its predictive performance.

Future studies should replicate the proposed framework across public, private, specialized, and fully digital banks to determine whether the structure and magnitude of heritage effects differ across banking models and competitive environments. Cross-national studies could examine whether institutional history, collective memory, cultural orientation, and trust in financial institutions alter the operation of brand heritage. Longitudinal transaction, digital-service, complaint, switching, and customer-retention data could be integrated with survey data to improve behavioral calibration and external validation of agent-based models. Future models may also incorporate macroeconomic shocks, cybersecurity events, regulatory change, price sensitivity, customer profitability, and competing digital financial platforms. Research could further examine network structure by comparing random, small-world, scale-free, and empirically observed customer networks to determine how word-of-mouth diffusion changes heritage outcomes. Additional segmentation by generation, digital literacy, duration of relationship, customer value, and service channel could also provide more precise insight into heterogeneous customer responses.

Bank managers should treat brand heritage as a contemporary strategic capability rather than as a promotional emphasis on organizational age. Heritage communication should be coordinated with digital transformation, service quality, employee behavior, and customer experience so that current interactions consistently validate the historical promise of the institution. Historical narratives, symbols, social contributions, and organizational values can be incorporated into branch design, digital platforms, corporate communications, customer onboarding, and employee training without compromising modernization. Different customer segments should receive differentiated expressions of heritage: older and long-standing customers may respond more strongly to continuity, memory, and tradition, whereas younger customers are likely to require heritage to be expressed through secure, fast, innovative, and convenient digital experiences. Managers should also monitor trust, negative word-of-mouth, competitor attractiveness, and influential customers as early-warning indicators because deterioration in these areas can rapidly weaken the value of accumulated heritage. Before implementing costly brand policies, banks can use the proposed simulation framework to test alternative combinations of heritage communication, digital investment, employee development, and customer-experience initiatives and select strategies that generate stronger long-term loyalty and retention.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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