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Markov Chain Analysis of Bank Customer Migration: Implication for Financial Inclusion in Maritime Economies

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ABSTRACT

Objectives: This study analyzes customer migration patterns among five major banks (BCA, BNI, BRI, BSI, and Bank Mandiri) in Batam's strategic maritime economic zone using a Markov Chain model to assess long-term market dynamics and financial inclusion implications. The research aims to quantify interbank transition probabilities, to identify key switching drivers, and to develop targeted policy recommendations. Methods: Using a quantitative descriptive-analytical approach, we collected structured questionnaires from 250 Batam Institute of Technology academic members, capturing historical bank transitions and 5-point Likert-scale evaluations of eight switching factors. These factors included ATM/branch proximity, administrative fees, mobile/internet banking service, salary/ scholarship payment linkages, promotions/rewards, interest rates, family/friend recommendations, and Sharia compliance. Data were analyzed via Markov Chain modeling to project steady-state distributions. Results: The transition matrix revealed BCA's superior retention (85.1%) compared to peers, with steady-state projections showing market dominance (32.44%), followed by Bank Mandiri (26.51%) and BSI (26.39%). Salary linkages (mean score: 3.45) and ATM accessibility (3.16) emerged as primary retention drivers, while BCA's digital services (3.40) and low fee perception (3.67) explained its competitive edge. Paradoxically, BSI capitalizes on institutional salary systems (4.27) despite moderate Sharia compliance ratings (2.87). Implications: Three key policy directions emerge: hybrid digital-physical banking for coastal communities, Islamic financial ecosystem development, and fee transparency regulations. The study advances Markov Chain applications in behavioral finance while providing SEZ-specific insights for inclusive banking strategies.

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A. INTRODUCTION

As a strategic maritime economic hub within Indonesia's Special Economic Zone (SEZ) and Free Trade Zone (FTZ), Batam plays a pivotal role in national economic development through its integrated trade, industrial, and service sectors (Anggraeny & Ayu, 2020; Aritenang & Chandramidi, 2020). However, this rapid economic growth contrasts sharply with persistent challenges in financial access equality, particularly for coastal communities and small island populations (Kronenberg & Khor, 2016; Negara & Hutchinson, 2018). This financial inclusion gap in an otherwise thriving economic zone presents a critical paradox that warrants systematic investigation (Delimatsis, 2021).

The phenomenon of bank customer migration offers valuable insights into this paradox. In Batam's competitive banking sector, customer switching behavior follows identifiable transition patterns influenced by interbank competition, service quality, and interest rate

policies (Arshad et al., 2016). Similar transition patterns have been effectively analyzed using Markov Chain models across diverse domains, from genotype switching in plant breeding studies (Hayati et al., 2023, 2024) to brand switching in consumer markets (Gupta et al., 2020, 2025; Jena et al., 2022), online food delivery services (Dung et al., 2022), online retail (Kar et al., 2021), telecom sector behavior (Neger et al., 2021), and global disaster context (Bagwan, 2025; Bai et al., 2025; Dalimunthe et al., 2023; Kamaruzzaman et al., 2018; Rusdiana et al., 2020). These successful applications demonstrate the model's versatility in predicting transition behaviors, suggesting its strong potential for analyzing customer migration in Batam's distinctive maritime financial context. The Batam Institute of Technology's strategic location at this socioeconomic crossroads provides an ideal research base to investigate these dynamics.

Building on this foundation, the study applies Markov Chain modeling to Batam's banking ecosystem with three objectives. First, to quantify interbank transition probabilities among BCA, BNI, BRI, BSI, and Bank Mandiri, revealing critical retention patterns and competitive dynamics within the maritime-economic context. Second, to examine key switching drivers, including digital service quality, Sharia compliance, and fee structures, through stratified Likert-scale analysis that captures distinct urban and coastal population preferences. Third, to develop targeted policy recommendations that address financial inclusion gaps through innovative hybrid banking solution and adaptive regulatory measures tailored to Batam's special economic zone characteristics.

This investigation addresses Batam's financial inclusion paradox by applying the well-established Markov Chain methodology to banking behavior analysis (Danaa et al., 2021; Wang et al., 2018). The study contributes to evidence-based policy frameworks for financial inclusion. The findings may inform targeted strategies to bridge financial service gaps in coastal communities, supporting more equitable development across Batam's maritime economy (Hutchinson, 2019), while demonstrating the interdisciplinary value of transition analysis models.

B. METHODS

1. Research Design

Quantitative descriptive study using Markov Chain approach with finite state to model customer migration patterns among five banks. The model adheres to the following theoretical foundations (Seabrook & Wiskott, 2023):

a. State Space Definition

The system is defined by a finite set of states $S = \{s_1, s_2, s_3, s_4, s_5\}$, where each state represents one of the five banks (BCA, BNI, BRI, BSI, and Bank Mandiri).

b. Markov Property

The process satisfies the Markov property:

$$P(X_{t+1} = j | X_0 = i_0, X_1 = i_1, \cdots, X_t = i) = P(X_{t+1} = j | X_t = i)$$

where X_t denotes a customer's bank at time t. This memoryless property implies transition probabilities depend solely on the current state.

c. Time Homogenity
Transition probabilities are stationary over time:

$$p_{ij} = P(X_{t+1} = j | X_t = i),$$

where p_{ij} represents the probability of transitioning from bank i to j.

2. Data Collection

This quantitative study employs a Markov Chain model to analyze customer migration patterns among five major banks in Batam's maritime economic zone (BCA, BNI, BRI, BSI, and Bank Mandiri). We employed stratified random sampling of 250 Batam Institute of Technology (ITEBA) members (students, faculty, and staff) to capture urban vs coastal backgrounds, diverse banking relationship (all five target banks represented), and varied income levels (based on position categories). This approach ensure coverage of Batam's key demographic segments while maintaining feasibility. The questionnaire was designed to capture two primary categories of data. Transition data, comprising respondents' current and previous bank affiliations to trace customer migration patterns. Switching drivers, evaluating eight influencing factors through a 5-point Likert scale (Kim & Jindabot, 2021), 1: strongly disagree; 2: disagree; 3: neutral; 4: agree; and 5: strongly agree. These factors included:

a. ATM/branch proximity (Thaichon et al., 2017; Zhao et al., 2022),
b. Administrative fees (Thaichon et al., 2017; Zhao et al., 2022),
c. Mobile/internet banking service (Thaichon et al., 2017; Zhao et al., 2022),
d. Salary/scholarship payment linkages (Kanz et al., 2020),
e. Promotions/rewards (Song et al., 2020; Vincenzo & Jayadi, 2023),
f. Interest rates (Thaichon et al., 2017; Zhao et al., 2022),
g. Family/friend recommendations (Fei et al., 2020; Nurani et al., 2024), and
h. Sharia compliance (Arshad et al., 2016; Ghamry & Shamma, 2022).

Data collection adhered to ethical protocols, ensuring anonymity and requiring informed consent from all respondents prior to survey administration.

3. Data Analysis

The analytical process employed a sequential, three phase approach to transform raw survey data into actionable insights about customer migration patterns. This staged methodology ensured rigorous validation at each step while maintaining direct applicability to Batam's banking context:

a. Transition Probability Matrix
We model customer migration patterns between banks as a Markov process, where transition probabilities represent the likelihood of customers moving from one bank to another. These probabilities were calculated based on observed switching patterns in our survey data.

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} & p_{15} \\ p_{21} & p_{22} & p_{23} & p_{24} & p_{25} \\ p_{31} & p_{32} & p_{33} & p_{34} & p_{35} \\ p_{41} & p_{42} & p_{43} & p_{44} & p_{45} \\ p_{51} & p_{52} & p_{53} & p_{54} & p_{55} \end{bmatrix} \text{ where } p_{ij} = \frac{n_{ij}}{\sum_{k=1}^{5} n_{ik}}. \quad (1)$$

The matrix adheres to two fundamental properties: (1) Non negativity: $p_{ij} \geq 0$ for all i, j; and (2) Row normalization: $\sum_j p_{ij} = 1$ for all i. The empirical P matrix satisfies all theoretical Markov properties while capturing Batam's unique banking dynamics, namely diagonal dominance (high p_{ii}) reflects customer loyalty and off-diagonal patterns reveal competitive advantages.

b. Steady-State Distribution

The steady-state distribution ($\boldsymbol{\pi}$) represents the long-term equilibrium probabilities of customers being in each bank state (BCA, BNI, BRI, BSI, and Bank Mandiri) after infinite transitions. The steady-state vector $\boldsymbol{\pi} = (\pi_1, \pi_2, \pi_3, \pi_4, \pi_5)$ is the unique non-negative solution to:

$$\pi_j = \sum_{i=1}^{\infty} \pi_i p_{ij} \text{ and } \sum_{j=1}^{\infty} \pi_j = 1 \text{ with } j \in \{1,2,\cdots\}. \quad (2)$$

Here, $\boldsymbol{\pi} = (\pi_1, \pi_2, \pi_3, \pi_4, \pi_5)$ is the steady-state probability vector, also termed the stationary distribution or equilibrium distribution (Odhiambo et al., 2020).

c. Switching Driver Analysis

This phase systematically evaluated the relative importance of switching factors through comparative analysis of two complementary dimensions, overall switching drivers and bank specific attraction factors. The dual layer analysis enabled ranking of drivers both universally and by bank, providing a nuanced understanding of how general preferences interact with institutional strengths/weaknesses in Batam's unique context.

C. RESULT AND DISCUSSION

1. Customer Transition Results

Survey responses from 250 ITEBA members were aggregated to count customer movements between the five banks (BCA, BNI, BRI, BSI, and Bank Mandiri) over a specified period. The raw transition counts are summarized, as shown in Table 1.

Table 1. Customer Migration Data

From \ To	BCA	BNI	BRI	BSI	Bank Mandiri	Total Outflows
BCA	57	0	2	1	7	67
BNI	4	31	1	6	1	43
BRI	3	2	17	2	2	26
BSI	1	1	2	39	4	47
Bank Mandiri	7	3	0	6	51	67
Total Inflows	72	37	22	54	65	250

The transition probability matrix was constructed through a systematic process that converted raw customer migration data into probabilistic form. For instance, based on Table 1, the data showed that out of 26 customers initially with BRI, 17 remained with BRI, while 3 moved to BCA, 2 to BNI, 2 to BSI, and 2 to Bank Mandiri. Similar counts were collected for all other banks, resulting in a complete 5×5 migration count matrix. To derive the transition probabilities, each row of the count matrix was normalized by its respective row sum, ensuring that the probabilities satisfied the Markov property. This was achieved using MLE, for example, the transition probabilities for BRI to BCA, BNI, and BSI were computed as follows:

$$p_{\text{BRI,BCA}} = \frac{3}{26} = 0.11539,$$
$$p_{\text{BRI,BNI}} = \frac{2}{26} = 0.07692,$$
$$p_{\text{BRI,BSI}} = \frac{2}{26} = 0.07692,$$

and similarly for other transitions. This process was repeated for all banks, yielding the final transition matrix P,

$$P = \begin{bmatrix} 0.85075 & 0.00000 & 0.02985 & 0.01492 & 0.10448 \\ 0.09302 & 0.72093 & 0.02326 & 0.13953 & 0.02326 \\ 0.11539 & 0.07692 & 0.65385 & 0.07692 & 0.07692 \\ 0.02128 & 0.02128 & 0.04255 & 0.82979 & 0.08510 \\ 0.10448 & 0.04478 & 0.00000 & 0.08955 & 0.76119 \end{bmatrix}. \quad (3)$$

BCA dominates Batam's banking market with the highest retention rate (85.1%), followed by Bank Mandiri (76.1%), exhibiting the strongest customer loyalty. In contrast, BRI shows the lowest retention (65.4%), losing 11.5% of its customers to BCA. While BNI faces significant outflow to BSI (14%). BCA's broad appeal is evident as it attracts customers from all competing banks (most notably 11.55% from BRI) while retaining nearly all of its own clientele, whereas BSI's strongest inflow comes from BNI (14%). Zero entries reflect structural asymmetries in Batam's banking flows.

2. Long-Term Market Share

The steps to obtain the steady-state distribution ($\boldsymbol{\pi}$) are carried out by formulating and solving the steady-state equations numerically. From the transition matrix P, the steady-state equations are derived:

$$\pi_1 = 0.85075\pi_1 + 0.09302\pi_2 + 0.11539\pi_3 + 0.02128\pi_4 + 0.10448\pi_5$$
$$\pi_2 = 0.00000\pi_1 + 0.72093\pi_2 + 0.07692\pi_3 + 0.02128\pi_4 + 0.04478\pi_5$$
$$\pi_3 = 0.02985\pi_1 + 0.02326\pi_2 + 0.65385\pi_3 + 0.04255\pi_4 + 0.00000\pi_5$$
$$\pi_4 = 0.01492\pi_1 + 0.13953\pi_2 + 0.07692\pi_3 + 0.82979\pi_4 + 0.08955\pi_5$$
$$\pi_5 = 0.10448\pi_1 + 0.02326\pi_2 + 0.07692\pi_3 + 0.08510\pi_4 + 0.76119\pi_5$$

Including the normalization condition:

$$\pi_1 + \pi_2 + \pi_3 + \pi_4 + \pi_5 = 1. \quad (4)$$

The system of equations is solved using Gaussian elimination. Solving $\boldsymbol{\pi}$ yielded the long-term equilibrium probabilities of customers being in each bank state:

$$\begin{matrix} & \text{BCA} & \text{BNI} & \text{BRI} & \text{BSI} & \text{Bank Mandiri} \\ \boldsymbol{\pi} = [& 0.32443 & 0.08080 & 0.06584 & 0.26388 & 0.26505 \ ]. \end{matrix} \quad (5)$$

The steady-state distribution $\boldsymbol{\pi}$ paints a concerning portrait of Batam's future banking landscape, with profound implications for maritime financial inclusion. Our analysis projects extreme market concentration among three dominant players, BCA (32.44%), Bank Mandiri (26.51%), and BSI (26.39%), collectively commanding 86.34% of long-term market share, while traditional banks BNI (8.08%) and BRI (6.58%) face progressive marginalization. These projections mathematically manifest the underlying switching drivers that will be fully analyzed in the subsequent section, where BCA's digital supremacy (3.40 service score), Bank Mandiri's institutional advantages, and BSI's niche appeal despite moderate Sharia compliance (2.87) become central to understanding these trends.

The steady-state analysis yields critical insights for Batam's maritime economy. BCA's dominance validates its digital strategies, while BSI's substantial market presence confirms growing demand for Sharia-compliant services. However, the alarming trajectories of BRI and BNI indicate potential market concentration risks that may undermine competitive dynamics, ultimately limiting-consumer choice and potentially hindering financial inclusion efforts across Batam's diverse economic landscape. These findings underscore the need for strategic interventions to maintain a balanced and competitive banking sector.

3. Switching Factor Analysis

The Likert scale survey (1-5) reveals the key factors influencing customer migration between banks. By analyzing these drivers, it can be explained why BCA, Bank Mandiri, and BSI dominate the steady-state distribution, while BRI and BNI struggle to retain customers, as shown in Table 2.

Table 2. Overall Switching Drivers (All Banks Combined)

Factor	Mean Score	Rank
Salary/scholarship payment linkages	3.45	1
ATM/branch proximity	3.16	2
Mobile/internet banking service	3.15	3
Interest rates	3.11	4
Administrative fees	3.09	5
Family/friend recommendations	2.93	6
Promotions/rewards	2.91	7
Sharia compliance	2.80	8

Based on Table 2, salary/scholarship payment linkage emerge as the most influential factor, underscoring the critical role of institutional banking relationships in customer retention. This is closely followed by ATM/branch proximity and mobile/internet banking services, indicating

that customers prioritize both physical accessibility and digital convenience. Interest rates and administrative fees also play significant but secondary roles, reflecting sensitivity to financial costs.

In contrast, promotions/rewards, family/friend recommendations, and Sharia compliance exhibit weaker influence, suggesting that marketing campaigns and social referrals are less decisive than core service quality and institutional ties. These findings highlight a market where functional reliability (salary linkages, digital access) outweighs peripheral incentives (promotions, social influence), with Sharia compliance remaining a niche driver despite its growing relevance in Indonesia's Islamic finance landscape. For banks to compete effectively, they must prioritize strengthening institutional partnerships, expanding digital infrastructure, and optimizing fee structures, as these dimensions collectively shape customer loyalty in Batam's maritime economy.

Table 3. Bank-Specific Attraction Factors (Mean Score)

Factor	BCA	BNI	BRI	BSI	Bank Mandiri
Salary/scholarship payment linkages	3.07	3.83	2.40	4.27	3.21
ATM/branch proximity	3.40	3.83	3.00	2.80	3.07
Mobile/internet banking service	3.40	3.33	2.80	2.73	3.36
Interest rates	3.27	3.00	2.40	3.13	3.21
Administrative fees	3.67	2.33	2.40	2.93	3.21
Family/friend recommendations	3.13	3.33	3.00	2.80	2.64
Promotions/rewards	3.27	2.67	2.60	2.73	2.93
Sharia compliance	2.73	3.67	2.60	2.87	2.50

Based on Table 3, BCA emerges as Batam's dominant bank due to its balanced strengths in digital services, low administrative fees, and competitive interest rates. Its extensive ATM network and reputation for reliability make it the preferred choice for urban customers, particularly those prioritizing convenience and cost efficiency.

a. Bank Mandiri secures its second-place position through strong institutional linkages, particularly salary and scholarship payments, coupled with robust digital banking services. Its appeal lies in serving corporate clients and employees tied to formal payroll systems, ensuring steady customer retention.
b. BSI carves out significant niche by excelling in Sharia-compliant service and unmatched salary linkages, especially with government and Islamic institutions. While its overall Sharia compliance score is moderate, it remains the top choice for religiously motivated customers and those connected to Islamic financial ecosystems.
c. BNI struggles with low retention primarily due to high perceived fees, despite having the best physical accessibility. Paradoxically, its strong Sharia compliance score suggests untapped potential in Islamic banking, which it currently fails to leverage effectively.
d. BRI faces the steepest challenges, dragged down by weak digital services, uncompetitive interest rates, and poor salary linkages. Its decline highlights the risk of neglecting digital transformation and institutional partnerships in a market increasingly driven by convenience and financial anchors.

4. Policy Implications

Based on the steady-state distribution and switching driver analysis, three critical policy interventions are needed to promote financial inclusion in Batam's maritime economy. To begin with hybrid banking infrastructure. Leverage BCA's digital leadership (3.40 service score) and BRI's physical reach to develop integrated coastal service models, countering BCA's projected 32.44% market dominance that risks marginalizing digitally excluded communities.

In addition, Islamic finance ecosystem development. Capitalize on BSI's 26.39% market share by expanding beyond salary-linked products through targeted Sharia-compliant solutions for maritime SMEs, addressing the gap between its institutional usage (4.27 linkage score) and moderate Sharia compliance (2.87). Last but not least, pro-competition fee framework. Implement fee transparency standards and essential service price caps to mitigate BNI's customer attrition linked to high perceived fees (2.33 vs industry 3.09), while preserving its physical accessibility advantages (3.83 ATM score).

Our findings refine conventional banking transition models by revealing how maritme SEZ dynamics uniquely reshape driver hierarchies. While confirming established drivers like ATM/branch proximity (Thaichon et al., 2017) and digital services (Zhao et al., 2022), we identify salary linkages (3.45 mean score) as Batam's dominant factor, contrasting with non-SEZ studies where they play secondary roles (Kanz et al., 2020). Similarly, Sharia compliance (2.87) drives BSI's disproportionate market share (26.39%), a phenomenon undocumented in conventional markets but aligning with Ghamry & Shamma's (2022) Islamic finance prediction. These SEZ-specific pattern necessitate our tailored policy framework, while challenging assumptions about promotion efficacy (Vincenzo & Jayadi, 2023)

D. CONCLUSION AND SUGGESTIONS

This study advances our understanding of banking dynamics in maritime Special Economic Zones through three pivotal contributions. By successfully adapting Markov Chain modelling to Batam's unique banking ecosystem, we demonstrate its efficacy in predicting customer migration patterns where traditional financial analyses fall short, particularly in capturing the interplay between digital adoption (BCA's 3.40 service score) and physical access needs (BRI's coastal network challenges). Our integrated analysis of steady-state probabilities and switching drivers reveals a looming crisis: the projected triopoly of BCA (32.44%), Bank Mandiri (26.51%), and BSI (26.39%) risks marginalizing 14.66% of customers reliant on BRI/BNI's physical services, threatening inclusive growth in archipelagic communities. The dominant role of salary linkages (3.45) and digital accessibility (3.16) underscores the need for hybrid banking solutions. The unexpected disconnect between BSI's market share and moderate Sharia compliance scores (2.87) challenges conventional transition theories, suggesting maritime communities prioritize institutional trust over doctrinal purity in Islamic finance. These outcomes carry strategic recommendations. For policymakers, mandate interoperability between BCA's digital platforms and BRI's rural networks. For banks, develop Sharia-compliant digital products tailored to maritime SMEs. While our sample provides robust initial insights, this study has limitations that warrant future research. The samples were taken mainly from academic communities around urban centers. The Markov model assumes time-homogeneous transitions, whereas seasonal maritime economic fluctuations may introduce variability and

cultural factors influencing Sharia banking preferences were not qualitatively explored. Future studies should address these gaps through stratified coastal sampling, time-varying Markov models, and mixed-methods approaches to fully capture the socio-economic dimensions of banking transitions in maritime economies.

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