Stochastic Modeling of Customer Retention: A Markovian Analysis of Multi-Channel Distribution in the Vacation Rental Market

Prof. M.Cannas
Tutor M. Vaccargiu

Alessia A. Sini | Alice Zuddas | Sara M. Grandi

INTRODUCTION:

STUDY OVERVIEW

Data

Napoleon

DTMC Framework

This study investigates customer loyalty dynamics across three distinct distribution channels for a vacation rental agency. By employing a Discrete-Time Markov Chain (DTMC) framework, we analyze empirical data from the 2023-2025 period.

KEY FINDING & IMPLICATIONS

Napoleon

$$\pi_S = 0.552$$

Our findings identify 'Napoleon' as the channel with the highest stationary probability of retention ($\pi_S = 0.552$), providing a data-driven basis for strategic marketing reorienttion and CRM development.

RESEARCH FRAMEWORK & BOOKING CHANNELS:

The Paradigm: In vacation rentals, Retention Cost is significantly lower than Acquisition Cost.

Core Objective: Identify channel maximizing Customer Lifetime Value (CLV).

Research Question: Which channel generates highest long-term loyalty?

DIRECT BOOKINGS

Key Feature: Internal Management

Advantage: 0% intermediary commissions.

Focus: Direct control over the guest relationship.

NAPOLEON

Key Feature: Specialized Digital Portal.

Advantage: High-tech booking interface.

Focus: Modern digital distribution & visibility.

SARDEGNA TRAVEL

Key Feature: Traditional Tour Operator.

Advantage: Focused on offline/consolidated distribution.

Focus: Niche market expertise & curated sales.

METHODOLOGY: The Markovian Framework

Theoretical Approach

Stochastic Process: Future states depend strictly on the present (Markov Property).

2023-2025

Time-Homogeneity: Transition probabilities (P_{ij}) remain constant over the 2023-2025 timeframe.

P

Transition Matrix (P): Algebraic model to calculate state-to-state movement.

State Space (Ω)

S

N

State S (Stay): Booking completed during the observation year.

State N (No Stay): No booking recorded during the observation year.

Data & Sample

Longitudinal Study: Tracking behavior across 2023, 2024, and 2025.

50x3 = 150

Sample Size: 50 customers per channel (N=150 total data points).

Scope: Comparative analysis of 3 channels (Direct, Napoleon, Sardegna Travel).

THE STRATEGIC VALUE OF MODEL:

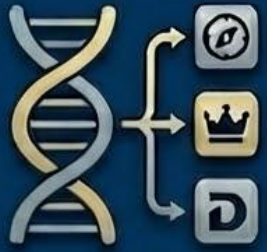
Why is this the superior choice for the agency?

1. Dynamic Modeling

They capture the flow between pure retention and the recovery of inactive leads.

2. Predictive Power

Through the *Steady State* calculation, we can forecast where the system will stabilize in the long run.



3. Channel Benchmarking

We can isolate the 'behavioral DNA' of each platform to see which is structurally superior at fostering loyalty.

4. Resource Allocation

The model pinpoints exactly where 'leakage' or churn identifying whether a channel requires defensive retention tactics (like CRM) or offensive acquisition strategies.

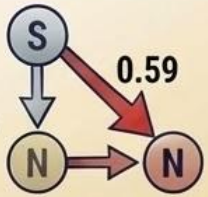
DATA PROCESSING:

P_{Direct}

$$\begin{pmatrix} 0.41 & \mathbf{0.59} \\ 0.45 & 0.55 \end{pmatrix}$$

Direct (The Churn Paradox)

High turnover rate; over 50% of direct stayers do not return ($P_{S \to N}$=0.59).

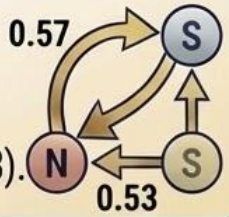


$P_{Napoleon}$

$$\begin{pmatrix} \mathbf{0.57} & 0.43 \\ \mathbf{0.53} & 0.47 \end{pmatrix}$$

Napoleon (Market Leader)

High retention ($P_{S \to S}$=0.57) and robust customer recovery ($P_{N \to S}$=0.53).

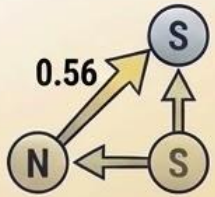


$P_{Sardegna}$

$$\begin{pmatrix} 0.49 & 0.51 \\ \mathbf{0.56} & 0.44 \end{pmatrix}$$

Sardegna Travel (Acquisition Engine)

Strongest ability to attract new/inactive guests ($P_{N \to S}$=0.56).



1. Napoleon: 57% ★ **2. Sardegna Travel:** 49% **3. Direct:** 41%

COMPUTATIONAL IMPLEMENTATION IN R:

THE MATHEMATICAL PROBLEM

To find the long-term probability (π), we solve the balance equation:

$$\pi P = \pi$$

subject to the constraint that the sum of probabilities must equal 1 ($\sum \pi_i = 1$).

TRANSLATION INTO R CODE

The core logic lies in transforming the system into a solvable $Ax = b$ form:

- **Matrix A:** Combines the transition equations ($1 - P_{1,1}$ and $-P_{2,1}$) with the normalization constraint (the row of 1s).
- **Vector b:** Sets the target results (0 for the difference, 1 for the total sum).
- `solve()` **Function:** Applies matrix inversion to find the equilibrium point.

CASE STUDY: NAPOLEON'S BEHAVIOR

Applying the function to the observed data:

Transition	Count	Probability (P)
State A → A	47	0.47
State B → A	43	0.43

Final Result: $pi_S = 0.552$

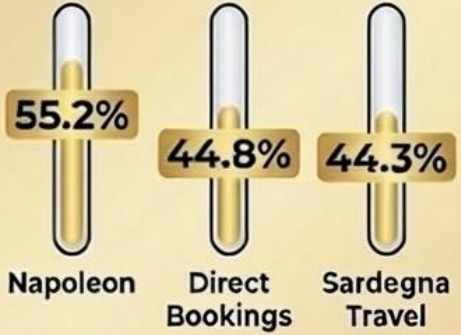
Interpretation: In the long run, Napoleon will be in the analyzed state **55.2%** of the time.

FINAL COMPARISON & THE 'FIDELITY GAP':

THE STEADY STATE CONCEPT

The heart of our analysis is the Steady State. This represents the long-term equilibrium—the probability that a customer will be in the 'Stay' state after an indefinite number of years, assuming current conditions persist. It is the definitive indicator of intrinsic loyalty potential.

COMPARATIVE RESULTS



The results identify a clear winner, with Napoleon leading followed by Direct and Sardegna Travel.

THE 'FIDELITY GAP' OPPORTUNITY

We have identified a 'Fidelity Cap' of **over 10%** between the leading portal and direct management. This gap represents a significant opportunity for the agency to recover margins by improving its internal engagement processes.

ECONOMIC PARAMETERS & ACTION COSTS:

Beyond Retention:
The Economic Factor: While retention rates show customer behavior, the agency must account for operational costs to determine true profitability.

Revenue Assumption:
A value of **100 €** represents the assumed average booking revenue for every "Stay" state.

Action Costs (c):

Direttе: 0 € (Direct channel, no external commission).

Napoleon: 15 € (Approx. 15% OTA commission).

Sardegna Travel: 20 € (Higher commission and promotional costs).

The Reward Function:
The model calculates R(s,a) by subtracting action costs from booking revenue

MDP RESULTS – IDENTIFYING THE OPTIMAL POLICY

Long-Run Expected Reward: The MDP identifies the strategy that maximizes net profit over time, balancing retention and costs.

COMPARATIVE RESULTS

Dirette: ~44.9 €
(Optimal Strategy)

Napoleon: **~40.2 €**

Sardegna Travel: **~32.3 €**

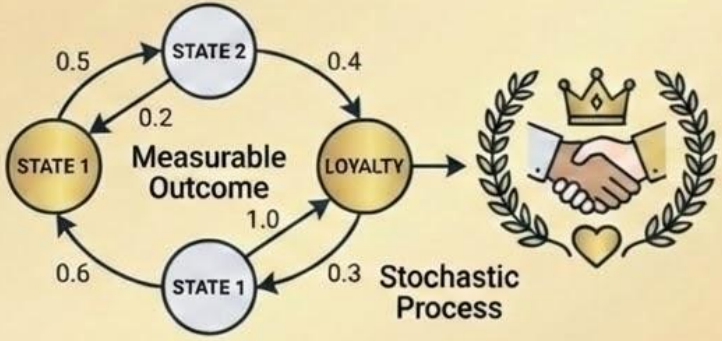
THE PROFIT PARADOX

Although Napoleon has the highest long-run probability of 'Stay,' its commission costs significantly reduce the net reward.

CONCLUSION: The Direct channel is the optimal booking strategy because the absence of fees compensates for its lower retention rate

CONCLUSION:

MARKOV CHAINS & CUSTOMER LOYALTY



Our application of Markov Chains proves that customer loyalty is a measurable stochastic outcome rather than a random variable.

STABILIZING DIRECT BOOKINGS

While Napoleon is currently the most reliable driver, adopting digital engagement strategies can stabilize the direct booking base and maximize long-term profitability.

STRATEGIC MANAGERIAL POLICIES

Based on this evidence, we propose three targeted policies:

NAPOLEON: Secure High-Performing Segment

Collaborate on exclusive discounts for 'repeaters' to secure the high-performing segment.

DIRECT: Implement Post-Stay CRM

To reduce the **59%** churn rate, send targeted incentives exactly nine months after the last stay during the peak booking window.
Steady state **0.552.**

SARDEGNA TRAVEL: Lead-Generation Funnel

Utilize as a lead-generation funnel, converting guests to the direct channel after their first year.

STRATEGIC INTEGRATION & PROFIT RECOVERY

Closing the Gap: The **"Fidelity Gap"** (10%) represents a specific opportunity to move **high-retention customers** from Napoleon to the Direct channel.

DATA-DRIVEN DECISION MAKING

DEFENSIVE TACTICS:
Use Napoleon to secure the high-performing segment.

OFFENSIVE CONVERSION:
Use post-stay CRM to convert Napoleon guests into Direct bookers to capture the full **100 €** revenue without commissions.

FINAL TAKEAWAY:
Lower operational costs can effectively compensate for reduced customer retention, highlighting the importance of integrating economic variables into stochastic models.

THANK YOU FOR YOUR ATTENTION!

Alessia A. Sini | Alice Zuddas | Sara Marie Grandi