

Analysis of Book Loan Transition Patterns Using Markov Chains

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Abstract

University libraries serve as strategic information hubs supporting academic activities. A key challenge is leveraging borrowing data to inform evidence-based collection planning. This study aims to analyze patterns of book borrowing transitions using Markov Chains. The data utilized consists of physical book borrowing records sorted by member and transaction time. The Markov Chain method was applied to construct a transition probability matrix, thereby identifying dominant borrowing sequences. The results reveal transition patterns between books, which librarians can use to plan collections more effectively. These findings are expected to help improve the efficiency of collection management and support data-driven decision-making.

Keywords: *Markov Chain, Transition Patterns, Book Borrowing, University Library*

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2nd International Conference on Islamic Community Studies (ICICS)

Theme: History of Malay Civilisation and Islamic Human Capacity and Halal Hub in the Globalization Era

<https://proceeding.pancabudi.ac.id/index.php/ICIE/index>

Introduction

Libraries are scientific and cultural institutions that serve as centers for providing information, knowledge, and support for academic activities. University libraries act as information centers and support for academic activities, research, and the advancement of knowledge [1]. The success of a library is not only measured by the completeness of its collection but also by the level of collection utilization by patrons. Book circulation data reflects user behavior and serves as a strategic asset for decision-making in collection management [2].

In the context of higher education, libraries play a vital role in supporting the learning process, research, and the advancement of knowledge. A library's success is not only measured by the comprehensiveness of its collection but also by the extent to which users utilize the collection. High levels of book borrowing activity serve as a key indicator of the library's effectiveness in meeting users' information needs [3].

As the volume of circulation data generated from daily borrowing activities increases, libraries face challenges in utilizing this data optimally. Circulation data stored in automated systems is often used merely as administrative records and has not been fully leveraged to generate strategic insights. In fact, circulation data is structured data that can be analyzed to understand user behavior, including borrowing trends and relationships between collections.

Based on previous research, most studies have focused on analyzing borrowing frequency or on using statistical and machine-learning-based predictive methods. However, analysis of book borrowing sequences or transition patterns remains rare, so the opportunity to optimize data-driven collection planning has not been fully realized [4][2], [5].

Analyzing book borrowing patterns is important because it provides insight into users' actual preferences. These patterns not only indicate which books are frequently borrowed but also the borrowing sequences that reflect the flow of users' information needs. Understanding borrowing sequences enables libraries to identify interconnections between collections, such as which books tend to be borrowed after a specific book. This information is highly relevant for supporting more targeted and empirically grounded collection planning.

One approach for analyzing borrowing sequence patterns is the Markov Chain. A Markov Chain is a simple probabilistic model that models transitions between states based on transition probabilities. In the library context, each state can be represented as a book or a book category, while transitions describe the movement of borrowing from one book to another. This approach is relatively simple to implement but can provide meaningful insights into trends in borrowing behavior [6], [7].

Therefore, this study was conducted to analyze book borrowing transition patterns using Markov chains to support data-driven library collection planning. By understanding these transition patterns, libraries are expected to improve the effectiveness of collection management and develop acquisition strategies that are more relevant to patrons' needs.

Literature Review

1. Library Collection Management

University libraries must provide relevant and up-to-date collections for students and faculty. Collection utilization rates serve as an indicator of success, which can be measured through borrowing data. Borrowing patterns help librarians identify popular books and pinpoint underutilized collections [2], [5].

2. Analysis of Book Borrowing Data

Borrowing data stored in the library automation system includes important information such as member ID, book title, and borrowing/return dates. Analysis of historical data allows for the identification of frequently borrowed books, borrowing frequency, and relationships between collections [8], [9], [10].

3. Markov Chain

A Markov Chain is a probabilistic model that models transitions between states based on transition probabilities. Each state can be a book or a book category, while a transition describes a borrowing movement between states [7]. Advantages of Markov Chains: a. Simple and easy to implement

- b. Provides insights into user behavior
- c. SuiFigure for analyzing sequences or transition patterns

In the context of library research, Markov Chains can be used to [11]: a.

Forming a transition probability matrix between books

- b. Identifying the most dominant borrowing sequences
- c. Support data-driven decision-making

Research Methodology 1. Data Types and Sources

This study uses secondary data in the form of book borrowing transaction data obtained from the library system of the State Islamic University of North Sumatra (UINSU). The data used includes: 1) User ID, 2) Book Title, 3) Borrowing Date, and 4) Return Date. This is time-series data per member, enabling the formation of book-borrowing sequences over time.

2. Data Preprocessing

The pre-processing stage was conducted to ensure the data was ready for use in building the Markov Chain model. The steps taken included:

- a. Data cleaning: Removing duplicate data and removing data with empty values
- b. Data sorting: Data is sorted by member ID and borrowing date to form a chronological sequence.
- c. Formation of transition pairs: For each member, transition pairs are formed based on the borrowing sequence: If a member borrows:
Book A → Book B → Book C
Then the following pair is formed:
A → B
B → C

3. Application of the Markov Chain

The Markov Chain model is used to analyze the probability of transition from one book to another.

a. Formation of the Frequency Matrix

From all the transition pairs formed, the frequency of occurrence of each pair is calculated: f_{ij} = the number of transitions from book i to book j

b. Formation of the Transition Probability Matrix

The frequency matrix is normalized into a probability matrix using:

$$P_{ij} = \frac{f_{ij}}{\sum_j f_{ij}}$$

Thus, each row represents the probability of transition from one book to another. This matrix is *square* (the number of rows and columns is equal) because each book can serve as both a starting *state* and a destination

4. Output

To identify dominant transition patterns, the five transition pairs with the highest probabilities are selected. These results are displayed in the following format:

- a. Top 5 Transition Figure
- b. Horizontal bar chart of transition probabilities

Results

1. Top 5 Transition Probabilities

Based on the calculation of the transition probability matrix using the Markov Chain model, five transition pairs with the highest probabilities were obtained, as shown in Figure



Figure 1. Top 5 Transition Probabilities

2. Interpretation of Results



Figure 2. Top 5 Highest Probability Transitions Chart

Based on the five transitions with the highest probability (1.0), the direction of the title shifts can be explained as follows:

- Fiqh Studies, including: Fiqh of Worship (Thaharah, Prayer, Zakat, Fasting). This indicates a deepening of the material from general fiqh concepts toward a specific discussion of worship.
- History of Islamic Education (Classical Period), including: The Mindset of the Wealthy. This illustrates a cross-disciplinary shift from historical studies of education to themes of self-development and economics.
- History of Islamic Education (Zuhairini), including: Reorientation of Islamic Education. This indicates continuity of topics within a single academic discipline, from history to the renewal of Islamic education.
- Nutrition and Efforts to Create Nutrition-Aware Families, including: Portrait of Coastal Communities. Indicates an expansion of context from family nutrition issues to social studies of communities.
- Reproductive Health Nutrition, including: Health Epidemiology. This demonstrates a progression from basic health topics toward analytical approaches and public health research.

In general, the transition pattern reveals a tendency toward deeper exploration of topics, a broader contextual scope, and interdisciplinary shifts in book-borrowing behavior.

Conclusion

This study applied a Markov Chain model to analyze book-borrowing transition patterns using historical library data. The analysis results indicate the presence of several transition pairs with a probability of 1.0, suggesting a deterministic transition pattern in the data. The emerging patterns reflect a tendency toward deeper exploration of topics within the same field, an expansion from conceptual material to analytical approaches, and cross-disciplinary shifts.

The results of this study can be practically utilized as a basis for developing a book recommendation system based on borrowing patterns. Transition probability information enables libraries to compile follow-up book recommendations for borrowers, organize the placement of related collections, and support decision-making in collection acquisition. Thus, the application of Markov Chain analysis has the potential to improve service effectiveness and library user satisfaction.

However, this study has several limitations, including the limited number and variety of transaction data, resulting in some probability values reaching 1.0 and producing patterns that tend to be deterministic. Additionally, the model is still first-order Markov-based, so it does not account for borrowing history beyond one step.

Therefore, future research is recommended to use a larger dataset with a longer time span, apply higher-order Markov Chains or combine them with other methods, and test the model's implementation in a real-world recommendation system to measure accuracy and user satisfaction. Overall, the Markov Chain model has proven capable of systematically and quantitatively identifying patterns of interrelationships among book titles and has the potential for further development in historical data-based recommendation systems.

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