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Design of a Predictive Model for Prospective New Students Using Monte Carlo Simulation

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A B S T R A C T

The competition between universities in the admission of new students is becoming increasingly intense, making it more difficult for the public, especially prospective students, to choose a study program. The Department of Hadith Sciences at UIN Syech M. Djamil Djambek Bukittinggi has fewer applicants compared to other departments due to the limited interest of prospective students in enrolling. In response to this issue, the author developed a Monte Carlo simulation predictive model that allows prospective students to estimate the number of applicants to the Department of Hadith Sciences for the upcoming academic year. The research technique employed in this study uses Monte Carlo simulation to apply this research. The number of students in the Department of Hadith Sciences who enrolled from 2019 to 2023 serves as the data used to predict the number of new student registrations. The accuracy of the simulation in estimating the number of new students who will enroll in the Department of Hadith Sciences is 218 students, with an average annual accuracy of 65.1%. By applying the Monte Carlo method, it is possible to predict the number of students who will enroll in the Department of Hadith Sciences with a relatively high level of accuracy in its application.

1. Introduction

The admission of new students is an annual routine activity carried out by every school and university. The increasing competition among universities to attract the interest of the public, especially prospective students, makes it more challenging for them to choose the right university. Likewise, the selection of a study program at the university of their choice becomes increasingly difficult for prospective students[1]. This choice depends on the interest of prospective students in selecting a university and the study program it offers, which is influenced by many preceding variables. These variables ensure that students make choices that are accurate and aligned with their expectations[2].

The selection of a university is closely tied to the selection of a study program at that university. The chosen study program will influence the university selected, as the program is directly related to achieving one's goals and future aspirations. When choosing a study program, both students and parents must consider various factors. These considerations include interests and talents, alignment with intellectual capabilities, financial capacity, and the reputation of the university and the chosen program. With these considerations in mind, students are expected to select a study program and university that best suits their circumstances, ensuring smooth academic progress and a successful future [3].

In today's era, education is of great importance to society. Indonesia has thousands of universities across the archipelago. Universities are scientific institutions tasked with providing education and instruction beyond the secondary level. They offer education and teaching based on Indonesia's national culture and

through scientific methods [4]. One type of higher education institution is the State Islamic University (UIN). UIN is a form of state Islamic university in Indonesia that offers academic education across a range of disciplines, including fields beyond Islamic sciences. UIN is one of the state Islamic higher education institutions, alongside the State Institute for Islamic Sciences (IAIN) and the State Islamic College (STAIN). One such institution in Indonesia is Sjech M. Djamil Djambek State Islamic University in Bukittinggi.

UIN Sjech M. Djamil Djambek is a public Islamic religious higher education institution located in Bukittinggi, West Sumatra, Indonesia. The university is named after Sjech M. Djamil Djambek, a pioneering Islamic reformer from West Sumatra, on June 30, 1997, during the 20th century. The student population of UIN Sjech M. Djamil Djambek currently stands at 16.170, a number that continues to grow each year [5]. UIN Sjech M. Djamil Djambek Bukittinggi is a public university that provides Islamic education in the city of Bukittinggi, Indonesia. UIN Sjech M. Djamil Djambek Bukittinggi was established in accordance with Presidential Decree No. 11, issued on March 21, 1997, or 12th of Zulkaidah 1417 in the Islamic calendar. The mission of UIN Sjech M. Djamil Djambek Bukittinggi is to deliver high-quality, open, and accountable higher education, while fostering institutional collaboration through networking. One of its goals is to produce graduates with academic, professional, and accountable capabilities who are competitive at both national and international levels.

Sjech M. Djamil Djambek State Islamic University (UIN) Bukittinggi has four faculties, one of which is the Faculty of Education and Teacher Training (FTIK). Within the Faculty of Education and Teacher Training, there are six undergraduate programs (S1), namely Arabic Language Education (PBA), Islamic Religious Education (PAI), Guidance and Counseling (BK), Mathematics Education (PMTK), English Language Education (PBI), and Informatics and Computer Engineering Education (PTIK). In the Informatics and Computer Engineering Education program, there is a course titled "Models and Simulations," which carries 2 credits (SKS) and is studied in the fourth semesteR [6]. One of the study programs that has gained particular attention is the Hadith sciences program.

The term "Hadith Sciences" refers to "the knowledge related to hadith." Given the many types of knowledge associated with hadith, scholars have proposed this broad definition. Scholars in this discipline study hadith extensively because it is the second most important source of guidance after the Qur'an. The sayings, actions, decisions, and characteristics of the Prophet are continuously transmitted and passed down from the companions to subsequent generations. Numerous books have been written on the study of hadith, and to this day, the study of hadith has evolved into its own distinct field of scholarship [7]. Imam As-Suyuthi defines Ilmu Hadith as the science that examines the methods of connecting a hadith to the Prophet Muhammad (PBUH), from its narrators (rawi) to its content (matn). Thus, Ilmu Hadith can be understood as the knowledge related to the Prophet, encompassing his actions, characteristics, and other aspects. This science also explores the chain of transmission of the Prophet's hadiths, from the narrators to the content of the hadith itself [8].

The Hadith Sciences program at UIN Bukittinggi was established in 2015 and received operational approval on January 28, 2015 (formerly IAIN Bukittinggi). The Hadith Sciences program at UIN Bukittinggi is the oldest Hadith department on the island of Sumatra, as no other campus on the island at that time had the courage to separate the Hadith Sciences department from the Qur'anic Exegesis (Tafsir) department. Despite its initial lack of interest, the program has since become a significant academic offering [6]. However, over time and with the efforts of the early generation in promoting the Hadith Sciences department, supported by the university, the reality today is that the Hadith Sciences department has fewer students compared to other departments.

Therefore, in facing the challenges of competition in the education sector, UIN Bukittinggi needs to understand and predict the interest of prospective new students, particularly for the Hadith Sciences department, over the next five years. By estimating the number of prospective students interested in enrolling, UIN Bukittinggi can plan its new student admission strategies, manage existing resources, and

identify measures to increase student interest. As one of the preferred public universities in Bukittinggi, UIN Bukittinggi will conduct new student admissions. Currently, the admission system is still very manual in predicting or estimating the number of students to be accepted, and the results remain uncertain. To address this need, modeling and simulation can be employed by analyzing sample data from previous years' admissions to forecast future enrollment trends [10]. One simulation modeling technique that can be utilized is the Monte Carlo method.

The Monte Carlo method is a computational algorithm that uses repeated random sampling to obtain results. It is a numerical technique described as a statistical simulation method. This method has been applied to processes involving random behavior and to measure physical parameters that are difficult or even impossible to calculate through experimental measurements. Fundamentally, the Monte Carlo method is used as a numerical procedure to estimate the expected value of a random variable [11]. Monte Carlo is a simulation technique used to generate random numbers from sample data. This method utilizes random numbers to perform its calculations. Applying the Monte Carlo method in predicting new student enrollment at UIN Bukittinggi is intended to forecast the number of prospective students based on data analysis from previous years' applicants. Based on this explanation, the researcher aims to design a prediction model for the admission of new students to the Hadith Sciences department using Monte Carlo simulation. By developing this simulation method, it is hoped that UIN Bukittinggi can better estimate the number of new students who will apply, not only to the Hadith Sciences department but also to other departments. This will enable UIN Bukittinggi to develop and enhance the quality of the university, thereby increasing interest among prospective students.

There is prior research comparable to this study. The first study used Monte Carlo simulation to estimate the number of prospective new students at Dehasen University Bengkulu. Conducted in 2020 by Al Akbar, Hendri Alamsyah, and Riska, this research aimed to explore the application of the Monte Carlo approach to generate data related to the analysis of the number of students to be admitted to the institution in the following year. A system was utilized for the analysis, and the results were then used to develop an application using the Visual Basic programming language [1]. In 2020, Rahmatia conducted a simulation study using the Monte Carlo approach, claiming to forecast the sales of HPAI products at HNI Halal Mart. The forecasted results demonstrated an average accuracy of 84.5%, which aided in selecting effective business strategies and facilitated decision-making [8]. Beni Mulyana conducted a third study in 2020 to estimate advertising revenue levels at Vand Advertising Printing, aiming to facilitate the development of timely and efficient business strategies for the business owner. The system, which employed the Monte Carlo method to anticipate advertising revenue levels, achieved an average accuracy of 90%, demonstrating its capability to predict revenue levels based on test results [9]. In 2020, Rahmatia conducted a simulation study using the Monte Carlo approach, claiming it could forecast the sales of HPAI products at HNI Halal Mart. The forecasted results demonstrated an average accuracy of 84.5%, which helped in selecting effective business strategies and facilitated decision-making [8]. Beni Mulyana conducted a third study in 2020 to estimate advertising revenue levels at Vand Advertising Printing, aiming to facilitate the development of timely and efficient business strategies for the owner. The system, which utilized the Monte Carlo method to predict advertising revenue levels, achieved an average accuracy of 90%. This demonstrated its ability to predict revenue levels based on test results, thereby assisting in the selection of appropriate business strategies to enhance profitability.

2. Method

The Research and Development (R&D) methodology is employed to outline the framework or steps to be implemented in the research. [12]. The subjects of this study are the validation and compilation of data from prospective new students from 2019 to 2023. The focus of the research is on the prediction simulation model designed to estimate the number of new students for the next five years in the Hadith Sciences department. The steps involved in utilizing the Monte Carlo simulation method are as follows:

2.1. Hadith Science Student Admissions Data

Collect information on student admissions for the Hadith Sciences program from 2019 to 2023 to estimate next year's admissions based on historical data. This will be done through observation, direct examination of the research subjects, and direct communication with the subjects.

2.2. Determining Probability Distribution

At this point, divide the frequency of student data by the total number of student data to determine the probability percentage of new student admissions to the Hadith Sciences program. This probability typically reveals patterns that can be used for prediction.

2.3. Performing Cumulative Distribution Calculations

Convert the standard probability distribution into a cumulative distribution by adding the values sequentially from the previous table. Then, review the table to check the results. Probability values that are in the range of 0.x, when accumulated, typically approach a final value of 1.

2.4. Setting Random Number Intervals

Establish random number intervals. At this stage, each possible value or outcome is represented by a series of integers, which are determined by calculating the cumulative distribution for each variable used in the simulation.

2.5. Using Random Numbers in Monte Carlo Simulations to Process Data

At this point, random numbers will be generated to obtain potential simulation outcomes. Using a specific type of random number generation, random numbers are created according to a particular pattern known as a distribution that follows a distribution function (RNG), namely : $Zi = (a*Zi-1 + c)\ m$ where : Zi = The i-th random number of the series (New RNG value) Zi-1 = Previous random number (Old RNG value) A = Multiplication constant C = Addition constant Mod m = Modulus [13].

2.6. Monte Carlo Simulation Results

The Monte Carlo simulation results, manual testing of the Monte Carlo technique, and PHP programming will be discussed. Additionally, the effectiveness of the Monte Carlo approach in predicting new student admissions to the Hadith Sciences program at Sjech M. Djamil Djambek University Bukittinggi will be examined.

2.7. Monte Carlo Simulation Model Formation Procedure

The procedure for developing a Monte Carlo simulation model involves the methods, steps, or stages required when using Monte Carlo simulation. This process must be conducted sequentially to produce predictions that are as accurate as possible and to maximize the calculation results. The steps involved in developing a predictive simulation model are as follows:

2.7.1. Registration Page

The Registration Page is a page that displays data on the number of new student applicants for the Hadith Sciences department at UIN Bukittinggi. The data table includes the faculty name, year, number of applicants, and number of registrations. This information can be viewed in Table 1.

Table 1. Cumulative Probability Page with Monte Carlo Simulation Method for Hadith Science Study Program at UIN Bukittinggi

Calculate Interval						
No	**Year**	**Number of Applicants**	**Probability**	**Cumulative**	**Interval**	
1	2019	3117	0,223	0,223	0	222
2	2020	3358	0,24	0,463	223	462

3	2021	3072	0,219	0,682	463	681
4	2022	2362	0,169	0.851	682	850
5	2023	2093	0,149	1	851	999

Table 2. Determination of Random Numbers

Generate Random Numbers				
Z_i	**$(a.Z_I) + C$**	**$(a.Z_I) + C$ mod m**	**3 digit number**	**Prediction**
1	2019	3117	0,223	0,223
2	2020	3358	0,24	0,463
3	2021	3072	0,219	0,682
4	2022	2362	0,169	0,851
5	2023	2093	0,149	1
The number of applicants in the following year is				2858

2.7.2. Monte Carlo Page

The Monte Carlo Page is where the results of the Monte Carlo algorithm calculations for predicting new student applicants for the following year will be displayed. To obtain results similar to those in the table above, it is necessary to process data from previous years' applicants. The initial process involves calculating the probability by dividing the number of applicants by the total number of applicants. This preliminary process produces Table 3.

Table 3. Probability of Applicants Data for the Hadith Sciences Program at UIN Bukittinggi

No	Period	Number	Probabilty
1	2019	3117	0,223
2	2020	3358	0,24
3	2021	3072	0,219
4	2022	2362	0,169
5	2023	2093	0,149
Total		14002	1

The next step is to calculate the cumulative probability distribution of the probability distribution variable by summing each probability value with the previous total. The following presents the calculation of the cumulative distribution :

2015 = 0.223

2016 = 0.223 + 0.24 = 0.463

2017 = 0.463 + 0.219 = 0.682

2018 = 0.682+ 0.169 = 0.851

2019 = 0.851+ 0.149 = 1

Next, intervals are created for each variable, followed by the generation of random numbers using the Monte Carlo simulation formula. From these random numbers, the following results can be obtained :

Z1 = ((a*(Z1-1)) + c) mod m

= ((32*78) + 25) mod 99

= 2521 mod 99

= 46

Z2 = ((a*(Z2-1)) + c) mod m

= ((32*46) + 25) mod 99

= 1497 mod 99

= 12

Z3 = ((a*(Z3-1)) + c) mod m

= ((32*12) + 25) mod 99

= 409 mod 99

= 13

Z4 = ((a*(Z4-1)) + c) mod m

= ((32*13) + 25) mod 99

= 441 mod 99

= 45

Z5 = ((a*(Z4-1)) + c) mod m

= ((32*45) + 25) mod 99

= 1465 mod 99

= 79

The final step is to create a simulation of an experiment using random numbers by utilizing the predetermined random numbers. The random numbers and predictions can be seen in Table 4.

Table 4. Random Numbers and Predictions

Z_i	$(a.Z_I) + C$	$(a.Z_I) + C \bmod m$	3 Digit Number	Prediction
1	2521	46	460	3358
2	1497	12	120	3117
3	409	13	130	3117
4	441	43	430	3358
5	456	79	790	2362
The number of applicants in the following year is (average prediction)				3062

The Monte Carlo calculation is significantly influenced by the generated random numbers, such that each random number used will produce different results from one another, but all remain predictive outcomes. Next, the simulation results of students from 2015 to 2019 will be compared with the results generated by Monte Carlo random numbers. This comparison can be seen in Table 5.

Table 5. Random Numbers and Predictions

No	Period	Simulation Results	Real Data	Accuracy
1	2015	3358	3117	92,8%
2	2016	3117	3358	92,8%
3	2017	3117	3072	98,6%
4	2018	3358	2362	70,3%
5	2019	2362	2093	88,6%

From the comparison table, the predicted simulation results for prospective students in 2020 amounted to 3,062, with an accuracy rate of 92.49%.

3. Results and Discussion

3.1. Analysis and Design Stages

Regarding the data analysis phase, the researcher will conduct an evaluation of the proposed system design. A simulation system will be developed to forecast the number of new applicants for the Hadith Sciences program. The system flowchart that will be constructed can be designed using the principles discussed in Chapter III, Research Methods, as shown in Figure 1.

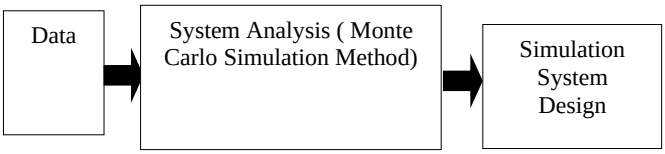

Figure 1. Analysis and Design Flow Chart [14].

Figure 1 illustrates the need for data collection for this study before starting system design. The Monte Carlo approach was applied to this data.

3.2. Monte Carlo Method Simulation Formation Procedure

There are several simulation stages that can be carried out when applying the Monte Carlo method in data processing. Below is Figure 2, which represents the flowchart of the Monte Carlo simulation process.

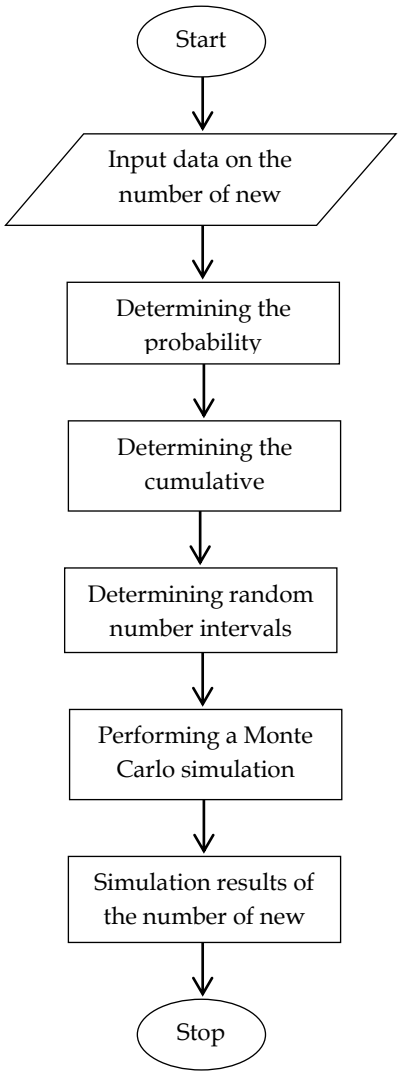

Figure 2. Monte Carlo Algorithm Flowchart

Figure 2 illustrates the process of using the Monte Carlo simulation as a method to predict the number of new student admissions. The breakdown of the process is as follows :

3.2.1. Input Data on the Number of New Prospective Students

Ensure that the data on the number of new prospective students is accessible before conducting system analysis using the Monte Carlo approach to anticipate the number of new applicants for the Hadith Sciences program. The primary data used in this research consists of the number of new applicants in 2019, 2020, 2021, 2022, and 2023. Table 6 presents the data on the number of new applicants.

Table 6. Number of new prospective students in the Hadith Science study program

No	Year	Number of prospective students
1	2019	260
2	2020	240
3	2021	88
4	2022	146
5	2023	190

(Source: Academic and Student Service Unit, UIN Bukittinggi)

3.2.2. Determining Probability Distribution

To determine the probability distribution of a variable using the formula :

$$P = \frac{J}{F}$$

Information :

P = Probability value

F = Frequency

J = Number of Frequency

The results of the probability distribution calculations based on the number of new students are presented in Table 7 below.

Table 7. Probability of Hadith Science Student Registrant Data

Period	Number	Probability
2019	260	0,281
2020	240	0,260
2021	88	0,095
2022	146	0,160
2023	190	0,205
Total	**924**	**1**

Based on the number of new students enrolled in the Hadith Science department per year divided by the total number of new students enrolled in the Hadith Sciences department over five years, the probability distribution values are obtained.

Calculating the probability value for 2019-2023 based on table 2 :

P1 : 260 / 924 = 0,28

P2 : 240 / 924 = 0,260

P3 : 88 / 924 = 0,095

P4 : 146 / 924 = 0,160

P5 : 190 / 924 = 0, 205

3.2.3. Determining Cumulative Probability Distribution

The first cumulative probability distribution, which is the same as the initial probability value, can be found by summing the probability distribution values with the total of the previous probability values. This results in the cumulative probability distribution.

The following is a distribution calculation for cumulative probability :

2019 = 0.281

2020 = 0.281 + 0.260 = 0.541

2021 = 0.541 + 0.095 = 0.636

2022 = 0.636 + 0.160 = 0.796

2023 = 0.796 + 0.205 = 1

So the cumulative table is as in table 8 below :

Table 8. Cumulative Probability and Frequency of Data on Student Registrants of Hadith Science

Period	Number	Probability	Cumulative
2019	260	0,281	0, 281
2020	240	0,260	0,541
2021	88	0,095	0,636
2022	146	0,160	0,796
2023	190	0,205	1
Total	**924**	**1**	

3.2.4. Determining Random Number Intervals

The interval values of random numbers are derived from the cumulative probability values obtained in the preceding stage before determining the random number intervals in this subsection. The random number interval boundaries, consisting of the initial and final random number values, define the random number itself. The following outlines the method for determining the boundary values of a random variable:

a. The value 1 serves as the initial limit value of the first variable.

b. The cumulative probability value of each variable is multiplied by 100 and rounded up to produce the final limit value.

c. The last limit value of the previous variable is used to determine the initial limit value of the second variable, and so on.

The following is the random number interval data that has been determined in table 9 :

Table 9. Calculation of Random Number Interval Values

Period	Number	Probability	Cumulative	Interval
2019	260	0,281	0, 281	1 28
2020	240	0,260	0,541	2 54
2021	88	0,095	0,636	9 64
2022	146	0,160	0,796	5 80
2023	190	0,205	1	5 100
Total	**924**	**1**		6 5 8 1

3.2.5. Generating Random Numbers

To form random numbers, use the following formula and conditions:

$$Z_i = ((a * (Z_i - 1) + c) \ mod \ m \quad (2)$$

First Experiment: a = 32, c = 25, m = 99, and Zo = 78. So from the search for random numbers using Monte Carlo, it can be seen in the following details:

Z_1 = ((32 * 78) + 25) mod 99
= (2496 + 25) mod 99
= 2521 mod 99
= 2521 - 2475
= 46

Z_2 = ((32 * 46) + 25) mod 99
= (1472 + 25) mod 99
= 1497 mod 99
= 1497 - 1485
= 12

Z_3 = ((32 * 12) + 25) mod 99
= (384 + 25) mod 99
= 409 mod 99
= 409 - 396
= 13

Z_4 = ((32 * 13) + 25) mod 99
= (416 + 25) mod 99
= 441 mod 99
= 441- 409
= 32

Z_5 = ((32 * 13) + 25) mod 99
= (416 + 25) mod 99
= 441 mod 99
= 441- 409
= 32

Z_6 = ((32 * 59) + 25) mod 99
= (1888 + 25) mod 99
= 1913 mod 99
= 1913 - 1881
= 32

The final stage involves creating a simulation of an experiment using random numbers by utilizing the predetermined random numbers, as shown in Table 10.

Table 10. Random Numbers of Student Number Data

Index i-th	Variables				Random Number (Zi + 1)
	A	Zi	C	M	
0	32	78	25	99	46
1	32	46	25	99	12
2	32	12	25	99	13
3	32	13	25	99	32
4	32	32	25	99	59
5	32	59	25	99	32
6	32	32	25	99	32

3.2.6. Performing Monte Carlo Simulations

The random number values and the random number interval values are compared in the simulation trial. The values obtained from the generated random numbers in the simulation results are compared with the random number interval values. The possible number of new students in 2018 is predicted using the simulation data from 2018, and the possible number of new students in 2019 is predicted using the simulation data from 2019. Table 11 presents the simulation results.

Table 11. Simulation Results of Prediction of Admission of Hadith Science Students

No	Period	Number of Students	Random Number	Simulation Results	Accuracy
1	2019	260	46	240	92,3%
2	2020	240	12	260	92,3%
3	2021	88	13	260	33,8%
4	2022	146	32	240	60,8%
5	2023	190	59	88	46,3%
Total		924		1088	325,5%
Average				218	65,1 %

The simulation results predicting the number of new students in the Hadith Science department for the year 2024 using the Monte Carlo approach are explained in Table 7. With an average accuracy rate of 65.1%, a total of 218 students are expected to enroll as predicted.

3.2.7. Simulation Results of the Number of New Registrants for the Following Year

To provide input for policy-making, the simulation results will demonstrate whether the Monte Carlo model can accurately project the number of prospective new students for the upcoming academic year. The details can be seen in Table 12.

Table 12. Simulation Results for New Students in the Hadith Science Department in the Following Year

No	Period	Number of Students	Random Number	Simulation Results	Accuracy
1	2019	260	46	240	92,3%
2	2020	240	12	260	92,3%
3	2021	88	13	260	33,8%
4	2022	146	32	240	60,8%
5	2023	190	59	88	46,3%
6	2024	218	32	240	65,1%

Discussion

This research results in a Monte Carlo simulation model for predicting the number of new students who will enroll in the Hadith Science department at UIN Sjech M. Djamil Djambek in the following year. With this simulation, it is hoped that predictions of applicant numbers will become more accurate and that it will contribute to an increase in the number of new students in the future.

This research is supported by historical data on the number of new students who enrolled over the past five years. In 2019, the number of applicants reached 260, with a prediction accuracy rate of 92.3%. In 2020, there was a decrease in interest, with 240 applicants and a drop in prediction accuracy to 33.8%. The downward trend continued in 2021, with only 88 applicants and a prediction accuracy remaining at 33.8%. However, in 2022, there was an increase to 146 applicants, and the prediction accuracy improved to 60.8%. In 2023, the number of applicants rose again to 190, although the prediction accuracy slightly declined to 46.3%. These data were obtained from the Academic and Student Services Unit at UIN Sjech M. Djamil Djambek.

Based on the Monte Carlo simulation method applied in this research, the prediction for the number of students enrolling from 2019 to 2023 averages 218, with an average prediction accuracy of 65.1%. This result aligns with the study conducted by Ringgo Dwika Putra, Yopi Apridiansyah, and Eka Sahputra in their work titled "Application of the Monte Carlo Method in Predicting New Student Enrollment at Universitas Muhammadiyah Bengkulu." Although there is a similarity in the approach used, this research focuses on developing and designing a more structured and comprehensible prediction model for both readers and future researchers.

4. Conclusion

Based on the research results detailed in this article, the author concludes that the Monte Carlo simulation model used has validity with a prediction accuracy rate of 65.1% in forecasting new student registrations for the Hadith Science program at UIN Sjech M. Djamil Djambek. This accuracy remains relevant despite a trend of decreasing interest in the program. The development of this model is expected to provide valuable insights and information for decision-makers at UIN Bukittinggi, particularly for the academic department of the Hadith Science program. With this information, it is hoped that campus capacity management can be carried out more effectively, strategies for new student admissions can be better planned, and efforts to increase prospective students' interest in the Hadith Science program can be identified and designed more accurately.

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