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GAME THEORY AND MARKOV CHAIN ANALYSIS OF THE DISPLACEMENT OF SHOPPING MALL VISITORS IN SURAKARTA CITY

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ABSTRACT

The era of globalization has led to changes in social patterns and lifestyles. With these changes, shopping malls were built to fulfill the community's needs. This study aims to analyze the displacement of visitors in three shopping malls in Surakarta City, namely Solo Paragon Mall, Solo Grand Mall, and Solo Square, using game theory and the Markov chain. Game theory is used to determine the optimal strategy of each shopping mall based on six indicators of visitor satisfaction, namely product diversity, presence of transportation modes, distance, price, facilities, and services. Saddle points are obtained by pure strategy. The calculation results with the game theory method resulted in three competitions. The first competition between Solo Paragon Mall and Solo Grand Mall obtained the optimal strategy of Solo Paragon Mall is product diversity. At the same time, Solo Grand Mall is the existence of transportation modes. The second competition between Solo Paragon Mall and Solo Square obtained the optimal strategy of Solo Paragon Mall, which is product diversity, while Solo Square's optimal strategy is service. Lastly, the third competition, Solo Grand Mall and Solo Square, obtained the optimal strategy of Solo Grand Mall is the presence of transportation modes and Solo Square is service. Markov chain is used to calculate the transition probability of visitors and steady state, which shows that Solo Paragon Mall is more desirable with a steady state probability of 0.4459, followed by Solo Square 0.3584 and Solo Grand Mall 0.1957. The results of this study can help shopping malls evaluate and improve their strategies to increase loyalty and attract new visitors.

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1. INTRODUCTION

The development of cities in Indonesia has led to changes in social patterns and lifestyle behaviors characterized by an inclination towards instant gratification. This consumer behavior has resulted in the emergence of industries to meet lifestyle needs, such as shopping malls. Shopping centers are characterized as places that offer a pleasant shopping experience, as well as serving as social and recreational facilities for various activities [1]. The city of Surakarta is one of the cities experiencing this development. Many residents of Surakarta now use shopping malls as venues for buying and selling transactions, meeting places, exchanging information, and even as locations for self-expression [2].

With the proliferation of shopping malls, competition has inevitably become intense. Shopping malls must innovate their service strategies to visitors to ensure business continuity. Otherwise, this could lead to a phenomenon known as brand switching among customers. Brand switching refers to the condition where consumers shift from using one product to another within the same category [3].

Two key concepts that can be used to analyze visitor switching are game theory and Markov chains. Game theory is a mathematical approach to formulating competition states and conflicts with various interests [4]. In the context of visitor switching among shopping malls, game theory can be applied to analyze the decisions made by visitors and how these decisions affect other visitors. Important factors influencing visitor satisfaction and their choices in shopping locations include product diversity, availability of transportation modes, distance between residences and shopping malls, price, facilities, and services. The goal of game theory methods is to predict and optimize the marketing strategies of each shopping mall. Markov chains are a method that describes the movement of several variables over a future time period based on the movement of those variables in the present [5]. Markov chains are used to illustrate how visitors switch from one shopping mall to another. The results obtained using Markov chains provide information about the level of interest the public has in visiting a particular shopping center.

In this study, game theory is used to determine the optimal strategies for shopping malls in the city of Surakarta based on six visitor satisfaction indicators, while Markov chains are employed to describe the movement of visitors from one shopping mall to another. The research data consists of primary data obtained from a questionnaire with 110 respondents. The data from the distributed questionnaires are then tested for validity and reliability to assess the accuracy of the instrument and the consistency of the questionnaire. The data used includes visitor satisfaction on a scale of 1-5 and the movement of visitors among Solo Paragon Mall, Solo Grand Mall, and Solo Square. The results of the optimal strategies and visitor movement predictions can serve as an evaluation for shopping mall management to attract more visitors.

2. RESEARCH METHODS

The data in this study are primary data obtained by distributing questionnaires through Google Form. The questionnaire was distributed in February - March 2024 and uploaded via social media Instagram, WhatsApp, and X (Twitter). The criteria for respondents are having visited shopping malls in Surakarta City, especially Solo Paragon Mall, Solo Grand Mall, and Solo Square, and domiciled in Surakarta. Before the data is calculated using the game theory and Markov chain methods, the validity and reliability are first tested through a preliminary questionnaire trial conducted on 30 respondents so that the test results are close to the normal curve. After the questionnaire was valid and reliable, the questionnaire was distributed to 100 respondents (the minimum number of respondents required by Lemeshow's formula). The research sample obtained in this study totaled 110 respondents. Two main concepts can be used in analyzing displacement visitors, namely game theory and Markov chains. Game theory is a mathematical approach to formulating competitive conditions and conflicts with various interests. The game theory method is used to analyze the optimal strategy of shopping malls in Surakarta. Furthermore, the Markov chain is a method that explains the movement of several variables in one time period in the future based on the movement of variables in the present.

The following are the research steps listed in **Figure 1**.

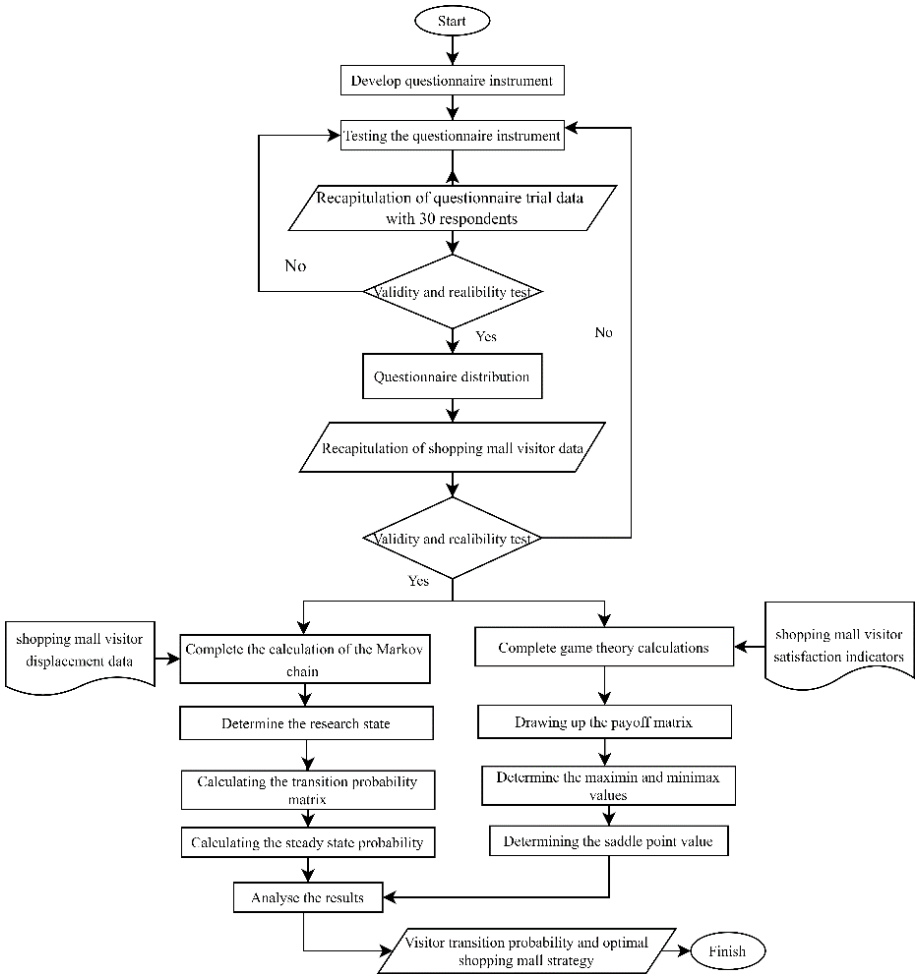

Figure 1. Flowchart of Research Steps

3. RESULTS AND DISCUSSION

3.1 Research Sample

The data used in this research is primary data by distributing questionnaires to Surakarta residents. The following shows the results based on Lemeshow's formula for determining the research sample size in a population of unknown size **[6]**.

$$\gamma = \frac{(1.96)^2 \times 0.5(1-0.5)}{(0.1)^2} = 96.04 \approx 97 \quad (1)$$

The results of the calculation using the Lemeshow formula show that the minimum sample required is 96.04 and then rounded up to 97. Then based on the questionnaires that have been distributed, 110 respondents were collected. Therefore, the sample can be used because it meets the criteria based on the results of the Lemeshow formula calculation.

3.2 Validity and Reliability Test

Testing the questionnaire in this study is a validity and reliability test, which is calculated using SPSS (Statistical Program for Social Science) 26 software**.** The validity test is used to state whether a questionnaire

is valid or not [7]. A measuring instrument or questionnaire is said to be valid if it has a correlation significance value of 95% or $\alpha = 0.05$ [8]. The preliminary questionnaire trial used 30 respondents so that the r_{table} value was 0.361. The following are the results of calculating the validity test of 3 shopping malls using SPSS 26, which appears in Table 1.

Table 1. Validity Test Results on Visitor Questionnaire of 3 Shopping Malls

Shopping Mall	Description
Solo Paragon Mall	Valid
Solo Grand Mall	Valid
Solo Square	Valid

The reliability test is used to measure the consistency of the questionnaire in a person's answer to a statement from time to time [9]. If the Cronbach's Alpha value is > 0.60, then the question items in the questionnaire are reliable [10]. The reliability test results obtained using the SPSS 26 application are presented in Table 2.

Table 2. Reliability Test Results on Visitor Questionnaire of 3 Shopping Malls

Shopping Mall	Description
Solo Paragon Mall	Reliable
Solo Grand Mall	Reliable
Solo Square	Reliable

3.2 Game Theory Solution

Game theory is one of the mathematical methods used in conflict or competition situations between various interests that face each other as competitors [11]. Game theory describes conflict and cooperation among intelligent and rational decision-makers, also known as players [12]. If the saddle point value is positive, the row player strategy is higher than the column player strategy [13]. Indicators of shopping mall visitor satisfaction variables used in the calculation of optimal strategies using game theory can be seen in Table 3.

Table 3. 6 Variable Indicators of Shopping Mall Visitor Satisfaction

Visitor Satisfaction Indicator	Variables		
	Solo Paragon Mall	Solo Grand Mall	Solo Square
Product diversity	P_1	G_1	S_1
Existence of transport modes	P_2	G_2	S_2
Distance between residence and shopping mall	P_3	G_3	S_3
Price	P_4	G_4	S_4
Facilities	P_5	G_5	S_5
Services	P_6	G_6	S_6

In this study, the competition value of the three shopping malls is obtained from the total value of each visitor satisfaction indicator variable (product diversity, existence of transportation modes, distance between residence and shopping mall, price, facilities, and services). This visitor satisfaction indicator is the strategy used by each shopping mall in competing. A payoff matrix is formed from the recapitulated visitor satisfaction data of the three shopping malls to be calculated using game theory. The pay-off in a game is a measure of how well a player runs the game [14]. In this game, players use a single strategy to get optimal results with a maximin = minimax value (saddle point). The following is the total result data for each indicator of visitor satisfaction, with the value range used from 1 to 5, where this value means the value of visitor satisfaction with the six variables that have been determined. The scale value is explained below:

1 = Not satisfied, 2 = Less satisfied, 3 = Normal, 4 = Satisfied, and 5 = Very Satisfied.

In determining the optimal strategy using the game theory method, recapitulation data based on visitor satisfaction indicators for Solo Paragon Mall, Solo Grand Mall, and Solo Square are needed, which are obtained through questionnaires. The following shows a recapitulation of the value of the Solo Paragon Mall visitor satisfaction indicator in Table 4.

Table 4. Recapitulation Values of Visitor Satisfaction Indicators at Solo Paragon Mall

Variable	Visitor Satisfaction Indicator	Value
P_1	Product diversity	1362
P_2	Existence of transport modes	1339
P_3	Distance between residence and shopping mall	1305
P_4	Price	1314
P_5	Facilities	1316
P_6	Services	1332

Based on **Table 4**, it is known that Solo Paragon Mall has the highest value in the product diversity indicator (P_1) with a total value of 1362, while the lowest value is the distance between the residence and the shopping mall (P_3) which is 1305.

Table 5. shows a recapitulation of the value of the Solo Grand Mall visitor satisfaction indicator.

Table 5. Recapitulation Values of Visitor Satisfaction Indicators at Solo Grand Mall

Variable	Visitor Satisfaction Indicator	Value
G_1	Product diversity	1158
G_2	Existence of transport modes	1360
G_3	Distance between residence and shopping mall	1283
G_4	Price	1333
G_5	Facilities	1152
G_6	Services	1262

Based on **Table 5**, there are six indicators of visitor satisfaction at Solo Grand Mall, which has the largest value in terms of the existence of transportation modes (G_2), namely, 1360, and the lowest value is in terms of facilities (G_5) with a total value of 1152.

Table 6. shows a recapitulation of the value of the Solo Grand Mall visitor satisfaction indicator.

Table 6. Recapitulation Values of Visitor Satisfaction Indicators at Solo Square

Variabel	Indikator Kepuasan Pengunjung	Nilai
S_1	Product diversity	1309
S_2	Existence of transport modes	1285
S_3	Distance between residence and shopping mall	1118
S_4	Price	1311
S_5	Facilities	1268
S_6	Services	1328

Based on **Table 6**, there are six indicators of visitor satisfaction at Solo Square, which have the largest value in the service indicator (S_6) with a value of 1328, and the lowest value is the distance between the residence and the shopping mall (S_3) worth 1118. Completion of game theory begins with creating a payoff matrix. The results of the recapitulation of visitor satisfaction indicator values from each shopping mall are then formed into a payoff matrix by calculating the difference in value in the competition between player I and player II. Based on the calculation of the C_2^3 combination of the three shopping malls, three competitions were obtained.

The payoff matrix of the three competing shopping malls is then used to solve the game calculations using pure strategy, mixed strategy, and alternative methods in the form of linear programs to obtain saddle points **[15]**. Pure strategy is a game in which each player chooses one strategy with a probability of 1, while the other strategies have a probability of 0. Pure strategy is done by finding the smallest value in each row and the largest value in each column. The following is the calculation of the pure strategy of the three competitions.

Table 7. Pure Strategy in the Competition Between Solo Paragon Mall and Solo Grand Mall

		Solo Grand Mall (Player II)						Maximin
		G_1	G_2	G_3	G_4	G_5	G_6	
Solo Paragon Mall (Player I)	P_1	204	2	79	29	210	100	2
	P_2	181	-21	56	6	187	77	-21
	P_3	147	-55	22	-28	153	43	-55
	P_4	156	-46	31	-19	162	52	-46
	P_5	158	-44	33	-17	164	54	-17
	P_6	174	-28	49	-1	180	70	-28
Minimax		204	2	79	29	210	100	2

From Table 7, it is known that the maximin and minimax values in the competition between Solo Paragon Mall and Solo Grand Mall have the same result of 2. This means that there is a saddle point, so the game is solved by pure strategy.

Table 8. Pure Strategy in the Competition Between Solo Paragon Mall and Solo Square

		Solo Square (Player II)						Maximin
		S_1	S_2	S_3	S_4	S_5	S_6	
Solo Paragon Mall (Player I)	P_1	53	77	244	51	94	34	34
	P_2	30	54	221	28	71	11	11
	P_3	-4	20	187	-6	37	-23	-23
	P_4	5	29	196	3	46	-14	-14
	P_5	7	31	198	5	48	-12	-12
	P_6	23	47	214	21	64	4	4
Minimax		53	77	244	51	94	34	34

From the payoff matrix Table 8, it is known that the maximin and minimax values in the competition between Solo Paragon Mall and Solo Grand Mall have the same result, namely 34.

Table 9. Pure Strategy in the Competition Between Grand Mall and Solo Square

		Solo Square (Player II)						Maximin
		S_1	S_2	S_3	S_4	S_5	S_6	
Solo Grand Mall (Player I)	G_1	-151	-127	40	-153	-110	-170	-170
	G_2	51	75	242	49	92	32	32
	G_3	-26	-2	165	-28	15	-45	-45
	G_4	24	48	215	22	65	5	5
	G_5	-157	-133	34	-159	-116	-176	-176
	G_6	-47	-23	144	-49	-6	-66	-66
Minimax		51	75	242	49	92	32	32

From the payoff matrix Table 9, it is known that the maximin and minimax values in the competition between Solo Paragon Mall and Solo Grand Mall have the same result, namely 32. The calculation results from Table 7, Table 8, and Table 9. show that the minimum value is equal to the maximum value, so the solution used is a pure strategy so there is no need to do a mixed strategy.

3.3 Markov Chain

Markov chains were first introduced by A. A. Markov to predict the behavior of systems that make transitions from one state to another [16]. The probability of all future events $K_{t(j)}$ depends only on the event $K_{t(j-1)}$ and not on the previous events $K_{t(j-2)}, K_{t(j-3)}, \ldots, K_{t(j-n)}$ [17]. In the Markov chain method, there is a concept known as the transition probability matrix. The $n-$ step transition probability matrix is useful for calculating the probability of events occurring in n future periods based on events occurring in the present [18].

$$K_{t(j)} = K_{t(j-1)} \times P \tag{2}$$

$K_{t(j)}$: the probability of an event at $t(j)$,
p : transitional probability, and

$t(j)$: time $-j$

The state is the object under study [19]. This case relates to inter-competition shopping malls to look for visitor movements that occur between the three shopping malls. The states used are in Table 10.

Table 10. Determination of Research State

State	Shopping Mall
State 1	Solo Paragon Mall
State 2	Solo Grand Mall
State 3	Solo Square

The data used in the Markov chain calculation of visitor movement data for two periods is based on the most frequently visited shopping mall. This data is used to predict visitor movement in the next period until it reaches a steady state condition. The following Table 11 shows the recapitulation data of shopping mall visitor movements for two periods.

Table 11. Visitor Movement Patterns of 3 Shopping Malls Over Two Periods

Shopping Mall	Period 1	Acquisition	Lost	Loyal	Period 2
Solo Paragon Mall	67	23	45	22	45
Solo Grand Mall	32	20	26	6	26
Solo Square	11	35	7	4	39
Total	110	78	78	32	110

In Table 11, it is known that Solo Paragon Mall experienced many visitors moving to other shopping malls in the second period, namely 45 people. Then, Solo Square had the most additional visitors in the second period, namely 35 people. Solo Paragon Mall in the second period has the highest number of visitors while Solo Grand Mall is the mall with the lowest visitors. Next, the transition probability matrix is calculated, which is obtained by dividing the number of visitor movements by the total visitors in the initial period so that if each row is summed up, it will produce 1. The following calculation results are obtained in Table 12.

Table 12. Transition Probability Matrix

Shopping Mall	From	To			Total
		Solo Paragon Mall	Solo Grand Mall	Solo Square	
Solo Paragon Mall	67	0.328358209	0.28358209	0.388059701	1
Solo Grand Mall	32	0.53125	0.1875	0.28125	1
Solo Square	11	0.545454545	0.090909091	0.363636364	1

In Table 12, the visitor transition probability is known, so the next step in using the Markov chain is to determine the steady-state probability in a transition probability matrix followed by forecasting calculations of visitor movements from the initial period to obtain a steady-state condition. In this research, two methods were used to obtain steady-state conditions. First, solving the system of linear equations using the Gaussian elimination method. Second, to validate the calculation results, QM software is used. QM for Windows is software used to solve quantitative management problems in operations and production [20].

The results of solving using the Gaussian elimination method from a system of linear equations whose coefficients are obtained from Table 12 are as follows:

$$x_1 = 0.4459$$

$$x_2 = 0.1957$$

$$x_3 = 0.3584$$

Solving a system of linear equations is a steady state condition. System linear equations have a single solution because their coefficient matrix has a non-zero determinant (meaning that the system of linear equations is nonsingular). QM 5.3 for Windows application is used to validate the results of manual calculations to obtain steady state condition results with limitations in the 10th period shown in Figure 2.

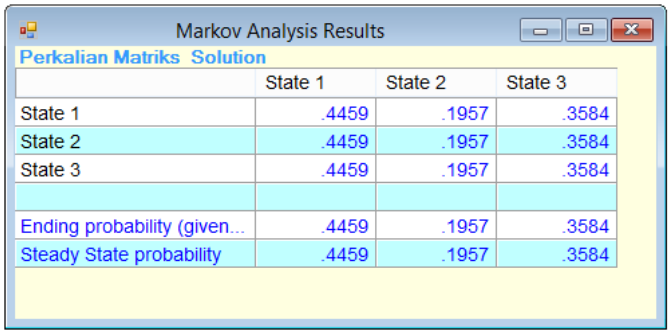

Figure 2. Results of Markov Chain Analysis During Steady State Conditions Using the QM Application

Based on the results of the steady state calculation using the QM 5.3 for Windows, the transition probability of Solo Paragon Mall is 0.4459, Solo Grand Mall is 0.1957, and Solo Square is 0.3584. The calculation of the transition probability of Solo Paragon Mall, Solo Grand Mall, and Solo Square is carried out to predict the probability of moving visitors in the future period. The following is the calculation of the transition probability based on **Equation (2)** from the 1st period to the 10th period in the future.

Probability in period –1

$$K_1 = [0.6090 \quad 0.2910 \quad 0.1000]$$

Probability in period – 2

$$K_2 = [0.6090 \quad 0.2910 \quad 0.1000] \times \begin{bmatrix} 0.328358209 & 0.28358209 & 0.388059701 \\ 0.53125 & 0.1875 & 0.28125 \\ 0.545454545 & 0.090909091 & 0.363636364 \end{bmatrix}$$
$$= [0.4091093538 \quad 0.236354901 \quad 0.3545355744]$$

$$\vdots$$

Probability in period – 10

$$K_{10} = [0.44587 \quad 0.19572 \quad 0.35840] \times \begin{bmatrix} 0.328358209 & 0.28358209 & 0.388059701 \\ 0.53125 & 0.1875 & 0.28125 \\ 0.545454545 & 0.090909091 & 0.363636364 \end{bmatrix}$$
$$= [0.4458761621 \; 0.1957224991 \; 0.3584013388]$$

The results of calculating the transition probability until the 10th period using the same formula are recapitulated in **Table 13** as follows.

Table 13. Recapitulation of Transition Probability of 3 Shopping Malls of 10 Periods

Period -	Solo Paragon Mall	Solo Grand Mall	Solo Square
Period 1	0.6090	0.2910	0.1000
Period 2	0.4091	0.2364	0.3545
Period 3	0.4533	0.1926	0.3542
Period 4	0.4443	0.1968	0.3588
Period 5	0.4462	0.1955	0.3583
Period 6	0.4458	0.1958	0.3584
Period 7	0.4459	0.1957	0.3584
Period 8	0.4459	0.1957	0.3584
Period 9	0.4459	0.1957	0.3584
Period 10	0.4459	0.1957	0.3584

The transition probability value of **Table 13** is converted into a percentage value in the next 10 periods. **Figure 2** is a percentage graph that illustrates the prediction of visitors to each shopping mall.

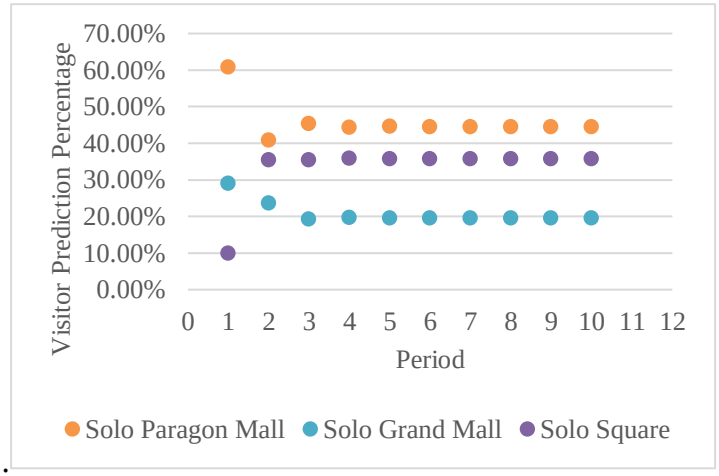

Figure 3. Percentage Graph Prediction of Visitors to Each Shopping Mall

Figure 3 shows the percentage of visitor predictions for the three shopping malls. Solo Paragon Mall in the 1st period has a percentage of 60.90%, then in the 2nd period, it is worth 40.91%, and in the 7th period, the percentage figure is constant at 44.59%. Then Solo Grand Mall in the 1st period had a percentage of 29.10%, then in the 2nd period, it was 23.64%, and in the 7th period, the percentage figure was constant at 19.57%. Furthermore, Solo Square in the 1st period had a percentage of 10% visitor displacement. This shows that in the 1st period, Solo Square had the lowest percentage of visitors compared to Solo Paragon and Solo Grand Mall, which was 10%. Then, in period 6 to period 10, Solo Square has a constant percentage of 35.84%; this percentage is higher than the total percentage of visitors to Solo Grand Mall.

4. CONCLUSIONS

Based on the research results, three competitions were obtained, namely the competition between Solo Paragon Mall and Solo Grand Mall, Solo Paragon Mall and Solo Square, and Solo Grand Mall and Solo Square. The first competition between Solo Paragon Mall and Solo Grand Mall obtained a game value of 2. The optimal strategy for the first competition is (P_1), (G_2). The second competition is (P_1), (S_6). The game value generated by both is 34. Furthermore, the third competition between Solo Grand Mall and Solo Square obtained a game value of 32. The optimal strategy is (G_2), (S_6). In research in this case, the saddle point value is positive, meaning the level of satisfaction satisfactory to Player I's visitors is higher than the level of visitor satisfaction in Player II. The Markov chain results show that each mall experiences a steady state condition, with the transition probability of Solo Paragon Mall being 0.4459 starting in the period - 7, then Solo Grand Mall with a transition probability of 0.1957 starting in the period - 7, and Solo Square which is 0.3584 starting in the period - 6. The size of the probability transitions shows people's interest in voting decisions for their favorite shopping mall. The greater the transition probability, the more people's interest in shopping malls is increasing.

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