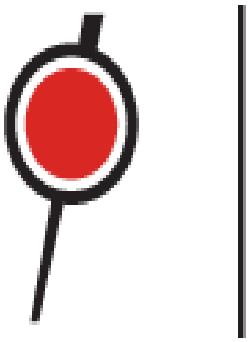

İstanbul Bilgi Üniversitesi

TERM PROJECT MONTE CARLO SIMULATION REPORT

DEPARTMENT OF INDUSTRIAL ENGINEERING
COURSE: IE 341 Modeling and Simulation
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Optimal Bank Offer Strategy in Deal or No Deal

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1.Purpose Of The Project

The main purpose of this project is to examine the effects of different strategies on accepting and rejecting bank offers during the game by creating a simulation based on the structure of the popular TV competition program "Deal or No Deal". The aim of the simulation is to model the risk-taking tendencies of the players throughout the competition and to compare the average money values paid by the bank as a result of various strategies.

While doing the "Deal or No Deal" project, we assume that we are a bank. Therefore, our main goal is to minimize the amount the bank will pay. To achieve this goal, the average money value in the remaining boxes of the contestant while the bank is making an offer is calculated and the simulation aims to offer an offer below this value.

2. Game Content

There are 26 boxes in total in the Deal or No Deal content. While writing the code, we set these currency values as 1, 10, 50, 100, 250, 500, 750, 1000, 2500, 5000, 7500, 10000, 15000, 20000, 25000, 50000, 75000, 100000, 150000, 200000, 250000, 300000, 400000, 500000, 750000, 1000000. The player starts the game by selecting a box and continues to open the remaining boxes according to the money values. As the contestant continues the game, the bank makes certain offers and the contestant is forced to choose between accepting the offer made by the bank and ending the game or not accepting the offer and taking a risk by opening the remaining boxes. The goal for the contestant is to earn the maximum amount of money he/she can by making the right moves (accepting the bank offer or taking risks and continuing to open boxes). However, as a bank, we aim to give the minimum amount of money we can.

3. How the Simulation Works

While doing this project, we set up a simulation for the last 5 boxes and beyond.

- First, 21 of the 26 boxes are randomly opened
- The game continues with the remaining 5 boxes
- The remaining boxes are reduced from 5 to 1 in each round
- When there are 5 and 2 boxes left in the game, the bank makes an offer
- According to the strategy the player has established at that moment, it is decided whether to accept the bank offer or not
- If the bank's offer is rejected, the game continues and one of the remaining boxes is chosen

4. Data Collection

In this project, we based our simulation on the Turkish version of *Deal or No Deal*, using the same format and the original 26 box values to create a realistic model. Simulations were initiated when 5 boxes remained, randomly selecting the remaining boxes and modeling the player's decision-making and the bank's offers from that point onward.In the second phase, the game was repeated 100 times, each representing a unique contestant. Each player was assigned an “alpha” value (between 0.2 and 0.95) to represent their risk profile, inspired by real contestants’ behavior. A lower alpha indicated a more risk-seeking player less likely to

accept offers, while a higher alpha reflected a more cautious player more inclined to accept them. Beta values represented the bank's offer aggressiveness and were adjusted according to the player's alpha. Against risk-seeking players (low alpha), the bank acted more aggressively with higher beta offers. For more cautious players (high alpha), lower beta values were sufficient. Beta values ranged between 0.1 and 0.5.

By collecting and applying these alpha and beta values, we realistically modeled both player and bank behaviors, making the game dynamics and decision processes more understandable and analytically accessible.

5. Strategies Used and Explanations

5.1) Simple Strategy

Formulation:

B = [min(Remaining boxes) + max(Remaining boxes)]/2

- B equals the average of the minimum and maximum of the remaining boxes.
- This strategy averages the lowest and highest values of the remaining available boxes. The player makes decisions by balancing how much he/she can win (maximum) and how much he/she can lose (minimum). This approach focuses on balance. Represents players with an average risk profile. Because it is not a lot of risk to take, but it is also not risk-free.

Advantages:

- This method is simple and understandable.
- Provides relief from unexpected effects.

Disadvantages:

- It ignores the mean value of the remaining boxes, so probability distributions are not taken into account.

5.2) Expected Value Strategy

Formulation:

B= (∑(Remaining boxes)/ Number of boxes remaining =E

- B is equal to the average of the remaining boxes, which is calculated by dividing the sum of the remaining boxes by the number of remaining boxes. This value is denoted by E.
- The player takes the arithmetic average of all the remaining boxes and compares this value with the bank's offer, making statistically rational decisions
- This strategy represents an approach independent of emotion, also because it is rational. The player aims to mathematically evaluate which values remain and the probability distribution.

Advantages:

- Expected earnings are predicted correctly
- Based on probability theory

Disadvantages:

- Does not match the player's real-life risk perception
- Does not model risk-averse behavior

5.3) Dynamic Strategy

Formulation:

$B = \alpha \times EB$

- B represents the target value to be used in the system. α is the weight coefficient (usually $0<\alpha<1$) but in our assumption it lies between 0.2 and 0.95 to be more real. EB appears as the average value of the remaining boxes (expected box content)
- The expected value is valued according to the player's risk perception. As the α value decreases, the player becomes more cautious and looks favorably upon lower bids.
- This strategy includes risk sensitivity that occurs according to the person. Even if each player has the same expected value, their risk-taking profile is different.

Advantages:

- Player type can be customize
- More close to real human life

Disadvantages:

- Since the α parameter is chosen in the range, different results may occur for each player
- It may lead to offers with low statistical accuracy

5.4) Aggressive Strategy

Formulation:

$B = min + \beta\ x\ (max - min)$

- B is equal to the minimum value plus beta times the difference between the maximum and minimum values.
- B represents a value that is linearly interpolated between the minimum and maximum values based on the weighting factor β.
- If β = 0, B equals the minimum.
  If β = 1, B equals the maximum.
  But in our assumption $0.2 < \beta < 0.5$, B lies between these values.
- β : Level of aggression

- Starting from the minimum value, the maximum is approached at a rate. The player aims for higher gains. It represents players who adopt a high risk, high reward approach. It symbolizes the kind of bold decisions that say “I either win big or I don’t win at all.”

Advantages:

- This method is in pursuit of big rewards.
- It enables decisive and quick decision making.

Disadvantages:

- Low bids are easily rejected.
- Most of the time, the player will not accept any offer and will settle for the value that comes out of the remaining box.

5.5) Smart Hybrid Strategy

Formulation:

$B = \alpha \times E + (1 - \alpha) \times [(min + max)/2]$

- B is calculated as a weighted average of E and the midpoint between the minimum and maximum values, where α (alpha) is the weighting factor.
- α =Risk factor of the player (0.2-0.95)
- The expected value is combined with the simple strategy. The α value determines how much weight is given to each strategy:
  If α=1, just Expected Value

  If α=0, just Simple Strategy

- It is suitable for players who make balanced decisions, combining both logic and intuition. This strategy represents the user who says “I am rational but also cautious”.

Advantages:

- This method is flexible.
- Adaptable to different risk profiles.
- Provides realistic player modeling.

Disadvantages:

- There may be uncertainty arising from the choice of the α value.

Comparative Evaluation

Strategy	The Logical Basis	Player Profile	Strengths	Weakness
Simple	min-max average	Medium risk	Simple and understandable	Does not contain probability information
Expected Value	Arithmetic mean	Rational	Statistical accuracy	Does not reflect human psychology
Dynamic	α × expected value	Risk perception	Customizable	Very dependent on α
Aggresive	min + β(max-min)	High risk	Big earning potential	High risk of loss
Smart Hybrid	α × EV + (1-α) × Simple	Balanced	Realistic, adaptive	Dependent on setting parameters

6. Acceptance Probability Function

The bid (B) obtained as a result of each strategy is compared with the expected value of the remaining boxes (E). According to this comparison, the probability of the bid being accepted is calculated with the following logistic function:

$p = 1 / (1 + e^{(-k \times (B - \alpha \times E))})$

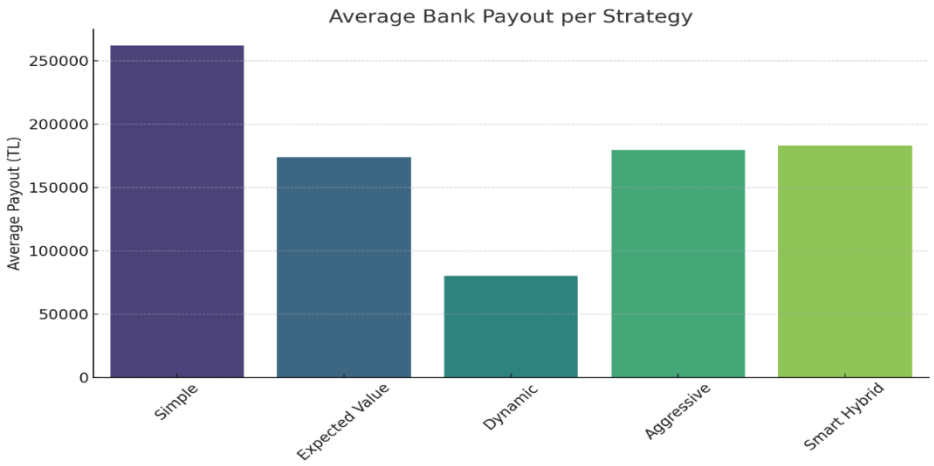
- *k: sensitivity coefficient (k=5)*
- *α: player's risk sensitivity*
- *p: probability that the bank's offer will be accepted*
- *e: Euler number (~2.718) is the base of the natural logarithm.*

Thanks to this function, more attractive offers have a higher probability of acceptance.

7) Evaluation of Results Over 100 Simulations

For each strategy, the simulation was run 100 times and the average bank payouts were calculated. The table below shows the one example simulation comparative performance of these strategies and here is the visualization of an example simulation;

Simulation number	Simple	Expected Value	Dynamic	Aggressive	Smart Hybrid
1	150,005.00 TL	16,512.00 TL	174,011.00 TL	100,000.00 TL	209,465.00 TL
2	50,050.00 TL	82,350.00 TL	18,061.00 TL	50,005.00 TL	312,761.00 TL
3	500,025.00 TL	205,251.00 TL	107,910.00 TL	7,501.00 TL	345,329.00 TL
4	12,750.00 TL	70,510.00 TL	35,691.00 TL	306,000.00 TL	72,969.00 TL
5	100,005.00 TL	213,003.00 TL	357,812.00 TL	200,000.00 TL	37,281.00 TL
6	500,025.00 TL	274,100.00 TL	117,107.00 TL	97,000.00 TL	414,598.00 TL
7	500,050.00 TL	382,150.00 TL	56,149.00 TL	200,300.00 TL	513,045.00 TL
8	375,500.00 TL	59,350.00 TL	52,535.00 TL	23,000.00 TL	72,163.00 TL
9	12,501.00 TL	219,150.00 TL	78,793.00 TL	160,450.00 TL	184,090.00 TL
10	200,001.00 TL	243,700.00 TL	47,776.00 TL	100,005.00 TL	232,626.00 TL
11	125,050.00 TL	192,021.00 TL	162,860.00 TL	1,000.00 TL	410,873.00 TL
12	12,750.00 TL	45,251.00 TL	38,268.00 TL	30,040.00 TL	58,327.00 TL
13	502,500.00 TL	160,110.00 TL	89,960.00 TL	15,035.00 TL	176,710.00 TL
14	200,005.00 TL	282,200.00 TL	94,305.00 TL	209,000.00 TL	3,969.00 TL
15	200,025.00 TL	17,102.00 TL	29,093.00 TL	200,001.00 TL	62,940.00 TL
16	125,025.00 TL	176,000.00 TL	5,000.00 TL	90,001.00 TL	164,338.00 TL
17	250,250.00 TL	176,520.00 TL	25,809.00 TL	200,060.00 TL	351,055.00 TL
18	500,250.00 TL	6,900.00 TL	141,128.00 TL	300,000.00 TL	113,824.00 TL
19	150,250.00 TL	245,150.00 TL	121,621.00 TL	75,035.00 TL	137,373.00 TL
20	375,001.00 TL	270,160.00 TL	6,675.00 TL	250,005.00 TL	108,261.00 TL
21	125,250.00 TL	32,350.00 TL	130,555.00 TL	1.00 TL	36,503.00 TL
22	375,125.00 TL	232,250.00 TL	49,032.00 TL	200,300.00 TL	436,201.00 TL
23	12,525.00 TL	211,800.00 TL	76,153.00 TL	60,001.00 TL	243,554.00 TL
24	375,125.00 TL	135,250.00 TL	150,994.00 TL	150,070.00 TL	300,789.00 TL
25	125,025.00 TL	60,160.00 TL	40,278.00 TL	30,001.00 TL	106,381.00 TL
26	150,025.00 TL	180,700.00 TL	42,701.00 TL	40,150.00 TL	172,757.00 TL
27	500,250.00 TL	276,500.00 TL	44,252.00 TL	300,001.00 TL	32,454.00 TL
28	125,001.00 TL	80,800.00 TL	53,423.00 TL	40,200.00 TL	80,528.00 TL
29	500,001.00 TL	264,500.00 TL	26,787.00 TL	250,005.00 TL	448,446.00 TL
30	500,025.00 TL	257,010.00 TL	13,982.00 TL	104,000.00 TL	206,354.00 TL
31	200,005.00 TL	194,150.00 TL	60,760.00 TL	200,300.00 TL	30,620.00 TL
32	200,025.00 TL	138,020.00 TL	25,000.00 TL	160,300.00 TL	76,747.00 TL
33	375,375.00 TL	115,550.00 TL	190,626.00 TL	100,000.00 TL	89,964.00 TL
34	150,250.00 TL	294,500.00 TL	46,024.00 TL	160,001.00 TL	315,759.00 TL
35	150,001.00 TL	291,520.00 TL	6,863.00 TL	200,080.00 TL	258,586.00 TL
36	500,005.00 TL	233,070.00 TL	48,898.00 TL	380,000.00 TL	334,868.00 TL
37	375,375.00 TL	235,500.00 TL	140,890.00 TL	50,800.00 TL	179,921.00 TL
38	376,250.00 TL	290,201.00 TL	38,795.00 TL	300,150.00 TL	62,787.00 TL
39	375,375.00 TL	361,550.00 TL	142,619.00 TL	3,007.00 TL	6,529.00 TL
40	125,001.00 TL	150,500.00 TL	587.00 TL	500.00 TL	138,033.00 TL
41	500,001.00 TL	173,250.00 TL	162,590.00 TL	250.00 TL	75,883.00 TL
42	103,750.00 TL	265,010.00 TL	95,764.00 TL	60,006.00 TL	166,200.00 TL
43	150,125.00 TL	103,000.00 TL	1,325.00 TL	150,007.00 TL	48,254.00 TL
44	125,050.00 TL	75,032.00 TL	47,363.00 TL	160,450.00 TL	217,225.00 TL
45	150,005.00 TL	253,000.00 TL	72,706.00 TL	400,001.00 TL	61,656.00 TL
46	10,001.00 TL	217,100.00 TL	191,322.00 TL	300,000.00 TL	8,636.00 TL
47	500,005.00 TL	114,102.00 TL	3,818.00 TL	225,007.00 TL	12,504.00 TL
48	375,500.00 TL	77,150.00 TL	25,201.00 TL	80,001.00 TL	100,179.00 TL
49	260,000.00 TL	265,020.00 TL	34,845.00 TL	400,030.00 TL	325,977.00 TL
50	2,525.00 TL	136,100.00 TL	31,726.00 TL	200,500.00 TL	45,791.00 TL
51	375,050.00 TL	213,550.00 TL	39,599.00 TL	203,000.00 TL	145,211.00 TL
52	100,050.00 TL	5,652.00 TL	71,424.00 TL	500,000.00 TL	97,661.00 TL
53	150,005.00 TL	181,001.00 TL	23,320.00 TL	125,001.00 TL	327,367.00 TL
54	260,000.00 TL	303,550.00 TL	79,910.00 TL	120,001.00 TL	48,528.00 TL
55	150,005.00 TL	105,370.00 TL	20,165.00 TL	200,450.00 TL	8,343.00 TL
56	507,500.00 TL	345,000.00 TL	29,431.00 TL	150,350.00 TL	176,334.00 TL
57	150,025.00 TL	125,200.00 TL	46,974.00 TL	30,008.00 TL	84,835.00 TL
58	75,005.00 TL	113,200.00 TL	86,065.00 TL	301,500.00 TL	288,438.00 TL
59	600,000.00 TL	133,200.00 TL	143,102.00 TL	225,070.00 TL	138,449.00 TL
60	200,375.00 TL	161,511.00 TL	27,350.00 TL	150,070.00 TL	275,263.00 TL
61	500,005.00 TL	220,500.00 TL	232,459.00 TL	150,000.00 TL	238,188.00 TL
62	500,025.00 TL	106,501.00 TL	35,611.00 TL	150,001.00 TL	454,180.00 TL
63	250,001.00 TL	231,600.00 TL	135,210.00 TL	120,001.00 TL	169,032.00 TL
64	375,025.00 TL	215,250.00 TL	44,011.00 TL	250,025.00 TL	182,722.00 TL
65	375,005.00 TL	235,501.00 TL	7,087.00 TL	120,001.00 TL	72,543.00 TL
66	207,500.00 TL	204,350.00 TL	168,311.00 TL	15,070.00 TL	92,351.00 TL
67	500,001.00 TL	311,010.00 TL	208,568.00 TL	4,200.00 TL	86,626.00 TL
68	375,025.00 TL	102,101.00 TL	31,628.00 TL	80,001.00 TL	8,538.00 TL
69	250,025.00 TL	33,252.00 TL	209,700.00 TL	1,000,000.00 T	401,565.00 TL
70	150,375.00 TL	206,500.00 TL	74,361.00 TL	50,125.00 TL	332,082.00 TL
71	150,025.00 TL	94,510.00 TL	3,969.00 TL	200,200.00 TL	53,399.00 TL
72	151,250.00 TL	85,012.00 TL	1,234.00 TL	120,070.00 TL	374,001.00 TL
73	500,001.00 TL	302,500.00 TL	148,210.00 TL	300,000.00 TL	180,865.00 TL
74	37,525.00 TL	350,600.00 TL	223,670.00 TL	1,000.00 TL	370,890.00 TL
75	100,025.00 TL	360,300.00 TL	50,000.00 TL	235,500.00 TL	3,846.00 TL
76	382,500.00 TL	180,162.00 TL	65,791.00 TL	225,175.00 TL	197,789.00 TL
77	375,125.00 TL	220,650.00 TL	93,610.00 TL	200,300.00 TL	104,460.00 TL
78	375,125.00 TL	20,500.00 TL	85,792.00 TL	200,060.00 TL	80,978.00 TL
79	375,001.00 TL	325,000.00 TL	80,668.00 TL	150,007.00 TL	372,500.00 TL
80	151,250.00 TL	231,650.00 TL	10,000.00 TL	100,000.00 TL	74,212.00 TL
81	257,500.00 TL	112,250.00 TL	51,185.00 TL	200,025.00 TL	316,148.00 TL
82	500,001.00 TL	45,510.00 TL	210,807.00 TL	90,035.00 TL	125,242.00 TL
83	500,250.00 TL	144,550.00 TL	100,000.00 TL	160,001.00 TL	414,953.00 TL
84	200,025.00 TL	253,052.00 TL	57,617.00 TL	30,001.00 TL	324,461.00 TL
85	500,375.00 TL	175,200.00 TL	28,210.00 TL	250,025.00 TL	11,815.00 TL
86	500,025.00 TL	189,000.00 TL	21,032.00 TL	15,000.00 TL	9,545.00 TL
87	375,001.00 TL	135,010.00 TL	78,255.00 TL	200,450.00 TL	239,990.00 TL
88	125,001.00 TL	150,131.00 TL	23,160.00 TL	300,035.00 TL	137,120.00 TL
89	100,050.00 TL	30,180.00 TL	9,837.00 TL	500,500.00 TL	145,597.00 TL
90	75,125.00 TL	5,262.00 TL	105,169.00 TL	80,060.00 TL	110,736.00 TL
91	100,025.00 TL	269,150.00 TL	104,028.00 TL	200,450.00 TL	76,507.00 TL
92	150,005.00 TL	71,002.00 TL	70,276.00 TL	400,001.00 TL	222,281.00 TL
93	75,001.00 TL	93,200.00 TL	3,387.00 TL	150,400.00 TL	22,503.00 TL
94	150,050.00 TL	37,020.00 TL	4,129.00 TL	403,000.00 TL	104,630.00 TL
95	25,001.00 TL	22,221.00 TL	750,000.00 TL	100,150.00 TL	179,047.00 TL
96	3,775.00 TL	105,501.00 TL	21,062.00 TL	505,000.00 TL	421,881.00 TL
97	250,005.00 TL	202,010.00 TL	97,652.00 TL	228,500.00 TL	374,156.00 TL
98	125,025.00 TL	205,000.00 TL	23,175.00 TL	500,025.00 TL	479,531.00 TL
99	500,005.00 TL	251,000.00 TL	250.00 TL	500,001.00 TL	234,175.00 TL
100	376,250.00 TL	105,701.00 TL	8,418.00 TL	120,060.00 TL	299,193.00 TL
Average Payout	261,723.18 TL	173,787.68 TL	80,013.22 TL	179,314.62 TL	182,927.90 TL



8) Determining the Best Strategy

In this simulation, the “best strategy” is defined from the bank’s perspective as the one that results in the lowest average payout to players. The bank’s goal is to minimize its total payments by offering the lowest possible deals that players are still likely to consider. Based on the results from 100 simulations, the **Dynamic Strategy** emerged as the most effective in minimizing payouts. By adjusting offers according to the player's risk profile, it often leads players to continue the game rather than accept early offers. This allows the bank to reduce its payouts while maintaining player engagement.

Compared to other strategies:

- **Aggressive Strategy** can result in higher payouts when cautious players accept aggressive offers.
- **Simple Strategy** consistently presents high, fixed offers, leading to the highest average payouts.
- **Expected Value Strategy** provides mathematically balanced offers but may not always align with minimizing the bank’s costs.
- **Smart Hybrid Strategy** uses a more adaptive approach by combining expected value and player behavior, yet still results in higher average payouts than the Dynamic Strategy.

From an optimization and decision analysis perspective, the **Dynamic Strategy** is the most efficient approach for the bank to minimize its financial exposure while maintaining strategic control over player decisions.

9) General Evaluation and Recommendations

- The risk factor (α) and aggressiveness level (β) that affect the player's decisions have been successfully integrated into the simulation.
- Dynamic and flexible strategies reflect the different decision profiles of individuals.

10) Conclusion

This project presented a game-based analysis by combining simulation and decision theory. It has been successfully demonstrated how players make decisions according to 5 different strategies, how they face the consequences of these decisions, and how the risk-benefit balance can be mathematically modeled. And at the end we found that **Dynamic Strategy gives the minimum average payout for bank.**