

Monopoly is one of the most common board games that puts capitalism into action. In this game, players roll two six-sided dice to move around the game board, buying and trading properties and using the proceeds to develop houses and hotels. The board has a total of 40 spaces running from 0-39 (Taylor 2019). The spaces have been divided into 28 properties, 6 card spaces, two tax spaces and 4 corner spaces. Players collect ‘rents’ from their opponents with the intention of driving them into bankruptcy. At the same time, money can be lost and gained through Chance as well as Community Chest cards. The winner in this game is the last player remaining after the other players go ‘bankrupt’.

The dice are the most common element in Monopoly movement; when rolling two dice, the possible sums range between 2 and 12. The total possible outcomes can be calculated as:

$$\text{Total possible outcomes} = 6 \times 6 = 36$$

By letting X be the random variable representing the sum of the two dice, the probability mass function $P(X = k)$ is calculated by counting the combinations that result in sum k .

The table below indicates the probability distribution:

Table 1: Probability distribution

Sum (k)	Combinations	Count	Probability $P(X = k)$
2	(1,1)	1	0.028
3	(1,2), (2,1)	2	0.056
4	(1,3), (2,2), (3,1)	3	0.083
5	(1,4), (2,3), (3,2), (4,1)	4	0.111
6	(1,5), (2,4), (3,3), (4,2), (5,1)	5	0.139
7	(1,6), (2,5), (3,4), (4,3), (5,2), (6,1)	6	0.167
8	(2,6), (3,5), (4,4), (5,3), (6,2)	5	0.139
9	(3,6), (4,5), (5,4), (6,3)	4	0.111
10	(4,6), (5,5), (6,4)	3	0.083
11	(5,6), (6,5)	2	0.056

12	(6,6)	1	0.028
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The most probable roll from the table above is 7. This suggests that for any given square, the square placed 7 spaces away is the most likely destination.

Although the dice roll suggests the basic movement, special squares alter the movement and the most impactful square is square 30, '**Go to Jail**'. When the Monopoly player lands on square 30, they will be moved to square 10, '**Jail**' (Garg 2022).

Expected Movement Per Roll

The likelihood of landing on a given property depends entirely on its position and the transition rules. For this exploration, we will assume uniform movement based on dice outcome. The expected value when the dice are rolled is calculated as:

$$E(X) = \sum x P(x)$$

To find the term for a sum of 2 (count 1):

$$2 \times P(X = 2) = \frac{2 \times 1}{36} = 0.056$$

To find the term for a sum of 3 (count 2):

$$3 \times P(X = 3) = \frac{3 \times 2}{36} = 0.167$$

The table below summarizes the terms for every sum and their total, the expected value:

Table 2: Expected values

Sum (x)	Count	$x P(x)$
2	1	0.056
3	2	0.167
4	3	0.333
5	4	0.556
6	5	0.833

7	6	1.167
8	5	1.111
9	4	1.000
10	3	0.833
11	2	0.611
12	1	0.333
$E(X) = \sum x P(x)$		7.000

Based on these calculations, on average players advance 7 spaces per roll.

The Effect of Special Squares

The most important square in the game of Monopoly is **Go to Jail**, designated as square **30**. When a player lands on this square, they move to square 10, **Jail** (Palmer 2021). This suggests that the movement of a player cannot be indicated by adding dice results to their current position.

For example, consider a player who is on square 23 and rolls a 7:

$$23 + 7 = 30$$

Therefore, the player lands on '**Go to Jail**'. However, instead of remaining on square 30, the player is moved to square 10.

The special squares create the difference between the theoretical dice probability and the actual probability of landing on a square. Based on this situation, the Monopoly board can be modelled using conditional probability.

Probability of Landing on a Particular Square

To find the likelihood of landing on each square, let's assume that the player is not in jail and there are no Chance or Community Chest cards involved.

Assume the player is at square 0, **Go**.

The likelihood of landing on square 7 after one roll is:

$$P(X = 7) = \frac{6}{36}$$

Thus:

$$P(\text{square } 7) = 0.167$$

The likelihood of landing on square 6 is:

$$P(X = 6) = \frac{5}{36} = 0.139$$

Thus, after one roll from Go, square 7 has a greater likelihood of being reached than square 6.

After several turns, the starting position will change and this will affect the probability of landing on a particular property. This scenario can be represented using transition probability.

If a player is on square i , then the likelihood of moving to square j can be written as:

$$P_{ij} = P(\text{move from square } i \text{ to square } j)$$

Effect of Jail on Probability

The jail makes the game of Monopoly different. There are several scenarios in which the player can enter jail:

1. Land on Go to Jail
2. Draw a card that sends them to Jail
3. Roll doubles three times consecutively

When the player is in jail, they cannot move normally until they leave.

The likelihood of rolling doubles on one turn is:

$$P(\text{doubles}) = \frac{6}{36} = \frac{1}{6}$$

The likelihood of rolling doubles three consecutive times is:

$$\left(\frac{1}{6}\right)^3 = 0.00463 = 0.463\%$$

The probability is very small, but as games progress it becomes relevant.

Landing Probability and Expected Rent

The likelihood of landing on a property is important because landing is directly connected to rent.

The formula for expected rent is given as:

$$E(R) = \textit{probability} \times \textit{rent}$$

In Monopoly, rent is described as the amount of money a player pays when they land on another player's property. Each property has a fixed rent value (\$) and a cost of purchase (in case the player wishes to buy the property).

Table 3: Cost of renting some properties

Property name	Rent price (\$)	Rent (1 house)	Rent (2 houses)	Rent (hotel)
Mediterranean Avenue	2	10	30	250
Boardwalk	50	200	600	2000
Park Place	35	175	500	1500
Illinois Avenue	20	100	300	1100

The probability of landing on each property is the long-term probability that Collins (1997) calculated for a player who leaves jail immediately; it takes into account Go to Jail and the Chance and Community Chest cards.

Consider the expected rent for Mediterranean Avenue:

$$r = \$2$$

$$p = 0.021$$

$$E(R) = p \times r = 0.021 \times \$2 = \$0.042$$

The table below summarizes the expected rents for four properties:

Table 4: Expected rent

Property name	Rent price (\$)	Probability	E(R) (\$)
Mediterranean Avenue	2	0.021	0.042
Boardwalk	50	0.026	1.300
Park Place	35	0.022	0.770
Illinois Avenue	20	0.032	0.640

Conclusion

The aim of this investigation was to calculate dice probabilities and expected rent in Monopoly. When two six-sided dice are rolled, the most likely outcome is 7 with probability:

$$P(X = 7) = \frac{6}{36} = 16.7\%$$

The expected sum of two dice is:

$$E(X) = 7$$

This suggests that a player moves approximately 7 spaces per roll. This is, however, affected by special rules like Go to Jail, Jail, Chance cards, Community Chest cards and rolling doubles.

Limitations

Some of the weaknesses of my mathematical model include: First, there are numerous rules of the game Monopoly that dictate movement, for example Chance cards, Community Chest cards, Jail and doubles. These should not be overlooked if one is to have an accurate representation of the game.

Second, the decisions made by players are not always the same. There are situations where the player has the freedom to decide on what properties to buy and even to develop them.

References

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