Orange is the new Dark Blue - *Analysis of Monopoly Properties*

Abstract
This paper provides an analysis of investment return in the popular board game *Monopoly* using a simulated model. After comparing the model's results using a variety of methods, it is clear that the orange set of properties provide the best return on investment.

Introduction
On countless friendly game nights, many people become faced with an important question; How does one most effectively win a game of *Monopoly*? Despite common belief, the orange properties are much more profitable than the dark blue set. In order to prove this, an analysis of property sets using data from simulated simplified games is performed.

Methods
The chosen method for analyzing the best properties was to compare their **r**eturn **o**n **i**nvestment (ROI), defined as the value of $currency\ generated\ by\ property / currency\ cost\ of\ property$. This helps account for the varied property and housing presented by each set of properties. Unless otherwise stated, the cost of housing is included in the cost of the property.

This method requires knowledge of the chance to land on each property. Since *Monopoly* has a set of complicated mechanics for determining moves, this was chosen to be done with a simulated model rather than pure calculations.

In this simulated model, the player participates in a simplified version of *Monopoly*. The board, chance cards, and community chest cards are identical to a traditional game of *Monopoly*. Each round is completed as follows:

1. The player rolls two dice.
2. If the two dice are equal to each other, and the player has rolled the set of dice three times this round, the player is moved to the 'Jail' space and the round ends.
3. The player advances an amount of spaces equal to the sum of the two dice last rolled.
4. If the player is located on the 'To Jail' space, they will be moved to the 'Jail' space. If the player is on a 'Community Chest' or 'Chance' space, a random card from the corresponding deck will be randomly selected. If the card instructs the player to move, the instructions are followed.
5. The current round and space the player is currently occupying is added to the dataset.
6. If the dice rolled in step 1 were equal to each other, repeat steps 1-6. Otherwise, the round ends.

The simulated model consists of 100,000 players. The players all start on the 'Go' space and follow the movement instructions each round. The simulation lasts a total of 250 rounds. The dataset contains the amount of players at a given space on a given turn.

Results

In order to analyze the data, each point in the dataset is first divided by the number of players (n=100,000). This averages the data to represent only one player moving around the game board.

For the first analysis, six copies of the dataset are first made. An amount of houses is assigned to each dataset copy, ranging from 0 to 6, where 6 represents a hotel. The data points in each dataset are modified as follows:

$$new\ datapoint\ = \frac{amount\ of\ players\ on\ property * cost\ of\ landing\ on\ property\ with\ amount\ of\ houses}{initial\ property\ cost + number\ of\ houses * cost\ per\ house}$$

This results in the ROI for each property on a given turn, with any amount of housing.

As players need to own a full set of properties to purchase housing on them, and cannot build housing on properties in a set that includes other properties with lower amounts of housing, each color set of properties are grouped together and averaged. This is done to make the data easier to visualize.

The resulting information is then graphed (Fig. 1)

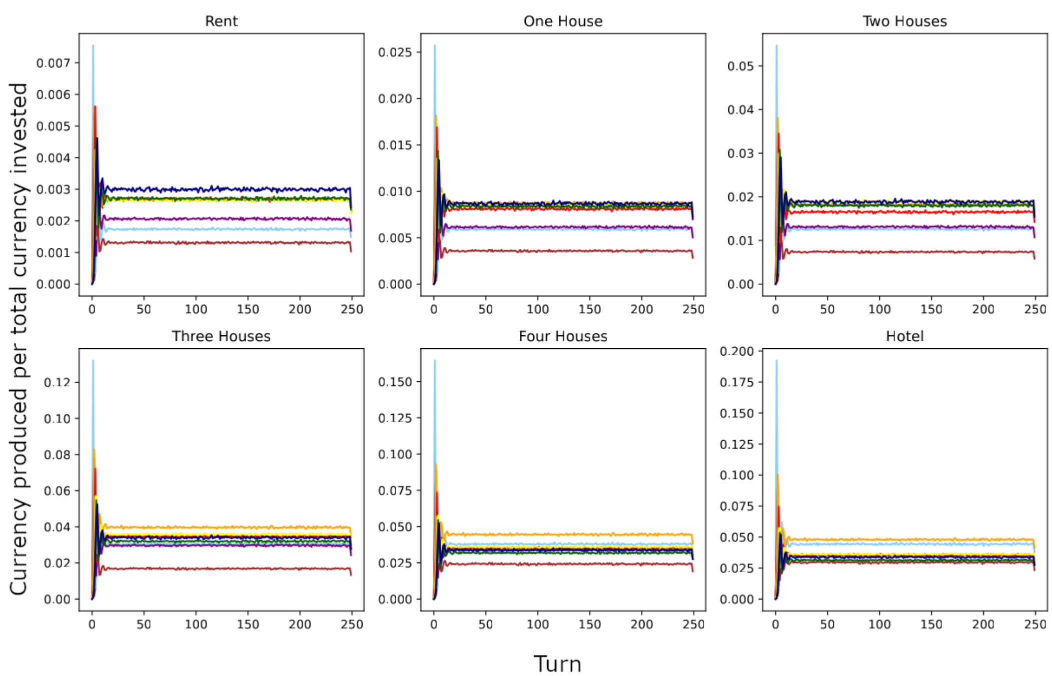

Figure 1. ROI with various amounts of houses. The line colors are equal to the corresponding color of the property set. Note that each graph uses a different scale on the y axis.

As these graphs contain so much variance, they are slightly harder to decipher. To address this issue, the modified data is used to create cumulative graphs instead, where each point is simultaneously modified to equal the sum of all previous points and itself. (Fig. 2).

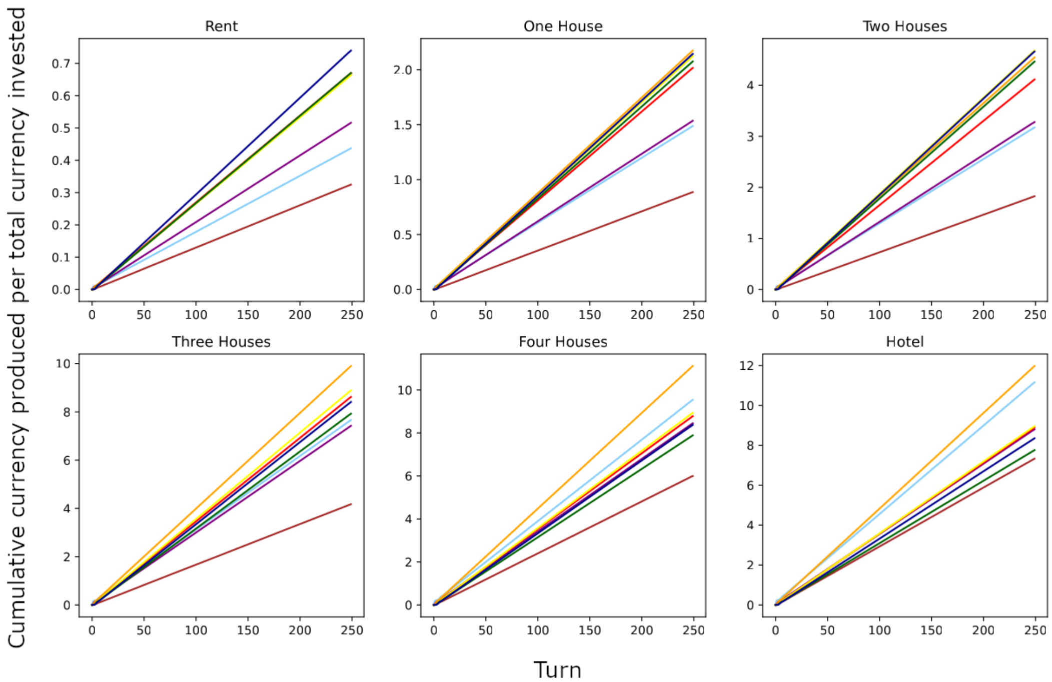

Figure 2. Cumulative ROI. The line colors are equal to the corresponding color of the property set. Note that each graph uses a different scale on the y axis.

Since these values are mostly linear, the 250th value in each graph is chosen to represent that property set for that amount of houses. The information is then condensed into a single graph.

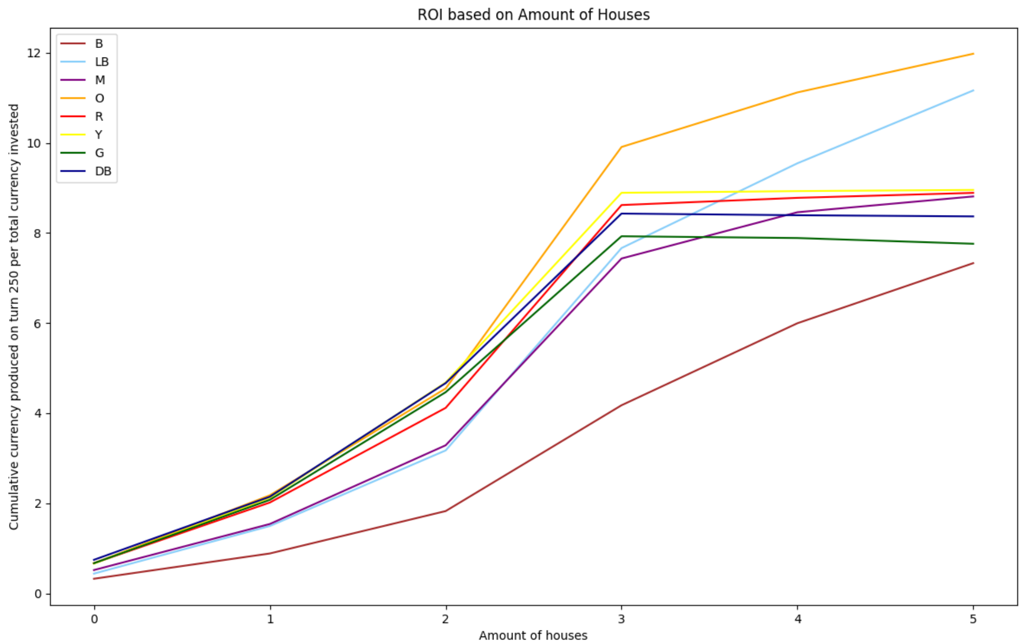

Figure 3. Turn 250 cumulative ROI for each amount of houses.

With ‘Rent’, there is a wide spread between different properties. However, this category is unimportant. Most properties do not remain without housing for long, and even in the event a full property set is unable to be obtained, the ROI is so low it is mostly negligible. For any given property set without housing, a 100% ROI will take over 250 turns. Even if this is achieved, as a general trend currency is added to the game over time, making the eventual return much less significant than the purchase.

For ‘One House’ and ‘Two Houses’, there appears to be three distinct categories. The first category, the brown properties, have a significantly lower ROI than the rest of the properties. The second category, containing the purple and light blue properties, has about twice the ROI as the first category. The third category, containing all unmentioned properties, has about three times the ROI as the first category.

The remaining three categories have similar results. The orange set always has the best ROI, and the brown set the worst. The remaining properties are scattered between them. Notably on both the later two graphs, the light blue properties only have a slightly worse ROI than the orange ones. It is also distinguishable that the majority of properties do not have significant changes in their ROI after three houses are created.

Overall, the orange properties seem to be the best choice for ROI, followed by the light blue ones.

While a high ROI is great for making your investment back, enough currency needs to first be obtained to make those investments. A high ROI in the ‘Hotel’ category is much less significant if it cannot be reached in a timely manner starting without any housing. This second analysis attempts to address this issue.

Using the same simulated data as before, the natural progression of a *Monopoly* game is modeled. Each property set is purchased on turn 0 starting with no housing. The original dataset is used to calculate the amount of currency each property generates on a given turn. Starting with turn 0, the total amount of currency generated from each property set is tracked. Whenever a property set generates enough revenue to purchase housing, it is assigned to the property in the set with the least amount of housing. In the event of a tie, it is assigned to the property furthest from the 'Go' pace in the direction of player movement.

ROI is derived for each property set by dividing the tracked currency amount by the starting purchase cost of the property set. The value of housing on the properties are considered to be a part of their tracked currency when being graphed.

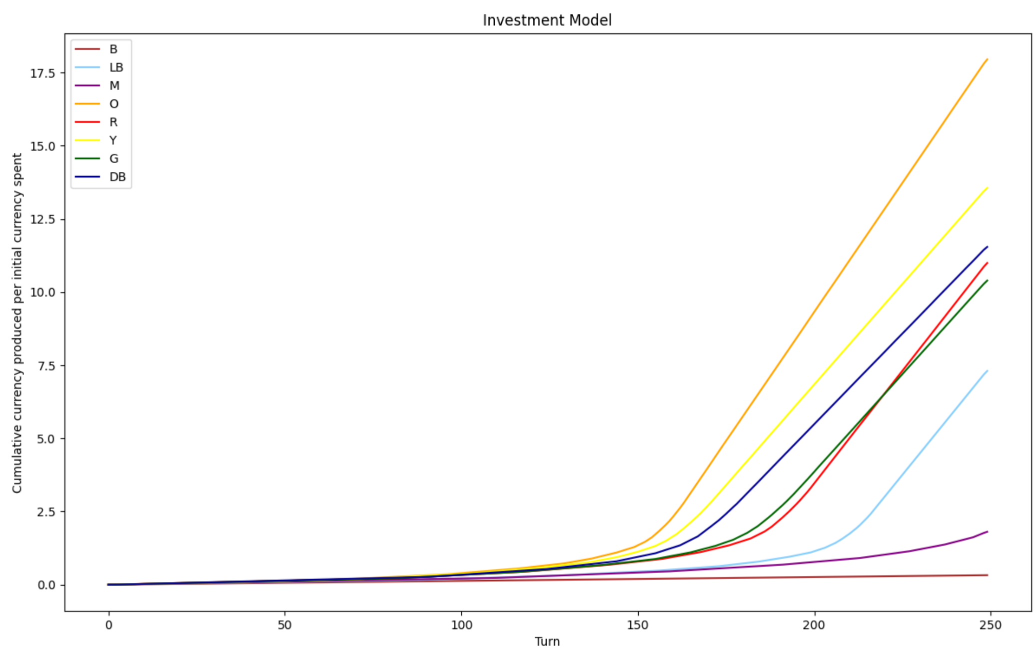

Figure 4. Cumulative ROI from reinvestment model. The value of purchased housing is considered to be profit.

It's important to note that since this model does not consider the housing on properties to be a cost but rather a result of the initial investment, the change in ROI between turns will differ from previous models.

From this analysis, the investment into the orange properties grows much faster than any of the other property sets (Fig. 4).

While the light blue property set had only a slightly smaller ROI than the orange property set in the categories of 'Hotel' and 'Four Houses' (Fig. 3), it takes a noticeably longer time to reach the maximum amount of housing when compared to other property sets.

The brown and purple properties suffer from a more extreme version of this effect.

Discussion

The model assumes that players are immediately released from jail, resulting in no loss of turns. This is not true of all *Monopoly* games and results in decreased accuracy of the model.

It should be noted that games of *Monopoly* can be performed with varying amounts of players. This model assumes only one other player. This does not affect this analysis as an increase in players equally affects all properties.

As a result of their unique mechanics, the railroad and company properties were not included in this model. They might be considered significantly better properties than the ones analyzed with this model.

Conclusion

The orange properties have the best ROI in 4 out of the 6 initial categories (Fig. 3). The orange properties also have a significantly faster growth then all others in the second model (Fig 3.). According to this analysis, the orange properties are by far the best.

The yellow properties are the most comparable to the orange properties. They have a slightly lower growth and start to scale up later (Fig. 4).

The dark blue, red, and green properties all have similar results by turn 250 (Fig. 4). Notably, the dark blue properties reach hotels the fastest out of these properties. Depending on whether the hotel cost is included in the property cost, the set of properties with the eventual highest ROI will differ.

The light blue properties can provide plenty of value when equipped with hotels, but it takes a while to get to that point (Fig. 4). They are best used in conjunction with another set of properties, otherwise many turns are spent with lower amounts of housing.

The brown and purple properties should be avoided almost entirely. Not only are they among the worst in terms of ROI (Fig 2.) with higher amounts of housing, they also take a significant amount of time to reach that point. (Fig. 4)