DETERMINING THE PATTERNS AND IMPACT OF NATURAL PROPERTY GROUP DEVELOPMENT IN "-OPOLY" TYPE GAMES THROUGH COMPUTER SIMULATION

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ABSTRACT

This paper extends earlier work on a computer simulation that determines patterns of natural property group development during play of a game and the impact of this development on the results of ~opoly type games. This extension adds the dimensions of developing natural property groups and a more sophisticated mortgaging strategy to the previous simulation which focused on a simplified set of constraints and the dimensions of cash position and simulated buying behavior. In this paper our focus is on examining the effects of introducing property development into the simulation especially in terms of the impact on cash flow and on game termination. Both these factors have the potential to determine when and how such a game can be effectively used as a classroom simulation. Previous results, reviewed in this paper, indicate that chance or luck play a less important role than one may suspect. Once again there seems to be a consistent first player advantage in being able to gather property groups and, with a twist, winning the game. A key question addressed in this simulation is to what extent this "first-mover advantage" is sustained when property development is added. Results indicate that, while there are some exceptions, the first player advantage appears to hold when property development is added. These results add substance to the discussions and strategic implications of using this game as a classroom simulation.

INTRODUCTION

With numerous versions on the market, both licensed and non-affiliated, the basic rules and layout of "~opoly" type games are standard and generally familiar. One of the reasons for the popularity of the game and its various versions is a perceived combination of risk and strategy that people find intriguing. While using the game in certain modified arrangements as a class simulation, questions arose regarding how much risk and how much strategy can be experienced in the limited time frame that a class allows. In our previous versions of the simulation we examined attempts to "speed-up" the game; versions were tried with modifications to shorten the game that require a certain number of properties be distributed and purchased prior to the initiation of play. This previous work illustrated that even as the number of players in the game increases, the number of total turns needed to complete the distribution and purchase of properties (average turns per player x the number of players) is consistently about 124.

Since, in essence, one would win the game by eliminating the cash and equity of competing players, the ability to collect substantial rents following property development is an important part of game play. This expectation motivated the additions made in this version of the simulation and the change in parameters that were central to our investigation.

The key reporting items of the simulation were the cash/resource position of each of the players, the number of wins for each of the players, and the dependence of wins on the number of turns the players have. The simulation was run for 3, 4, 5 and 6 player games. Further the simulation was run modifying the number of total turns for the game beginning at 200 turns and stopping with 600 turns proceeding in increments of 50.

THE PREVIOUS SIMULATIONS

The simulation is written in Java, and uses a random number generator for rolls of the dice. The simulation can be run for any number of players. With any fixed number of players the simulation can be run for a large number of games. The simulation continues until all available properties are allocated, in general following the rule of such games that even if a player who lands on a property chooses not the purchase it – the property is distributed by means of an auction. In the first version of the simulation, whenever a player landed on a property the player was allocated that property. All prices and currency levels will be set according to those used in the original and most traditional version of the game now copyrighted Hasbro. In the second version of the simulation, players purchase un-purchased properties if they have the cash available, and if they do not the properties are "auctioned" based on several variables. Players are also required to pay or receive cash based on the standard rules of the game. To simplify this version of the simulation, no property improvements were included, as the primary questions deal with property distribution and not cash position.

During an auction the simulation acts in place of the players; the basic assumption is the players act in a manner, whenever reasonable, to prevent the establishment of a natural property group by another player. Though all players utilize a single strategy when one considers all the cases it does appear somewhat complicated.

If the current player does not have the resources required to purchase the property and no natural property group is possible, there are two possibilities for subsequent action that depend upon whether the property could lead to a monopoly or not. If not, there is first a cash auction. The player with the largest cash balance wins the auction. If auction winner has a cash balance that exceeds half the purchase price of the property then that player pays the smaller of the purchase price and the player's cash balance. If the auction winner does not have the requisite cash, the price of the property is set randomly at 0.5, 0.6, 0.7, 0.8, 0.9 or 1.0 the purchase price and the player pays by mortgaging the needed amount of property. If the auction winner does not possess sufficient property to meet the set price they receive the property but are left with no resources.

The remaining case occurs when the available property can lead to a natural property grouping. The player with the possibility of a natural property grouping can allocate up to 90% of their resources (not including properties from natural property groupings) to the winning the auction. The remaining players can allocate up to 75% of their resources to winning the auction. The auction winner is the player with the largest auction allocation. The actual cost of purchasing the property via this auction process is the minimum of three times the purchase price of the property and $1 more than the second highest bid in the auction.

THE CURRENT SIMULATION

There are three areas, natural property group development (improvement), paying off mortgages, and an enhanced mortgaging strategy, that were developed or modified to implement this version of the simulation. Each is examined briefly in turn.

Natural property group development (improvement).

During each turn a player with a property group and a minimum cash balance of $400 can allocate up to 50% of that balance toward development of their property group(s). The houses are purchased and placed uniformly on the properties within a property group from the last property in the group to the first in the group. If a player has multiple property groups, a maximum of three houses are built on a property group

until all properties in all property groups have been developed to the three house level. The development is performed in order from the lowest cost property group to the highest cost property group.

Paying off the mortgage on properties.

Each turn a player has the opportunity to pay off mortgaged property, however property group development occurs before paying off a mortgage. To be eligible for mortgage pay off, the player must have a minimum cash balance of $500 and can spend up to 25% of their cash balance for this purpose. The order in which property is selected for pay off is clockwise around the board from properties in the least expensive property groups to the most expensive property group.

Mortgaging strategy.

A player's mortgaging strategy occurs in four phases. In phase one, property not currently mortgaged, that is not a railroad, and is not part of a natural property grouping held by the player is available for mortgaging. In phase two, the simulation allows railroad holdings to be available for mortgaging. In phase three, all natural property groupings that are not developed (have no improvements) are available for mortgaging. In phase four, first houses on a natural property grouping and then the property itself are available for mortgaging. Each phase terminates when enough monies have been collected to pay the bill or all property available during the phase is mortgaged. If the monies obtained from mortgaging during phase j are not sufficient to pay the bill, the simulation moves to phase j+1. If phase four does not provide sufficient funds to pay the bill the player is bankrupt.

QUESTIONS

The previous simulation, with no initial property distribution, indicated that approximately 124 turns were needed before all properties were distributed, and this number was independent of the number of players (from two to six). In addition, the likelihood of natural property groupings was fairly low (see Table 1 and Chart 1)

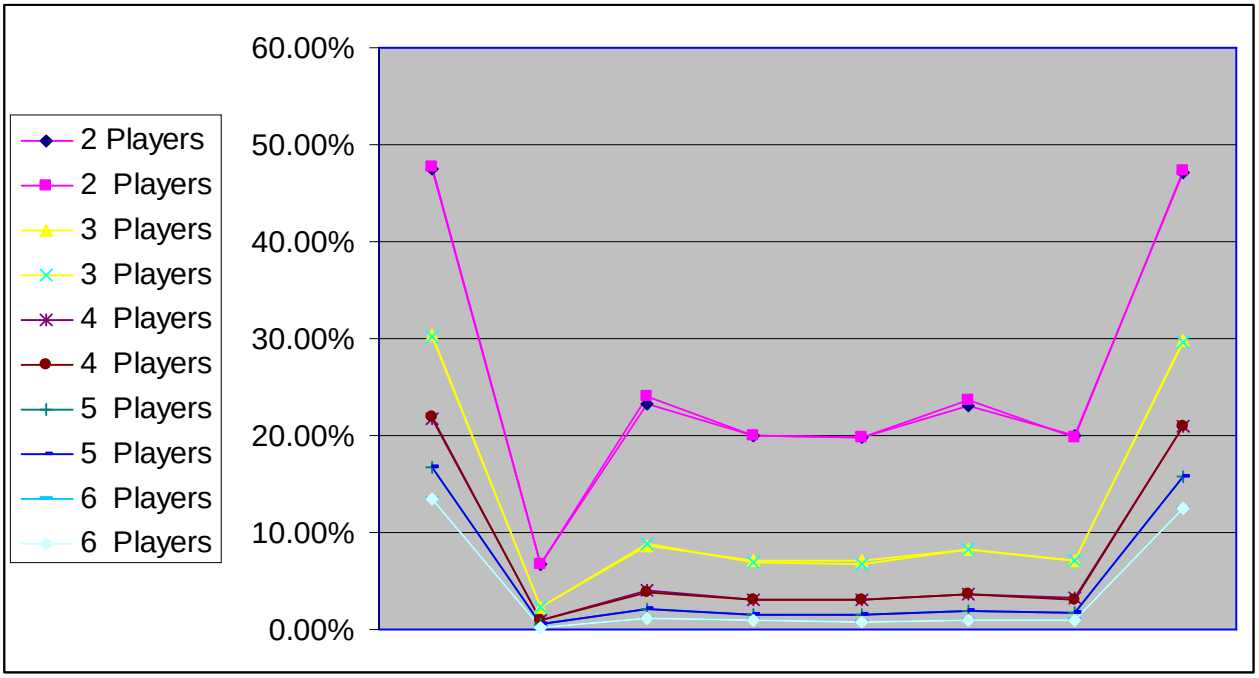
Table 1: Probabilities of a natural grouping (average of 2,000,000 trials)

Property Group	0	1	2	3	4	5	6	7
2 Players	47.53%	6.77%	23.70%	19.98%	19.76%	23.37%	19.91%	47.16%
3 Players	30.28%	2.35%	8.77%	7.02%	6.89%	8.24%	7.05%	29.72%
4 Players	21.81%	1.01%	3.96%	3.14%	3.07%	3.65%	3.17%	21.00%
5 Players	16.78%	0.49%	2.08%	1.59%	1.55%	1.84%	1.64%	15.82%
6 Players	13.41%	0.25%	1.15%	0.89%	0.83%	1.02%	0.91%	12.46%

Property Groups 0 and 7 have two properties - others have three

The previous simulation also showed a consistent bias in favor of the earlier players in achieving natural groupings (a first-mover advantage), and this was repeated regardless of player number. The runs of the simulation indicated that there was approximately a seven to ten percent reduction from each player to the next, regardless of the number of players. Of the results found by running the simulation, the positive bias toward moving earlier was one of the most interesting.

Chart 1: Graph of Probabilities of a natural grouping



With the addition of the cash constraints on the simulation, we address the following questions:

- **Question 1: Is there an significant advantage to going first in the game as opposed to second or later positions in terms of:**
  - **a) Number of property groups gathered?**
  - **b) Cash?**
  - **c) Property value?**
  - **d) Likelihood to win the game?**

- **Question 2: How does the number of players impact the previous answer?**

- **Question 3: How does length of play (number of moves) impact Questions 1 and 2?**

RESULTS AND ANALYSIS

A series of simulation runs provided the data for the results shown in the following charts and tables. Each simulation was set to run one million games for a set number of players from 3 to 6, and for a set number of turns. In an effort to determine that the simulation results were consistent, in several cases the same run was done multiple times. While there was some variation between identical runs (which is to be expected when using simulation to help determine trends and estimate probabilities) the trends from run to run were remarkably consistent indicating that a one-million game simulation run is of a sufficient length to use for the purposes of comparison and analysis.

As a base comparison, Chart 2 shows data for a four-player game of multiple lengths (one million simulated games at each length) with Cash and Property Value (determined as the stated mortgage value of owned but un-mortgaged properties) averages for all players in the game. Chart two also shows frequencies for total number of Bankrupt Players as well as for the total number of games won (the simulation terminates a run when the number of remaining players equals 1, and totals are averaged at that point.)

Chart 2:

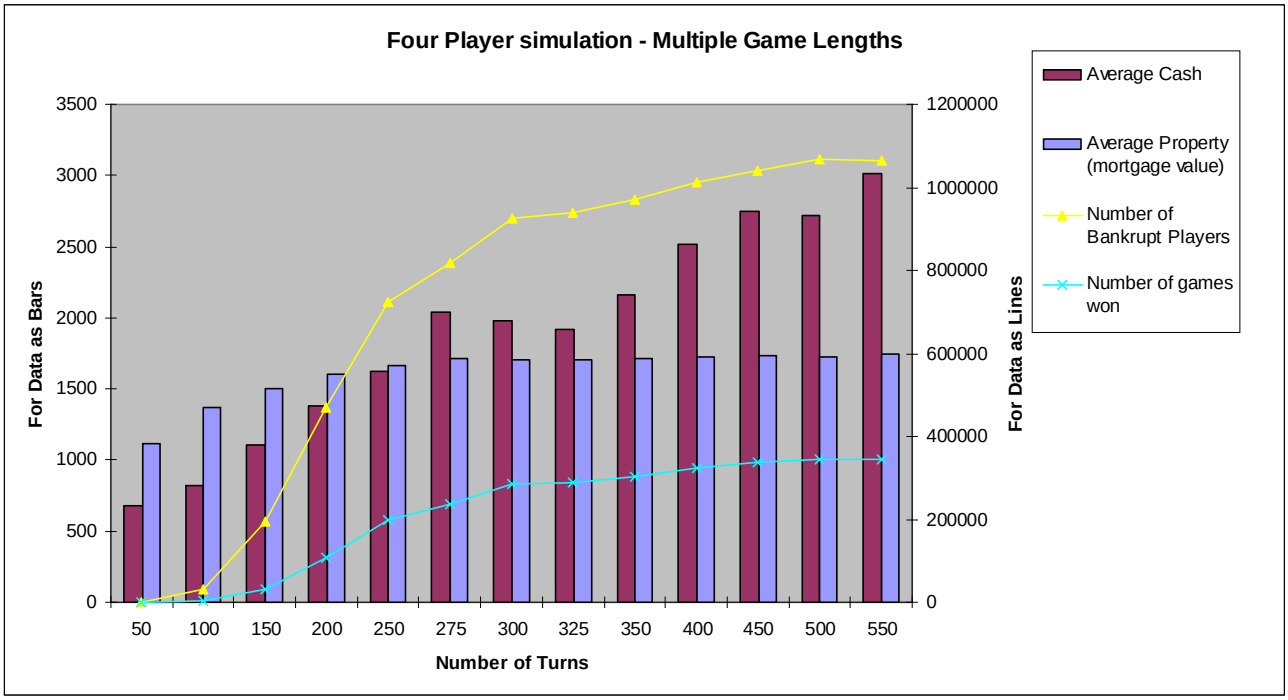


Chart 2 shows that for four players that with property development the number of bankruptcies and games won increases dramatically once the average point of all properties being distributed is reached (approximately 125 turns [10]) then begins to level off about 250 turns. At that point property values reach their average maximum (all properties which can be developed are fully developed, after which there is a slight decrease in average cash until about 325 turns. After that point, few additional games are won, and few additional bankruptcies occur, however average cash continues to increase. At 600 turns for 4 players only about 35% of all the games played have been won. Extrapolating from this data, we infer that based on the constraints of the current simulation the vast majority of four player games will never end in a winner, regardless of the length of the simulation. The pattern of these results is very similar for three, five and six player games as well. For comparison purposes, for a three player game at 600 turns, 53% of the games played resulted in a winner. A five-player and a six-player game, the 600 turn win percentages were 23% and 17% respectively. Interestingly, these results are not far different at 600 turns than they are at 400 turns, where the 3, 4, 5 & 6 player win percentages are: 52%, 32%, 22% and 16%.

A key question for this paper is whether the addition of property development (houses & hotels) and the corresponding changes in player cash flows has a significant impact on the game. A comparison of the data presented in tables 2 and 3 provide insight. Table 2 is drawn from the earlier version of the simulation which did not include property development while Table 3 is constructed from the results of the current simulation. The average mortgage value of all distributed property is 2865, so if evenly divided the expected value of undeveloped un-mortgaged property among the players would be that

shown in Table 2. Both simulations allowed players to mortgage properties to raise cash. The difference between the expected value of property and the results of the simulation shown in the fourth column is thus explained by players owning properties that remain mortgaged at the termination point of the simulation.

Table 2: Data from an average 1 million runs without property development [6]
(based on an average of 5 1-million game runs terminating when all properties were distributed)

Players	Average Cash	Expected Value of Property (mortgage value)	Average Property (mortgage value)	Number of Bankrupt Players	Number of games won
3	939	955.0	835	1700	58.60
4	1013	716.3	683	320	0.20
5	1062	573.0	560	73	0.00
6	1134	477.5	471	24	0.00

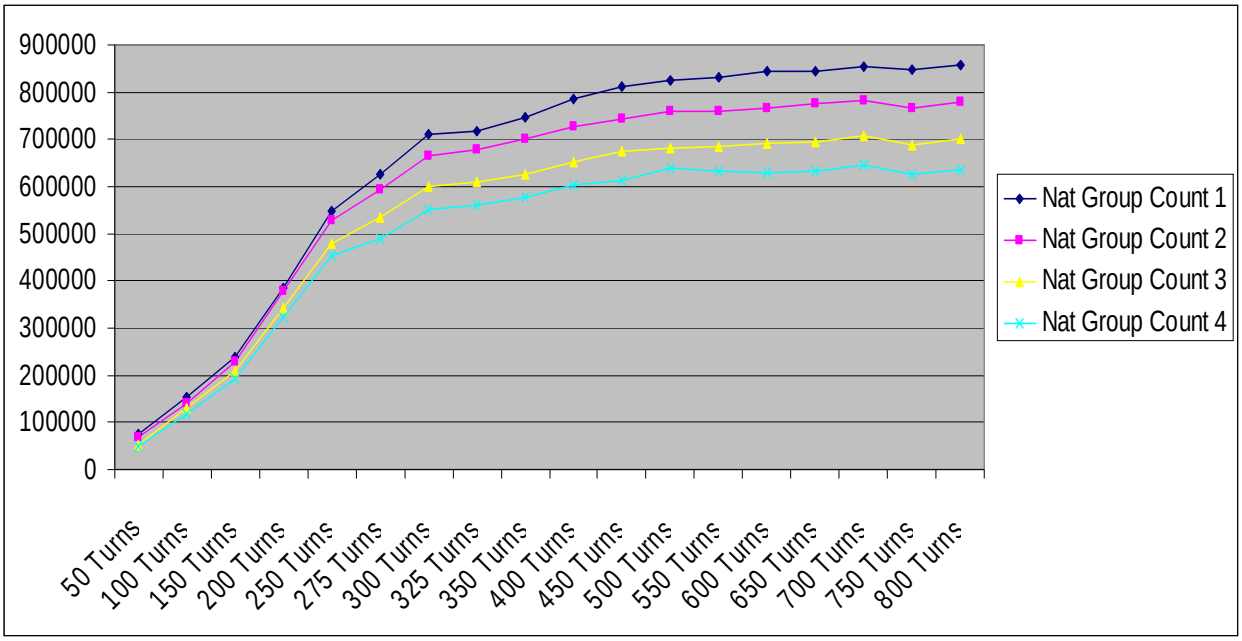
Table 3: Data from a 1-million game run with property development terminating at 125 turns (the average point at which all properties are distributed)

Players	Average Cash	Expected Value of Undeveloped Property (mortgage value)	Face Value of Owned Properties and Improvements	Average Property (mortgage value of properties and improvements)	Number of Bankrupt Players	Number of games won
3	785	955.0	1828	914	123653	33575
4	897	716.3	1426	713	90617	10719
5	991	573.0	1151	575.5	69691	3846
6	1081	477.5	958	479	55653	1397

The differences between the result without property development (Table 2) and with property development (Table 3) are substantial. With development, property values are slightly higher than those of the previous simulation indicating that some amount of development has taken place by this point in the game. Perhaps the starkest contrast between the two simulations is in the number of bankrupt players and games won. In the earlier simulation (no development) there was only one game won at this point out of 5 million 4 player simulations, and no games won out of 5 million 5 player or 6 player simulations. While the raw numbers of bankrupt players and wins out of a million games are still fairly low in the second simulation, the magnitude of the differences indicates that property development plays a key role in the game – slightly decreasing average player wealth (the total of cash and property) and substantially increasing the probability that one or more players will be forced out of the game by the average point at which all properties have been distributed.

From this point we can begin to explore whether property development impacts the advantages found in the previous simulation of going first, or before later players. Charts 3, 4, 5 & 6 show how property groupings, cash, property values, bankruptcies and wins vary for a four-player set of simulations over various game lengths from 50-800 turns

Chart 3: Property Groups for a Four-Player Simulation over Various Game Lengths



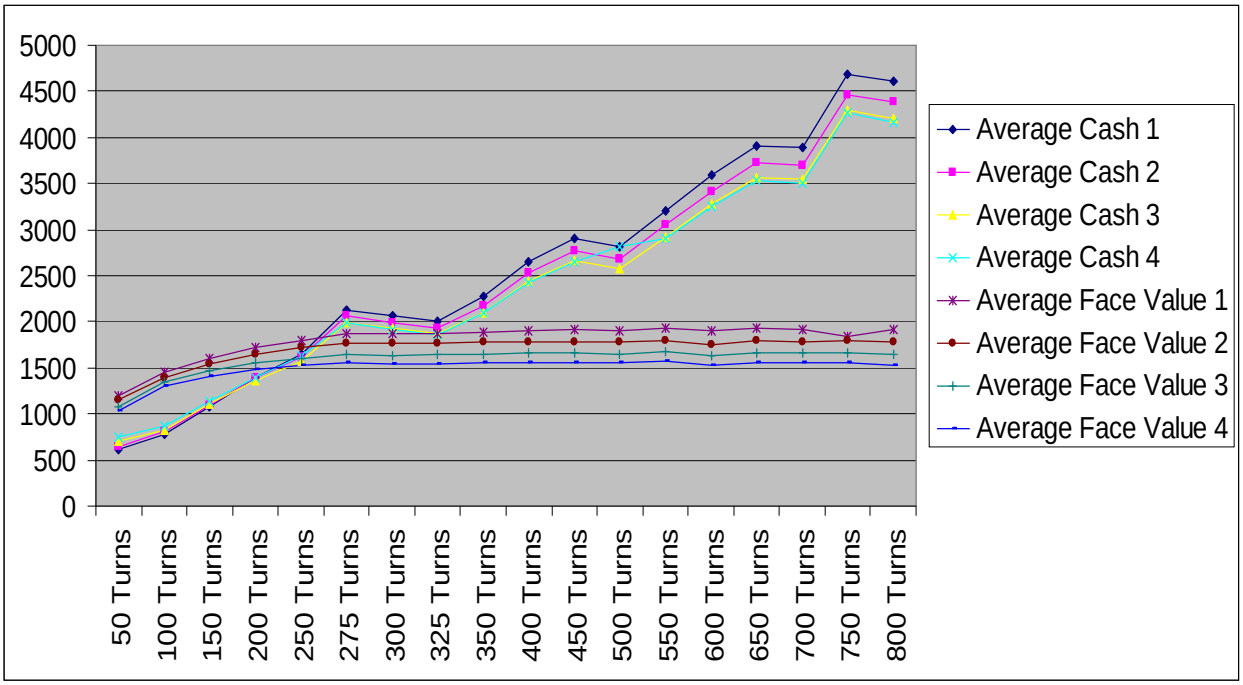
Data based on one million games per simulation run.

Chart three shows how property groups vary from player to player. It is interesting to note that the number of property groups owned by any given player levels off at about 275 turns, the same place where average property for all players trails off. Since previous simulations [10] have indicated that all properties should be distributed at an average of 125 moves, some explanation for property groupings to continue to increase is warranted. Trading of properties from one player to another is not allowed in this simulation (this will be added in future simulations) so that cannot account for this discrepancy. The only way that a player can gain additional properties to create a property group is to bankrupt another player, thus obtaining the bankrupt player's properties. Chart 5 indicates a significant shift in bankrupt players over the same range that the natural property groups continue to increase, thus providing an explanation for the phenomenon.

Player 1 retains a significant advantage over later players, and there appears to be a consistent advantage for each earlier player over later players. This result is consistent with findings from the earlier version of the simulation, and indicates that while development does impact property group holdings later in the game as a result of wins and losses; there remains a consistent and predictable first mover advantage in obtaining property groups.

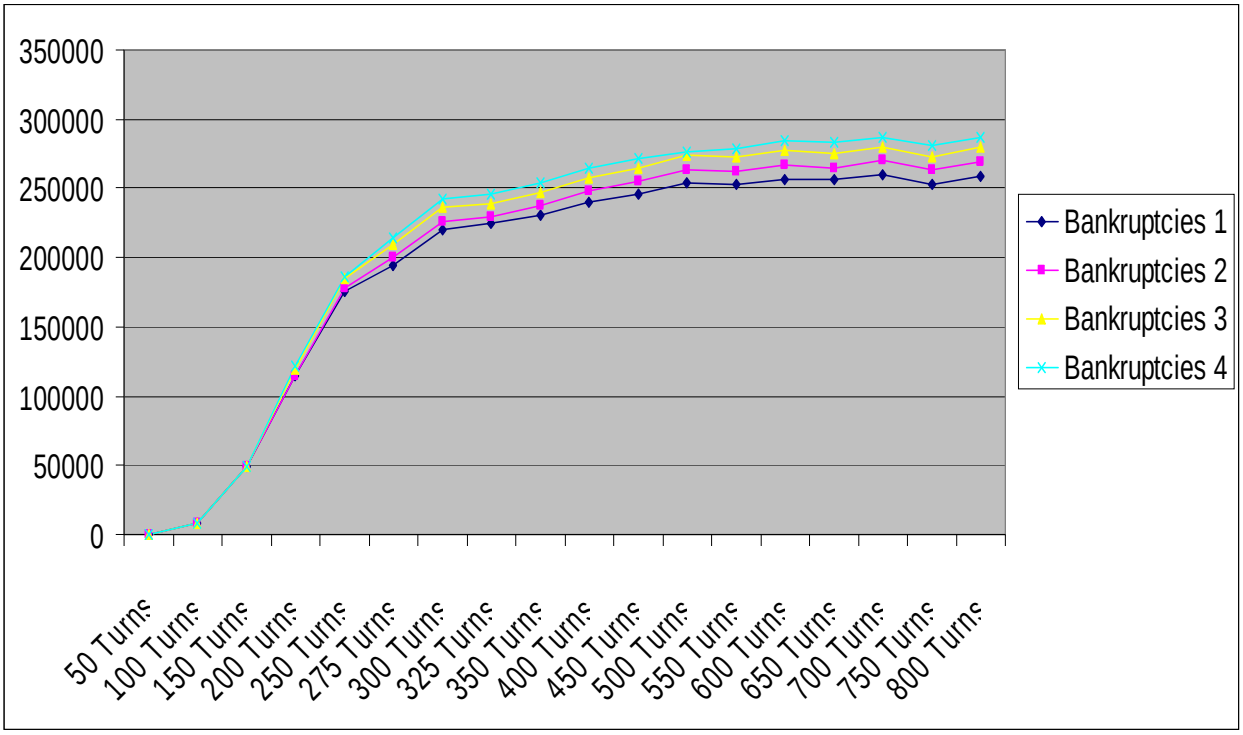
Chart four shows cash and face value by player over several game lengths. Because face value should be related to property groups (complete or partial) a similar pattern between number of property groups and face value is to be expected. This pattern does emerge, and once again player one has an advantage in property ownership as measured by face value. Amount of cash on hand presents a slightly different, but again predictable story. Early in the game (before about 250 turns) player one has a lower amount of cash than other players, with player four having the highest amount. This is due to the increased opportunities that the earlier players have to purchase properties. This situation reverses at about 250 turns, and player one again emerges with an advantage and the first mover advantage seems to remain fairly consistent throughout the remainder of the game lengths investigated.

Chart 4: Cash and Face Value for a Four-Player Simulation over Various Game Lengths



Data based on one million games per simulation run.

Chart 5 Number of Bankruptcies for a Four-Player Simulation over Various Game Lengths

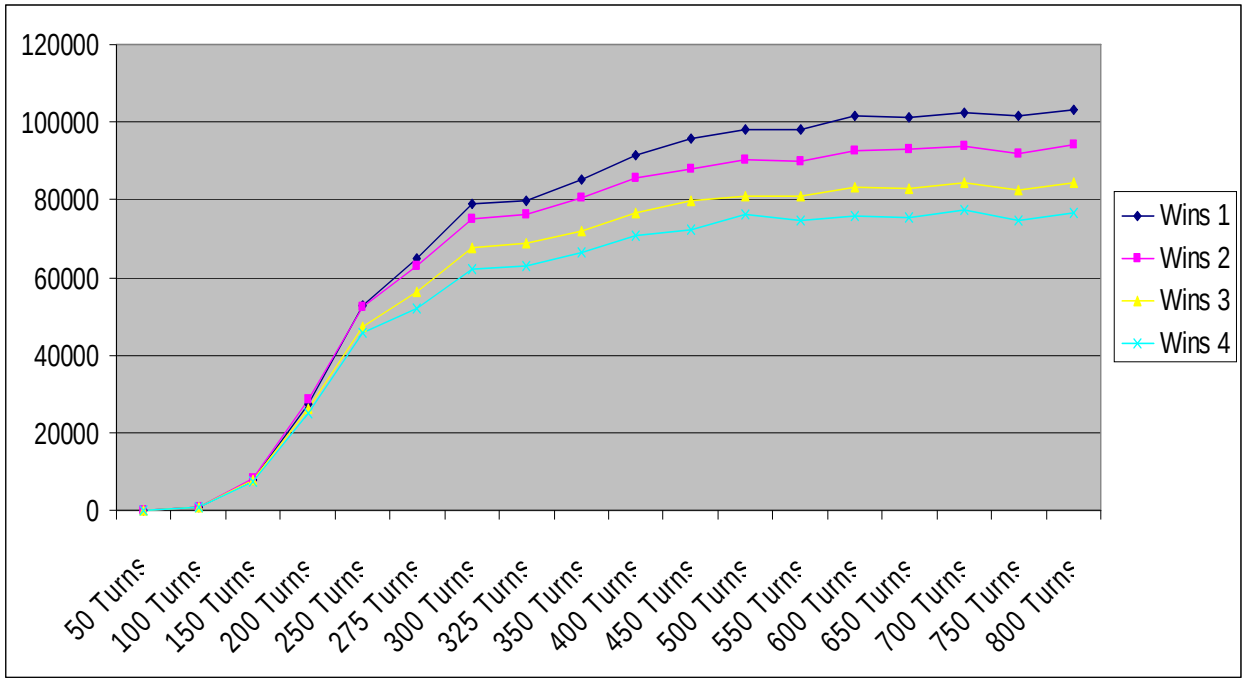


Data based on one million games per simulation run.

Bankruptcies per player at various game lengths are presented in Chart 5. Up through approximate 250 moves the number and rate of bankruptcies for each player is fairly consistent. A clear pattern emerges

from that point on, however, indicating that later players are more likely than earlier players to have gone bankrupt, thus again reinforcing the concept of a first-mover advantage in the game.

Chart 6 Number of Wins for a Four-Player Simulation over Various Game Lengths



Data based on one million games per simulation run.

The last issue then is whether or not the other variables measured do in fact relate to the likelihood of a player winning the game. As expected, Chart 6 indicates that earlier players do have a higher likelihood of winning the game than later players, and this manifests quite clearly after about 250 turns. While not presented in this paper in the interest of space, the results for three, five, and six players are all quite similar to the results for four players shown. In each case, 250 moves seems to be the point after which a first mover advantage is clear and sustained. This is also about the point where property development reaches its maximum (see Chart 2).

Of some key interest is the likelihood of winning earlier in the game (prior to 250 turns). Tables 4, 5 and 6 present an analysis of multiple player numbers and key variables at 200, 400 and 600 turns respectively. The 400 and 600 turn data indicate a clear and convincing advantage for earlier players at these points, regardless of player number. In stark contrast, at 200 moves the second player is more likely to have won the game than the first player, and in a six player game that advantage extends to player three as well. A probable explanation for this phenomenon is that of cash flow. Earlier in the game, early players have more opportunities to purchase properties and thus are cash poor relative to later players, but at this point the earlier players have not had the opportunity to develop those properties to a sufficient level to take advantage of their assets. The second player, however, has a sufficient amount of cash to have a slightly better "survival" rate at this point. While this is an interesting result, and certainly worthy of discussion when using the game as a classroom simulation, it is important to note that while there are real differences in win rates at this point in the game, the raw number differences are small, reflecting less that 2/10^{ths} of 1% of all the games played in a simulation run.

CONCLUSIONS AND OBSERVATIONS

In general, the simulation is designed to answer some specific questions that will help the instructor use such a game in a classroom. Of particular interest are implications regarding business policy and strategy. Effective classroom exercises require a short learning curve, which is one reason that ~opoly type games make an attractive exercise. On the other hand, the length of such games is a negative in a classroom setting. The simulation presented in this paper can help in determining the factors that influence strategic success, and how various uncertain decision environments can be improved through modeling. Connections between the research questions and intended course use include first mover advantages in the market, the impact of long term vs. short term strategic planning and the impact of additional competitors in the environment. Record keeping and investment returns can also be tracked by students and discussed in the classroom setting.

The simulation provides a basis for discussion in a business strategy/policy class that substantially enhances the use of the game as a classroom exercise. In any given semester, only a limited amount of time can be used for game play, and it is not only impractical but impossible for enough games to be played for students to see what can be observed through analysis of the simulation data. In addition, any one game is likely to have enough variance from the means that students will be unable to discern patterns that become clear when multiple games are played.

This simulation and those leading up to it are at best approximations of player behaviors. In addition, none of these simulations allow properties to be traded, which is a key behavioral part of the game. The largest remaining question then is whether trading of properties between players will impact the win/loss patterns and first mover advantages seen in the current simulation. Adding trading to the simulation is the next logical step in this research path, and should be completed and reported in an upcoming paper.

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Table 4: 200 turns

		Average Cash	% change from Previous Player	% change from First Player	Average Face Value	% change from Previous Player	% change from First Player	Nat Group Count	% change from Previous Player	% change from First Player	Bankruptcies	% change from Previous Player	% change from First Player	Wins	% change from Previous Player	% change from First Player
3 players	1	1405			2235			958036			206719			89574		
	2	1384	-1%	-1%	2143	-4%	-4%	935295	-2%	-2%	207963	1%	1%	91384	2%	2%
	3	1374	-1%	-2%	2011	-6%	-10%	856356	-8%	-11%	214938	3%	4%	84271	-8%	-6%
4 players	1	1394			1715			383405			114248			27248		
	2	1386	-1%	-1%	1653	-4%	-4%	377070	-2%	-2%	114394	0%	0%	28578	5%	5%
	3	1361	-2%	-2%	1558	-6%	-9%	342793	-9%	-11%	119975	5%	5%	26102	-9%	-4%
	4	1385	2%	-1%	1487	-5%	-13%	321928	-6%	-16%	121812	2%	7%	25038	-4%	-8%
5 players	1	1436			1398			230082			92944			16325		
	2	1430	0%	0%	1345	-4%	-4%	229213	0%	0%	93037	0%	0%	17605	8%	8%
	3	1415	-1%	-1%	1269	-6%	-9%	209046	-9%	-9%	96280	3%	4%	16008	-9%	-2%
	4	1404	-1%	-2%	1206	-5%	-14%	193269	-8%	-16%	98831	3%	6%	14955	-7%	-8%
	5	1440	3%	0%	1151	-5%	-18%	183450	-5%	-20%	99246	0%	7%	14571	-3%	-11%
6 players	1	1501			1159			113281			51367			5329		
	2	1500	0%	0%	1110	-4%	-4%	111237	-2%	-2%	51830	1%	1%	5794	9%	9%
	3	1487	-1%	-1%	1052	-5%	-9%	102068	-8%	-10%	52480	1%	2%	5400	-7%	1%
	4	1482	0%	-1%	998	-5%	-14%	94596	-7%	-16%	53636	2%	4%	5017	-7%	-6%
	5	1478	0%	-2%	951	-5%	-18%	88354	-7%	-22%	54999	3%	7%	4767	-5%	-11%
	6	1523	3%	1%	906	-5%	-22%	81565	-8%	-28%	54910	0%	7%	4441	-7%	-17%

Table 5: 400 Turns

		Average Cash	% change from Previous Player	% change from First Player	Average Face Value	% change from Previous Player	% change from First Player	Nat Group Count	% change from Previous Player	% change from First Player	Bankruptcies	% change from Previous Player	% change from First Player	Wins	% change from Previous Player	% change from First Player
3 players	1	2461			2372			1546650			338313			185484		
	2	2322	-6%	-6%	2197	-7%	-7%	1437765	-7%	-7%	352246	4%	4%	173133	-7%	-7%
	3	2241	-3%	-9%	2032	-8%	-14%	1308320	-9%	-15%	368930	5%	9%	157555	-9%	-15%
4 players	1	2649			1908			785372			240398			91661		
	2	2535	-4%	-4%	1785	-6%	-6%	728372	-7%	-7%	247933	3%	3%	85520	-7%	-7%
	3	2439	-4%	-8%	1656	-7%	-13%	653726	-10%	-17%	257968	4%	7%	76485	-11%	-17%
	4	2421	-1%	-9%	1557	-6%	-18%	602617	-8%	-23%	264403	2%	10%	70627	-8%	-23%
5 players	1	2611			1532			444880			172701			50620		
	2	2526	-3%	-3%	1443	-6%	-6%	414839	-7%	-7%	176784	2%	2%	47560	-6%	-6%
	3	2454	-3%	-6%	1354	-6%	-12%	378281	-9%	-15%	181867	3%	5%	43328	-9%	-14%
	4	2389	-3%	-9%	1271	-6%	-17%	342532	-9%	-23%	186610	3%	8%	39168	-10%	-23%
	5	2336	-2%	-11%	1200	-6%	-22%	315616	-8%	-29%	190261	2%	10%	36018	-8%	-29%
6 players	1	2466			1277			284643			130688			32067		
	2	2397	-3%	-3%	1200	-6%	-6%	262088	-8%	-8%	133623	2%	2%	29685	-7%	-7%
	3	2340	-2%	-5%	1131	-6%	-11%	240182	-8%	-16%	136655	2%	5%	27221	-8%	-15%
	4	2289	-2%	-7%	1065	-6%	-17%	219929	-8%	-23%	139447	2%	7%	24894	-9%	-22%
	5	2240	-2%	-9%	1005	-6%	-21%	201475	-8%	-29%	141869	2%	9%	22781	-8%	-29%
	6	2286	2%	-7%	953	-5%	-25%	187524	-7%	-34%	143175	1%	10%	21250	-7%	-34%

Table 6: 600 Turns

		Average Cash	% change from Previous Player	% change from First Player	Average Face Value	% change from Previous Player	% change from First Player	Nat Group Count	% change from Previous Player	% change from First Player	Bankruptcies	% change from Previous Player	% change from First Player	Wins	% change from Previous Player	% change from First Player
3 players	1	3270			2390			1636720			355492			199560		
	2	3086	-6%	-6%	2205	-8%	-8%	1508761	-8%	-8%	372176	5%	5%	184016	-8%	-8%
	3	2982	-3%	-9%	2037	-8%	-15%	1369545	-9%	-16%	389878	5%	10%	167014	-9%	-16%
4 players	1	3590			1898			844785			256700			101771		
	2	3415	-5%	-5%	1754	-8%	-8%	767413	-9%	-9%	266643	4%	4%	92743	-9%	-9%
	3	3275	-4%	-9%	1629	-7%	-14%	691270	-10%	-18%	276901	4%	8%	83396	-10%	-18%
	4	3247	-1%	-10%	1523	-7%	-20%	628259	-9%	-26%	284447	3%	11%	75718	-9%	-26%
5 players	1	3408			1552			483391			184569			56756		
	2	3270	-4%	-4%	1451	-7%	-7%	442507	-8%	-8%	189913	3%	3%	52004	-8%	-8%
	3	3155	-4%	-7%	1354	-7%	-13%	398469	-10%	-18%	195801	3%	6%	46720	-10%	-18%
	4	3046	-3%	-11%	1267	-6%	-18%	360883	-9%	-25%	200987	3%	9%	42271	-10%	-26%
	5	3075	1%	-10%	1200	-5%	-23%	335552	-7%	-31%	203535	1%	10%	39294	-7%	-31%
6 players	1	3271			1289			303482			138530			35172		
	2	3149	-4%	-4%	1209	-6%	-6%	278347	-8%	-8%	141836	2%	2%	32241	-8%	-8%
	3	3051	-3%	-7%	1138	-6%	-12%	254903	-8%	-16%	145127	2%	5%	29479	-9%	-16%
	4	2955	-3%	-10%	1067	-6%	-17%	229846	-10%	-24%	148656	2%	7%	26523	-10%	-25%
	5	2875	-3%	-12%	1009	-5%	-22%	212812	-7%	-30%	150876	1%	9%	24560	-7%	-30%
	6	3066	7%	-6%	953	-6%	-26%	195519	-8%	-36%	151404	0%	9%	22545	-8%	-36%