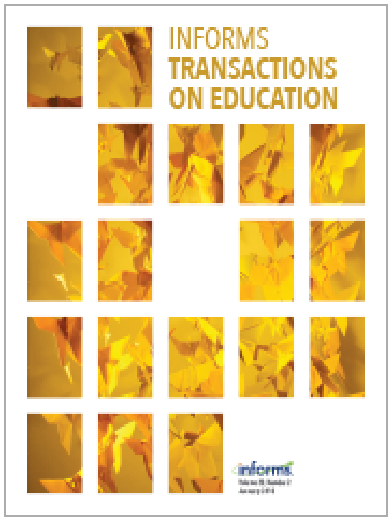

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The Stock Portfolio Game

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Abstract

One of the objectives of the stock portfolio game is to introduce undergraduate engineering students to the application of optimization techniques for stock portfolio selection. Ideally students playing the game would have basic background in linear algebra, calculus, and statistics. The general idea of the game is to present teams of students with real historical performance data for stocks with different levels of returns and variability so that they make decisions concerning the allocation of limited funds among these stocks. The game is played in four rounds within an hour-long session. The teams, comprised of no more than four students, are provided with an initial virtual investment fund, which they have to allocate or reallocate based on the information presented. The team with the most money in its investment account at the end of the game is declared the winner. Once the results of the game are known, one or more teams are asked to share their investment strategy with the rest of the group. This discussion forms the starting point for the last part of the session when the lecturer puts the investment game in the perspective of an optimization problem. At the end of the session basic principles of Markowitz's portfolio theory are presented and applied to the data given to the students.

Editor's note: This is a pdf copy of an html document which resides at http://ite.pubs.informs.org/Vo8No1/Villalobos/ (Volume 8, Number 1, September 2007)

1. Introduction

The use of optimization techniques in financial applications is not new. For instance, Markowitz developed his now famous portfolio optimization theory in the 1950s (Markowitz, 1952). However, most of the development in the areas of financial optimization remained generally within economics and finance. Nevertheless, in the last fifteen years the operations research (OR) and industrial engineering communities have begun to develop and use decision-support tools for financial applications such as portfolio selection and risk management. This has been driven, in part, by increasing numbers of graduates entering the financial sector from OR and industrial engineering programs. In fact, entire programs dedicated to financial engineering or financial mathematics have been created throughout the world; currently there are more than 30 such programs in the United States (International Association of Financial Engineers[1], 2007). However, the majority of these programs are offered only at the graduate level. Thus, one of the main objectives of the game presented in this paper is to introduce undergraduate students to some of the issues and tools of financial engineering to make them aware of financial engineering related career paths. Another objective of the game is to introduce these students to applications of optimization techniques to financial investment problems.

Evidence of the benefits in using games and simulation approaches to business and other fields has been extensively discussed in the literature. For instance, Lean et al. (2006) present an overview of the current practices of using games in higher education and what they perceive as the barriers to the adoption of games in the classroom. Wolfe and Crookal (1998) present a brief review of the history of simulation/gaming and discuss the maturity and the challenges of the field.

Although the practice of teaching games has been adopted in practically every field of higher education, game applications in management have a long and unique history. For instance, Faria and Wellington (2004) claim that the first use of business-related games can be traced back to China as far as 5,000 years ago;

(1) http://www.iafe.org/resources_acad.html

business simulation games can be traced back to at least 50 years. Based on surveys, Faria and Wellington found that the use of simulation games in business schools is widespread with more than 95% of these schools using some type of business simulation games at the time of their study. Surprisingly, however, among the different disciplines of the business schools, finance reported one of the lowest utilization rates of business simulation games.

Regarding the commercial market for business simulation games, Summers (2004) reports that the annual revenue of the business simulation gaming industry was approximately $500 million at the time of the study and has considerable growth potential. There are also several commercially available stock market simulators. The characteristics, use, and pedagogical benefits of these games have been reported in literature as well (Wood et. al, 1992, Maier, 2002). A classic example of these commercial simulators is the National SMS®, a trademark of Stock-Trak, Inc. (2007). In this game the user is given a $100,000 virtual account to invest over several weeks using real stock market information. Students compete against other students based on the performance of their investments. This simulator is particularly popular among high schools in the United States.

The Stock Market Game ™ , sponsored by the Foundation for Investor Education (2007), is perhaps the most popular stock simulator game and has been used by millions of students (Maier, 2002). Common characteristics of these games include that they are played over several weeks and that they aim to introduce the participants to stock picking strategies. Unlike stock simulators, the Stock Market Game is meant to be played in a one-hour long session and its main objective is to introduce students to the decision making process behind investment strategies rather than to develop a successful investment strategy.

The stock game to be presented was developed to be played as part of an undergraduate engineering economy course as an introduction to the principles of portfolio selection and optimization. The game has also been used to showcase potential graduate students some of the non-traditional fields in which industrial engineers currently work.

In the remainder of this paper we discuss in detail this game and its use to introduce portfolio optimization techniques. In Section 2, the game and its rules are presented; in this section, the different phases of the game are discussed, and the material used to play the game is also introduced. Section 3 gives general recommendations about the organization and what the students will need in order to play the game. Section 4 discusses the stock data set used to play the game and also gives recommendations related to alternative stock data. Section 5 presents some results and lessons learned in using the stock portfolio game. Finally, Section 6 presents some conclusions.

2. The Game

The Stock Market Game introduces financial engineering and mathematics students to models used to support financial investment decisions. Although the game has been played at the graduate level, it is assumed that the players are sophomore or junior level students who have taken basic courses in statistics and calculus. The minimum knowledge required to play the game includes the ability to compute average and standard deviations as well as the ability to obtain simple derivatives of quadratic functions.

The game is designed to be played during a 1-hour class session, and it is recommended that each session be followed by an in-depth discussion of the optimization problems derived from the game. The session is divided into three phases: introducing the game to students, playing the game, and putting the stock portfolio formation in the context of an optimization problem. A general explanation of the game is given next.

The game begins when a virtual investment account with a balance of $100,000 is created for each team of students. See Section 3 for recommendations on how the teams can be organized. These funds are considered "loans" that must be repaid, along with accrued interest, during the game in two installments of $55,000 each. The funds in the virtual account must be invested in a combination of seven stocks (A through G) as well as a "risk-free" investment that yields an interest of 2% per game period. The total balance in the investment account can be invested among the seven stocks and the risk-free investment in any way the team decides. Throughout the game, each team will make three investment decisions: one initial allocation of funds and two reallocations. Before every allocation/reallocation decision, the teams are given historical information on the adjusted daily closing price of the seven stocks for the previous several months. Thus, the value of the investment account is determined by the total funds allocated to each stock in the previous decision point (DP) and the performance of the stocks since then. Figure 1 shows the timeline corresponding to the DPs of the stock game.

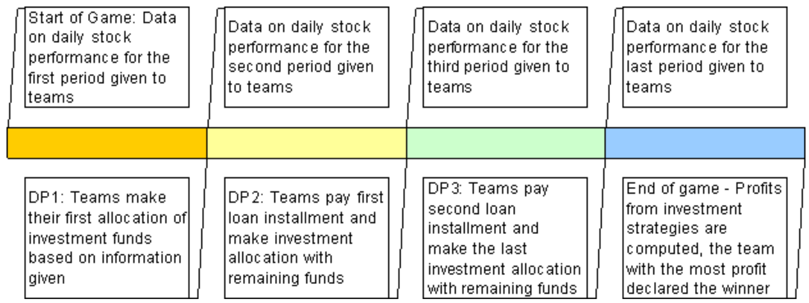

Figure 1: Decision Points Timeline

In DPs two and three, the teams need to make an installment payment of $55,000. If the value of the investment account for a team is less than $55,000 that team is declared "bankrupt" and not allowed to continue playing the game. Due to the selection of the stocks, it is impossible for the teams to become bankrupt at the time of the first reallocation (DP2). However, it is common for one or two teams to be unable to make the second installment payment (DP3), thus resulting in bankruptcy. At the discretion of the instructor, bankrupt teams can continue playing by borrowing additional funds or by joining some of the other teams still in the competition.

After the students are given the rules, they may use any tools they consider appropriate to make the best possible investment decisions. No formal objective is given to the students to force debate among the members of the team on which objective is best to pursue. For instance, an obvious objective is to maximize profits; a less obvious objective is to minimize the probability of bankruptcy.

2.1. First Phase: Organization and Introduction to the Game

The first activity consists of organizing the students into teams. See Section 3 for recommendations on how the teams can be organized. Ideally, the students would have elementary knowledge of stocks and stock markets. However, to ensure that the students have the information needed to play the game an explanation of stocks, stock markets, and stock closing prices is given at the beginning of the session or during a prior session. As part of the introduction, a graph with the adjusted closing prices of two stocks is presented to make observations on the erratic behavior of the stock prices and the difficulty of predicting the performance of the stocks.

The next part of the session consists of describing the game to the students and discussing the rules, which are then illustrated by playing a reduced version of the game involving two investment periods and two stocks. The student version of the PowerPoint file used in this part of the session can be downloaded from J. Rene Villalobos's Stock Game website[(2)].

2.2. Second Phase: Playing the Game

In the second part of the session the actual game is played. Before making the first investment decision the teams are provided with information reflecting the adjusted daily closing prices of the seven stocks for approximately 2½ years of actual trading. The last closing price is assumed to be the current price of each stock. This means that the teams can buy a share of a stock at the last closing price. It is also assumed that no commission is charged on any of the transactions. Figure 2 presents the information given to the students. This information is based on the performance of real stocks with different levels of average returns and volatility. Once the information is available, the teams have approximately seven minutes to make the allocation of funds among the different investment opportunities. This allocation takes the form of percentages of the total investment fund that each team wants to allo-

(2) http://eal.asu.edu/stockgame

cate to each investment option. Because shorting stocks is not allowed, only non-negative percentages are reported. Using the last closing price given, the percentages are translated into shares of stocks to determine the resulting investment portfolio. The purchase of fractions of shares is allowed.

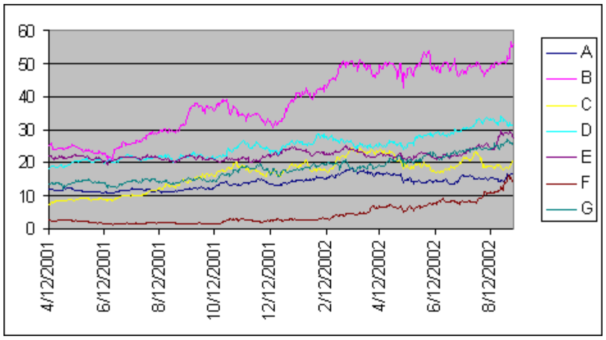

Figure 2: First data set

After the initial allocation, the teams will have two opportunities to change the original investment before the game ends.

Once the teams turn in their original investment allocation (DP1) the second round of the game starts. In the second round the teams are presented with the performance of each of the stocks for approximately two additional years. This information is depicted in Figure 3 below. Using the last stock closing the current value of the portfolio is calculated. From this value the first installment payment of $55,000 is deducted to determine the current value of the investment account. The balance of the investment accounts is shared with the rest of teams; this way, each team knows its overall position in the game and can assess how effective their strategy is and whether it needs to be changed.

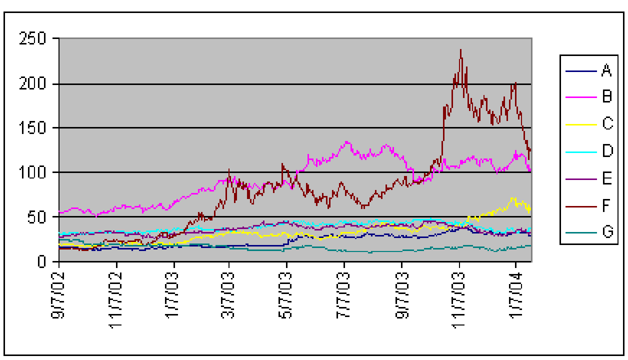

Figure 3: Second data set

As previously explained, the stock information that has been used so far to play the game precludes any team from going bankrupt at this point; thus, the teams will have approximately seven minutes to discuss investment strategies and turn in their new allocation of funds (DP2). However, if a different set of stocks is used and the result of bankruptcy is then possible, it is up to the instructor's discretion to decide if bankrupt teams can continue playing the game by borrowing additional funds or joining with another team. It is highly suggested that all students continue to participate in the game at this point, as the main objective of the game is to keep students actively involved in the decision making process.

In the third round, once again the teams are given data on the performance of the different stocks for approximately the next two years (Figure 4), the resulting value of the current portfolio is calculated, and the second installment payment of $55,000 is deducted. Those teams with negative account balances leave the game; the rest of the teams are given seven minutes to adjust their strategy and make the final investment allocation (DP3). As shown in Figure 4, some of the stocks register negative performance during the period. Thus, there is a high possibility that one or more teams will be forced into bankruptcy because they are unable too make the second payment. This is particularly true for investment portfolios that had large positions in Stocks B and C. The recommendations previously given for the bankrupt teams also apply this time.

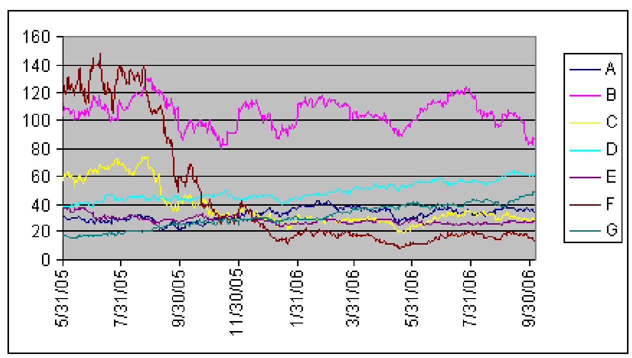

Figure 4: Third data set

In the final round of the game the teams receive data on the performance of the stocks for a last time period (Figure 5). The value of the last closing price for the stocks is used to compute the final value of the investment account for each team. The final value is used to determine the ranking of the teams in terms of their investment performance. The team with the highest value investment account is the overall winner of the game.

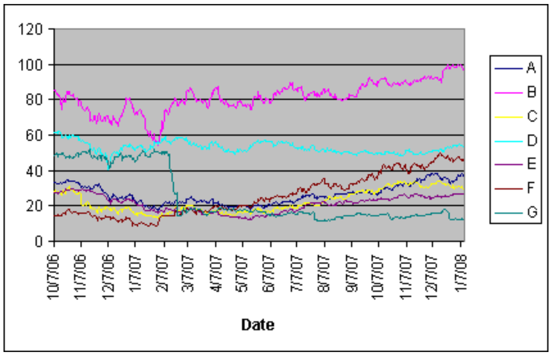

Figure 5: Last data set

2.3. Third Phase: The Game as an Optimization Problem

The objective of this phase is to put stock selection in the context of an optimization problem. After the results of the game are announced the instructor asks the winning team and an additional team, which has used an innovative approach, to share with the rest of the participants the strategies and tools, if any, used to identify investment stocks. Although the strategies presented may vary, the winning team usually cites strategies based on investing in stocks offering the best price improvement combined with stocks prices that did not show significant losses over time. Many teams compute some expected price change per period while other teams compute the variance of the stocks prices. The instructor will use the presentation as a starting point for a discussion to make the connection between higher returns and higher variability of the stocks. To do this the instructor will unveil the overall data used and the corresponding stocks and ticker symbols. Figure 6 presents the closing price data for each stock used, their corresponding ticker symbols, and the average daily prices.

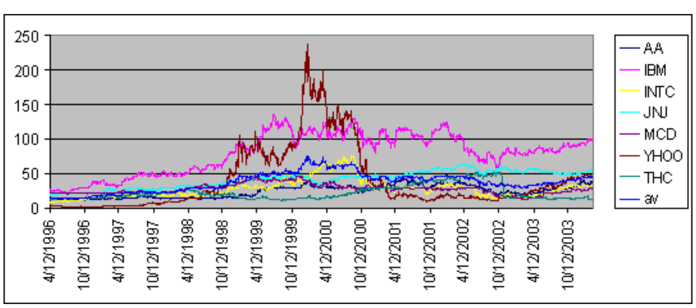

Figure 6: Complete data set with proper ticker symbols and chronology

The semi annual average return and standard deviation are computed and presented to the students in tabular form and in a mean standard deviation format (Figure 7). This information introduces basic concepts of efficient frontier for the selection of stocks and the stock selection problem as Markowitz's

	Semi-annual	
	Avg. Return	Std. Dev.
MCD	0.02808	0.20174
THC	0.05618	0.29198
JNJ	0.06815	0.10048
avg. Index	0.10074	0.25596
AA	0.11176	0.27262
IBM	0.11791	0.23888
INTC	0.16103	0.41510
YHOO	0.59845	1.24228

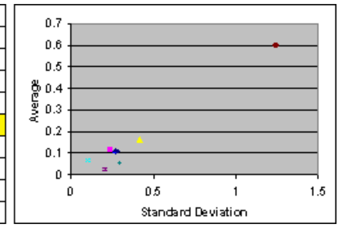

Figure 7: Average returns and standard deviations for the different stocks

stock optimization problem. The return on the portfolio concept is introduced using a 2-asset portfolio and developing its expected return and standard deviation, namely.

$$\sigma(\alpha) = \sqrt{(1-\alpha)^2\sigma_1^2 + 2\alpha(1-\alpha)\sigma_{12} + \alpha^2\sigma_2^2}$$
$$\sigma(\alpha) = \sqrt{(1-\alpha)^2\sigma_1^2 + 2\rho\alpha(1-\alpha)\sigma_1\sigma_2 + \alpha^2\sigma_2^2} \qquad (1)$$

where ρ represents the correlation between the two assets, α represents the weight given to asset 2, and σ represents the standard deviation of each of the assets. Equation 1 highlights two issues: the reduced variability of a portfolio when compared to that of individual assets and the existence of an optimal weight allocation to minimize this standard deviation. Figure 8 shows three assets in a mean standard deviation graph of different daily returns and standard deviations as the weights of the assets in a 2-asset portfolio are varied from 0 to 1. This figure also introduces the topic of efficient frontier of the Markowitz portfolio theory.

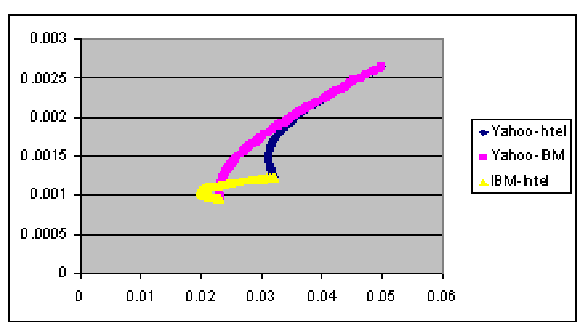

Figure 8: 2-asset portfolio returns and standard deviations

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Finally, if there is enough time left in the class session, the optimization problem is simplified so that it can be solved by Lagrangian relaxation. The simplification consists of allowing negative values (or shortage of stocks) to set up the problem. If any negative value is obtained, it is set to zero, thus rebalancing the portfolio with the positive values. Although this is not strictly valid, it is done to keep the formulation as simple as possible. Otherwise the solution of a quadratic objective function would be required. This simplification is explained to the students so that they are aware that the model can be improved to better reflect the real life problem.

Once the problem is expressed as a Lagrangian relaxation problem, derivatives are taken to obtain a set of linear equations that can be easily solved. The unknowns in the equations are the percentage to invest in each of the stocks at each stage of the game. This technique is applied to the stock information provided to the students at each stage to obtain the portfolio composition. The results so obtained are then compared to those obtained by the students. If there is no class time remaining, a follow-up session can be held to review the overall optimization. A PowerPoint presentation including all the details of game, including the mathematical development, can be downloaded from J. Rene Villalobos's Stock Game website[3].

3. Session Organization

To ensure an orderly and successful session, material to be used should be prepared and organized ahead of time according to the class size and classroom type. We have played the game under different settings with class sizes ranging from small (around 13 students) to large (around 70 students) and with different classroom layouts and infrastructure. To ensure effective participation of all students, we recommend that each team be limited to no more than four students. For small class sizes the membership in the teams can be left to the students' discretion and determined at the beginning of the class. For large class sizes it is recommended that teams be organized prior to the beginning of the class. A strategy that has worked well in the past is to form the teams according to seating assignments. For instance, four students seated side-by-side in the same row would form a team. In any case no more than five minutes should be spent in the organization of teams.

Different types of classroom infrastructure have been used to give the data sets to the teams, to receive fund allocation, and to communicate current results. The instructor must have a personal computer for the instructor connected to a projector, and a computer should be setup for each team. Each computer must have access to an electronic worksheet such as Excel. Although not strictly necessary, a computer-mediated classroom enabled by instructional software such as Blackboard is useful to communicate information between the instructor and the teams and vice versa. However, if access to this type of infrastructure is not available communication can also be done through other file transfer mechanisms such as Flash memory drives or floppy disks.

It is also recommended that a teaching assistant be present in the classroom to receive teams allocations and make computations on the current value of each team's investment accounts. This leaves the instructor free to interact with the students and conduct the game.

Before the class begins, it is also important to prepare forms that will be used for the teams to communicate their allocations in each round of the game. A set of sample forms can be downloaded from J. Rene Villalobos's Stock Game website[4].

4. Data Set Used and Other Relevant Information

The stock performance data set that we have used is based on the adjusted closing prices for seven different stocks from April 1996 to March 2003. This data set was partitioned into four files and given to the students as the stock performance information for each round. However, the data were slightly modified so that the students did not know the actual time period for that date. For instance, the first data set shows an initial date of April 12, 2001, when in fact the real initial date was April 12, 1996. This was done so that the students were not able to guess in retrospect how the market would perform in a particular time period.

(3) http://eal.asu.edu/stockgame/
(4) http://eal.asu.edu/stockgame/

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The data set chosen for this game corresponds to stocks: American Airlines (AA), International Business Machines (IBM), Intel (INTC), Johnson & Johnson (JNJ), McDonald's (MCD), Yahoo (YHOO), and Tenet Healthcare (THC). These stocks were selected to obtain a diverse sample of stock average performance and volatility. The names of the stocks were withheld from the students to ensure they would base their selections strictly on stock performance for the periods. The stocks were identified by the letters A through G. At the end of the game, the names of the stocks and the timing information should be revealed to the students. This will allow them to review their investments and determine whether they would have changed their decisions based on the new information given.

The data and all of the material used in the game can be accessed on J. Rene Villalobos's Stock Game website. The set of stocks and time periods used can be easily changed if the game is used frequently or in different sections of a class during the same semester. However, it is recommended that stocks from different industry segments be used to highlight the point that different returns are expected for different levels of volatility.

5. Results and Lessons Learned

The stock portfolio game has been played for about four years. One of the main results from playing the game at an undergraduate level has been a significant increase of interest in financial decision analysis. Before playing the game, the students were asked to assess their knowledge of stocks, portfolios, and markets. Although most knew something about markets, stock prices, and indices, few had any knowledge of stock selection techniques, and even fewer knew about portfolio information. At the end of the game the students have greater knowledge in these areas, but more importantly they have wrestled with conflicting objectives such as maximizing portfolio value while not falling into bankruptcy. Throughout the game the teams address these issues on an *ad hoc* basis.

Students also show a very high level of intra-team engagement, particularly as they learn their overall position (based on stock allocations results) and try to maintain or reach the top position. The game forces students to tackle issues related to making choices between higher stock returns with higher levels of variability or lower return and lower variability. The instructor should encourage discussion of these conflicting choices by commenting on the performance of certain stocks. For instance, the instructor could mention the high level of volatility exhibited by the data series corresponding to Yahoo!. Ideally, the level of interest present in the game is maintained in the second part of the session when basic models for portfolio formation are introduced.

Because the primary objectives of the game are to introduce students to the application of optimization techniques for stock portfolio selection and to entice them to consider pursuing a career in financial engineering, the success of the game should be judged by the interest produced among the students rather than by the performance of the stock selection strategies of the teams. While a metric to measure this success is difficult to establish, we have noted an increasing number of engineering students (beyond those in industrial engineering) inquiring about advanced courses dealing with portfolio optimization and financial modeling.

The game is played under a strict time schedule. For instance, if the game is played in a 50-minute session, the introduction takes about 10 minutes, playing the game takes about 28 minutes, and the discussion/modeling phase takes about 12 minutes. This time schedule can be modified to meet the specific objectives of the instructor. For instance, the current three DPs could be reduced to two in order to allow additional time for discussions amongst the teams or the discussion of model building. Also, as previously mentioned, an additional session could be held to discuss the details of the models and to apply these models to the stock information given to the teams. Students are usually interested in the comparison between the performances of the strategies used in the game against those resulting from applying the analytical models; a discussion of this could also be done in an additional session.

6. Conclusions

The use of stock simulation games is valuable for introducing engineering students with limited knowledge of finance and financial markets to the principles of portfolio optimization and financial risk management. The stock portfolio game is easy to play and amenable to the intuitive introduction of more advanced optimization topics.

The game has been played for about four years under different classroom settings, group sizes, and class levels. While the game has had a good level of acceptance among students and much success, according to the objectives set for the game there is room for improvement in terms of tailoring the game to different audiences, class settings, and time available.

7. Acknowledgments

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