2008

Mortgage refinancing under uncertainty : switching from adjustable-rate to fixed-rate

Joseph C. Curatolo
Lehigh University

Curatolo, Joseph C., II

Mortgage Refinancing under Uncertainty: Switching From Adjustable-Rate to Fixed Rate

May 2008

Mortgage Refinancing under Uncertainty: Switching From Adjustable-Rate to Fixed-Rate

by

Joseph C. Curatolo II

A Thesis
Presented to the Graduate and Research Committee
of Lehigh University
in Candidacy for the Degree of
Master of Science

in

Industrial Engineering

Lehigh University
May 2008

CERTIFICATE OF APPROVAL

This thesis is accepted and approved in partial fulfillment of the requirements for the Master of Science.

4/25/08
Date

Thesis Advisor

Chairperson of Department

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

We study two different strategies which can be used for optimal decision-making in refinancing from an adjustable-rate mortgage (ARM) to a fixed-rate mortgage (FRM). The first strategy we discuss, expectations-based decision-making, assumes knowledge of future interest rates and compares the net present value of the current ARM versus the net present value of refinancing to a FRM. This strategy instructs the borrower to switch to a FRM during the first period which provides a reduction in net present value. The second strategy we evaluate, heuristic-based decision-making, uses a simple rule-of-thumb requiring a specific rate reduction from the initial ARM contract rate for the refinancing decision, without knowledge of future interest rates. Applying both strategies, we find that the expectations-based strategy provides reduction in net present value over the base-case ARM, but does not always perform better than the heuristic-based strategy. We argue that this occurs because the expectations-based strategy does not evaluate the potential for further benefit by holding the ARM until interest rates fall even further. We also find that heuristics can provide benefit in the mortgage refinancing decision, but unfortunately do not consistently provide improvement over holding the ARM to its maturity.

INTRODUCTION

ARMs are a popular choice for borrowers because they allow the borrower to afford a house which they may not be able to afford otherwise, primarily because of the lower initial payments required for ARM borrowers. In return for the advantage of these lower initial payments, also known as a teaser period, borrowers bear a portion of the interest rate risk for the loan. ARM loans typically begin with a stated interest rate, which tends to either increase or decrease over time in relation to a stated market or bank-specific index. The ARM borrower benefits if interest rates fall because the borrowers' monthly payments will be lower through time. By the same logic, the ARM borrower can suffer dramatic increases in monthly payments from rising interest rates. These increasing monthly payments can diverge dramatically from the initial monthly payment, and unfortunately, can cause bankruptcy in many cases.

Nothaft and Wang (1992) discuss the relative demand for FRMs and ARMs based on market rates. They found that ARMs tend to be in high demand when FRM rates are high because borrowers see no need to lock in a high FRM when they can obtain an ARM which is likely to have decreasing rates in the future. They also found that ARMs are in high demand when the FRM-ARM differential spread is high because the borrower sees significant benefit in the lower initial rate under this scenario. In fact, they found that a 30 basis point reduction in the FRM-ARM spread would decrease the national ARM share by as much as 10 percentage points.

Follain, Scott, and Yang (1992) discuss the use of option pricing theory to analyze the market-wide mortgage prepayment functions for borrowers currently holding standard FRMs. They argue that it is necessary to consider all future refinancing possibilities, not just the payment savings relative to refinancing costs in a given year of fallen interest rates.

Follain and Tzang (1988) discuss using the present value of all future costs from the current FRM versus the present value of all future costs from a new FRM and its associated transaction costs. They use this approach to define a required rate reduction necessary to justify refinancing with a new mortgage, and find that the rate reduction required for an average scenario and a person with a holding period of 10 years is 0.6%.

In this thesis, we present a model to deal with the mortgage refinancing decision under uncertainty of future interest rates. Specifically, the purpose of the model is to assist mortgage borrowers who are currently holding Adjustable-Rate Mortgages (ARM) in the decision to hold their mortgage or switch to a Fixed-Rate Mortgage (FRM). The model utilizes two different methods for deciding whether to refinance the mortgage, and if so, during which period.

CHAPTER 1: METHODS OF DECISION-MAKING

This thesis will explore two different methods discussed in theory and used in practice for refinancing decision-making. The first method assumes knowledge of all future interest rates, and makes decisions based on the net present value of two alternatives. At each time period, the present value of future payments under the ARM scenario is compared to the present value under the FRM scenario, both discounted at the current FRM contract rate. If the present value under the ARM scenario is less than the one under the FRM scenario, then the borrower chooses to maintain his or her current status and continue making payments on his or her ARM. If the present value under the FRM scenario is less than the one under the ARM scenario, then the borrower chooses to switch over to a FRM at the current rate and incur all associated costs with this switch. This method switches to a FRM at the first period in which the FRM scenario is more attractive than the ARM, and does not consider switching during future periods which may be the truly optimal strategy.

The second method is a simple heuristic which uses the rule of thumb that a specific and predetermined decrease in annual rate from the initial rate mandates a refinance to a FRM with a lower interest rate. The model tests multiple values for this heuristic ranging from a 0.5% to 2.5% reduction from the initial rate. At each time period, if the current interest rate for that period is less than the initial rate by a stated amount of percentage points, then the borrower chooses to switch to a FRM.

CHAPTER 2: MODEL BACKGROUND

Adjustable-Rate Mortgage Parameters

ARM Rates

As mentioned above, ARM borrowers assume a portion of the interest rate risk within the loan from the mortgage rate's reflection of current economic and market conditions. In order to limit the borrowers' exposure to this risk, the ARM contract typically includes several conditions between borrower and lender regarding permissible fluctuations in the rate of the mortgage. According to the Consumer Handbook on Adjustable Rate Mortgages published by The Federal Reserve Board (2006), the most important of these elements include the initial interest rate, initial discounts, adjustment period, initial fixed period, index rate, margin, rate changes and stated interest rate caps.

The initial interest rate, typically based on an index, is the opening rate for the ARM mortgage. This initial interest rate is commonly reduced by an initial discount, which provides a reduction of the fully indexed rate to entice borrowers. The model for this thesis uses an initial fully indexed rate of 9.50% with an initial discount of 1.00%, leading to a first-year mortgage rate of 8.50%.

The adjustment period for an ARM is the length of time that the loan maintains a uniform mortgage rate. Most ARMs adjust their rate annually over the entire course of the loan. Hybrid ARMs are ARMs that have an initial fixed period longer than one year, followed by the typical yearly adjustment period for the remainder of the loan. The model for this thesis uses a standard ARM structure, with an initial fixed period of one year followed by annual adjustment periods for the remainder of the loan.

The index rate for an ARM is the basis for determining the annual mortgage contract rate, or the fully indexed rate. The index rate is based upon an underlying financial index which changes on a monthly basis. Common indices used for ARMs include the Monthly Treasury Average (MTA), Constant Maturity Treasury (CMT), London Interbank Offered Rate (LIBOR), and 11th District Cost of Funds Index (COFI). The model for this thesis uses the 1-Year Constant Maturity Treasury (CMT) as its index, although it could be easily modified to utilize one of the other commonly used indices. The margin for an ARM is the amount of interest added to the index rate for determining the annual mortgage rate, or the fully indexed rate. The model for this thesis uses a constant ARM-CMT margin of 2.00% above the index rate to arrive at the fully indexed rate.

The model is designed to help the borrower decide whether she should switch to a FRM from the current ARM based on the information available regarding future interest rates and interest rate changes. The CMT rate is permitted to change once each month in twenty-one discrete amounts from -3.00% and 3.00% in varying increments, with more potential values near zero. This rate change is determined from a discrete random probability distribution with different probabilities assigned to each of the twenty-one possible rate changes. This model allows the CMT rate to fluctuate between 1.00% and 16.00%, a range based on empirical data regarding this financial index. Summary statistics for the monthly CMT values from April 1971 to March 2008, as collected from the Federal Reserve website, can be seen below in Table 1. These values were used to create the feasible range of CMT values and the associated discrete probabilities for this index.

Statistic	Value
Mean	6.53%
Median	5.98%
Max	16.72%
Min	1.01%

Table 1: CMT Monthly Summary Statistics from April 1971 to March 2008

The probability assigned to each of these twenty-one possible rate changes is determined by the CMT rate of the previous period. A high CMT rate in the previous period results in a probability distribution favoring decreases in the CMT. A low CMT rate in the previous period results in a probability distribution favoring increases in the CMT. This is done to approximate a mean-reverting process. Probability distributions were generated and utilized for six specific intervals of previous period CMT rates between the maximum 16% CMT rate and the minimum 1% CMT rate, based on monthly historical data regarding the CMT from the Federal Reserve Website. The discrete distributions for these six specific intervals can be seen in Table 2.

Current Period Rate Change (%)	Previous Period CMT (%): 1 to 4	4 to 5	5 to 7	7 to 10	10 to 14	14 to 16
-3.00%	0.00%	0.10%	0.50%	1.00%	1.00%	4.00%
-2.50%	0.00%	0.20%	0.50%	1.00%	2.00%	5.00%
-2.00%	0.00%	0.30%	0.75%	1.00%	3.00%	6.00%
-1.50%	0.00%	0.40%	1.00%	2.00%	4.00%	7.00%
-1.00%	0.50%	0.50%	1.25%	3.00%	6.00%	15.00%
-0.75%	0.50%	0.75%	2.00%	6.00%	8.00%	14.00%
-0.50%	1.00%	1.00%	3.00%	7.00%	11.00%	12.00%
-0.30%	1.50%	1.25%	4.00%	8.00%	13.00%	10.00%
-0.20%	2.00%	1.50%	5.00%	9.00%	12.00%	9.00%
-0.10%	2.50%	2.00%	6.00%	9.00%	9.00%	7.00%
0.00%	3.00%	8.00%	7.00%	6.00%	7.00%	4.00%
0.10%	4.00%	10.00%	9.00%	9.00%	6.00%	3.00%
0.20%	5.00%	13.00%	12.00%	9.00%	5.00%	2.00%
0.30%	7.00%	14.00%	13.00%	8.00%	4.00%	1.00%
0.50%	11.00%	15.00%	11.00%	7.00%	3.00%	0.50%
0.75%	13.00%	11.00%	8.00%	6.00%	2.00%	0.50%
1.00%	15.00%	8.00%	6.00%	3.00%	1.25%	0.00%
1.50%	12.00%	6.00%	4.00%	2.00%	1.00%	0.00%
2.00%	9.00%	4.00%	3.00%	1.00%	0.75%	0.00%
2.50%	8.00%	2.00%	2.00%	1.00%	0.50%	0.00%
3.00%	5.00%	1.00%	1.00%	1.00%	0.50%	0.00%
Sum	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 2: Discrete Distributions for CMT Rate Changes

The CMT value for each period is calculated by adding the rate change for the current period, as determined by the abovementioned probability distributions, to the CMT value of the previous period. The aforementioned ARM-CMT margin of 2.00% is then added to the current CMT value to determine the fully indexed rate for the period, prior to rate cap reductions. At this time, we apply the two previously described interest rate caps to ensure that the fully indexed rate is within the limits of the contract, specifically the periodic cap and the lifetime cap.

The first rate cap is the period rate cap, which states a maximum change in mortgage rate which can occur during an adjustment period from one year to the next. The model for this thesis uses a periodic cap of 1.00%, which means the fully indexed rate cannot change by more than 1.00% from one year to the next. The second rate cap is the lifetime cap, which states a maximum change in mortgage rate which can occur from the initial interest rate to any given period during the course of the loan. The model for this thesis uses a lifetime cap of 8.00%, which means the fully indexed rate cannot change by more than 8.00% from the initial rate for any payment during the length of the loan. A summary of the various features of the loan used for the model in this thesis can be seen within Table 3.

Loan Rate Features	
Initial CMT Rate	7.50%
ARM-CMT Margin	2.00%
Initial ARM Discount	1.00%
ARM Lifetime Increase Cap	8.00%
Minimum CMT Rate	1.00%
Maximum CMT Rate	16.00%
Periodic Cap	1.00%

Table 3: Rate Features of Model Loan

ARM Payments

The mortgage model determines a minimum monthly payment, $\mathbf{m_t}$, for the first month of each year based on the annual interest rate, $\mathbf{r_i}$, for the first month of that respective year. This is because adjustable rate mortgages only change their payment a maximum of once per year, based on the changes in the interest rate index during that respective year. This payment is provided in Equation 1.

$$m_t = \frac{P_{12*i} * \frac{r_i}{12}}{1 - \left(1 + \frac{r_i}{12}\right)^{-(T - 12*i)}} \tag{1}$$

Where:

m_t	*monthly payment for current month*
T	*total number of months in mortgage*
i	*current year {0,...,T}*
t	*current month {0,...,12T}*
r_i	*annual interest rate for first month of current year*
P_{12*i}	*principal remaining in first month of current year*

The current year for each month is calculated according to the operator in Equation 2.

$$i = \left\lfloor \frac{t}{12} \right\rfloor \tag{2}$$

The first monthly mortgage payment is made in month t=1, and the down payment is made in month t=0.

For model simplicity, it is assumed that the borrower makes the minimum monthly payment each month, with no additional payment beyond this minimum. The principal remaining for time period t, P_t, is calculated according to Equation 3.

$$P_t = P_{t-1} - l_t \tag{3}$$

Where:

P_t	*principal remaining in current month*
l_t	*principal portion of payment for current month*

The principal portion of payment for each month, l_t, is calculated according to Equation 4.

$$l_t = m_t - s_t \tag{4}$$

Where:

s_t *interest portion of payment for current month*

The interest portion of payment for each month, s_t, is calculated according to Equation 5.

$$s_t = r_t * P_{t-1} \tag{5}$$

Fixed-Rate Mortgage Parameters

FRM Rates

The mortgage contract rate is calculated separately for the FRM and the ARM, but is based on similar underlying financial instruments. Ideally, the ARM would be based on a short-term security such as the 1-year treasury and the FRM would be based on a long-term security such as the 30-year treasury. For simplicity of this model, the underlying rate used for both FRM and ARM is the index for a Constant Maturity Treasury of 1 year (CMT). The FRM contract rate is taken as the CMT rate plus the ARM margin of 2.00% plus an additional FRM-ARM spread which varies over time. The FRM-ARM spread is to account for the fact that the model bases the ARM on a 1-year CMT, while the FRM is a 30-year contract and does not always move in sync with the 1-year rates. Data for the 1-Year CMT, courtesy of the Federal Reserve, and data for the 1-Year ARM and 30-Year FRM data, courtesy of FHLMC (Freddie Mac), can be seen below in Figure 1.

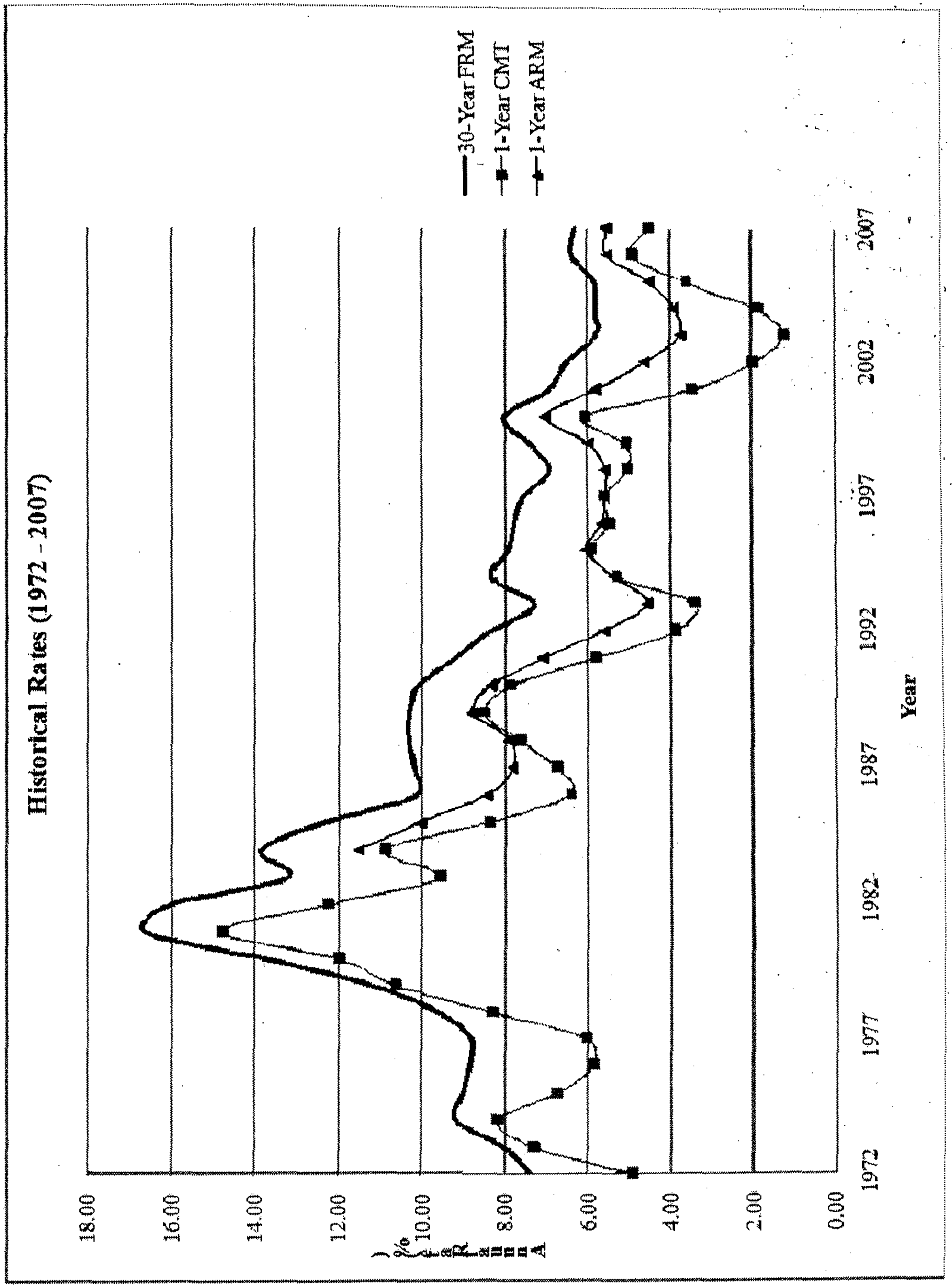

Figure 1: Historical Rates (1972 – 2007)

Source: 1-Year CMT data: Federal Reserve. 1-Year ARM and 30-Year FRM data: FHLMC (Freddie Mac)

The change in FRM-ARM spread for the model varies over time based on a discrete probability distribution because of this inconsistent spread which occurs in practice between the ARM and FRM rates. The distribution for this change was based on statistics calculated from monthly FHLMC data on 30-Year FRM and 1-Year ARM from the past 24 years. The summary statistics from this data can be seen in Table 4.

Statistic	Value
Mean	0.11%
Median	0.09%
Max	0.75%

Table 4: Change in FRM-ARM Spread Monthly Summary Statistics

The discrete probability distribution used in this model for the change in FRM-ARM spread, based on the above historical data, can be seen in Table 5.

FRM-ARM Spread Change	Probability
-0.7	0.20%
-0.6	0.30%
-0.5	0.50%
-0.4	1.00%
-0.3	5.00%
-0.2	10.00%
-0.1	20.00%
0	26.00%
0.1	20.00%
0.2	10.00%
0.3	5.00%
0.4	1.00%
0.5	0.50%
0.6	0.30%
0.7	0.20%
	100.00%

Table 5: Discrete Distribution for FRM-ARM Spread

FRM Payments

The calculations for the Fixed-Rate Mortgage are generally much simpler than the Adjustable-Rate Mortgage because the monthly mortgage payment is the same over the entire course of the mortgage. Specifically, the monthly payment, f_t, for a Fixed-Rate Mortgage is calculated according to the following equation.

$$f_t = \frac{P_{t-1} * \frac{k_t}{12}}{1 - \left(1 + \frac{k_t}{12}\right)^{-(T-t+1)}} \quad (6)$$

Where:

k_t *FRM annual rate*

CHAPTER 3: DECISION-MAKING PROCESS FOR REFINANCING

Transaction Costs

In order to switch to a FRM, the borrower will need to incur a potential prepayment penalty in addition to the settlement costs for obtaining the new FRM. The one-time prepayment penalty for each month, n_t, is calculated according to Equation 7.

$$n_t = y * P_t * \frac{5 - i}{5} \quad (7)$$

Where:

y *prepayment penalty rate*

In addition to the prepayment penalty, the borrower will also incur a one-time payments of closing costs, g_t,for opening up the new FRM. The closing costs payment is calculated according to Equation 8.

$$g_t = max\{a * P_t, \quad 2000\} \quad (8)$$

Where:

a *closing cost rate*

According to Freddie Mac, this closing cost rate (which includes the origination fee) is generally between 2% and 7% of the principal remaining on the loan. In this model, the closing cost rate is taken to be 2% of the principal remaining on the loan or $2,000, whichever is greater.

Expectations-Based Decision-Making

The borrower has the option to continue making payments on her current ARM, or switch to a FRM. With perfect information of future interest rates, this decision should be made based on the present value of future payments made under both scenarios, considering all transaction costs and future loan payments dictated by movements in the interest rate. Therefore, the borrower will switch to a FRM when the following equality holds true:

$$PV(ARM) > PV(FRM) + g_t + n_t \quad (9)$$

Where:

$PV(ARM)$	*present value of all future monthly payments under ARM scenario discounted at current FRM rate*
$PV(FRM)$	*present value of all future payments by switching to a FRM discounted at current FRM rate*

This decision is made on a period-by-period basis, and therefore disregards the potential of waiting to switch during a later period which may be the truly optimal strategy in terms of net present value.

Heuristic-Based Decision-Making

In practice, the refinancing decision is typically made based on a simple rule-of-thumb heuristic. Borrowers will decide to refinance their ARM to a FRM upon realization of a specific and predetermined reduction in annual rate, *h*, from the initial rate. The value of this required rate reduction has typically been discussed as 1%- 2% from the initial rate, although there is no industry-wide consensus on this value. Therefore, the borrower will switch to a FRM when the following equality holds true:

$$r_{i=0} - k_t \geq h \tag{10}$$

Where:

$r_{i=0}$	*initial ARM annual rate*
k_t	*current FRM annual contract rate*
h	*required spread between initial ARM annual rate a current FRM annual contract rate*

We performed this heuristic-driven process on the same model used above for expectations-based decision-making. For this process, the instruction to refinance is provided upon achieving a specified rate reduction, instead of present value calculations. At each time period, if the current interest rate for that period is less than the initial rate by a stated amount of percentage points, then the borrower chooses to refinance the mortgage and switch to a FRM. This required rate reduction was varied from 0.5% to 2.5%.

CHAPTER 4: RESULTS

Both models above, expectations-based decision-making and heuristic-based decision-making, were iterated 2000 times each using a Monte-Carlo simulation. Each iteration collected data on the net present value of both decision-making strategies utilized (heuristic-based and expectations-based) and the net present value of maintaining the ARM for the life of the mortgage (the baseline strategy). This simulation provided 2000 values of output for the CMT, the net present value of the baseline strategy, the net present value of the expectations-based strategy, and the net present value of the heuristic-based strategy. Distributions for these outputs can be seen in Appendix A.

A graph displaying the range of values and mean value for each of the strategies can be seen below in Figure 2. As this graph shows, each strategy provided a mean net present value below the baseline strategy. Furthermore, each strategy provided a maximum net present value no higher than and a minimum net present value lower than the baseline strategy. We therefore conclude that each strategy performs as well or better than the baseline strategy, as expected.

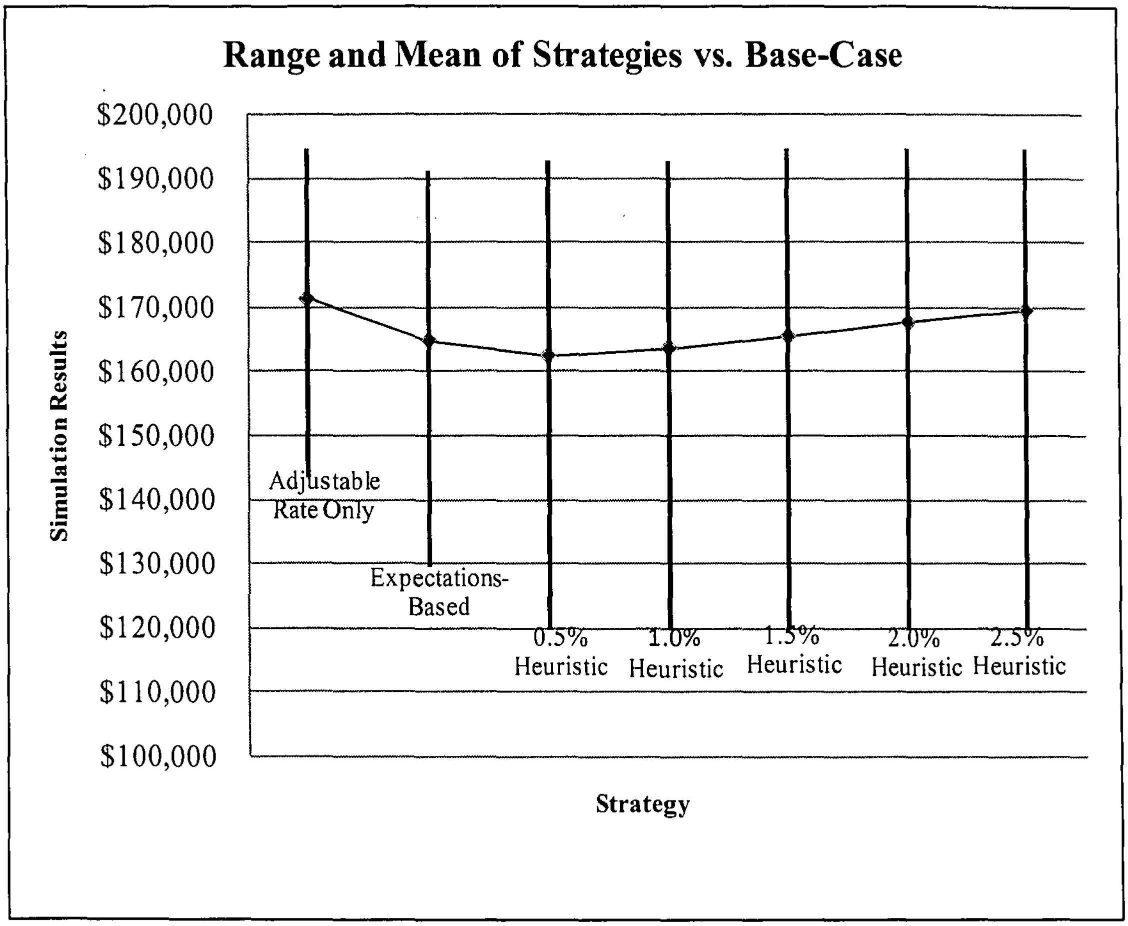

Figure 2: Range of Values and Mean Value for Each Strategy and Base-Case

For each iteration of the simulation, data was collected on the relative benefit of using the expectations-based strategy compared to the baseline strategy. This relative benefit was quantified as the ratio of the difference between the two net present values compared to the net present value of the baseline strategy. A graph of this data can be seen below in Figure 3. The expectations-based strategy generally performed better than the baseline strategy, as expected, with a mean improvement of 3.9% and a maximum improvement of 21.4%.

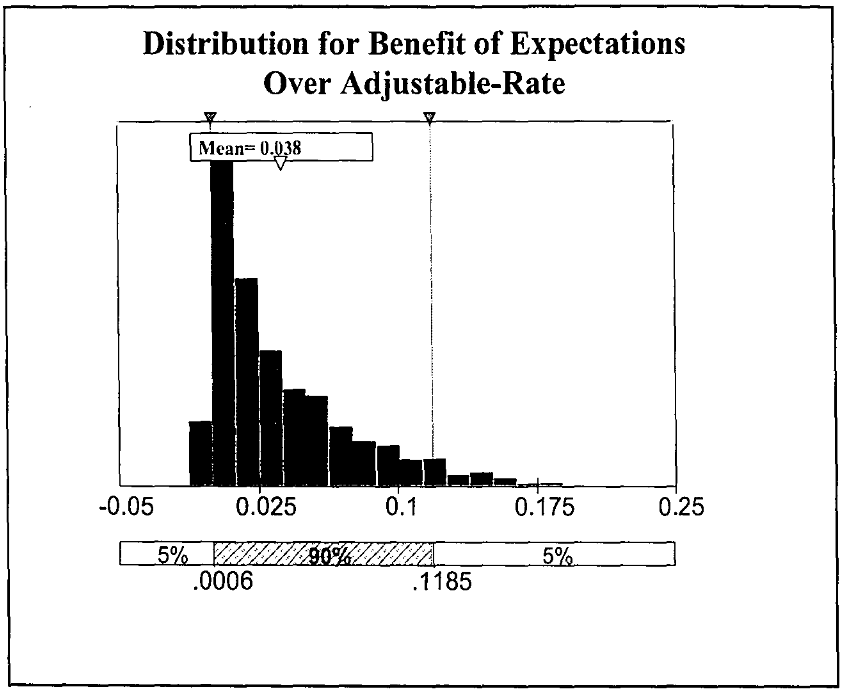

Figure 3: Distribution for Benefit of Expectations-Based Strategy to Baseline Case

For each iteration of the simulation, data was also collected on the relative benefit of using the expectations-based strategy compared to the 1.0% heuristic-based strategy. This relative benefit was quantified as the ratio of the difference between the two net present values compared to the net present value of the 1.0% heuristic-based strategy. A graph of this data can be seen below in Figure 4. Negative values in this figure represent times when the 1.0% heuristic-based strategy performed better than the expectations-based strategy. In fact, the mean of this ratio was -1.1%, indicating that the heuristic performed better than expectations-based strategy on average. This is because the expectations-based strategy is switching during the first period with a favorable difference in net present value from the baseline strategy, instead of waiting for the truly optimum period in the time horizon. This means that the expectations-based strategy, in some cases, is losing the benefit of waiting for interest rates to fall further, and choosing the first period to switch where the present value inequality holds true.

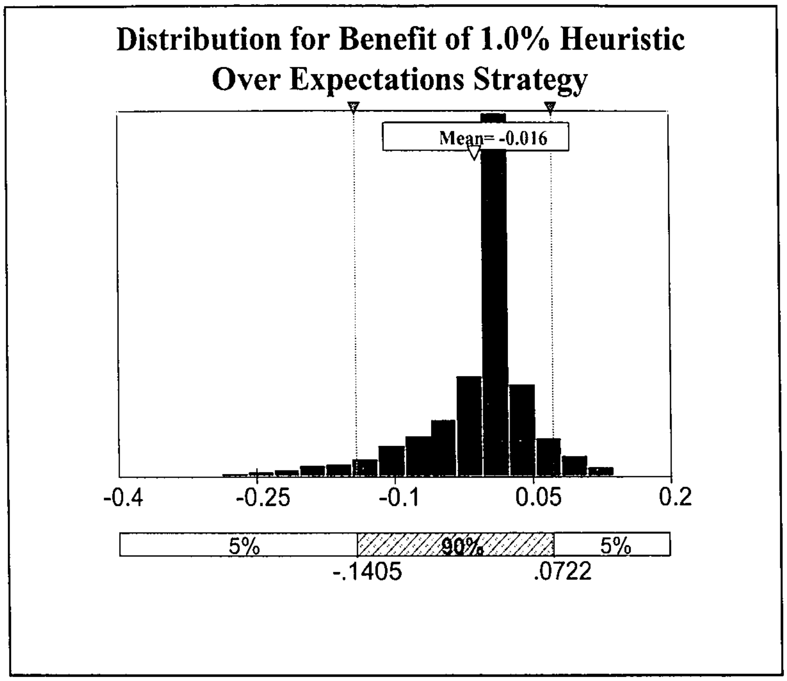

Figure 4: Distribution for Benefit of Expectations-Based Strategy to 1.0% Heuristic

The five heuristic-based strategies were compared to each other based on range and mean. The data from this comparison can be seen graphically as Figure 5 below. As the graph shows, the 0.5% heuristic-based strategy performs better than its counterparts based on mean and maximum values; the minimum value is essentially the same for all five strategies.

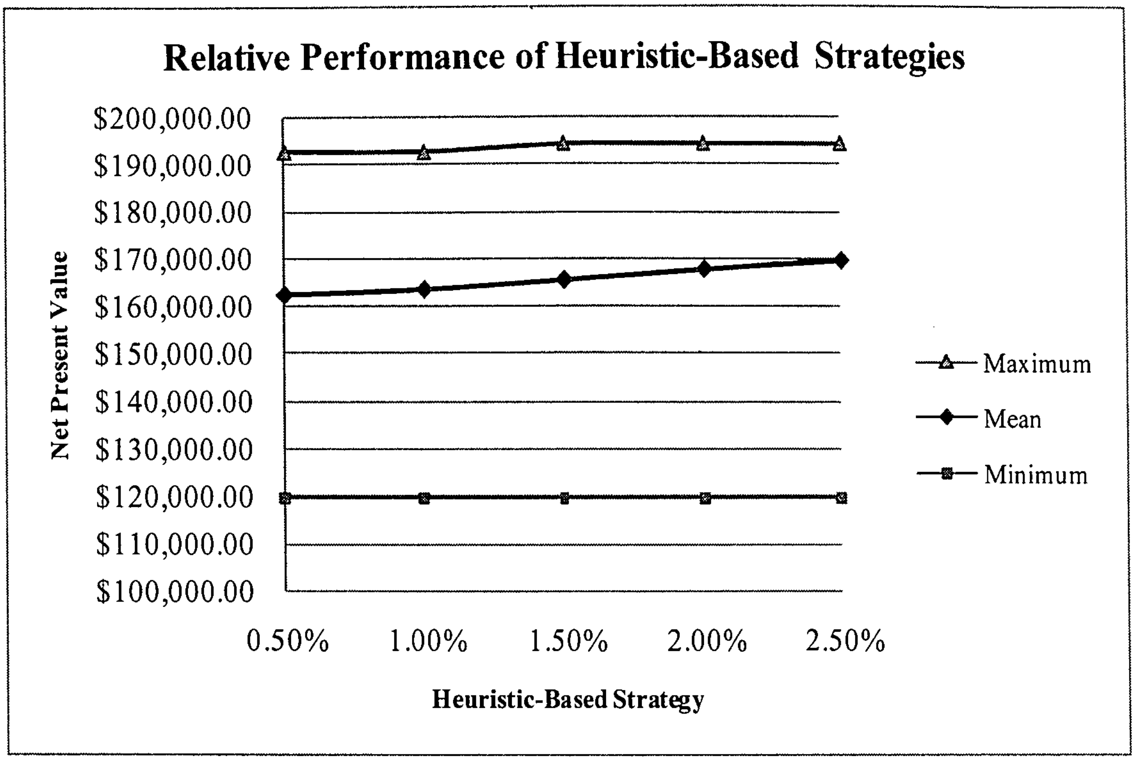

Figure 5: Relative Performance of Heuristic-Based Strategies

CONCLUSION

We have tested the relative benefit of maintaining an ARM for its lifetime versus using an expectations-based and a heuristics-based strategy for refinancing decision-making. We have shown that heuristics can provide benefit to the borrower on the basis of mean net present value, but can also cause higher payments in certain scenarios. This poses a problem to the borrower because he or she only has one opportunity to refinance, and is not guaranteed a benefit from refinancing based on any of the heuristics. Our numerical experiments suggest that under the conditions described in this thesis, a required rate reduction of 0.5% provides more benefit to the borrower than the other four rate reductions evaluated.

Moreover, we have shown that the expectations-based strategy discussed in this thesis does not provide better performance in terms of net present value than a heuristic-based strategy. This is because the expectations-based strategy is not waiting for the optimal period to switch, but instead switching at the first period which provides a benefit.

There are several possible extensions of this work which could prove useful and interesting. First, this model could be tested with historical interest rates from the past thirty years, instead of the randomly generated rates, to compare results. Second, the model could be extended to operate using market-driven interest rate expectations for the first few years and then switch to the randomly generated rates described in this thesis for the remainder of the time periods. Another possible extension would be converting the expectations-based strategy into a perfect-information strategy. In this sense, the strategy would evaluate the benefit of switching at all possible periods, and switch during the period which provides the most benefit over the base-case in terms of net present value. Finally, the model could include a finite set of possible mortgage lengths, i.e., 15 years, 20 years, 30 years, for refinancing.

REFERENCES

Follain, James R., and Tzang, Dan-Nein. "The Interest Rate Differential and Refinancing a Home Mortgage?' *The Appraisal Journal* 61 (1988), 243-251.

Follain, James R., Louis O. Scott, and Tai-Le Yang. "Microfoundations of a Mortgage Prepayment Function," *Journal of Real Estate Finance and Economics* 5 (1992), 197-217.

Nothafi, Frank, and George Wang. "Determinants of the ARM Share of National and Regional Lending," *Journal of Real Estate Finance and Economics* 5 (1992), 219-234.

APPENDIX A: SIMULATION DISTRIBUTIONS

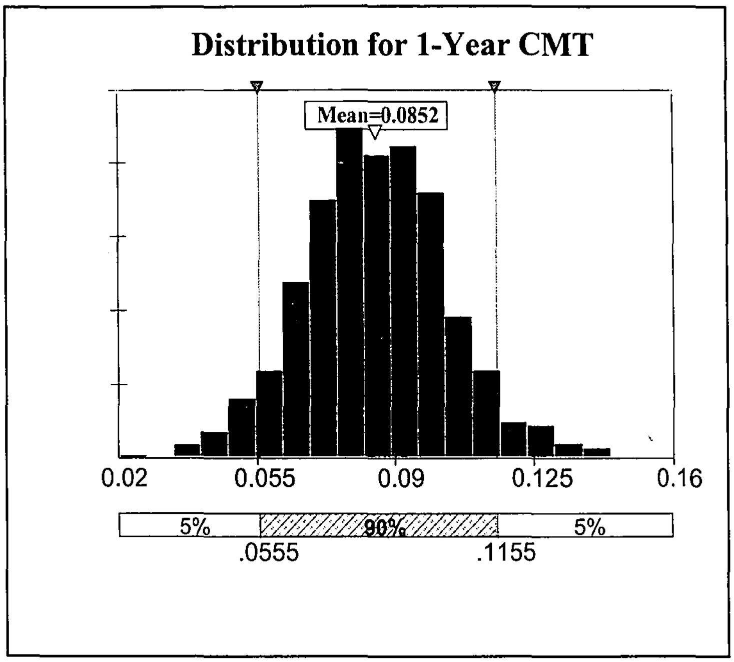

Figure 6: Distribution for 1-Year CMT

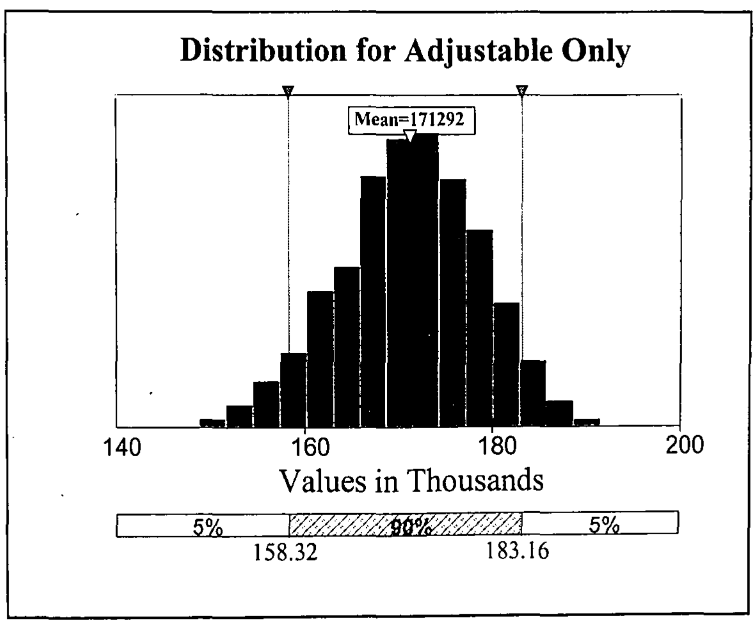

Figure 7: Distribution of Net Present Value for Baseline Strategy

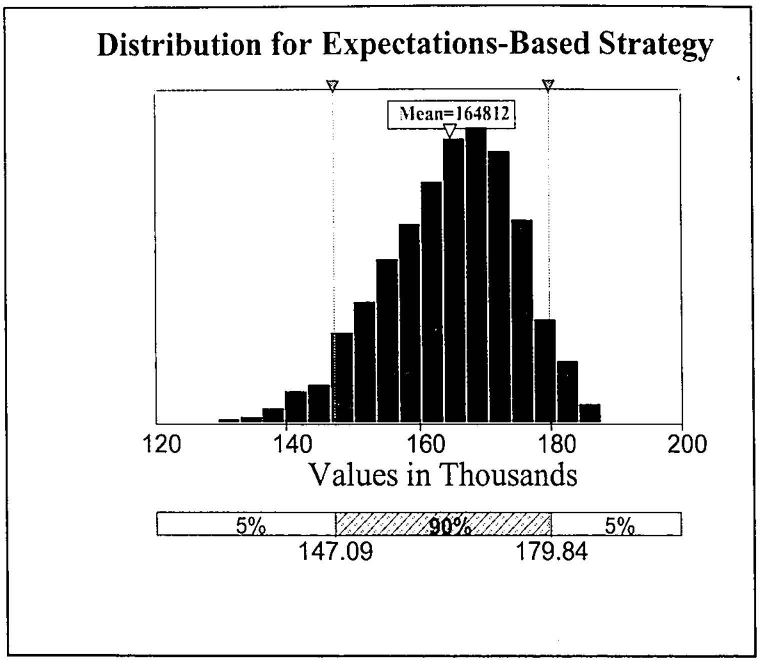

Figure 8: Distribution of Net Present Value for Expectations-Based Strategy

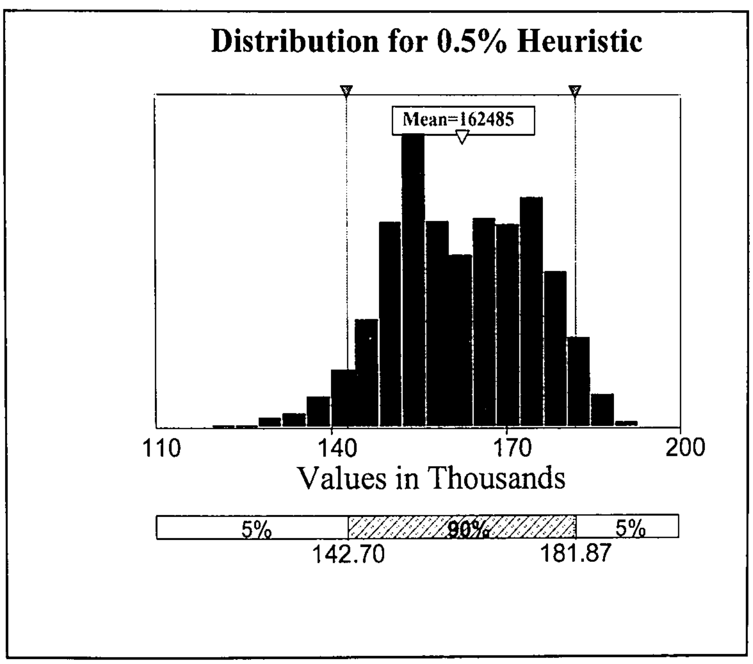

Figure 9: Distribution of Net Present Value for 0.5% Heuristic-Based Strategy

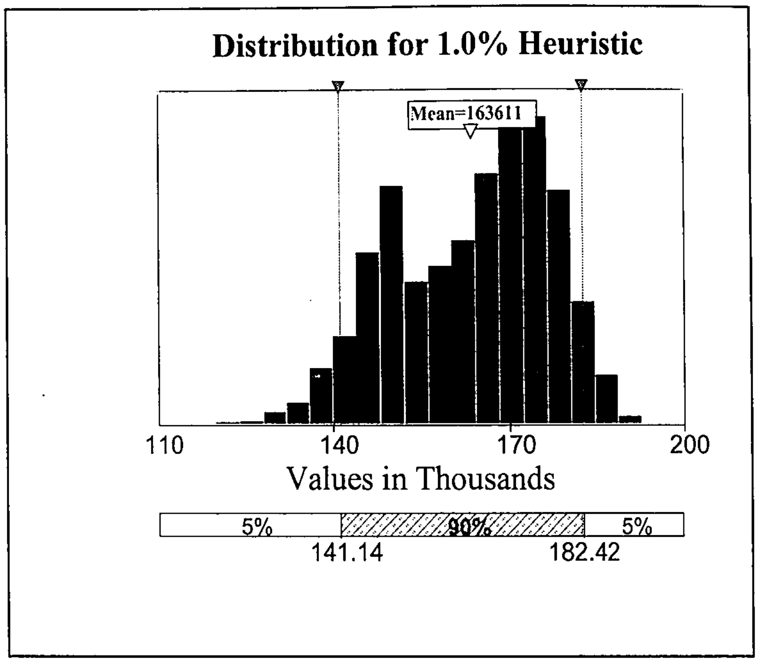

Figure 10: Distribution of Net Present Value for 1.0% Heuristic-Based Strategy

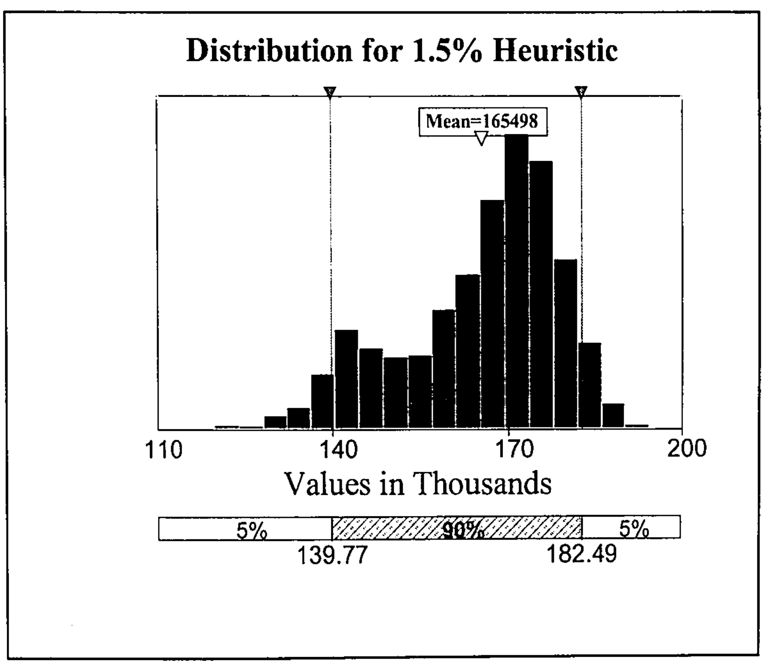

Figure 11: Distribution of Net Present Value for 1.5% Heuristic-Based Strategy

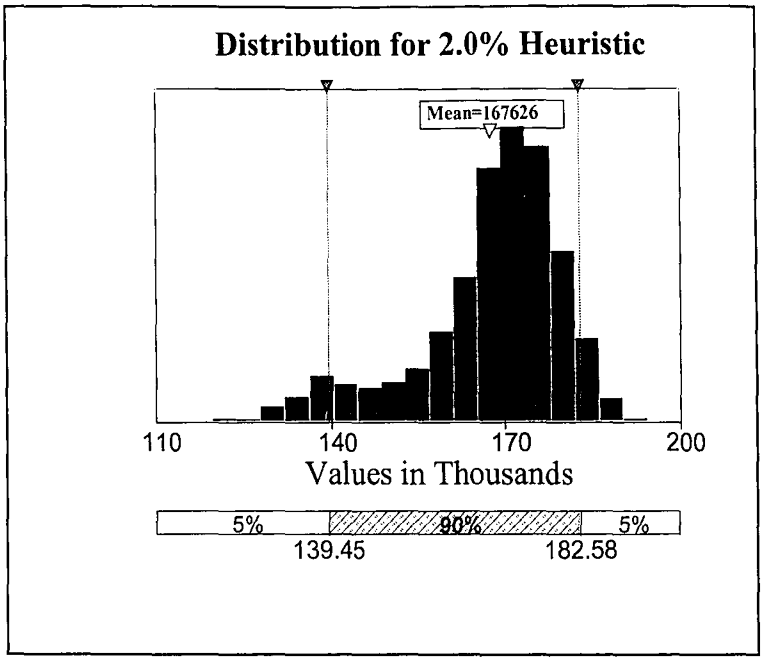

Figure 12: Distribution of Net Present Value for 2.0% Heuristic-Based Strategy

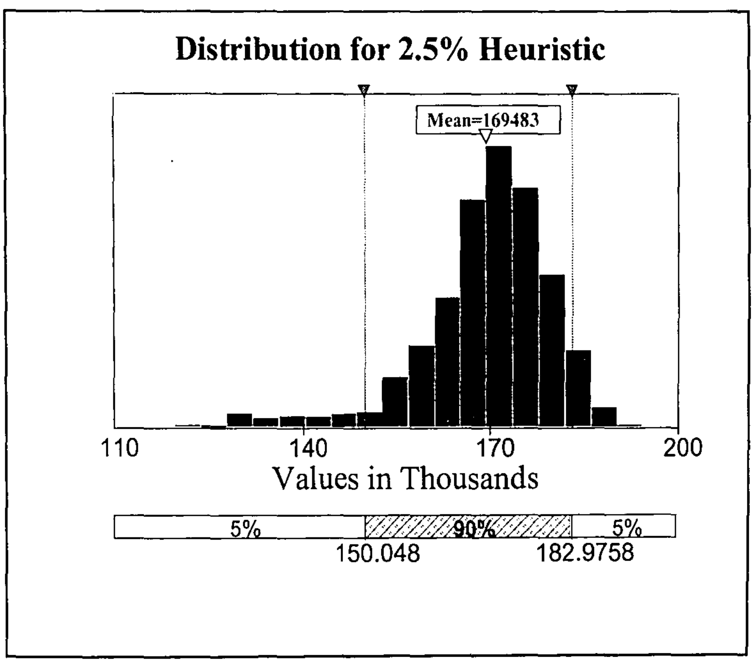

Figure 13: Distribution of Net Present Value for 2.5% Heuristic-Based Strategy

VITA

Joseph Curatolo II was born in 1984. He graduated in 2003 from High Technology High School in Lincroft, New Jersey. He received a Bachelor of Science in Integrated Business & Engineering in 2007 and a Bachelor of Science in Civil Engineering in 2008, both from Lehigh University. He was awarded a Presidential Scholarship from Lehigh University for the academic year 2007-2008, and plans to graduate in May 2008 with a Master of Science in Industrial Engineering.

END OF TITLE