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DYNAMIC SPENDING AND RISK-BASED SIMULATION IN RETIREMENT PLANNING

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ABSTRACT

This study employed the RISK simulation to estimate the net portfolio value of a long-term investment in a diversified asset allocation. The simulations take into consideration the risk associated with that investment as presented a number of possible investment scenarios in fixed income and equity securities. The possible set of portfolio weights for combinations of the different securities are considered in each simulation. The model constraint is that asset weights in the portfolio must add up to one. The simulations construct future scenarios by randomly choosing past scenarios and assigning higher probabilities to more recent years. Further, the estimated future value of the investment is then deflated with the deflation factor to determine the present value in today's Thai baht. For each simulated scenario, the model presents the risk associated with the investment – the value at risk (VaR) – which captures the maximum possible expected portfolio value. Finally, the paper further develops the portfolio optimization technique to determine optimal asset allocation in achieving the desired investment goal to assist retirees when planning their retirement funds by considering any risk associated with simulated scenarios.

Contribution/Originality: This study contributes to the existing literature by employing a risk-based model, known as the Monte Carlo simulation and portfolio optimization, to construct the optimal portfolio for retirement planning in Thailand.

1. INTRODUCTION

Retirement planning is a topic of current interest, particularly in a country with an ageing population such as Thailand. With the advent of medical technology and improved living conditions, the average life expectancy around the world continues to rise. Against this backdrop, longer lifespans have made retirement planning unprecedentedly important. In Thailand, the baby boom generation – those who were born during the postwar period of 1946 to 1964 – accounted for a quarter of the total Thai population in 2019. Nevertheless, despite increases in life longevity, many Thai boomers still struggle in their post-retirement lives. According to the Household Socio-Economic Survey 2019, an average boomer household[1] currently has a net worth of less than 170,000 Thai Baht in financial assets, excluding the value of their home equity. Considering the Thai boomers' financial situations in conjunction with the rising life expectancies, the roles of retirement planning and financial

[1]Defined as a household whose head is 55 years old and above using the Household Socio-Economic Survey conducted by the National Statistical Office, Thailand.

advice have proved to be crucial and inevitable parts for baby boomers, and eventually every Thai person, in preparing for an ageing society.

The common goal for retirees is to have enough money saved at retirement to support the desired living needs for life after retirement, with an additional number of years as a buffer. Other than the set amount of money that retirees have to save in advance, another crucial aspect to take into consideration is the level of confidence and risk associated with the retirement plan to ensure it will hold up under possible scenarios and assumptions that could affect their investment results. Once a person decides how much they need to save for retirement based on their needs and the risk associated with the investment, they can optimize their investment portfolio by allocating assets to different risks and returns patterns.

Recently, financial products have been increasingly developed and equipped with program-based simulations to proxy the possible investment scenarios that may be faced by investors in the future. Though such financial services are already in place and have been offered by financial institutions in Thailand, some people who are not accustomed to financial and statistical simulations may find retirement planning too complex. Hence, due to the abundance of choices presented, people can be overwhelmed with the investment advice on which will be the best one for them.

This research employed a risk-based model, known as the Monte Carlo simulation, to construct the optimal portfolio for retirement planning in Thailand. Each simulation represents a possible set of allocated investment weights of different securities where the sum of portfolio weights is equal to one. As suggested by a previous framework developed by Abuizam (2009), the model employed the Monte Carlo simulation technique to create sets of future investment scenarios with probability distributions randomly chosen from past scenarios and higher probability weights given to more recent years. The risk associated with the investment is also included in the simulations in terms of the value at risk, or VaR, which, in this paper, is defined as the lowest possible expected return of 5% in each investment scenario. This is to show the minimum portfolio value that an investor can achieve in each simulated scenario. It is also important to note that the estimated value of the investment is deflated using the inflation rate to determine terminal wealth in today's Thai baht amount.

Finally, according to Panyagometh (2013), the RISKOptimizer program by Palisade also provides a portfolio optimization tool to determine optimal investment allocation in meeting the investment objectives, i.e., retirement goal or terminal wealth that an investor desires to have at the end of the investment horizon. With the help of the RISKOptimizer tool, this paper can further develop optimal portfolio allocations using varying simulated investment scenarios through risk-based models to assist people in planning their retirement funds.

2. LITERATURE REVIEW.

Several pieces of literature have incorporated programming processes into retirement investment in which dynamic programming can be used in portfolio optimization, asset allocation or utility maximization of terminal wealth. Abuizam (2009) developed a risk-based model for retirement planning by employing the Monte Carlo simulations with the use of @RISK Simulation Software by Palisade. In the study, Treasury bonds, Treasury bills and equities were considered along with different damping factors to determine the estimated value of investments in today's dollar term in each scenario. Through the use of a bootstrapping simulation approach and the RISKOptimizer program, Panyagometh (2011) determined the optimal asset allocation of common equity, commodity and government bonds in the Thai market to achieve the target rate of returns by minimizing portfolio risks measured through standard deviation. Additionally, a more recent study by Panyagometh (2013) also employed the RISKOptimizer program with the Monte Carlo simulation and genetic algorithm-based optimization techniques to evaluate the efficiency of Dollar Cost Averaging (DCA) and the Value Average (VA) investment strategies for retirement, considering the investment horizon and terminal wealth target.

Moreover, there is useful previous research that has explored the optimal portfolio structures in order to achieve the maximum utility of terminal retirement wealth. Ho, Milevsky, & Robinson (1994) developed an analytical model incorporating mortality tables, rates of returns and a range of realistic values of wealth to determine portfolio optimization between risky securities and risk-free assets, particularly equities and treasury bills, by minimizing probabilities of failure to consume at the desired level over the course of their expected lifetime. The results show that portfolios with equities perform better than other portfolios constructed by conventional strategies. Milevsky, Ho, & Robinson (1997) continued their study and adopted the Monte Carlo simulation technique to determine contributing factors in retirement investment allocation. The results suggest that desired level of consumption, existing wealth, age and gender are key determinants of asset allocation that should be considered before planning an investment.

By adopting the Monte Carlo approach, Pye (1999, 2000) ran simulations to examine the sustainability of retirement and endowment fund planning. The studies found that conservation of withdrawal rates will sustain if the portfolio yields real expected returns of 8% and the standard deviation of the returns is 18%. Additionally, Pye (2001) examined withdrawal management that enables retirees to withdraw the lower of the previous amount (in the real terms) or the amortized portion of the portfolio value using periods of the retirement plan and required rate of return of the portfolio. Assuming that security returns are distributed normally with a hypothetical 9% mean real rate of return and an 18% standard deviation, Pye reports that a 4.5% real withdrawal rate would require that 17% of retirees reduce real withdrawals within 20 years. Furthermore, the 5% worst off retirees would need to reduce their withdrawals by at least 47%, even if the median portfolio value has approximately doubled.

Vora & McGinnis (2000) suggested that the optimal asset allocation should be 100% equity and gradually reallocated to bonds as the time of retirement approaches. Cooley, Hubbard, & Walz (2003) employed both the Monte Carlo simulation and an overlapping historic period calculation to determine portfolio returns and highlight the importance of dominated stock for sustainability over longer investment periods. Booth (2004) also used the Monte Carlo simulation to analyze retirement targets and asset allocation using log-normal distribution. A function of the equity allocation is used to determine the minimum wealth required to achieve the retirement target. The empirical result illustrates that the longer the time horizon is lengthened, the more the equities are optimized.

Stout & John (2006) and Stout (2008) found that portfolio performance and remaining life expectancy contribute to an increase in overall periodic withdrawal rates of portfolios. In addition, their studies suggest that general recommendations for a retirement investment portfolio should consist of 50% to 75% of equity to total assets in the portfolio. Similar findings were achieved by Spitzer (2008) and Hughen, Laatsch, & Klein (2002). In the study, Spitzer (2008) concluded that increases in periodic withdrawal adjustment can also decrease the risk of running out of money. Meanwhile, Hughen et al. (2002) suggested that retirement portfolios should consist of a 100% equity allocation as it yields higher terminal wealth and also suggested that distributions from a retirement portfolio can be increased through a dynamic asset allocation strategy using the cost of lifetime annuitization as a benchmark. Cong & Oosterlee (2016) determined the optimal portfolio by proposing the forward and backward approaches, considering a multi-stage strategy and local quadratic optimization, respectively. Through the use of the Monte Carlo simulation approach with numerical experiments, satisfactory results can be obtained. Forsyth & Vetzal (2019) used the multi-period criteria to find optimal asset allocation of an investor saving for retirement by considering the bond index and stock index. The research compares the optimal deterministic strategies based on minimizing the variance of cumulative terminal wealth and adaptive strategies based on time-consistent mean-variance and quadratic shortfall. The result shows that adaptive strategies with a parameter of constant risk aversion outperform deterministic strategies. Estrada (2016) studied the retirement asset allocation of international evidence from 19 countries and suggested that the most effective portfolio allocation can consist of 100% equity or 60% equity and 40% bonds. Recent research from Estrada (2020) proposed closed-form solutions with an empirical base case, sensitivity analysis and Monte Carlo simulations to generate the target retirement portfolio. Regarding the accumulation and the withdrawal periods as well as the backward assessment, the relevant variables were considered at the beginning and the individual investors can start saving early to create their target portfolios.

3. METHOD

The data used in the paper consists of the historical annual returns for each of the financial assets, including Thai government bonds, the Treasury bill and the value-weighted equity index as reported by the Thai Bond Market Association (ThaiBMA) and the Stock Exchange of Thailand (SET) over the period from 2002 to 2019. The corresponding headline inflation rates were obtained from Bloomberg.

As an experimental exercise, this paper considered a retirement plan for a fixed number of years. It was assumed that a 30-year-old investor who plans to retire at age 60 should contribute 30,000 baht at the beginning of each of the next 30 years into a retirement fund, which comprises of three securities, including stocks, short-term Thai government bonds and long-term Thai government bonds. Then, the weights of the fixed portfolio were chosen for each security in order to maximize expected portfolio value, which were calculated in terms of present value. In consideration of the downside risk, the value at risk (VaR) methods were applied and defined as the fifth percentile of probability distribution.

The modelling simulations are based on the framework developed by Abuizam (2009) and summarized as follows.

First, the historical annual returns on stocks and corporate bonds, including a three-month Treasury bill, ten-year Thai government bond yields, SET Total Return Index with dividend reinvestment and corresponding inflation rates were selected as portfolio assets. The sample period used in the paper is from 2002 to 2019. The historical data was collected from ThaiBMA, SET and Bloomberg, with summary statistics presented in Appendix 1.

Then, in order to simulate possible scenarios that an investor may face in the future, 15 trials of investment weights were constructed where each set of weights should add up to 1. Appendix 2 presents all trial weights used throughout the paper.

Next, the scenario approach was used to generate future values from historical returns and inflation factors. Each historical year was considered as a possible scenario, where each scenario specified the returns and inflation factor for that year. Then, the model will randomly choose one of these scenarios for future years and use a weight associated with each scenario by giving a greater likelihood to more recent years. That is, the highest weight of one will be assigned to the most recent year, 2019. After that, the damping factor, calculated by multiplying the weight from next year, will be assigned to the preceding year. The probability distribution for a damping factor is presented in Appendix 3.

In consideration of the present value concept, the deflation factor was calculated. For the first year, the deflation factor is equal to one divided by the inflation factor for the first year. For the following years, the deflation factors are equal to one divided by the product of the inflation factor for the first year, and so on. The final cash value in calculated in today's Thai baht term using the deflator factor.

To calculate terminal wealth or final cash value, we considered the initial investment of 30,000 being invested using the trial investment weights for the randomly selected scenario year (30 years of work). The starting cash amount for the second year is equal to the ending cash amount for the first year plus the additional 30,000, assuming the starting cash amount grows in each year. In order to estimate the value of the investment at the end of the investment period in today's dollars, the final cash amount at the end of the 30 years is multiplied by the deflator for year 30, which is similar to the net present value calculation, except that the inflation rates are not constant throughout the 30 years.

Finally, the research methodology model employed the Monte Carlo simulation from the @RISK simulation program with 1,000 realizations (iterations) to simulate 30 scenarios, one for each year in an investment horizon. As such, each scenario in the model was randomly selected based on the probability distribution where a higher probability would be assigned to recent years, indicating that they have a greater chance of being chosen. Then, the model ran 1,000 iterations for each simulation and tested 15 simulations, one for each trial investment weight. Finally, those 15 simulations were repeated for each damping factor.

Table 1. Mean of Final Cash (today's Thai Baht) and Value at Risk for 0.92 and 0.93 Damping Factors

Sim. No.	Trial Invest. Weights			DF = 0.92		DF = 0.93	
	SET TRI	3M Bond	10Y Bond	Mean	VAR 5%	Mean	VAR 5%
1	0.9	0.05	0.05	5,052,300.15	4,833,361.84	5,031,630.18	4,845,213.84
2	0.8	0.1	0.1	4,521,903.95	4,324,440.26	4,509,611.17	4,346,621.82
3	0.7	0.15	0.15	4,002,296.71	3,817,040.06	3,989,581.88	3,835,381.99
4	0.6	0.2	0.2	3,479,836.81	3,331,084.96	3,464,216.92	3,340,581.35
5	0.5	0.25	0.25	2,954,095.05	2,826,697.00	2,940,956.54	2,832,290.91
6	0.4	0.3	0.3	2,431,840.43	2,337,157.11	2,418,730.53	2,335,809.83
7	0.3	0.35	0.35	1,907,760.75	1,833,258.38	1,898,286.21	1,832,491.84
8	0.2	0.4	0.4	1,380,794.02	1,329,829.95	1,378,108.08	1,333,406.82
9	0.1	0.45	0.45	858,751.28	832,463	855,622.16	831,941
10	0	0.5	0.5	334,857.15	328,274	333,901.93	328,080
11	0.5	0.3	0.2	2,948,441.98	2,834,892.76	2,940,645.65	2,832,802.71
12	0.5	0.2	0.3	2,955,991.99	2,838,830.92	2,945,290.72	2,843,340.89
13	0.4	0.2	0.4	2,429,083.23	2,328,443.79	2,414,974.55	2,330,240.22
14	0.4	0.2	0.4	2,435,707.44	2,335,040.58	2,421,787.01	2,421,787.01
15	0.25	0.5	0.25	1,640,212.23	1,576,338.00	1,634,950.72	1,580,814.07

Table 2. Mean of Final Cash (today's Thai Baht) and Value at Risk for 0.94 and 0.95 Damping Factors.

Sim. No.	Trial Invest. Weights			DF = 0.94		DF = 0.95	
	SET TRI	3M Bond	10Y Bond	Mean	VAR 5%	Mean	VAR 5%
1	0.9	0.05	0.05	5,012,968.09	4,845,191.05	5,170,077.23	4,998,918.67
2	0.8	0.1	0.1	4,497,209.28	4,346,773.95	4,634,725.60	4,485,033.61
3	0.7	0.15	0.15	3,970,218.97	3,830,959.78	4,096,791.00	3,963,783.38
4	0.6	0.2	0.2	3,453,957.85	3,342,408.82	3,559,161.63	3,446,005.25
5	0.5	0.25	0.25	2,935,170.47	2,838,401.85	3,019,712.65	2,922,520.91
6	0.4	0.3	0.3	2,413,556.08	2,342,815.36	2,482,683.19	2,411,959.15
7	0.3	0.35	0.35	1,896,101.89	1,843,182.86	1,948,860.60	1,891,355.83
8	0.2	0.4	0.4	1,373,583.86	1,335,955.66	1,411,696.02	1,372,396.83
9	0.1	0.45	0.45	853,906.73	832,387	874,954.33	854,977
10	0	0.5	0.5	333,755.66	328,709	338,784.69	333,766
11	0.5	0.3	0.2	2,935,182.76	2,843,495.43	3,021,033.59	2,921,057.85
12	0.5	0.2	0.3	2,934,742.88	2,841,289.71	3,024,164.37	2,931,703.59
13	0.4	0.2	0.4	2,408,706.60	2,334,876.47	2,482,133.70	2,407,235.36
14	0.4	0.2	0.4	2,417,754.48	2,336,319.74	2,485,306.93	2,412,146.29
15	0.25	0.5	0.25	1,629,971.83	1,583,840.92	1,674,791.54	1,629,134.72

Table 3. Mean of Final Cash (today's Thai Baht) and Value at Risk for 0.96 and 0.97 Damping Factors.

Sim. No.	Trial Invest. Weights			DF = 0.96		DF = 0.97	
	SET TRI	3M Bond	10Y Bond	Mean	VAR 5%	Mean	VAR 5%
1	0.9	0.05	0.05	5,128,960.75	4,996,131.73	5,097,381.84	5,000,491.32
2	0.8	0.1	0.1	4,594,099.26	4,473,942.78	4,568,850.00	4,488,711.57
3	0.7	0.15	0.15	4,060,681.36	3,957,340.62	4,039,181.38	3,967,876.83
4	0.6	0.2	0.2	3,529,157.45	3,440,247.65	3,509,087.85	3,440,661.01
5	0.5	0.25	0.25	2,997,676.03	2,923,476.45	2,980,544.83	2,922,662.18
6	0.4	0.3	0.3	2,465,769.63	2,404,904.00	2,452,344.17	2,406,110.56
7	0.3	0.35	0.35	1,935,083.36	1,890,310.07	1,922,042.65	1,889,175.78
8	0.2	0.4	0.4	1,402,001.92	1,371,454.29	1,393,407.50	1,371,108.16
9	0.1	0.45	0.45	869,734.46	852,827	864,771.16	852,546
10	0	0.5	0.5	337,232.53	333,249	336,334.15	333,280
11	0.5	0.3	0.2	2,997,388.25	2,919,681.31	2,979,745.97	2,922,784.41
12	0.5	0.2	0.3	3,000,312.35	2,927,975.17	2,984,642.91	2,929,363.20
13	0.4	0.2	0.4	2,461,423.07	2,401,954.37	2,447,917.90	2,405,518.42
14	0.4	0.2	0.4	2,469,797.34	2,407,991.60	2,454,730.18	2,408,841.68
15	0.25	0.5	0.25	1,662,652.50	1,623,036.55	1,653,770.92	1,625,322.69

4. RESULTS

The simulation results computed by the Palisade @RISK simulations for the 15-trial investment weights are presented in Tables 1, 2, 3 and 4. Table 1 summarizes the mean final cash in today's Thai baht together with the corresponding value at 5% risk for 0.92 and 0.93 damping factors; Table 2 shows the results for 0.94 and 0.95 damping factors; Table 3 shows the results for 0.96 and 0.97 damping factors; and Table 4 shows the results for 0.98 and 0.99 damping factors.

Table 4. Mean of Final Cash (today's Thai Baht) and Value at Risk for 0.98 and 0.99 Damping Factors.

Sim. No.	Trial Invest. Weights			DF = 0.98		DF = 0.99	
	SET TRI	3M Bond	10Y Bond	Mean	VAR 5%	Mean	VAR 5%
1	0.9	0.05	0.05	5,072,589.98	5,006,232.26	5,075,627.13	5,033,902.32
2	0.8	0.1	0.1	4,546,663.12	4,493,226.31	4,549,520.58	4,511,624.34
3	0.7	0.15	0.15	4,020,416.07	3,969,762.33	4,023,359.41	3,990,368.11
4	0.6	0.2	0.2	3,495,414.96	3,452,999.88	3,496,328.60	3,466,955.04
5	0.5	0.25	0.25	2,967,415.05	2,929,278.33	2,969,969.23	2,947,429.33
6	0.4	0.3	0.3	2,441,552.21	2,412,719.26	2,443,014.24	2,425,430.57
7	0.3	0.35	0.35	1,915,445.77	1,893,126.34	1,915,554.94	1,901,894.34
8	0.2	0.4	0.4	1,388,685.40	1,374,368.80	1,389,236.23	1,379,880.20
9	0.1	0.45	0.45	861,956.39	854,145.00	862,257.95	856,686.00
10	0	0.5	0.5	335,547.04	333,536.00	335,640.47	334,402.00
11	0.5	0.3	0.2	2,967,208.37	2,931,433.19	2,967,139.26	2,943,587.18
12	0.5	0.2	0.3	2,970,720.61	2,933,112.21	2,970,659.30	2,945,492.21
13	0.4	0.2	0.4	2,438,142.16	2,408,281.10	2,439,316.34	2,421,518.24
14	0.4	0.2	0.4	2,446,043.48	2,416,286.29	2,445,201.07	2,425,646.86
15	0.25	0.5	0.25	1,647,176.79	1,627,895.63	1,647,963.29	1,635,860.18

5. DISCUSSION

As different damping factors indicate different probability distributions in the scenario selection, the results from different simulation scenarios are expected to differ. The results from the simulations show that the first trial investment weight, which heavily invests in stocks, yield the highest final investment value in all cases of varying damping factors. This is mainly attributable to a higher expected return of stock returns relative to debt securities (see Appendix 2).

The phenomenon is consistent with the financial concept of "high risk, high expected return". Furthermore, the scenario that yields the highest final investment is when a damping factor of 0.95 is used, with a mean final cash in present value terms of 5,170,077.23 Thai baht, and its 5% VaR is 4,998,918.67 Thai baht. This means that if a person decides today to invest 30,000 Thai baht per year for 30 years until retirement in a portfolio consisting of 90% stocks in the SET, 5% in a three-month Thai government treasury bill and 5% in a ten-year Thai government bond, he or she will end up with a value very close to the simulated value shown in the above table depending on the damping factor chosen in the scenario. In a case where the chosen damping factor is 0.95, its VaR value means that there is a 5% chance that the retiree will end up with no more than 4,998,918.67 Thai baht in his or her retirement fund, compared to an expected value of 5,170,077.23 Thai baht.

The @RISK program also produces summary statistics and graphs for a simulation output spreadsheet. Hence, to further discuss the distribution of simulated results, the histogram of the mean final cash value from the first simulation that yields the highest final investment value (a portfolio which has 90% of invested stocks in the SET, 5% invested in a three-month Thai government treasury bill and 5% invested in a ten-year Thai government bond when a damping factor of 0.95 is chosen) is shown in Figure 1.

The results presented in the experimental case are consistent with the historical data collected during a sample period from 2002 to 2019. That is, the chosen investment weights in stocks, a three-month Thai government treasury bill and a ten-year Thai government bond that yield the highest final cash amount in present value terms of 95%, 5% and 5%, respectively, conform to the expected returns and standard deviations of those three selected assets within the sample period. Stock investments with the highest investment weight, represented in the SET Total Return Index with dividends reinvested, are shown to have the highest expected return among the three assets with a 12.57% average annual expected return from 2002 to 2019. In terms of volatility, the average standard deviation of stock investment in the Thai stock market during the sample period is 30.12% annually, which is moderate compared to a 40.56% and 25.76% average annual standard deviation of the three-month Thai government bill and ten-year Thai government bond, respectively. The remaining 10% of investment weights are equally shared between the three-month Thai government bill and ten-year Thai government bond, despite the negative average annual returns during the sample period of -2.26% and -5.26%, respectively. The negative returns are due to the decreasing trend in interest rates attributable to expansionary monetary policy in Thailand in recent years. Appendix 1 and Appendix 2 show historical data from 2002 to 2019, as well as expected returns and standard deviations of assets from 2002 to 2019.

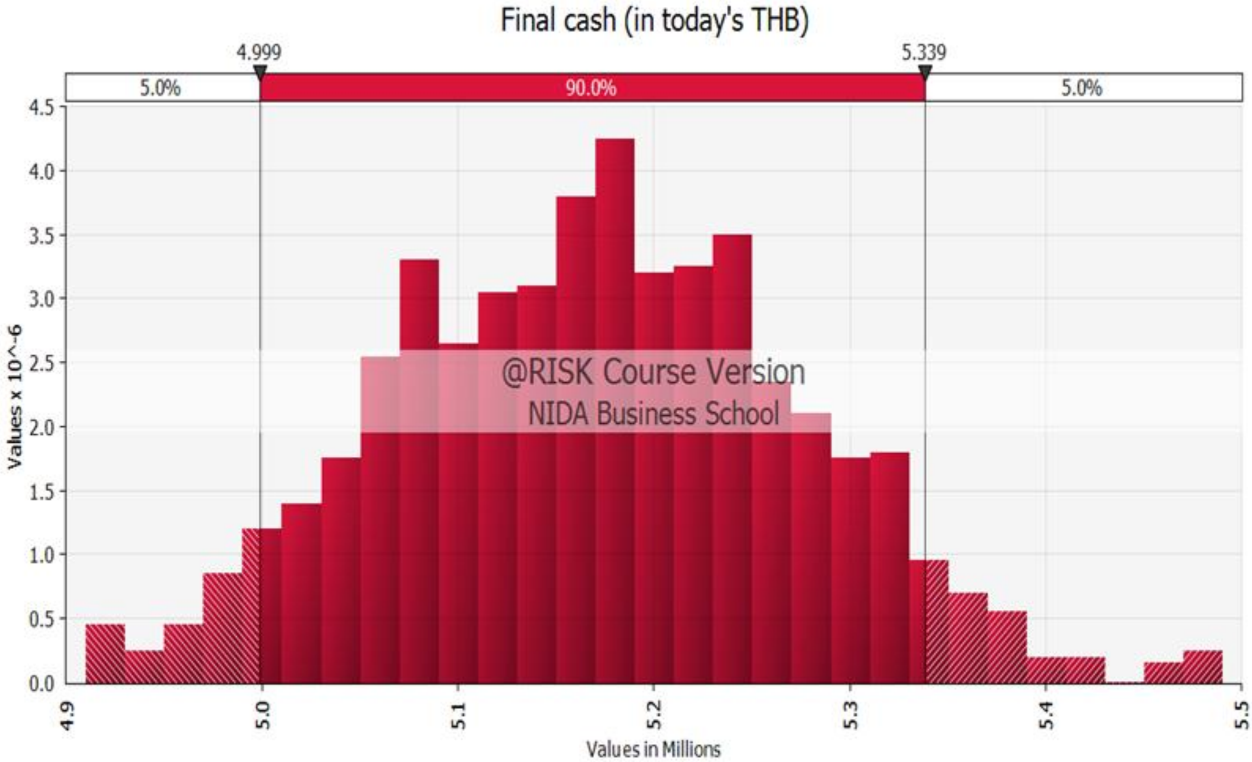

Figure 1. Final cash (today's Thai Baht) histogram distribution for simulation #1 (SET: 90% 3M-Bond: 5% and 10Y-Bond: 5%) and a 0.95 damping factor.

As displayed in Figure 1, the histogram of the final cash, when the damping factor of 0.95 is largely a normal distribution, indicates that most values cluster around the mean. With the probability being normally distributed, the data variation is not quite as large, which is reflected in the narrow difference between a minimum final cash of 4,876,833.21 Thai baht and a maximum final cash of 5,543,773.09 Thai baht.

Having determined the probability of fulfilling the retirement goal as well as associated downside risks reflected by the VaR concept using the Monte Carlo simulation technique, there is a key consideration left unanswered in retirement planning – portfolio optimization. To answer this, we used the example of the investor in the previous section with a further assumption that he or she has set an investment target of 5,000,000 Thai baht. One benefit of the @RISK simulation is that it provides a risk optimization tool to determine the best allocation of the investment portfolio to maximize the final value of the retirement goal. With the use of the RISKOptimizer, the paper further developed the optimal asset allocation, in the case of Thailand, with the investment objectives (or model constraints) of minimizing the portfolio standard deviation over the course of investment horizon, the mean of the final cash value in today's Thai baht must not be lower than 5,000,000 Thai baht, and the sum of all three invested assets – stocks in the SET, three-month Thai government Treasury bill, and ten-year Thai government bond – must be equal to one. Based on the Monte Carlo simulation approach, the RISKOptimizer simulates scenarios using the probability distributions of various outcomes occurring in order to determine the best asset weights that satisfy all the model constraints. Note that, throughout the optimization process, the probability distribution used in the simulation model is also defined by the damping factors as used in the previous part. The optimal asset weights in achieving 5,000,000 Thai baht using different damping factors are presented in Table 5.

As shown in Table 5, it is clearly seen that in each case the highest weights are given to stock investment with the weights almost equal to 100%. This is mainly due to a considerably higher expected return and lower standard deviation of stocks compared with Thai government bonds (Appendix 2).

Table 5. Optimal asset allocation for an investor with a 30-year investment goal of 5,000,000 THB final cash in retirement portfolio with varying damping factor scenarios.

Optimization Goal: Final Cash = 5,000,0000 in today's THB			
Damping Factor	**Asset Weighting**		
	SET TRI	**3M Bond**	**10Year Bond**
0.99	90.38%	9.62%	0.00%
0.98	89.55%	10.45%	0.00%
0.97	92.05%	3.97%	3.97%
0.96	92.86%	7.14%	0.00%
0.95	87.54%	12.46%	0.00%
0.94	92.09%	7.91%	0.00%
0.93	89.58%	10.42%	0.00%
0.92	88.94%	9.48%	1.58%

6. CONCLUSION

Several pieces of literature and financial planners have adopted the Monte Carlo simulation approach in financial planning and retirement investment as its probability simulation can be used to approximate scenarios that are likely to happen in the future. Furthermore, with a model design that is capable of handling input changes and model iterations, financial planners can benefit greatly from the use of the Monte Carlo simulation to determine the effects of changes in any parameter that could alter the results of investment value. In this paper, some parameters were held constant for simplicity purposes, such as the number of years to retirement, the amount of annual contribution, and other samples of input parameters; hence, any changes made within the model will change the course of the output results.

Using the @RISK simulation by Palisade helps financial planners and people planning for their retirement to determine the probability of meeting the specific investment goal at a certain time over the investment horizon in the future. This is achieved through the advanced Monte Carlo simulation approach provided by the @RISK program that provides a risk-analysis tool in a spreadsheet model. The final investment results are computed through the generation of thousands of possible scenarios in the future that a person's investment course would look like over the years until the year of retirement. Therefore, simulated scenarios not only show what is likely happen to the chosen investment plan but also how likely it is to happen with the probability distribution concept provided. Finally, the paper further utilized the RISKOptimizer tool to determine optimal asset allocation in meeting investment goals. As such, a risk-based model for retirement planning using the Monte Carlo simulation and @RISK technique can allow people to plan their retirement fund and help them to forecast how much they will have in their retirement fund considering each investment scenario and how much and how should they allocate their funds to each asset to achieve their investment target while considering any risk associated with their investment plan.

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Appendix 1. Historical Data from 2002 to 2019.

Year	SET TRI	3M Bond	10Y Bond	Inflation Rate
2002	1,202.67	1.71	3.64	1.66
2003	2,722.29	1.06	4.94	1.75
2004	2,432.59	1.85	4.85	2.97
2005	2,705.51	3.88	5.47	5.78
2006	2,698.53	4.93	5.44	3.57
2007	3,545.11	3.19	4.94	3.09
2008	1,946.38	2.10	2.69	0.44
2009	3,335.04	1.14	4.34	3.51
2010	4,929.32	1.97	3.77	3.06
2011	5,111.29	3.14	3.35	3.53
2012	7,183.05	2.76	3.52	3.63
2013	6,922.33	2.31	3.98	1.67
2014	8,245.87	2.05	2.83	0.60
2015	7,319.63	1.50	2.51	0.01
2016	9,065.29	1.50	2.67	1.13
2017	10,633.50	1.19	2.54	0.78
2018	9,774.16	1.61	2.51	0.36
2019	10,193.52	1.17	1.49	0.87

Source: The data from Stock Exchange of Thailand, Bond Market Association and Bank of Thailand.

Appendix 2. Expected Return and Standard Deviation of Assets in a Sample Period from 2002 to 2019.

	SET TRI	3M Bond	10Y Bond
E[R]	12.57%	-2.26%	-5.26%
SD	30.12%	40.56%	25.76%

Appendix 3. Trial Investment Weights.

	Portfolio Allocation		
Simulation #	**SET TRI**	**3M Bond**	**10Y Bond**
1	0.9	0.05	0.05
2	0.8	0.1	0.1
3	0.7	0.15	0.15
4	0.6	0.2	0.2
5	0.5	0.25	0.25
6	0.4	0.3	0.3
7	0.3	0.35	0.35
8	0.2	0.4	0.4
9	0.1	0.45	0.45
10	0	0.5	0.5
11	0.5	0.3	0.2
12	0.5	0.2	0.3
13	0.4	0.4	0.2
14	0.4	0.2	0.4
15	0.25	0.5	0.25