

# **Mathematical models and simulations in Excel: the case of the Marion Investment Company**

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## **ABSTRACT**

The Marion Financial Group case illustrates how the application of models and simulations can be used in personal financial planning. By working through the case, students will learn to assess core concepts of mathematical models and simulations, such as “what-if” analysis, expected value evaluation, and outcome assessment.

Keywords: Mathematical models, simulation, what-if analysis

## **INTRODUCTION**

Mathematical models use a system of mathematical relationships and expressions to represent problems. Simulations allow decision makers to learn about a real system by experimenting with mathematical models that represent that system. Typical simulators allow decision makers to assign specific values to control variables and then use random number generators to assign probabilistic inputs. Decision makers can then assess the outcomes of various sets of inputs (Anderson, et al., 2001).

Previous studies have presented various financial modeling tactics and algorithms (Tian, Benkrid, 2010). However, there are relatively few resources intended to provide hands-on experience for students engaged in learning basic financial simulator development and assessment. The models and simulators presented in this case is designed to introduce students to model and simulator creation, use, and assessment. In addition, the case is intended to demonstrate how simulators that use probabilistic inputs may provide different outcomes than simpler models that use only control variables.

This case assumes that students have basic ability in Microsoft Excel. Students should be able to input simple mathematical expressions, interpret and create nested IF functions, and use the FV and RAND functions.

## **LEARNING OBJECTIVES**

1. Students will be able to use Excel spreadsheets to create mathematical models and simulations.
2. Students will be able to use simulations to perform what-if analysis.
3. Students will be able to use simulations to perform risk analysis and evaluate alternatives.

## **OVERVIEW**

Welcome to the Marion Investment Company (MIC). MIC specializes in long-term personal retirement planning and wealth management. MIC specializes in helping families achieve financial security.

Typically, MIC seeks clients with above-average financial savvy. However, as a result of the economic downturn that began in 2008, MIC began to target the large market of individuals and families with relatively little knowledge of personal finances or investing. Company research and interviews with top partners and salespeople indicate that the investment decisions of clients with little to no investing experience are often strongly influenced by simple demonstrations of various investment strategies and their expected outcomes. As a result, the company has developed a set of Microsoft Excel worksheets that are intended to be tools for salespeople to use during sales calls to customers. The worksheets allow salespeople to

demonstrate to customers how various dollar amounts, invested at various levels of expected return (and risk) accumulate wealth over time.

Assume that you are a recent hire at MIC, and that part of your training involves learning the new simulation tool. Once you have mastered the tool, you should be able to do the following:

- 1) Show customers the expected return on simple investment models. Such models assume constant returns over long periods of time.
- 2) Show customers the expected returns on more complex investment simulations. Such models assume that investment returns will vary from year to year.

The simulator tool created by MIC, and a tutorial (workbench) intended to familiarize you with the simulator, are available from the website listed in Appendix A. Please download the workbench and the simulator now, and proceed through the instructions in the workbench.

## TEACHING NOTES AND SOLUTIONS TO QUESTIONS

1a) \$588,356.89

1b) \$566,621.18

1c) \$936,264.05

1d) \$450,263.65

2a) age 32

2b) age 36

3a) age 55

3b) \$449,830

4a) \$267,634

4b)  $\$449,830 - \$267,634 = \$182,196$

5a) \$234,631

5b) The formula in cell B14 should be: `=AVERAGE(F14:AX14)` The average return should be 5%

5c) To create this model, do the following:

- 1) Enter 1200 into cell E22
- 2) Enter 1200 into cell E24
- 3) Enter `=$B$14` into cell F21
- 4) Copy cell F

- 5) 21 to cells G21 through AX21 (G21:AX21)
- 6) Enter -8 into cells J21, O21, T21, Y21, AD21, AI21, AN21, AS21, and AX21
- 7) Copy cell E22 to cells F22 through AX22 (F22:AX22)
- 8) Enter =E24\*F21 into cell F23
- 9) Enter = E24+F22+F23 into cell F24
- 10) Copy the values in cells F23 and F24 into the range G23 to AX24 (G23:AX24)

5d) According to model 2a, if you invest in the relatively riskier portfolio that has mostly high years (an 8% gain) but also some low years (an 8% loss), you will have \$234,631 at age 65. If you invest in the relatively safe portfolio, you will have \$145, 904 at age 65. In fact, after age 30, the relatively risky portfolio (Model 2A) has a better return each year, even after significant losses, then the relatively safe portfolio (Model 2B).

- 6a) Students should run the simulation 10 times and put the results into Table 1.
- 6b) Students should calculate the mean value from Table 1.
- 6c) ADVANCED question– Instructors can ask students to calculate the standard deviation of their returns. Also, you can ask questions such as “About what percent of the time will you have a return greater than \$x” or “About what percent of the time would you have achieved a return greater than you would have had in the relatively safe portfolio (Model 2B)?” Also, students may be asked for the best-case and worst-case scenarios based on the outcomes of their simulation runs. (Note: Each student should have different best-case and worst-case scenarios!)

- 7) To create Model 4:
  - A) Enter =RAND() into cell F36
  - B) Enter =IF(F36<0.05,-0.2,IF(F36<0.15,-0.15,IF(F36<0.9,0.07,0.15))) into cell F37
  - C) copy the formula from cell F37 to cells G37 through AS37 (G37:AS37)
  - D) Enter \$1200 in cell E38
  - E) copy cell E38 from cell F38 to cell N38 (F38:N38)
  - F) Enter \$2400 in cell O38
  - G) copy cell O38 from cell P38 to cell X38 (P38:X38)
  - H) Enter \$3600 in cell Y38
  - I) copy cell Y38 from cell Z38 to cell AH38 (Z38:AH38)
  - J) Enter \$4500 in cell AI38
  - K) copy cell AI38 from cell AJ38 to cell AN38 (AJ38:AN38)
  - L) Enter =RAND() in cell F36
  - M) Copy cell F36 from cell G36 to cell AS36 (G36:AS36)
  - N) Enter \$1200 in cell E40
  - O) Enter =E40\*F36 into cell F39 (
  - P) Enter =E40+F38+F39 into cell F40

Q) Copy the values in cells F39 and F40 into the range G39 to AS40 (G39:AS40)

7a) The formula to execute the rule for returns (as entered into cell F37 by students) should be one of the following (the formulas are logically equivalent):

=IF(F36<0.05,-0.2,IF(F36<0.15,-0.15,IF(F36<0.9,0.07,0.15)))

OR

=IF(F36>0.95,-0.2,IF(F36>0.85,-0.15,IF(F36>0.10,0.07,0.15)))

OR

=IF(F36<0.10,0.15,IF(F36<0.85,0.07,IF(F36<0.95,-.15,-0.20)))

OR

=IF(F36>0.90,0.15,IF(F36>0.15,0.07,IF(F36>0.05,-.15,-0.20)))

7b) Students should enter the values of their simulations into Table 2

7c) Students should report the mean of the numbers reported in table 2.

ADVANCED question– Instructors can ask students to calculate the standard deviation of their returns. Also, you can ask questions such as “About what percent of the time will you have a return greater than \$x” or “About what percent of the time would you have achieved a return greater than you would have had in the relatively safe portfolio (Model 2B)?” Also, students may be asked for the best-case and worst-case scenarios based on the outcomes of their simulation runs. (Note: Each student should have different best-case and worst-case scenarios!)

## REFERENCES

Anderson, David R., Sweeney, Dennis J., Williams, Thomas A., Camm, Jeffery D., Martin, R. Kipp (2011). *An Introduction to Management Science: Quantitative Approaches to Decision Making* (13<sup>th</sup> ed.). Mason, Ohio: Cengage

Tian, Xiang; Benkrid, Khaled (2010) High-Performance Quasi-Monte Carlo Financial Simulation: FPGA vs. GPP vs. GPU. *ACM Transactions on Reconfigurable Technology and Systems*, 3(4), Article No. 26

## APPENDIX A

The student workbook and Excel file associated with this case can be downloaded for free from the website:

[www.joehasley.com](http://www.joehasley.com)