



Markowitz Portfolio Learning Design in Financial Mathematics with Technology-Based Stock Investment Simulation Practice

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Abstract

In an era of global economic uncertainty, mastering the concept of portfolio management is important for students in preparing themselves to face the challenges of the financial world. This study aims to design financial mathematics learning by integrating Markowitz's portfolio theory and technology-based stock investment simulation practices. The approach used includes the use of digital platforms to obtain historical stock data and stock market simulations for virtual investment practices. The results of the study indicate that the use of this method can improve students' understanding of the concepts of diversification, expected returns, and risk management in investment portfolios. With an interactive and practical approach, students can gain direct experience in building an optimal portfolio based on the Markowitz mean-variance model and implementing it in stock investment simulations. This study makes a significant contribution to the development of students' financial literacy by utilizing digital technology effectively.

Keywords: Portfolio, financial mathematics, stock investment simulation, markowitz.

1. Introduction

In the modern economic era full of uncertainty, a good understanding of investment and portfolio management is a very important skill. The Markowitz portfolio is one of the models used to help investors maximize returns by considering the level of acceptable risk (Cunningham, 2024). However, this concept is often considered difficult to understand by students, especially in the context of learning financial mathematics at the secondary and tertiary levels. Therefore, a learning approach is needed that is able to integrate theory with real practice, so that students can understand the concept more deeply.

Previous research has shown that the use of technology in learning can improve students' understanding of complex concepts in financial mathematics (Vodenska, 2016). Digital simulations and online platforms allow students to learn portfolio theory interactively and dynamically. However, most studies still focus on the use of technology in general and have not specifically examined how technology can be used to facilitate learning Markowitz portfolio theory.

On the other hand, direct practice in stock investment has been shown to improve students' practical skills and financial literacy. Stock market simulations allow students to experience firsthand how to make investment decisions, monitor portfolio performance, and manage risk (Rodiyah, 2019). However, many simulation programs currently available are not integrated with financial mathematics curricula, so students may have difficulty connecting theory to practice.

This study aims to fill this gap by proposing a learning design that integrates Markowitz's portfolio theory with technology-based stock investment simulation practices. This approach is expected to provide a more comprehensive learning experience, which not only improves students' theoretical understanding but also their practical skills in managing investment portfolios.

The main problem raised in this study is how to make the Markowitz portfolio concept more understandable and relevant to students in a real-world context. In addition, this study also seeks to explore how the use of digital media and investment simulations can increase students' interest and motivation in studying financial mathematics.

The purpose of this study is to design and implement a learning model that combines theory and practice in portfolio management. By using digital media and investment simulations, students are expected to be able to understand the basic concepts in Markowitz's portfolio theory, such as diversification, expected return, and risk, and be able to apply these concepts in investment decision making.

This research is expected to provide significant contributions to the development of financial mathematics learning methods. By integrating Markowitz's portfolio theory with stock investment simulation practices, students can gain skills that are relevant to the needs of the financial workforce. In addition, this research is also expected to improve students' financial literacy, which is an important aspect in facing global economic challenges.

In the context of education, the use of technology in learning has become one of the main trends in recent years. However, it is important to ensure that the technology used truly supports the achievement of learning objectives and is not just an additional tool that is less effective. Therefore, this study will also evaluate the effectiveness of the learning media used, including digital simulations and portfolio management applications.

The usefulness of this research includes several aspects. First, for educational institutions, the results of this study can be used as a basis for developing a financial mathematics curriculum that is more relevant to the needs of students. Second, for teachers, this research can provide guidance in designing and implementing learning that integrates theory and practice. Third, for students, this research can improve their understanding of portfolio management and prepare them to face challenges in the workplace.

2. Literature Review

2.1. Financial Mathematics

Financial mathematics is a branch of mathematics used to analyze and solve financial problems, such as compound interest, present value, and investment management. In practice, financial mathematics covers a variety of concepts relevant to everyday life, including interest calculations, amortization, and cash flow analysis. The ability to understand these concepts is essential for students in facing global economic challenges (Yang, 2017).

In learning, financial mathematics provides a foundation for students to understand investment management and financial decision making. With a good understanding of the time value of money, students can evaluate various investment options and calculate the returns and risks involved. This allows them to make wiser decisions in managing their personal and professional finances (Hapsari et al., 2024).

In addition, financial mathematics also plays an important role in developing financial literacy. Good financial literacy allows individuals to manage their finances effectively, reduce the risk of excessive debt, and prepare for a more stable financial future (Apriliani, 2024).

2.2. Markowitz Portfolio Theory

Markowitz portfolio theory, first introduced by Harry Markowitz in 1952, is one of the basic models in managing investment portfolios. This theory emphasizes the importance of diversification in reducing investment risk. Diversification means allocating funds to various types of assets to reduce the risk of losses that may occur due to market fluctuations (Muthohiroh, 2021).

The main concept in this theory is that investors should consider a combination of assets that provide maximum expected returns with an acceptable level of risk. By using the covariance and variance matrices of asset returns, this theory allows investors to build an efficient portfolio, known as the Efficient Frontier (Okwaro, 2021).

In an educational context, Markowitz portfolio theory can be an effective tool for teaching students about risk management and investment decision making. By understanding how to calculate expected returns and portfolio risk, students can learn how to manage their own investment portfolios more effectively. In addition, the use of digital simulations in learning can make it easier for students to understand these complex concepts more practically.

2.3. Technology-Based Stock Portfolio Learning Media

The use of technology in learning has become a major trend in the world of education. Digital media can facilitate more interactive and engaging learning, especially in the field of financial mathematics which is often considered difficult by students. Digital platforms such as stock market simulations, portfolio management applications, and online courses can be used to improve students' understanding of investment concepts and portfolio management (Khurana, 2023).

Stock market simulations allow students to learn about investing in a safe and controlled environment. Students can make investment decisions based on real market data and monitor their portfolio performance in real time (Marriot et al., 2015; Pichop, 2024). This experience can provide students with deeper insights into how the stock market functions and how investment decisions affect portfolio performance.

In addition, the use of digital media also allows for more flexible and adaptive learning. Students can access learning materials anytime and anywhere, according to their needs and learning pace. This is especially important in the context of learning financial mathematics, which requires a deep understanding of various concepts and analysis techniques.

The use of digital media in learning financial mathematics can also increase students' motivation and interest in learning the topic. By utilizing technology that is familiar to their daily lives, students can feel more involved in the learning process and more motivated to understand the concepts taught.

3. Materials and Methods

3.1. Materials

This study uses various digital learning resources available online, such as stock market simulations and portfolio management applications. Some of the platforms used include investment simulation applications, Learning Management Systems (LMS), and financial data analysis software. In addition, additional teaching materials in the form of modules and learning videos are prepared to strengthen students' understanding of the Markowitz portfolio concept.

The learning materials are designed to cover basic concepts of financial mathematics, portfolio theory, and stock investment practices. This material is tailored to the needs of students with diverse educational backgrounds, so that it can be easily accessed and understood.

3.2. Methods

This study implements a stock portfolio learning method for students using stock investment simulation practices. Students will be introduced to the basic concepts of the Markowitz portfolio through theoretical learning first. After that, they will practice directly using a digital simulation platform to create an investment portfolio.

In this simulation practice, students will select various stocks for their portfolio, monitor investment performance periodically, and conduct risk and return analysis of the portfolios they build. This approach is expected to improve students' understanding of portfolio theory and provide practical experience in managing stock investments.

4. Results and Discussion

4.1. Markowitz Portfolio Model

The Markowitz Model calculation theory, developed by Harry Markowitz in 1952, is the basis of modern portfolio theory and focuses on managing risk and return in investment. This model introduces the concept of diversification as a strategy to reduce portfolio risk (Leković, 2021). Investors can achieve an optimal portfolio by combining various assets, where the risk associated with an individual investment is offset by the performance of other assets in the same portfolio. The calculation of the optimal portfolio in the Markowitz model can be done in several stages:

1. Calculating daily returns for each stock (Islam and Sultana, 2015):

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}} \quad (1)$$

where

- $R_{i,t}$: daily return for stock i at time t
- $P_{i,t}$: the closing price of stock i at time t
- $P_{i,t-1}$: the closing price of stock i at time $t - 1$

2. Calculate the average return for each stock

$$\mu_i = \frac{1}{T} \sum_{t=1}^T R_{i,t} \quad (2)$$

where

- μ_i : average stock return i
- T : number of time periods (number of days)

3. Calculating standard deviation (Sigma) for each stock

$$\sigma_i = \sqrt{\frac{1}{T} \sum_{t=1}^T (R_{i,t} - \mu_i)^2} \quad (3)$$

where

- σ_i : standard deviation of stock returns i

4. Calculating the covariance between two stocks

$$Cov(R_i, R_j) = \frac{1}{T} \sum_{t=1}^T (R_{i,t} - \mu_i) (R_{j,t} - \mu_j) \quad (4)$$

where

R_i, R_j : return from shares i and j
 μ_i and μ_j : average stock return i and j

5. Calculating portfolio variance

$$\sigma_p^2 = \frac{1}{T} \sum_{i=1}^N w_i^2 \sigma_i^2 + \sum_{i=1}^N \sum_{j \neq i}^N w_i w_j Cov(R_i R_j) \quad (5)$$

where

σ_p^2 : variance of the portfolio
 w_i : weight of stock i in the portfolio
 N : number of stocks in a portfolio

6. Calculating the Ratio (Sharpe Ratio)

$$Ratio = \frac{\mu_p - r_f}{\sigma_i} \quad (6)$$

where

μ_p : average portfolio return
 r_f : risk-free rate of return (expected return)
 σ_i : portfolio standard deviation

4.2. Stock Investment Simulation Platform

1) Yahoo Finance is one of the popular platforms for searching for historical stock data. To obtain historical data, users can follow these steps:

- Visit the Yahoo Finance website (<https://finance.yahoo.com>).
- Search for the desired stock symbol in the search field, as seen in Figure 1.
- Click the "Historical Data" tab in the menu as seen in Figure 2 and Figure 3.
- Set the desired data time range (for example, the last year).
- Click "Download" to download the file in CSV format that can be used for further analysis.

Yahoo Finance provides historical data that includes closing prices, trading volumes, and other data relevant to portfolio analysis. This historical data is very important for students and researchers who want to analyze stock price movements over a certain period of time.

Yahoo Finance allows users to download this data in CSV (Comma Separated Values) format, which can be opened with software such as Microsoft Excel or Google Sheets for further analysis. The data obtained includes opening prices, closing prices, highest prices, lowest prices, and daily trading volumes. This allows students to calculate the daily or monthly returns required in the Markowitz portfolio model.

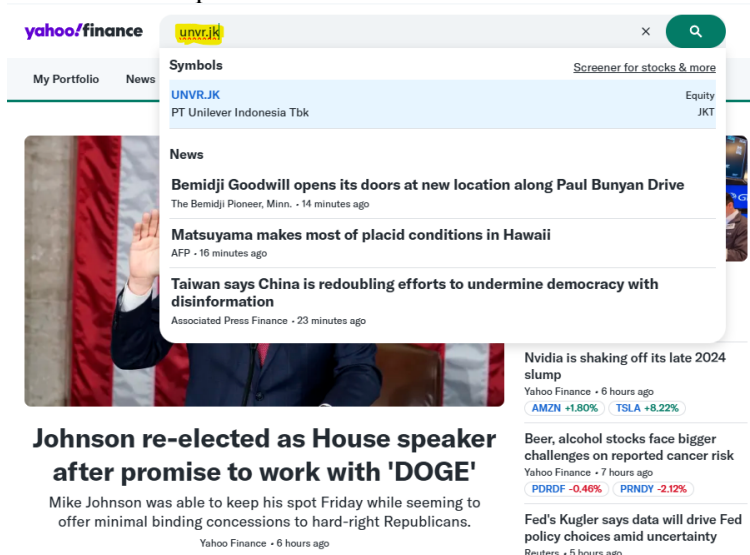


Figure 1: Stock data search view on yahoo finance

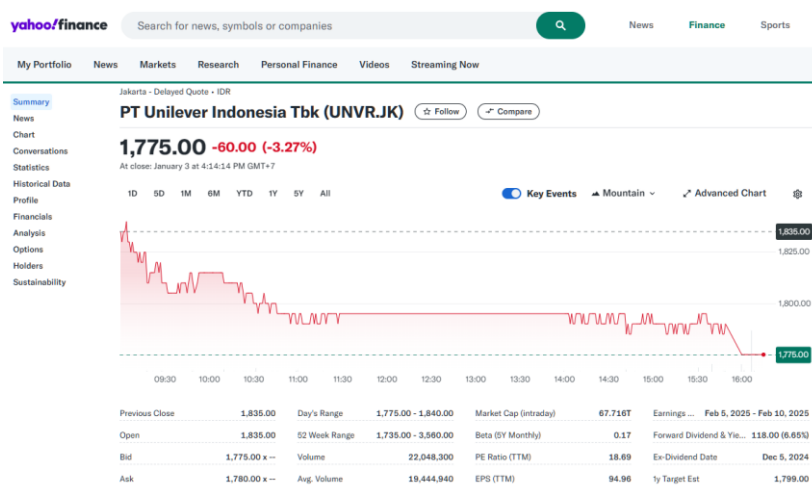


Figure 2: Summary of selected stock data

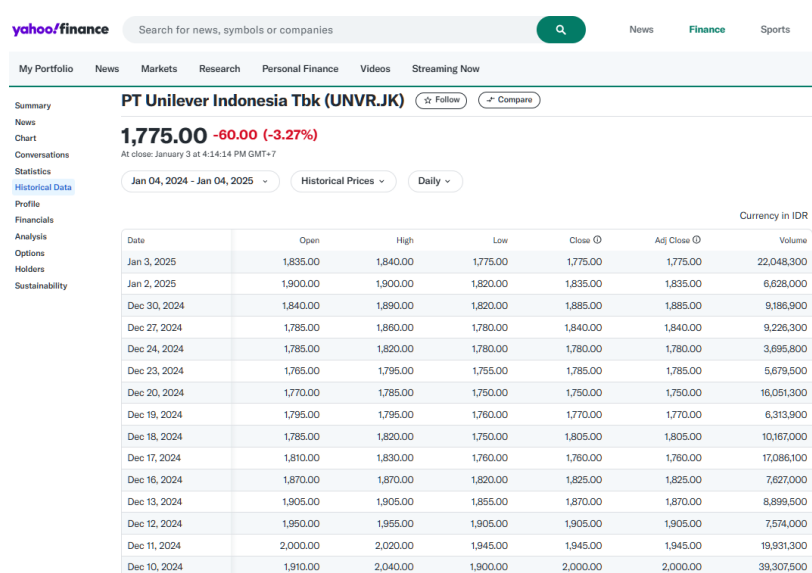


Figure 3: Historical data of selected stocks

2) Investopedia Simulator is a stock investment simulation platform that allows users to perform virtual trading in a realistic environment. This platform is designed to provide a learning experience for students and beginners in the world of investment. How Investopedia Simulator works:

- Users register an account on the Investopedia Simulator.
- After registering, users get virtual capital that can be used to buy and sell stocks, an example of the virtual capital display can be seen in Figure 4.
- Users can select stocks from major stock exchanges and make transactions like in a real stock market.
- This simulator provides analysis tools that allow users to monitor the performance of their portfolios.

To implement the results of the optimal portfolio calculation based on Markowitz's theory:

- Enter the calculated stock weights into the simulator.
- Make stock purchases according to the predetermined weights.
- Monitor portfolio performance periodically and make adjustments if necessary.

Investopedia Simulator provides valuable practical experience in understanding the concept of investment and portfolio management, while honing investment decision-making skills. Students can allocate virtual funds according to the calculated optimal portfolio weights. They can buy stocks based on predetermined proportions and monitor portfolio performance periodically, making adjustments if necessary. This provides hands-on experience in managing investments without any real financial risk.

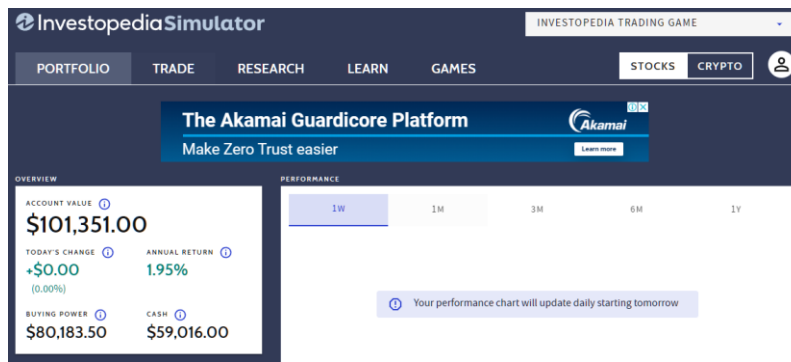


Figure 4: Virtual capital display for stock investment simulation

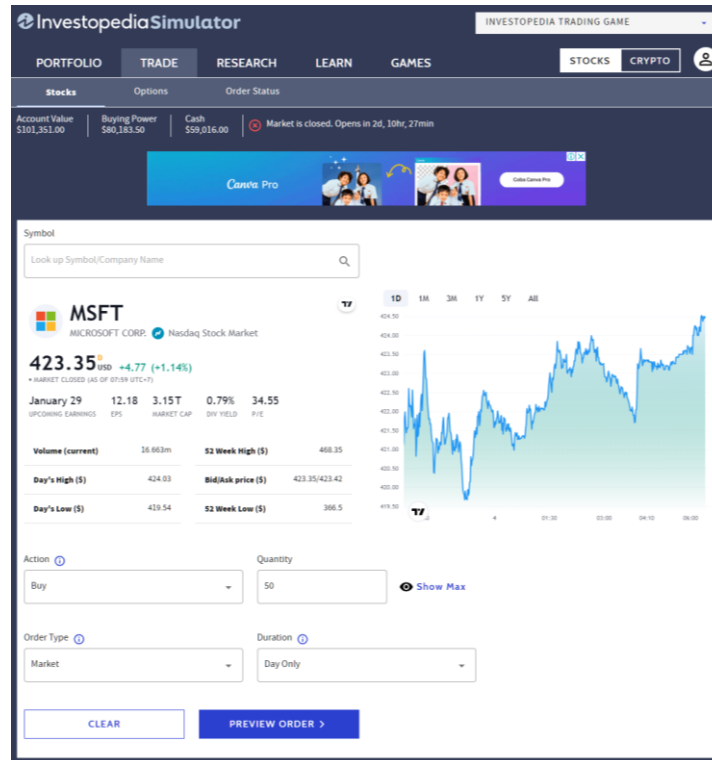


Figure 5: Stock purchase menu display

PERFORMANCE HISTORY					
Date	Cash	Stock Portfolio Value	Options Portfolio Value	Shorted Stock Portfolio Value	Account Value
12/31/2024	\$59,016.00	\$44,899.00	\$0.00	\$0.00	\$103,915.00
12/27/2024	\$59,016.00	\$44,899.00	\$0.00	\$0.00	\$103,915.00
12/20/2024	\$59,016.00	\$44,899.00	\$0.00	\$0.00	\$103,915.00
12/13/2024	\$59,016.00	\$44,899.00	\$0.00	\$0.00	\$103,915.00
12/06/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
11/26/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
11/19/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
11/12/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
11/05/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
10/29/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
10/22/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
10/16/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00
10/10/2024	\$58,933.00	\$42,304.00	\$0.00	\$0.00	\$101,237.00

Figure 6: Stock portfolio performance display

5. Conclusion

This study has designed a financial mathematics learning method that combines Markowitz's portfolio theory with stock investment simulation practices using a digital platform. Through this approach, students can understand more deeply the concept of portfolio management, including diversification, expected returns, and risk management. The use of platforms such as Yahoo Finance to obtain historical stock data and Investopedia Simulator for investment simulation practices allows students to connect theory with practice directly. This model provides a more contextual, interactive, and applicable learning experience. Thus, this study contributes to improving students' financial literacy and preparing them to face the challenges of the world of work in finance. The results of this study also show that the use of technology in learning financial mathematics can increase students' motivation and interest in understanding complex and applicable concepts.

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