

**Portfolio Optimisation   
using Modern Portfolio Theory & Python**

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**Acknowledgements**

**Abstract**

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# Introduction

## Background

This section aims to set the scene of the project, providing context and introducing the problem at hand. An investment is defined as “The Action or process of investing money for profit” (Oxford Dictionary, 2017). There are lots of different options that investors are faced with when it comes to choosing what to invest in. There are stocks, bonds, options, futures and countless more to consider. For this project, the focus is going to be on stocks. A stock is a portion of shares issued by a company (Oxford Dictionary, 2017). When investing into stocks, or anything for that matter, the general goal is going to be that when it comes time to sell, they have risen in value enough that the investor has made a profit. However, making that profit almost never comes free. Each investment typically has an “Expected Return” and a “Risk” aspect associated with it. These can be defined in a number of ways. In the context of this project, “Expected Return” is defined as the anticipated profit or loss on an investment characterised by a historical average. “Risk” is defined as the volatility of an investment’s return, which is effectively the likelihood that an investment’s actual return will be different to the expected return. This is characterised as variance. The best possible investment would be one that had a very high return with no risk attached. Sadly, this is never the case as almost every investment is guaranteed to have some kind of inherent risk (Thangavelu, 2015). To achieve those higher returns, investors have to be prepared to take on the extra risk involved in doing so.

It would be unusual for investors to only invest in one asset at a time Instead, what is created is a portfolio. A portfolio is “a range of investments held by a person or organisation” (Oxford Dictionary, 2017). Traditionally when creating portfolios, investors would select assets using anecdotal analysis or statistics of each asset individually. This changed when Harry Markowitz’s paper “Portfolio Selection” was released in March 1952 compiled within The Journal of Finance. Markowitz put forward among others, the idea of looking at how assets move and interact with the portfolio as a whole rather than on an individual basis. Instead of looking at an asset’s individual variance, it instead considers the risk of the portfolio to be determined by the covariance between each asset. In finance, covariance is a measure of how much the returns of two assets move together, contextualising the risk of a specific asset with the rest of the portfolio (Investopedia, 2017). Markowitz theorised that investors can potentially decrease the amount of risk they are having to take for the same return through means of diversification (Shipway, 2009). By spreading investments out over a larger number of diverse assets, the risk associated is generally going to be lower than if the investments were made in only one or two assets. This is due to each asset reacting differently to certain scenarios. With a large and diverse portfolio, there are going to be scenarios in which some assets will pay off, and some that won’t (Elton and Gruber, 1997).

The main goal of portfolio theory is to distribute your investments between each asset optimally. Markowitz assumes that all investors are risk averse when it comes to choosing portfolios, meaning that if there are two portfolios with the same return, the investor will always go for the one with less risk (Kaplan, 1998). He said that for every level of risk, there exists what he described as an “efficient portfolio”. This being the portfolio that provides the maximum return for that specific amount of risk. These “efficient portfolios” formed what Markowitz called the “Efficient Frontier” (Elton et al, 1978). The Mean-Variance analysis techniques featured within Modern Portfolio Theory provides insight into mathematical ways of identifying and calculating ways to achieve these efficient portfolios by optimising the trade-off between risk and return. Portfolios can be optimised to achieve lots of different aims. Not all investors are the same, some are a lot more comfortable making higher risk investments to get those bigger returns. With the introduction of mathematics and computation into finance, optimisations can be quickly performed to achieve these efficient portfolios with minimum variance, maximum return or somewhere in between. It is this area in which the project will take place; using mean-variance analysis to craft and optimise select portfolios.

## Aims & Objectives

### Aim & Rationale

The aim and rationale of this project is to create a proprietary asset allocation system that demonstrates the effectiveness of Modern Portfolio Theory in creating investment strategies. It should be able to retrieve relevant and up-to date stock data providing visualisation and descriptive analysis to the user. It will allow the user to craft a portfolio using their choice of stocks from the available selection. Using concepts from Modern Portfolio Theory such as Mean-Variance analysis, this portfolio can then be optimised in order to achieve the user’s desired goals. The statistics of the portfolio’s potential performance will be displayed by the system so the user then decide whether to proceed with that portfolio as their investment strategy.

### Objectives

The objectives of this project are to:

* Research and develop a greater understanding of Modern Portfolio Theory to help pinpoint requirements and guide implementation.
* Find and consider various options for a reliable online source of relevant financial data.
* Implement solutions using Python to achieve the following:
  + A retrieval system to fetch up-to-date price data for a specified list of stocks.
  + Perform statistical analysis on the data to provide the user with descriptive summaries of each stock as well as graphic visualisation.
  + Allow the user to craft custom portfolios manually choosing from the available selection.
  + Perform mean-variance optimisation to achieve the user’s desired portfolio goal.
  + Provide the user with summarising statistics of their optimised portfolio.
* Create a full graphical user interface to contain and situate the functionality of the solutions that have been created to form an interactive desktop application.

# Literature Review

# Methodology

Every project will usually have some kind of project management and software development methodology that it will follow. For very small projects, methodologies aren’t really much of a concern, as they generally don’t last long enough or aren’t intense enough to utilise the full benefit of following an established software development methodology. However, as the project grows in size, it becomes more and more important to be following a methodology as it can make time and cost more foreseeable, as well as boosting efficiency by sticking to a thought-out schedule. (Awad, 2005). This makes it important to consider a range of methodologies for both project management and software development. Before choosing the most optimal methodology, relevant analysis would need to done for this particular project.

All of the software development methodologies out there each have their own strengths and weaknesses that can become more or less apparent depending on the type of project. One of the most influential concepts that affects the viability of a software development methodology is the initial state of the software’s requirements (Balaji and Murugaiyan, 2012). The way the requirements were set out at the beginning was very uncertain. The artefact being produced from the project was always going to be making use of various concepts within Modern Portfolio Theory (MPT). As MPT is a relatively old theory, all concepts featured within it are already laid out and are not going to change. This makes it seem possible to create a full list of requirements from what had been researched, and proceeding with a traditional sequentially structured methodology such as Waterfall. Due to the sheer amount of concepts situated within MPT, it is extremely hard at the beginning of the project to fully gauge how many of these concepts were realistically going to be implemented, and in general, how far the artefact could go. This alone would rule out the use of a sequential methodology like Waterfall due to its rigid structure as it tends to benefit from having very well defined requirements, as well as a strong forecast for time and cost (Balaji and Murugaiyan, 2012).

Going off the exclusion of rigid methodologies such was Waterfall, the obvious choice is something a lot more flexible. Due to the initial lack of knowledge in the chosen field, determination of detailed requirements was not feasible, as well as calculating an accurate time plan for the project.

## Project Management

### Methodology

When deciding on a project management methodology, it is important to consider the unique characteristics about the project at hand.

### Time Planning

### Risk Management

As the project contained multiple software based components, it was important to consider some of the different risks that were involved. An essence of project management that could be utilised to summarise and handle this risk is what is called a Risk Matrix. A Risk Matrix can be defined as a structured approach to identifying risk, defining which risks are most dangerous to the project, what impact they might have, and how they can be dealt with (Garvey and Lansdowne, 1998).

A Risk Matrix has been formulated to provide evaluation and insight into potential risks that may be present within the project. <Talk about what is included in Risk Matrix>

<Risk Matrix Here>

### Development Tools

This section delves into the tools and applications that were used in the process of creating the project’s final artefact. It contains details pertaining to how and why that particular tool was chosen, comparing it to tools of a similar nature and ultimately why it was chosen.

#### Programming Language

One of the most important tools utilised in a software development project is the programming language that it is created in. There are programming languages that are much more suited to specific tasks than others and it’s helpful to pick a suitable one so as to not make things purposely difficult or inefficient. When deciding what programming language is going to be used, it is important to classify what kind of problems are needing to be solved using language. A brief overview of the tasks in this project involve a series of data analysis and handling techniques including fairly comprehensive mathematical procedures. Finally, the creation of a graphical user interface (GUI) is also necessary, which really requires some kind of object-oriented principles.

Based on the data handling and mathematical function requirements alone, some potential candidate languages would be Python (Python Software Foundation, 2017) and R (R Core Team). R is one of the most popular languages used in data science and provides a large majority of the utilities needed for the project. The R environment contains an integrated suite of facilities for data manipulation, calculation and graphical display (R Core Team, 2017). However, R unfortunately does not contain the object oriented features that would be necessary to create a GUI. Python on the other hand, was not initially designed as a data analysis tool. However, due to its general applicability, several high quality modules have been developed to handle and manipulate data, providing similar functionality to R. This has made Python extremely popular in the Data Science world and a real competitor to R (Muenchen, 2017). This makes Python the ideal choice for this project due to its versatility as it can perform everything necessary to assure its completion. There are quite a few different distributions of Python, each coming with their own pre-packaged modules. Since this project is fairly heavy on mathematical and data handling processes, Anaconda (Continuum Analytics, 2017) was the chosen distribution as it already contained a lot of the necessary Python modules with it, making it the logical choice.



Figure 1 - Graph showing the popularity of language in Data Science job listings. (Muenchen, 2017)

#### Integrated Development Environments (IDE)

IDEs can be fairly important when it comes to developing software. They package most of the fundamental tools that a developer is going to need into a single graphical user interface. This streamlines the process of writing code as it provides many quality of life improvements that can often be overlooked in terms of importance. Spyder (Spyder Developer Community, 2017) is a cross-platform IDE that is used for a lot of Python projects involving data processing and mathematics. Some of its main features that were utilised during the development process were things such as its integrated console, providing a quick and built-in way to run the program in development, making debugging and general program execution a lot faster. It provided instant, on-screen console output pertaining to the program as well as detailing bugs were they to occur.   
A minor but important feature none the less, was the syntax highlighting. It can be easy for code to get difficult to read and understand when the size of the project begins to ramp up. Spyder contains settings that allow full customisation syntax colours making Something that aids displaying code visually like syntax highlighting, makes it a lot easier to inspect the code for sources of error or areas to improve as elements within the code such as functions, classes and data types are visually differentiated.

## Software Development

# References