MIE479 Capstone - Final Report

---

finewbie: Robo-Advisor for Personal Asset-Liability Management

Prepared By: Jangwon Park | 1000724282
Sowmya Tata | 1000652279
Kai Zhang | 1000021898

Date: December 6, 2017

Table of Contents

Executive Summary

The proposed challenge is to design a personal asset-liability management tool which recommends the optimal investment strategies for any individual with any unique financial circumstances and profile, and for any type of goal he/she aspires to achieve through investing. The final outcome is a web-based robo-advisor which works on a complex, sophisticated optimization method, accounting for many realistic factors.

In tackling this problem, the team took on a unique perspective by answering the most fundamental question which defines a good engineering project -- which community is the most relevant community that could benefit tremendously from such a robo-advisor? Aptly named “finewbie”, our design addresses the challenges faced by many inexperienced college students today in the seemingly complicated world of finance by creating an intuitive, user-friendly web application of managing a personalized portfolio. This application is based on mean-variance stochastic optimization with reliable simulation of future uncertain asset prices via geometric Brownian motion.

1. Introduction

The design challenge is to develop a web application which integrates a user's assets and liabilities and finds the optimal investment strategies under uncertainty for each of his/her financial goals. Based on the user's background, financial information, and goals that he/she wishes to reach, the robo-advisor uses stochastic optimization to model the best portfolio to invest in. In the following paragraphs, we will describe the scope of our design as well as detailed aspects of the project such as objectives, metrics, constraints, and criteria.

1.1 Design Motivation & Stakeholders

An essential component of engineering design is to address a social need of a close community and create a positive impact. To this point, university students and recent graduates are the most immediate community around us. They will benefit significantly from this project because they tend to lack a good understanding of financial planning, thus making this project a very meaningful engineering design challenge. For this reason, our design will target university and recently graduate students.

There is research to show that university students need to improve their financial practices. [1] conducted a study to examine college students' financial management practices and discovered that while students were very good at avoiding writing bad cheques and at paying bills on time, they were least likely to save monthly, to have a budget, and to balance a checkbook. In other words, most are lacking good financial planning habits. [2] also discovered that financial literacy and wealth are positively correlated, supporting the idea that advancing financial planning habits and literacy through using our design will be beneficial to the students. Lastly, a study conducted in [3] also demonstrates that students only correctly answered 53% of their survey, strongly indicating a need to improve their financial literacy. Based on this information, apart from the optimization of portfolio allocation, we can use the web app to give students a simpler explanation of financial products and help them learn the basics of investing and financial planning.

Currently existing designs from well-known financial institutions are not suitable for our intended target audience due to a number of reasons. Well-established robo-advisors from Wealthfront, Betterment, and Fidelity Go are catered more towards US investors; some services are not available to Canadians at all; and smartphone applications only offer limited functionalities when they are free [4][5]. Canadian robo-advisors from companies like Nest Wealth charge a monthly fee which grows with the size of one's account in addition to all other management fees of ETFs, which are too much for a beginner investor with limited financial resources like students. Herein lies the gap that we plan to address -- the existing designs are not very usable and intuitive for university and recently graduated students in Canada. Therefore, scoping the challenge to this particular audience is valuable.

Scoping to students also creates ample opportunities to gather relevant usability test results. On campus, we can engage as many students to try our prototype as we can. Unlike other projects whose scopes span various age categories, our usability tests are conducted directly on our stakeholders, giving the most relevant results and honest feedback that we could get.

1.2 Objectives

The objectives of the design are below. This section only outlines high-level objectives of our design. Please refer to section 2.2.3 for the detailed mathematical formulation of the objective function of our optimization model.

- Ensure that the investor meets his/her financial goals in a way which minimizes risk while maximizing expected return to the extent which is in accordance with his/her risk attitude .
- Provide realistic and attainable investment strategies given the user's financial abilities, circumstances, and risk attitude for any number of financial goals.
- Design an intuitive, user-friendly web application for our target audience which enhances their financial literacy and understanding of investing and financial planning.
- Provide a transparent report of the performance of the user's portfolio and how well their financial goals are tracked.

1.3 Functions and Metrics

Functions provide quantitative means to evaluate objectives. The bullet points below each correspond to a bullet point above in section 1.2 in the order that they appear.

- MInimum risk while maximizing expected return to the extent as specified by the investor's risk attitude can be obtained by taking a weighted sum of the variance of portfolio value and expected portfolio value. if the user is more risk-averse, then this objective value becomes closer to 0.
- Investment strategies -- how much of each asset to buy or sell at each time period in a portfolio -- must be within the comfortable range of disposable income of each user. This is equal to the user's net income minus net current liabilities at maximum. All purchases of assets must come from this disposable income plus sales of other assets.
- Most (> 50%) of the responses in the final usability test of the web application should comprise only of satisfactory levels in terms of how easy it was to navigate through the website and how accessible the information was when there were terms that the user was not familiar with.
- Most (> 50%) of the responses in the final usability test of the web application should comprise only of satisfactory levels in terms of how easy it was to understand what was going on with the user's portfolio and financial goal tracking.

1.4 Constraints

There are a number of constraints associated with the design challenge. This section only outlines overall constraints imposed on the challenge itself. Please refer to section 2.2.3 for constraints specific to the optimization model.

- Each of the user's financial goals must be met at the end of the planning horizon.
- The user must not invest more money than their disposable income at each time period i.e. realistic investment strategies given the user's financial abilities and circumstances.
- The web application must contain a page for clarifying financial terminology.
- The web application must contain a page for sources of financial news and webinars for educational purposes.
- Python must be used as the main tool of development.

1.5 Design Values

- **Robustness**
  The model should be able to handle uncertainty of asset prices as well as changes made by the user to the financial goals. For example, there must be a way to project future asset returns to incorporate this data in optimization. Furthermore, if a user changes the length of the planning horizon or changes his/her risk attitude, for instance, the model should re-optimize based on this new information without errors.
- **Usability**
  Confusing financial terminology should be minimized on the web application; the web application should be intuitive to navigate; reporting of the performance of the portfolio and how financial goals are tracked should be visually appealing and easy to understand; and the questionnaire should be free of ambiguity and be kept succinct, which can be determined from the feedback from usability testing.
- **Efficiency**
  The optimization model must be balanced so that while taking in enough data, it does not take too long to optimize. Enough data may refer to the number of assets the model imports, the number of random scenarios of asset returns generated by the model if there is a stochastic element, etc. Too long can be defined by any waiting time greater than a few minutes for the portfolio to be rebalanced.

2. Business Logic

The business logic section outlines everything about the literature review of different stochastic optimization methods that have been applied in similar problems as well as our finalized method of optimization. Details include major assumptions of the finalized model, description of the model's objectives and constraints, explanation of how portfolios will be constructed and rebalanced over multiple periods, and the outputs of the model. Finally, backtesting results and some future improvements will be discussed.

2.1 Literature Review

In this section, we address literature review primarily for stochastic optimization methods and geometric Brownian motion that have been applied in similar financial planning problems. Other models considered, but rejected are reviewed in a later section "Documentation of alternative designs".

2.1.1 Stochastic programming

Multi-period stochastic programming is an optimization method which accounts for stochastic behavior of assets and a wide spectrum of realistic issues in financial planning. Many recent research has been done in applying variations of this method to both institutional and individual financial planning problems. The literature review on stochastic programming will focus on highlighting and analyzing each paper's major assumptions and approaches on the following areas which appear to be common:

- How is the uncertainty of asset returns treated and what methods were used?
- What are the objective functions?
- What do the constraints encapsulate? To what degree are these realistic?
- Ease of implementation and computational burden

[6] presents a generic framework for modeling multi-stage financial planning problem using stochastic optimization. It assumes a scenario tree in which the asset price could in theory fluctuate into any number of diversions. The tree is represented as follows:

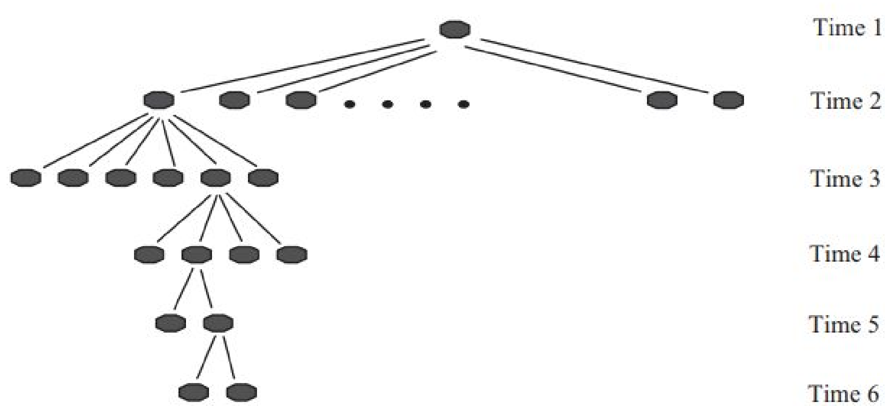


Figure 1. *An example scenario tree in [6]*

This makes the problem relatively complicated because it must employ a sophisticated method for scenario generation such as geometric Brownian motion (GBM) when defining how many scenarios should be generated to have reasonable representation of the uncertain future still remains a challenge. However, the paper proposes that the stochastic problem for the entire set of scenarios could be decomposed into sub-stochastic problems which only deal with smaller number of scenarios or even one scenario. This implies that while the model must be run as many times as there are scenarios, each problem is a relatively simple problem which can be solved more efficiently.

[4] presents a number of different objective functions that can be used in the model, all of which are based on the terminal wealth at the end of the planning horizon under each scenario. One example is to maximize the following:

$$Wealth = \sum_i assets - PV(liabilities).$$

The present value of the liabilities can be interpreted as the present value of the user's financial goal discounted to the time when the planning terminates. The sum of the assets is the net wealth of all assets in the user's portfolio also at the time when the planning terminates. The resulting objective function states that the user's net wealth from the portfolio minus his/her financial goal is maximized. Another example is a classical mean-variance function:

$$\text{Maximize } (1-\pi)Mean(W_\tau) - \pi\, Var(W_\tau).$$

The mean represents the mean of all terminal wealths from different scenarios and the variance is the variance among those values. The term π demonstrates risk attitude of the user; the closer it is to 1, the more risk averse he/she is. Other forms of utility functions can also be used.

[7] is another work in practical stochastic programming to solve financial planning problems. This work considers uncertainty in a far greater number of ways. For example, it assumes that the time horizon of financial planning, which is equal to the household life span, is stochastic in itself. This is unlike the assumption proposed in [6] where the length of the planning horizon is fixed. Similarly, cash flows are also uncertain because throughout one's entire life, incomes and liabilities are linked to future economic factors which are uncertain.

The time stages in the planning horizon correspond to major changes in life such as retirement, big purchases such as a home, etc. The financial planning problem at hand, therefore, is an all-encompassing lifelong financial planning rather than a financial goal-specific planning as [6] suggests, which is a notable difference between the two works. The scenario tree used in [7] is fundamentally similar to [6] and can be modeled in the following form:

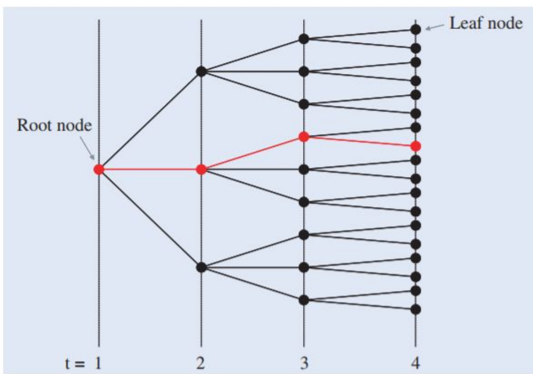


Figure 2. *An example scenario tree in [7]*

Since the paper does not restrict how many nodes each node can split into, the scenario tree remains fundamentally the same as one presented in [6].

[7] accounts for a very large number of decisions variables (18 in total, each of which are vectors or matrices) and constraints precisely because it is a lifelong financial planning problem and therefore must consider all the different possible types of income, types of loans, taxation, pensions, etc that are fully integrated into a single model.

The objective function presented in [7] maximizes the expected utility of lifelong consumption and can be formulated in the following form:

$$\mathbb{E}\left[\int_{t=1}^{T} 1_{\{\text{any alive},t\}} \mathrm{u}_t(\boldsymbol{C}_t)\right]$$

More specifically, [7] employs a piecewise linear utility function composed of three lines to model each goal.

In summary, [6] and [7] notably differ in the scale of the financial planning problem. While both propose a similar structure for the scenario tree, [7] entails much greater number of parameters and decision variables to consider because it is specifically modeled for life-long household financial planning. Since [6] is a general framework for a particular goal, it is easily extended to include more variables as we see fit and is a more suitable starting point for our design challenge.

Generally speaking, all works demonstrate that the constraints in their model must be handled as general linear constraints because some real-world issues are more difficult to capture within the network context. However, all works have shown that their constraints are capable of capturing management fees, transaction costs, and decision variables for additional purchases and sales of assets for rebalancing decisions as well as nonanticipativity, which means that decisions made at any time depends only on information known up to that point in time.

A major limitation of [6] includes that the number of scenarios to construct a reasonable representation of the uncertain future is poorly defined. For the purpose of this design challenge, the best approach is to have as many scenarios generated as possible, but restrict the run time of the model to be under a few minutes.

2.1.2 Geometric Brownian motion for scenario generation

Geometric Brownian motion (GBM) is a stochastic process by which asset prices can be simulated for future times based on the assets' historical mean return and volatility. It assumes that the random returns from one time to the immediately next time step are normally distributed about mean 0 and standard deviation of $\sqrt{\Delta t}$ where Δt is the time difference. This relationship is modeled in the following formula:

$$S_t = S_0 exp((\mu - 0.5\sigma^2) + \sigma W_t)$$

W_t is also a random process known as standard Brownian motion.

[8] presents a study dedicated to evaluating the performance of GBM by comparing the simulated stock prices to the actual stock prices. It investigates three metrics to evaluate and compare -- correlation coefficients between simulated and actual prices, mean absolute percentage error (MAPE), and a simple process to check whether simulated and actual prices moved in the same direction. The results show that while the correlation was weak, MAPE values were relatively low over all time periods and the directions matched most of the time. The study admits that there are a number of limitations to its study as it only pulls large companies' data from only Australia all with the same starting date. It nonetheless provides some support for the validity of GBM.

[9] further demonstrates the validity of GBM with an analysis of the performance of GBM with small-sized companies in Malaysia in which it discovered that MAPE values were consistently under 10%. This adds a new dimension of confidence to the validity of the model since unlike [8], the analysis was conducted with smaller sized companies in a completely different geographic region.

2.2 Finalized Method of Optimization

While stochastic programming requires heavy computation and is often burdened by the size of the problem, it is by far the most effective method of optimization which accounts for the most number of realistic factors.

Our finalized method of optimization will be mean-variance stochastic optimization based on Monte-Carlo simulation where the asset prices follow geometric Brownian motion (GBM). The objective function is the classical mean-variance function with the investor's risk aversion factor λ. More details will be discussed in the subsections below.

2.2.1 Major assumptions of the model and justifications

The following are major assumptions of our finalized model:

- Assets can be positively or negatively correlated i.e. their prices can go up or down at the same time. This accounts for any possible random movements of asset prices where they could move in the same or opposite directions.
- Asset prices follow geometric Brownian motion (GBM).
- Scenarios should be generated as many as possible but restricted so that the optimization finishes in relatively short amount of time (e.g. a few minutes). This further implies that there is a restriction on how frequent trading periods could be. For example, a long-term goal of 20 years of planning horizon will likely have annual trading periods.

- The probability of each scenario follows a normal distribution. This is a natural assumption given that we are using GBM to generate uncertain future asset returns. While asset prices are lognormally distributed, its random returns are normally distributed.
- All dividends are immediately reinvested. This is a necessary condition as the databases which have asset prices data are based on the same assumption.
- Interest rates on cash investments such as a savings account are constant throughout the planning horizon at 2% since Canada's long-term interest rates have historically been around 2%. This will simplify model formulation and not likely introduce any significant changes to optimization.
- Inflation is kept constant at 2% as this has been the historical average as well as the target.
- Transactions costs are constant throughout the planning horizon.
- Management fees of assets are constant throughout the planning horizon.
- No short selling allowed. This is to prevent our model from giving the user a speculative strategy of asset prices going down in the future before they are actually known.

2.2.2 Detailed explanation of how portfolios will be constructed

The type and number of assets used in our model and the selection rationale for the assets are justified in section 4.2. Please refer to this section for details.

The portfolio will be constructed according to the following model:

Minimize: $\lambda \frac{1}{S} \sum_{s=1}^{S} (W_s - W)^2 - (1 - \lambda) W$

Subject to these *equality* constraints:

$$\sum_{i=1}^{N} X(i,0) = b \qquad t = 0 \text{ constraint}$$

$$\sum_{i=1}^{N} (1 + r(i,1,s))X(i,0) + p(1,s) = \sum_{i=1}^{N} X(i,1,s),$$

$$\sum_{i=1}^{N} (1 + r(i,t,s))X(i,t-1,s) + p(t,s) = \sum_{i=1}^{N} X(i,t,s),$$

...

$$\sum_{i=1}^{N} (1 + r(i,T-1,s))X(i,T-2,s) + p(T-1,s)(1 - \xi_i) = \sum_{i=1}^{N} X(i,T-1,s)$$

$$\sum_{i=1}^{N} (1 + r(i,T,s))X(i,T-1,s) = \sum_{i=1}^{N} X(i,T,s), \qquad \forall\, s \in S \quad t = T \text{ constraint}$$

Subject to these *inequality* constraints:

$$\sum_{i=1}^{N} X(i,T,s)(1 - m(i)) \geq G \qquad \forall\, s \in S$$

$$X(i,0,s) \geq init\_alloc(i) \qquad \forall\, s \in S,\ i \in \{1, \ldots, N\}$$

$X(i,t,s) \geq 0, \quad \forall\ s \in S,\ t \in \{1, ..., T\},\ i \in \{1, ..., N\}$
$p(t,s) \geq 0, \quad \forall\ s \in S,\ t \in \{1, ..., T\},\ i \in \{1, ..., N\}$
$p(t,s) \leq D, \quad \forall\ s \in S,\ t \in \{1, ..., T\},\ i \in \{1, ..., N\}$

Parameters of the model

λ = investor's risk aversion factor $\in [0, 1]$
W_s = terminal wealth i.e. terminal portfolio value under scenario *s*
W = mean terminal wealth i.e. average portfolio value across all scenarios
S = total number of scenarios
N = number of assets
b = initial contribution to the financial goal
r(i,t,s) = random rate of return of asset *i* at time *t* under scenario *s*
m(i) = management fees + transaction costs of asset *i*
G = financial goal to reach in $
Init_alloc(i) = initial allocation in percentage recommended for asset *i* at *t* = 0. This will vary based on the investor's risk attitude.
T = time at which the planning horizon ends i.e. the final time period
D = maximum allowed contribution form investor in a given time period which is equal to the investor's net income - expenses for the given time period

Decision variables of the model

X(i,t,s) = total wealth held for asset *i* at time *t* under scenario *s*. This is expressed in dollar values as opposed to weights.
p(t,s) = additional direct contribution from the investor in a given single time period *t* under scenario *s*

The objective function is a dual objective which minimizes the variance of the total wealth across all the scenarios at the end of the planning horizon, but maximizes the average total wealth. The risk aversion factor λ indicates the relative importance of variance as compared to the expected value, and corresponds to the investor's risk attitude itself. By varying the value of λ, we can obtain an efficient frontier of wealth at the end of the planning horizon.

There are a number of equality constraints in the model, one for each time period. The first time constraint (*t = 0*) ensures that the total asset allocation is equal to the initial contribution that the user makes. At each time step from that point onwards, the value of each asset grows at its respective total returns, 1 + *r(i,t,s)*, which will vary under different scenarios. At the end of each time period, or at the beginning of each time step, the decision variable *p(t,s)* decides how much additional contribution the investor must make directly to the portfolio. This money will go towards purchasing additional shares of different assets. The net wealth at the end of that particular time step is therefore equal to the net wealth which has grown by the total returns from the previous time step plus the new amounts injected minus the transaction costs. There is an upper bound placed on *p* at each time step because otherwise, the model will output unrealistically large numbers for *p* that the investor cannot afford to contribute. Therefore, we restrict that *p* can be, at maximum, as large as the net disposable income of the user for a given time period. For instance, given annual trading frequency, if the user's salary net disposable income -- salary minus all living expense in a year -- is $10,000, then the value of *p* at any given time step will be less than or equal to $10,000. This is a necessary component of the formulation because if the initial contribution is too small for a goal too ambitious, *p* will help prevent the problem from becoming infeasible. During the final time period T, there is no *p* because we know that the goal will terminate immediately after; hence no need to buy additional shares.

At the end of the planning horizon, the terminal wealth, or the terminal portfolio value, under each scenario *s* must be greater than or equal to the target goal. By imposing an inequality constraint on meeting the target goal, we allow the portfolio to exceed it whenever it can.

The initial asset allocation at *t = 0* for each asset, *init_alloc(i)*, will be decided by the results from the risk attitude questionnaire. The user will fall into one of five categories of risk attitude according to our questionnaire -- conservative, moderately conservative, moderate, moderately aggressive, and aggressive -- each of which will recommend different starting asset allocation strategies. Please refer to section 3.3.2.1 for more details. This not only incorporates the investor's risk attitude into the model more accurately, it also helps avoid the problem of concentrating all wealth into a single asset throughout the optimization.

2.2.3 Outputs of the model

The outputs from the model include the portfolio's objective value itself as well as the investor's optimal investment strategies -- *p(t,s)* -- and asset allocation -- *X(i,t,s)* -- at each time step to the end of the planning horizon based on current asset prices and returns. The outputs also include other results of the model such as:

- Average portfolio value at the end of the planning horizon
- Average variance of portfolio across all scenarios at the end of the planning horizon
- Optimal asset allocation for the next time step
- Number of shares of each asset that the investor should be buying or selling by the next time step to meet the optimal asset allocation
- Percentage of the goal reached as well as its dollar value
- Holding period rate of return (HPRR).
- Time weighted rate of return (TWRR)
- Indicator variable called "ambitious" to indicate whether a goal is unattainable under the investor's current financial circumstances

<u>Measures of risk</u>
The primary risk measure of our model is the average variance of the portfolio values at the end of the planning horizon. By taking the square root of this variance, it signifies by how much, on average, the portfolio value under each scenario deviates from the mean portfolio value. This is measured in dollar value. Lower value implies that there is relatively little risk in ending up with a

portfolio that performs very poorly; that is, in all scenarios, one is likely to end up with a similarly performing portfolio. However, it also implies that the potential reward in ending up with a portfolio that performs really well is reduced.

Measures of performance

Two measures of performance are presented, which are also two of the simplest, yet arguably most important measures of performance for one's investment portfolio. Holding period rate of return (HPRR) is simply the rate of return on portfolio in a single time period. It provides a "snapshot" information to the investor and only provides insight into one time period.

Time weighted rate of return (TWRR) is the rate of return on portfolio for any given length of time that has elapsed with reference to $t = 0$. It is calculated by compounding HPRR at each time period. For instance, consider the following:

$t = 0$ to $t = 1$: $HPRR_0 = 0.04$
$t = 1$ to $t = 2$: $HPRR_1 = 0.06$

In each period respectively, HPRR is equal to 4% and 6%. Then the TWRR for these two periods is calculated by:

$$TWRR = (1 + HPRR_0)(1 + HPRR_1) - 1 = (1.04)(1.06) - 1 = 0.1024$$

With reference to $t = 0$, the TWRR is equal to 10.24%, implying that the initial portfolio value has increased by 10.24% throughout two time periods. The notion of "time weightedness" can partly be explained by how frequently the values appear in the compounded calculation. For instance, if HPRR values were 0.01 for nine time periods with the tenth one being 0.1, the compounded calculation gives more weight to 0.01 by compounding it nine times while 0.1 is compounded once.

2.2.4 How and when the portfolio is rebalanced

The portfolio is rebalanced at each time step based on the market performance during the previous time period. Rebalancing is achieved by redistributing the total wealth at that time among all assets which tends to favour assets that had relatively higher returns. By generating many scenarios, we reduce the likelihood that an asset had a terrible or terrific return purely by some rare chance, and thus avoid concentrating wealth in a single asset. The total wealth at this instant is equal to the total wealth from the previous time step plus the net growth of all assets in one time period plus any additional contribution that the investor made directly to the goal in one time period. Therefore, any additional purchases of shares is financed by sales of other assets and by the investor's contribution. This is best illustrated with a simple example of two assets:

Table 1. Two-asset example with one time period

Asset	t = 0	Contribution from investor (between time 0 to 1)	t = 1
A	70 *$7 / share	5	110 *$10 / share
B	30 *$2 / share		10 *$1 / share
Total wealth	100	-	120

The total wealth grew by $20, which should have come from the $5 contribution and the growth of asset prices. The share price of asset A increased by $3 whereas that of asset B decreased by $1. Since I held 10 shares of asset A and 15 shares of asset B, the net growth is equal to $3(10) - $1(15) = $30 - $15 = $15. The total wealth at t = 1 is, therefore, $100 + $5 + $15 = $120.

Even though asset A grew by $40 in net value, the number of shares that the investor has to buy in this time period is only 1 share (10 shares to 11 shares). The price of this 1 share is financed by: investor's contribution + sales of 5 shares of asset B = $5 + $5 = $10. This is exactly equal to one share price of asset A at t = 1. In this way, self-financing is satisfied.

2.2.5 How and when reoptimization takes place

Realistically speaking, reoptimization takes place when one time period has elapsed in real time. For instance, if the trading frequency is quarterly, then the model will reoptimize after three months. At each reoptimization, the model becomes smaller by one time period, and the initial allocation of assets is equal to the optimal asset allocation recommended at t = 1 from the previous model's optimization. The target goal will also **grow by inflation** at each reoptimization, where the rate is adjusted for the elapsed time period.

Reoptimization will also import new returns from the database because by end of one time period, new prices will be available. The model will need these values in order to calculate the "true" net value of the portfolio.

2.2.6 Documentation of alternative designs

<u>Cash-flow matching optimization</u>

Throughout the design process, there were many other elements of designs considered. One such model was the combination of MVO and cash-flow matching optimization. The idea is to convert all goals into a stream of cash flows that were to be met at regular intervals -- practically like liabilities. The cash-flow matching optimization attempts to meet each "liability" by matching it with cash flows from bonds, dividends from stocks, and direct contributions from the investor in the following fashion:

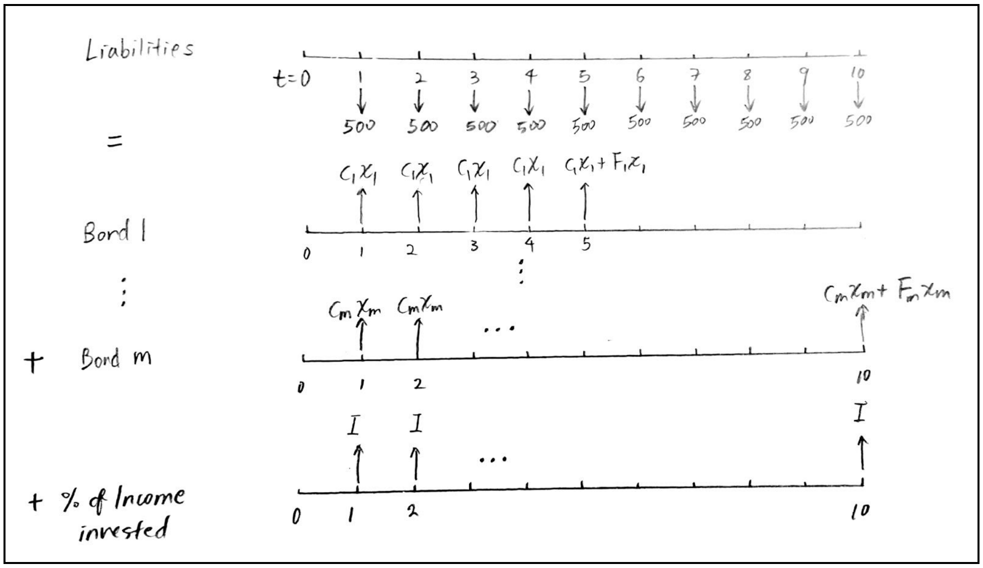


***Figure 3**. Example formulation of cash-flow matching portfolio*

The biggest downside of cash-flow matching optimization was the idea that all financial goals had to be converted to regular liabilities (negative cash flows) that the investor must meet starting now until the end of the planning horizon. There was little flexibility in investment decisions because it forced the user to meet regular payments at each time period no matter what. Though the amounts of the liabilities could be redistributed unevenly over the planning horizon for slightly more flexibility, the method of doing this was poorly defined and difficult to justify. Moreover, all bonds need to be purchased at $t = 0$ according to the cash-flow matching optimization method; however, the investor may not have enough funds to do this and therefore is not a realistic strategy.

Secondly, cash-flow matching optimization required all assets' face values and coupon payments to be known in advance. The unexpected roadblock was that not many databases granted free access to these information and often simply had no data at all aside from just bond yields.

Lastly, this model simply did not treat the uncertainty of the problem as appropriately as stochastic optimization based on Monte-Carlo simulation. No scenarios are generated to account for uncertain returns and the MVO was purely based on historical returns.

<u>Linear utility objective function</u>

The original objective function of stochastic optimization was a linear utility function in the following form: *maximize* $\sum_{s=1}^{S} P(s)[-r\, w(s) + q\, y(s)]$. The first successful optimization of this model resulted in enormous values of *y(s)* and *w(s)* (on the order of 10^{115} and 10^{137}) and always tended to reach the maximum number of iterations without reaching optimality. This implied that the model was attempting to produce unrealistically large numbers for these variables purely for the sake of maximizing the objective value. Since *y(s)* and *w(s)* are amounts by which the terminal portfolio value exceeds or falls short of the target goal respectively, exactly one of them should be zero at all times. Attempts to model this constraint, such as $y(s)w(s) = 0$, introduced a nonlinear constraint and was therefore aborted.

2.2.7 Implementation

As discussed in section 2.1.2, the geometric Brownian motion (GBM) formula for generating asset prices is $S_t = S_0 e^{(\mu - 0.5\sigma^2)t + \sigma W_t}$. This will be implemented in order of the following steps:

1. Obtain from Yahoo (or Quandl) 10 years worth of the historical prices of each asset. If the data available is less than 10 years, then import all data that is available. 7 years will be used to compute the model parameters such as the mean return and volatility of each asset, and the rest 3 years will be used for backtesting.
2. Calculate the historical mean return and volatility of each asset using functions from the numpy library in Python.
3. Set the initial price S_0 to be the latest price data available for each asset.
4. Generate a standard normal random variable of size equal to the total number of periods in the planning horizon. Perform a cumulative sum on this standard normal random variable and multiply it by the square root of the size of the time step. This is because W_t follows a normal distribution with mean 0 and variance $\sqrt{t}$. The cumulative sum makes sure that the new asset price always continues off of the asset price in the previous period.
5. Substitute the values found in steps 1 to 4 into the GBM formula for each value of t until T.
6. Repeat steps 1 to 5 at each optimization, but use more prices data to compute the model parameters. For example, if the trading frequency is quarterly, then in the next optimization the model uses 7.25 years of prices data and uses 2.75 years of prices for backtesting.

After the asset prices are generated, returns can be calculated easily by taking the difference between two asset prices that are adjacent in time and dividing it by the asset price from the earlier time of the two. These returns are equivalent to $r(i,t,s)$ in the constraints of the model.

The above procedure only describes the generation of one scenario. While it is always better to generate more scenarios since more implies better representation of the uncertain future, the number must be balanced with how long the model takes to optimize.

The previously described model will be rewritten in the form of a matrix so that it can be solved by the quadratic programming solver in Python, which only takes arguments in the following form:

$$\text{Minimize } x^T P x + q^T x$$
$$\text{Subject to:}$$
$$Gx \leq h$$
$$Ax = b$$

The construction of the matrix A, which includes the most number of constraints in our model, will be done in a nested loop fashion in which we update each element one at a time. The size of A will be preallocated with only 0's as its elements. The size of A depends on the total number of assets in the problem, the total number of periods remaining in the planning horizon, and the total number of scenarios. The row index of matrix A will refer to a specific scenario and a time period; each row of matrix A contains total returns of each asset, 1 - ξ_i terms, and as many -1 as there are assets. The negative ones implies that the right hand side of all time equality constraints in the model are moved to the left hand side to have them equate to 0.

The elements of the vector b will be mostly 0's because the right hand side of the equality constraint is equated to 0. The first element will be the user's initial contribution *b* and the last several elements will be equal to *G* (as many as there are scenarios). The vector h is also mostly 0 with several elements in the middle equal to *D* to restrict *p(t,s).*

Finally, the matrix P is a square matrix whose elements are mostly 0, but will compose of $1/S$ and 1 - $1/S$ terms (S = total number of scenarios) to compute the mean variance of the portfolio values. The vector q is also mostly zero with the last several entries equal to $1/S$ to compute the mean portfolio value.

2.2.8 Backtesting and stress testing results

<u>Results of optimization of various goals with different parameters</u>
Due to nearly infinitely many possibilities of examples we can test, we only present one representative short-term goal with relatively a low target. The results of **any** other goal with different lengths of time horizon, targets, initial contributions, or monthly contributions will look very similar provided that none of them are unreasonably out of range in relation to each other (e.g. reach $1M in only 2 years with only $100 of initial contribution). For convenience, risk aversion factor of 0.75 is used.

Table 2. Buy car in 3 years with quarterly trading

Goal	Parameters	0	1	2	3	4	5	6
Buy Car	Time Left [years]	3.00	2.75	2.50	2.25	2.00	1.75	1.50
	HPRR	0.00%	0.10%	0.50%	-5.90%	-1.40%	-11.30 %	8.10%
	TWRR	0.00%	0.10%	0.60%	-5.30%	-6.60%	-17.20 %	-10.50 %
	Variance	$57	$47.57	$57	$38.06	$36.38	$40.72	$57
	% Reached	14.29%	22.83%	31.42%	37.70%	45.57%	48.77%	61.03%
	Target	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000	$7,000

Table 2 cont'd.

Goal	Parameters	7	8	9	10	11	12
Buy Car	Time Left [years]	1.25	1.00	0.75	0.50	0.25	0.00
	HPRR	5.60%	-1.30%	5.30%	2.10%	*Optimization terminated due to goal reached*	
	TWRR	-5.50%	-6.70%	-1.80%	0.30%		
	Variance	\$51.31	\$44.69	\$40.94	\$38.35		
	% Reached	72.68%	79.76%	92.07%	101.49%		
	Target	\$7,000	\$7,000	\$7,000	\$7,000		

In this particular example, the simulated returns do not appear to be performing well as the portfolio only grew by 0.30% based on TWRR and the rest was financed through the investor's regular contributions in cash. The variance of the portfolio value is reasonably minimized in a certain range. However, a major issue is that the returns in each time period (HPRR) fluctuate largely; this perhaps calls for an improvement in implementing another risk measure to restrict the fluctuations.

<u>Validity of geometric Brownian motion (GBM)</u>

A basic test was done to compare the simulated prices from GBM with the actual prices of four different assets that we are using in our model -- SPY, IWM, VEU, and CSJ. The time period tested is from 2014-12-31 to 2017-12-31 (3 years) on monthly frequency.

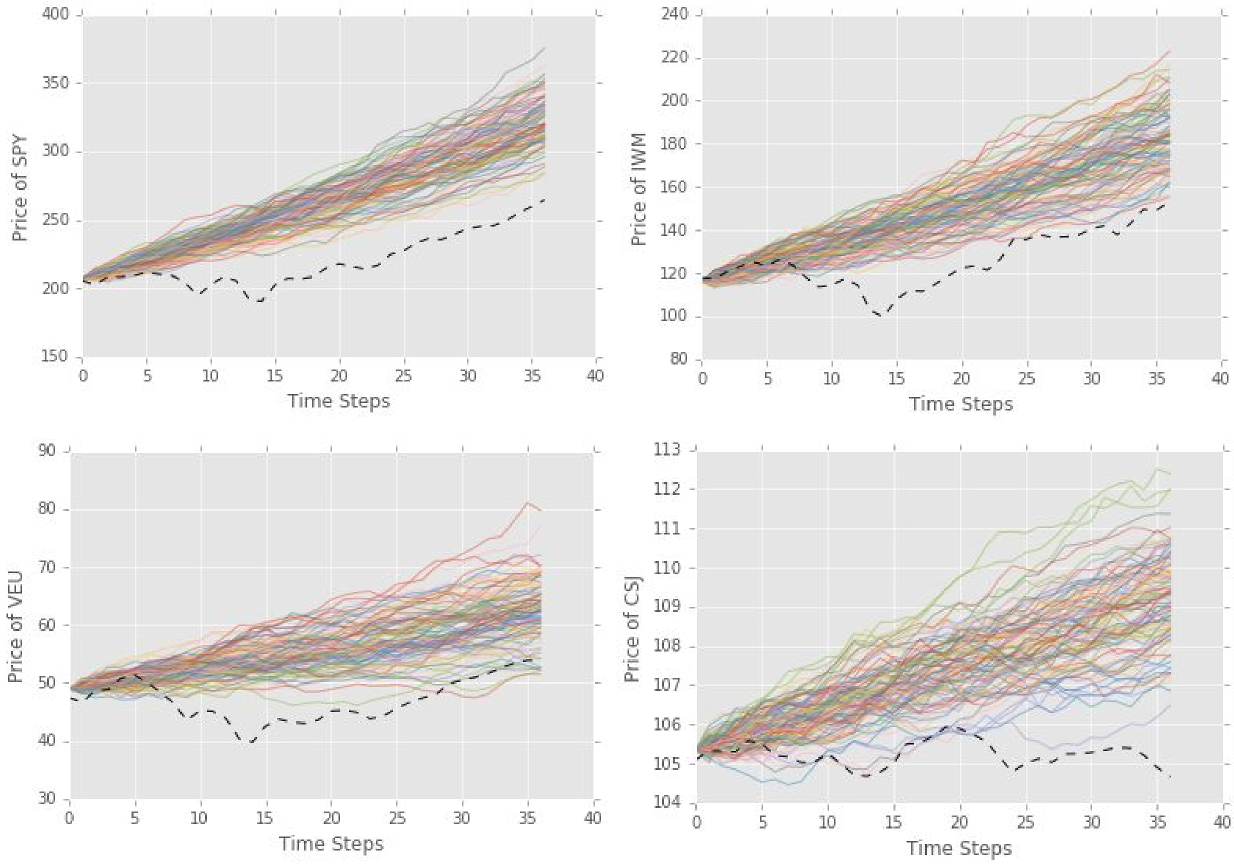


Figure 4. *Comparison of 100 simulated price paths with actual price paths for four assets*

The results are 100 simulated price paths from GBM and a black dotted line which represents the actual price path from 2014-12-31 to 2017-12-31. Nearly in all cases, the first five periods seem to be reasonably accurate since the actual price path falls within the range of 100 simulated price paths, indicating that it may be a good model for a relatively small-sized problems. However, subsequent periods after the fifth month demonstrate that simulated prices are almost always more optimistic than the actual prices. This poses one major issue for the model: the results of the portfolio from each optimization is likely too optimistic every time. As we run further optimizations, the mean portfolio value is therefore likely to decline because the actual prices are not as high as what we projected them to be. However, the actual price path still appears to follow more or less the same general trend as all other 100 simulated price paths which provides some validity to our model.

<u>Optimization with different risk attitudes for the identical problem</u>

The example problem for this test was a goal of $7,000 in 3 years with quarterly trading frequency (12-period tree). The initial contribution from the investor was $2,000 and monthly contribution capped at $200. Given this problem, the following is an efficient frontier obtained from varying the risk attitude of the investor, λ, gradually from 0 to 1 i.e. aggressive to conservative. The y-axis represents the objective value and the x-axis represents λ.

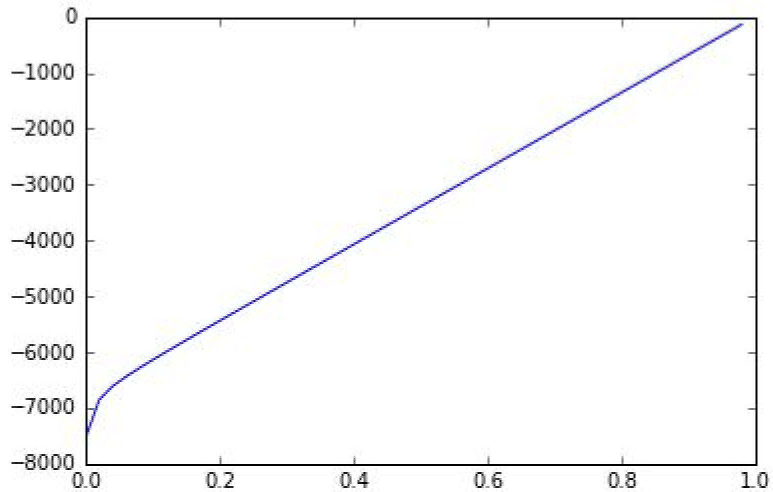


Figure 5. *Efficient frontier of objective value as risk attitude changes*

An interpretation of the efficient frontier is that there is a dramatic marginal increase in the objective value for values of λ in the interval of 0 to about 0.02. After this point, the tradeoff between the variance of the portfolio and the mean value of the portfolio appears to be linear. More practically, this implies that within the interval of 0 to 0.02, there exists dramatic changes in asset allocation and relatively little changes afterwards. This is confirmed by running the optimization for $\lambda = 0$, $\lambda = 0.02$, $\lambda = 0.5$, and $\lambda = 0.9$ separately.

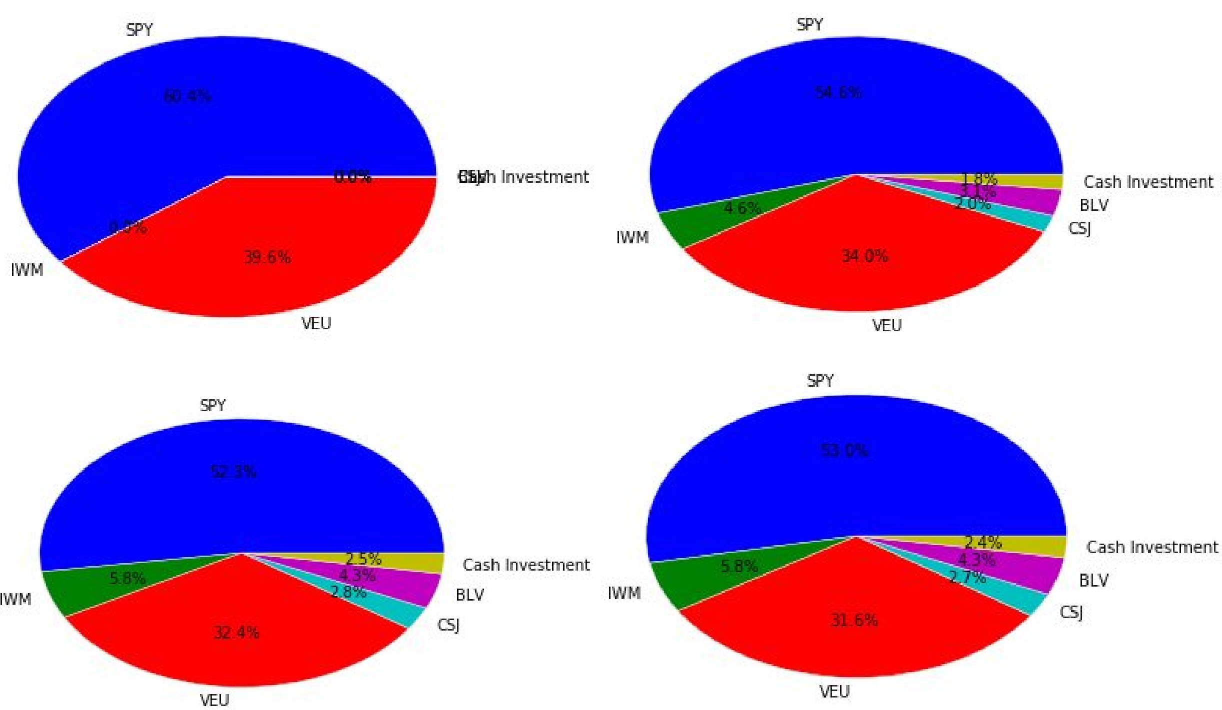


Figure 6. *Optimal asset allocation for the identical problem with $\lambda = 0$, $\lambda = 0.02$, $\lambda = 0.5$, and $\lambda = 0.9$*

From the top left corner to the bottom right in order (read from left to right), the asset allocation for $\lambda = 0$, $\lambda = 0.02$, $\lambda = 0.5$, and $\lambda = 0.9$ are presented. As hinted from the efficient frontier, the most dramatic changes in asset allocation resulted when λ was changed from 0 to 0.02. Afterwards, though changes are reflected, they are not as significant.

To account for this behaviour, the risk attitude score from the questionnaire is appropriately scaled to this significant interval of 0 to 0.02 rather than 0 to 1 to reflect that a change in attitude brings about a significant change in asset allocation.

<u>Results of running increasingly higher number of scenarios</u>
Increasing the number of scenarios has a great impact on slowing down the computation time of the model. A practical live demonstration of the application is only carried by 10 scenarios in the interest of time. Therefore, in this section we present some results of increasing higher number of scenarios.

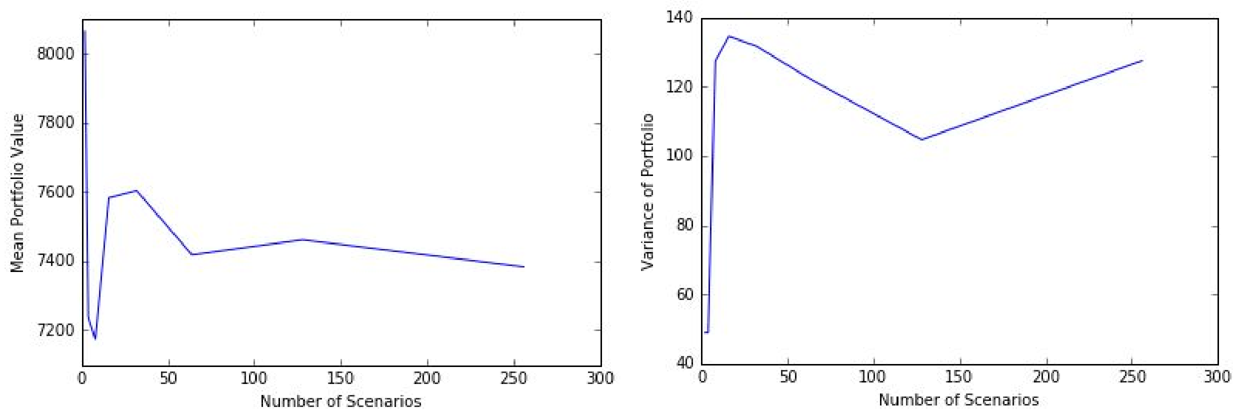


Figure 7. *Mean portfolio value vs number of scenarios (left) and variance of portfolio value vs number of scenarios (right)*

In both plots, the two most important outputs of the model -- the mean portfolio value and the mean variance of portfolio -- appear to be stabilizing as the number of scenarios increase. This demonstrates that the outcomes of the optimization ultimately settle down to values that only fluctuate negligibly with additional scenarios. When the percent changes of these two outputs under a satisfactory threshold, the number of scenarios at that point is the number at which optimality is achieved.

<u>Attempt to optimize after time remaining is 0 or after the target goal has been reached</u>
An attempt to optimize after time remaining has reached 0 will result in an error since the length of the tree is 0 i.e. non-existent. To allow the model to be robust against such a case, a condition was created to check the length of time remaining and to return "None" object by default. On the web application, the optimize button is automatically disabled as a result of this.

<u>One-period model</u>

Optimization with a one-period tree is a very different type of problem due to one major reason: rebalancing is pointless as the investment terminates in the immediately next time step. The net portfolio value is effectively equal to the sum of net values of each asset grown at their respective returns. This implies that there are no longer decision variables for *p(t,s)*, which are additional contributions made directly to the goal by the investor, since this contribution is used to buy additional shares for future optimization and there will be none in this case. Therefore, the model collapses to the following set of *equality* constraints:

$$\sum_{i=1}^{N} X(i,0) = b \qquad t = 0 \text{ constraint}$$

$$\sum_{i=1}^{N} (1 + r(i,1,s))X(i,0) = \sum_{i=1}^{N} X(i,1,s) \qquad t = T = 1 \text{ constraint}$$

The matrices for the one-period tree model are constructed slightly differently, and were implemented under the condition that the model only has one period left remaining.

<u>When the projected terminal portfolio value falls short of the target goal</u>

There are many test cases under which the target goal may not be achievable. With our model, we can assess whether a goal is achievable or not by comparing the mean portfolio value with the target goal itself; if the mean portfolio value is smaller than the goal, then it implies that under some scenarios, the investor may not end up with enough funds. Generally, this happens when the one or more of the following are present:

- The target goal is too high given the investor's financial circumstances.
- Regular contributions made by the investor are too small relative to the size of the goal.
- Initial contribution is too small relative to the size of the goal.
- Assets have terrible returns
- Planning horizon is too short relative to the size of the goal.

In such a case, we can formalize three different strategies to enable the investor to meet his/her goal:

1. Increase the length of the planning horizon,
2. Reduce the value of the target goal, and/or
3. Increase the amount of regular contributions from the investor

In this problem, we make the assumption that the second strategy is not easily compromised. In other words, the target goal is not as easily and flexibly changed. For example, an investor looking to buy a used car currently valued at $7,000 will not appreciate a lower-valued car since he/she is no longer sure if this will mean a car with unsatisfactory quality. Moreover, the investor must spend time again to research which cars are still decent and worth buying under $7,000, which requires a lot of effort. Reducing the value of the goal, therefore, affects much of the investor's behaviour and habits in order to compensate for the loss. Therefore, in consideration of all of these realistic factors, we will recommend either the first or the third strategy, or a combination of both. Increasing the goal, on the other hand, is always available as an option to the investor.

In theory, there are infinitely many different combinations of the first and third strategies. However, we limit this to five combinations based on the investor's response to one of questions in the risk questionnaire: "how important is it to meet your goal on time?". There are five responses to this question -- "not very important", "not important", "doesn't matter", "important", and "very important". As the timeliness of the goal becomes more important, we shift the weight to the third strategy in the following order which corresponds to the responses above: 0, 0.25, 0.5, 0.75, and 1. This implies, for instance, that if a goal is not important at all to meet on time, we recommend meeting this ambitious goal purely by lengthening the planning horizon.

Below is a simple example to illustrate the above. Suppose an investor aims for $100,000 in 2 years with only $1,000 initial contribution, $100 monthly contribution, and does not really care whether the goal is met on time or delayed. This is clearly an ambitious goal that is impossible to achieve in 2 years.

Table 3. Several optimization results for an ambitious goal which is clearly unattainable initially

Parameters	1	2	3	4
Time Horizon [years]	2.00	24.55	24.55	24.55
Monthly Contribution	$100	$2,343.75	$2,309.75	$2,318.54
Target Goal	$100,000	$100,000	$100,000	$100,000

As part of the algorithm, the time horizon as well as the monthly contribution were dramatically increased to prioritize attaining the goal in relatively fast time.

2.2.9 Limitations and future improvements

Validity of GBM

In summary of the observations in the previous section, GBM may be a good model for relatively small problems whose total number of periods are around 5. Subsequent simulations after that point are too optimistic and therefore the optimization results may be slightly misleading to the investor. The general trends, however, appear to be similar for simulated and actual price paths.

Formulating an integer programming such that the numbers of shares recommended to the user are integers

A limitation of the current model is that it suggests purchases or sales of partial shares of assets. While holding partial shares is valid, the investor is generally not allowed to buy or sell partial shares. Simply rounding the investment suggestions to whole numbers at the end of our model may not guarantee optimality. Therefore, given more time, some experiments will have to be conducted to see if manipulating all intermediate portfolio values such that the model outputs whole numbers for the shares is reasonably close to simply rounding our current investment suggestions.

Separating the importing of assets from the optimization model

Significant improvements need to be made to reduce the computation time of our model. Part of this can be done by segregating the importing of assets from the optimization model itself. As it is, the optimization function called "port_opt.py" calls the function "import_assets.py" within it. This implies we must first import all data as a necessary step before optimization. However, if we continuously run this function "import_assets.py" elsewhere at regular intervals and pass the asset returns data into "port_opt.py" as an argument when it is called, the run time will be shorter by exactly how long it takes to import all data, which can be significant especially if the connection to Yahoo Finance is slow and insecure.

Reformulation of stochastic programming

A possible reformulation of stochastic programming could dramatically improve the run time in which the decision variables are in terms of weights instead of dollar values. If the decision variables are in terms of dollar values, each scenario must be solved separately, introducing as many sets of decision variables as there are scenarios per time step. On the other hand, if the decision variables are in terms of weights, we can impose the same weights regardless of which scenario, which introduces only one set of decision variables per time step. This dramatic decrease in the number of decision variables may reduce the size of our problems considerably. However, this is a major change and further literature review must be done.

3. Front-End Development

The front end section outlines the content and design of the web app as well as the user's interactions with the web app. It will also describe the technology choices, design decisions and the updates we had to make along the way. Lastly, user testing protocols and the feedback from them will be discussed.

To reflect our design values for the web app, the main objectives for the front-end was to keep the app design simple and intuitive, while also adding elements explaining financial terms and such to the user. These themes will be very strongly reflected in our work flow of the app as well as its design.

3.1 Technologies Used

3.1.1 Programming languages

As none of our team members had experience with front-end development, the main factor to consider when picking software packages and languages was its ease of use and the support available in online communities. HTML and CSS are the absolute basics required for any web design and styling. We also used the jinja2 HTML scripting language to make rendering HTML templates easier but also to allow for additional functionality like passing variables through various web pages.

Originally, we planned on using Angular 4.0 and TypeScript files to help with interactivity and additional features. However, after working with HTML/ CSS and jinja2, we did not see a need to specifically code in Angular when all our required functionality could be done through existing languages. For our future improvements, we might reconsider using Angular.

For the overall front-end framework, Bootstrap was our choice. It is the most popular and widely used platform as compared to Semantic UI and Foundation, but also has a larger community support and regular, robust updates. We had been advised by our friends who had first hand experience with these frameworks and suggested that Bootstrap is the easiest to use for beginners. And true to their advice, using Bootstrap made adding repeated HTML elements very quick and efficient.

3.1.2 Other software packages and libraries

Additional packages downloaded are just as important as the overall choice of the programming language. Python, being a widely-used language, had an open-source library for almost any functionality. Most important ones for our purposes were:

- the Flask framework, to route the app flow and to allow the interaction between different components of the app
- pandas and numpy libraries, to assist in mathematical calculations and matrix arithmetic
- bokeh library, to take the data from the optimization model and to graph them.

The above packages were chosen from their widespread popularity and the tremendous amount of online tutorials and help available. bokeh, however, was a carefully selected package. We previously tried rendering graphs using other packages like matplotlib and pygal, both of which returned very low quality of graphs that did not meet our requirements. In order to add legends or display values at each point, a lot more manipulation of the original data had to be done as well, which would slow our entire process down. With bokeh, graphs with all the necessary components were very easy to render. It also comes with a toolbar on the side where you can zoom in on the graphs or save them. These functionalities will come in handy in the future when the goals get longer and complicated; for example, users have the option of zooming in on their “Market Value of Portfolio” graph or to save them locally for reference.

3.2 User Flow Diagram

The following flowchart describes the flow of the web app -- the chronological steps the user would take, common errors to consider, the different web pages created, and their interaction with each other. The diagram also incorporates the different collections of MongoDB we have and how the front-end retrieves and posts data to the database. Minimal yet representative paths are shown on the diagram for display purposes.

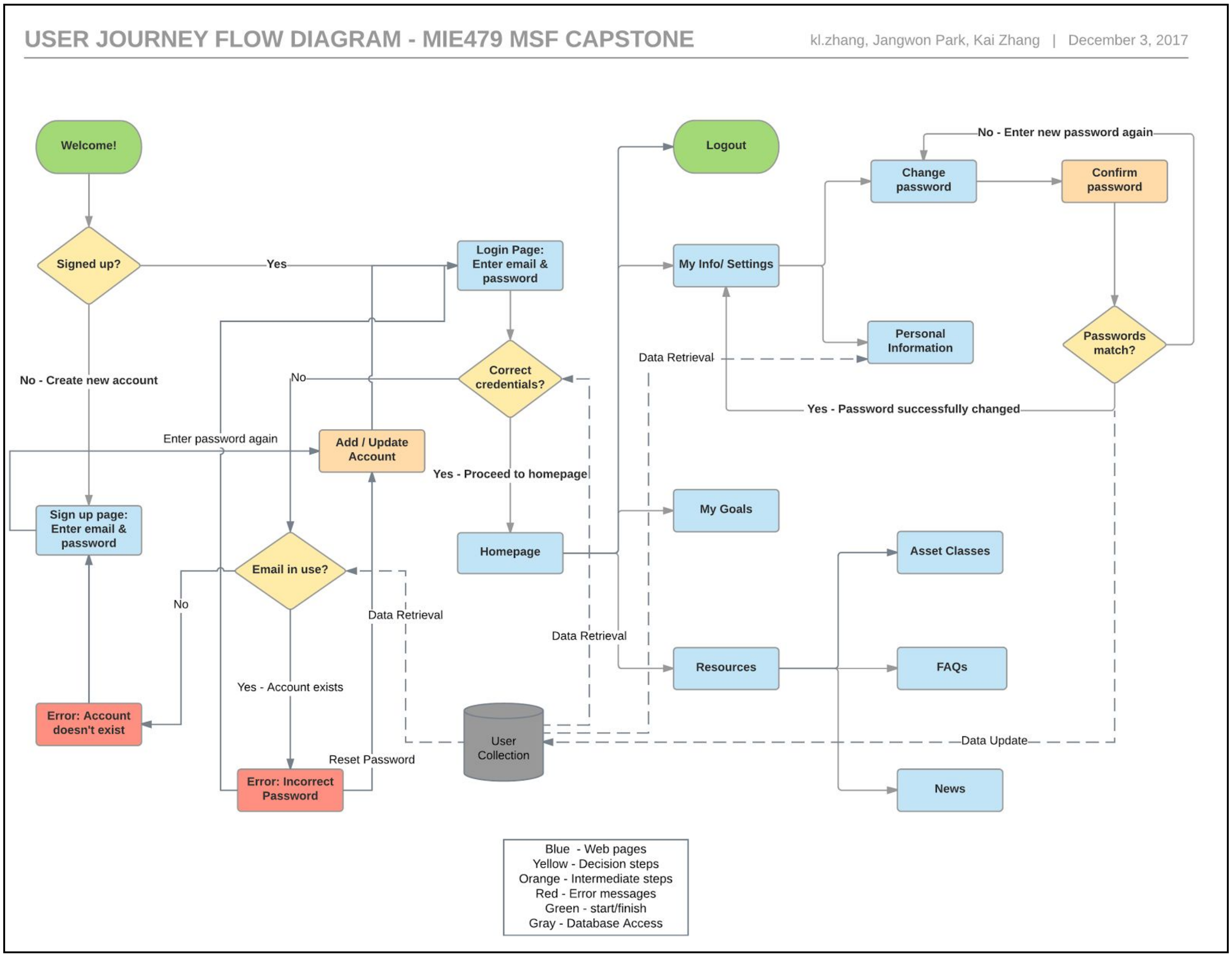


Figure 8. *User Flow and Data Retrieval Diagram - Main Pages*

Due to lack of space, the user flow after clicking on the "My Goals" page is presented in a separate diagram, shown below. The diagram presents the flow for one sample goal only, but every goal the user creates has the same pages.

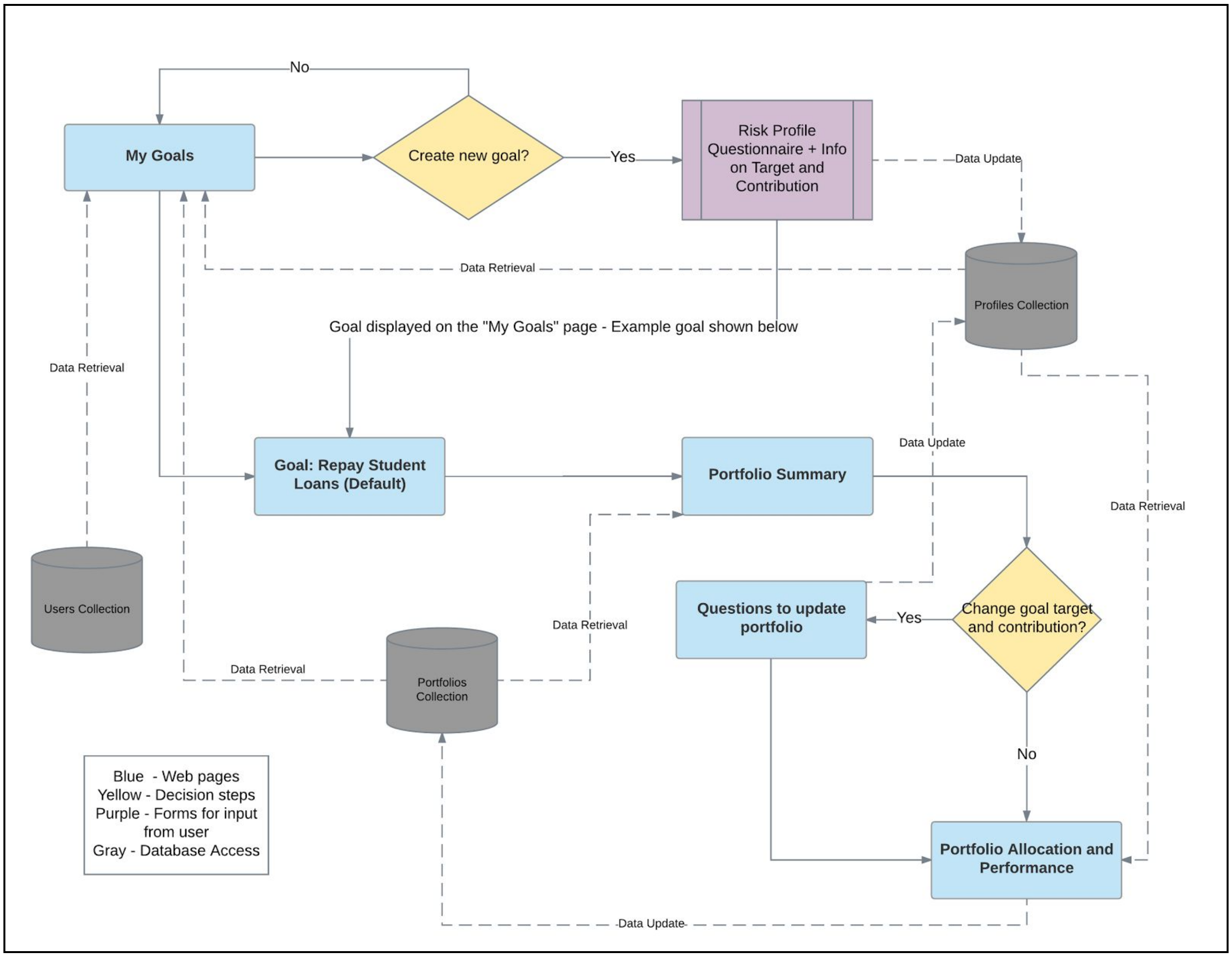


Figure 9. *Detailed layout of the "My Goals" page*

3.2 Student-friendly and Educative Content

The most important objective for our web app is to serve as an learning platform for our student stakeholders. As per our design objectives and constraints we initially set in sections 1.2 and 1.4 respectively, our web app has a page for "FAQs" which includes a simple explanation of financial terminology but also contains details on the basics of investing and portfolio management. Questions like "What is an ETF?" and "Why should my portfolio be diversified?" are answered concisely. Through this, we hope to give the user a quick rundown of how our app works and the financial principles behind it.

One page is dedicated to give users details on the assets we are investing their money in, and to display their current performance numbers in real time. This was done by incorporating RSS feeds into our web app. RSS (Really Simple Syndication) is an online tool that delivers automatic updates to Web content. We achieved this by retrieving latest RSS (Really Simple Syndication) Feed data from the NASDAQ website. We obtained custom feeds for the 5 ETFs that are part of our portfolio and displayed their current performance for the user's reference.

Another web page is also dedicated to basic financial and economic news. Once again, RSS feeds by subject (business, economics, investing basics) were chosen from the NASDAQ website. These subjects would have news and blog articles for the beginner investor to read through. Formatting related to the feed was done using an online tool to generate RSS feed boxes to embed into our HTML file.

Apart from these specific pages dedicated to user learning, throughout the web app, we have explanatory messages of what each form/ page does. For example, when the user creates a new goal, there are small explanations provided before any questions are asked. Following our design values, the homepage and other pages also help the user navigate well throughout the app.

3.3 Wireframes

The basic layout of our app changed from a mainly sidebar style navigation to a menu bar at top of the page style. From our initial design, the colour scheme has been changed to achieve a more minimalistic and sophisticated design. The space occupied by the header and sidebar has also been reduced, so as to give us more space for the main content on the web page. We also found it better to have the credits of the web app on the logout page, rather than have it as the footer of every page, thus saving some valuable screen space. The amount of information presented in the home screen has also been reduced to avoid overwhelming the user; rather, we redirect them to the different pages where they can carry out the necessary tasks. Sample of our prototype designs and the final design can be seen below, with more wireframes presented in Appendix A.

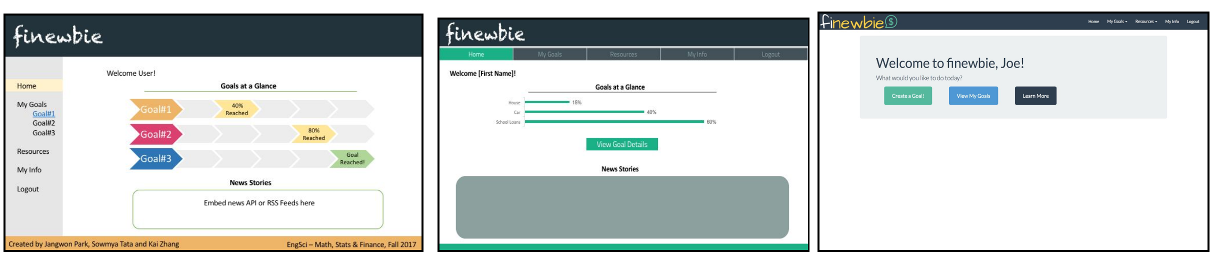


Figure 10. *Evolution of Web App Layout - first two pictures are templates, and the last screenshot is the final product*

3.4 Usability Testing

An iterative process with user feedback and continual improvement is the most important part of engineering design. Keeping in accordance with our design objectives and metrics of usability, dedicating part of our project timeline to user testing is essential. Furthermore, our target audience is comprised of university students and recent graduates (i.e. our peers) who are easily accessible to us, thus making user testing fundamental to our design process. In the following sections, we discuss user testing protocol and examples of where it was implemented.

3.4.1 Testing protocol / methodology

A simple Google search on usability testing resulted in a large number of guidelines, some for human-subject experiments while some others were for major corporate projects. Of these, we found two resources that were useful and could be modified for our use:

- "Usability Testing Basics" guide from the web services department at the University of Michigan. [12]
- A dashboard plan from the usability research and services firm, Userfocus (See Appendix B) [13]

Both these resources focused on software usability. The dashboard from Userfocus gives a brief overview of all the components involved in user testing while the guide from UMich provides specific examples on how we can measure usability of the website using metrics such as time on task, errors, mouse clicks etc.

Following the above resources as references, we simplified some of the steps as they are not applicable to our project. Usually, user testing protocol requires a business case as to why the user test is being carried out. In our case, we want to follow through with our design objectives of making our web app user-friendly and intuitive; given that we have the reasoning, this part need not be asked at every user test. Similarly, protocol asks for equipment and people in-charge to be defined. Given our small team and our task of creating a web app, our project is not extensive enough to require external equipment other than our laptops running the code and presenting surveys. Our classmates and friends that fall into the category of university students and recent graduates will be the subjects for all our user testing.

Thus, for the purposes for our project, the simplified testing protocol is as follows.

1) Definition: What idea or design aspect is being tested
2) Objectives: What do we want to gain/understand from this test? Hypothesis?
3) Test style: Surveys with comparative and qualitative feedback, asking the user to use our web app from beginning to end etc.

Other than small changes that we asked our friends during our development stage, we had three major user tests, listed and explained in detail below.

3.4.2 User testing example: risk profile questionnaire

We carried out a small user test amongst our friends to gain feedback on two versions of the risk profile questionnaire. Complying with our user testing protocol, we defined the following for our test.

- Definition: We want to decide which version of the risk profile questionnaire to pick
- Objectives: To understand which version students prefer, how they found the length of the questionnaire, the terminology found within it and positive/ negative aspects of either version

- Test style: Send two PDFs (for the two versions of the risk profile questionnaire) for the user to go through and a feedback survey form for them to fill out (See Appendix C for the questionnaires)

3.4.2.1 Test questionnaires and background

The first questionnaire was the Investor Profile Questionnaire from Charles Schwab (See Appendix C), which we particularly liked as it took into account the time horizon as well as the investor's risk aversion to assign them into one of five categories of investment strategy. This questionnaire provided all details on how to score the responses and gave a scale to map the users into the categories. Furthermore, this questionnaire also gave us recommended initial portfolio allocations amongst the five asset classes described further in section 4.2. Overall, this questionnaire was very thorough and gave us all the relevant information; one thing we were hesitant about was the financial jargon and the language of the questionnaire.

The second questionnaire was from the Ontario Securities Commission. To us, this questionnaire seemed much shorter and engaging, especially for our age group and students that might not have a deep understanding of investing. We changed the last two questions about timing and retirement into a question asking the user how long they have till they need to achieve their intended goal. To score these responses, we transferred the Charles Schwab scoring chart and recommended portfolio allocations.

3.4.2.2 Survey results

We sent out a feedback form to our friends (mix of undergraduate and graduate students as well recent working grads, some have financial background while some do not) asking them their thoughts on the two questionnaires mentioned above (See Appendix D). We received 12 responses and their comments proved very useful. Some of their comments are mentioned here.

Only 2 out of the 12 respondents were "very familiar" with the terms presented in the Charles Schwab questionnaire. Most of the comments were along the lines that the questions are intimidating, require a lot of thought for a questionnaire, are not framed in a simple context and are verbose.

On the other hand, for the Ontario Securities Commission's questionnaire, 9 out of the 12 respondents were "very familiar" with the terms presented. On the contrary to the earlier questionnaire, people found this one to be easy to understand, engaging, straightforward and presented in the context of winning money in a game show which they are more familiar with than asking them about investment performance. Lastly, 83% of the respondents said that the Charles Schwab questionnaire took longer to fill and 83% would prefer the Ontario Securities Commission's questionnaire.

3.3.2.3 Conclusions

From our user testing results, we received unanimous support for the Ontario Securities Commission’s questionnaire, which is the final version we used and to this questionnaire, we added some more questions on the goal that the user wants to define. Please see the latest questionnaire in the app screenshots under the title “Risk Profile” in Appendix A . This choice makes sense as it is doesn’t have financial jargon which might deter some students from using our web app and the questionnaire is shorter and simpler to follow. In compliance with the metrics and constraints we defined for ourselves, a majority (> 50%) agreed that the second version was easier to understand and that it took shorter time to fill it out. To convert the responses into a risk aversion score, we used the scoring guide from the Charles Schwab questionnaire; please refer to section [] for more details on implementation.

3.4.3 User testing example: web app layout

Next, we tested was the web app layout and the flow of the pages. This was carried by asking the stakeholders (university students) to go from the login page till the end, through all web pages in a low fidelity Powerpoint presentation. This presentation was animated to mimic the actual user flow as described in the previous section 3.2. Essentially, test subjects would see the full screen of the web app and by clicking on any of the buttons, be redirected to the slide with corresponding web page Please refer to Appendix A for wireframes that were the base of the Powerpoint slides used to test layout.

3.4.3.1 Background

After realizing that our initial web layout (black and yellow colour scheme) had issues to be fixed, a second prototype (grey and teal colour scheme) was created. Test subjects were asked to navigate through the app without any guidance or background info given - to simulate how real-life users who haven’t seen the app before would react. After they are done, we asked them for holistic comments on the proposed layout.

3.4.3.2 Conclusion

Everyone (100%) agreed that the user flow was simple to follow through. Having the menu bar present at the top of the page always helped users. The more they saw the menu bar, the more sense the entire app and its flow made. Even though with time, the process of using the app became obvious, some people suggested having messaging at the top of each page to describe what the page was about. They also suggested not cluttering all the pages with lots of information, but to leave white space on the page that lets the user to breathe and absorb all the information displayed.

3.4.4 User testing example: final “finewbie” testing

Our final test was to let our users test the final working web app. Once again, we asked 6 of our classmates to help us with testing. Unlike the previous holistic testing, this exercise asked users to focus on the details to better the user experience. Once you have a functional app, user satisfaction with the web app comes from fixing all the details to perfection.

3.4.4.1 Background

The web app was run on our laptops through locally hosted MongoDB servers. We gave about 15 minutes for everyone to look at all the pages of the app, and noted down their questions and concerns as they were talking to us about it while testing.

3.4.4.2 Conclusion

4 of the 6 people (66%) were very satisfied with our final design, a result that passed our criteria of achieving at least 50% responses in the final usability test of the web application should comprise only of satisfactory levels in terms of how easy it was to understand portfolio and historical goal tracking. Many other details were pointed out, some of which are listed below:

- Add “Back to My Goals” page in the Goal Summary page, so that user doesn’t have to go to the drop down menu in the header always
- Add light grey background and bigger font size for different sections of the questionnaire to make it readable
- Add message explaining why the “Optimize” button gets disabled
- Don’t clutter the home page with repeated information about goal performance, but rather use it to guide users to specific pages

3.5 Implementation and Changes Made

Implementation was a process of continually fixing bugs as they arose. Once we had a decent web app working, we kept changing details like arrangement of text boxes, rounded numbers in the display, font size, adding glyphicons etc. Below are some of the main highlights of our implementation.

3.5.1 Portfolio output display

One of the most critical parts that we get correctly in our design is to explain and display the results from the portfolio optimization and rebalancing to the user. Only if the user understands the results being displayed to them from the model, is our app successful in accomplishing its purpose of being a financial and investment planner.

At each time period, after the optimization model has run, the following results are displayed to the user:

- Net wealth at each time period
- Progress made towards goal (in percentage)
- How much of each asset the user must purchase or buy (this also includes any additional contribution that the user needs to make at that time period)

- Asset allocation at each time period, which already takes into account new purchases or sales the user must make
- Portfolio return and variance

The net wealth and progress made towards the goal are the main statistics that the user would need to know at first glance, and thus these two results were displayed at the top. Following these results are the other performance statistics and investment suggestion, and lastly graphs showing historical trends.

3.5.2 Risk profile assessment

Many risk profile questionnaires from common industry sources were looked at. For example, TD Securities and Vanguard had very long questionnaires, including the use of asset performance graphs and financial terms. For beginner investors and university students without a finance background, these would be tough to interpret and as such, we went with a questionnaire that was all text and simple to understand.

Based on our user testing previously explained in section 3.4.2, the final risk profile questionnaire is the modified version of the one by Ontario Securities Commission. Please see Appendix A "Risk Profile" screenshot to see the questionnaire. One step during the implementation was to construct a score scale based on the matrix the Charles Schwab Questionnaire had, with time horizon of goal and risk tolerance of user axes. The reference matrix was very useful as it neatly laid out the five categories of investors. For example, it did not allow portfolios to be very aggressive if their time horizon was small. Below you can find the original score matrix and our modified version of it.

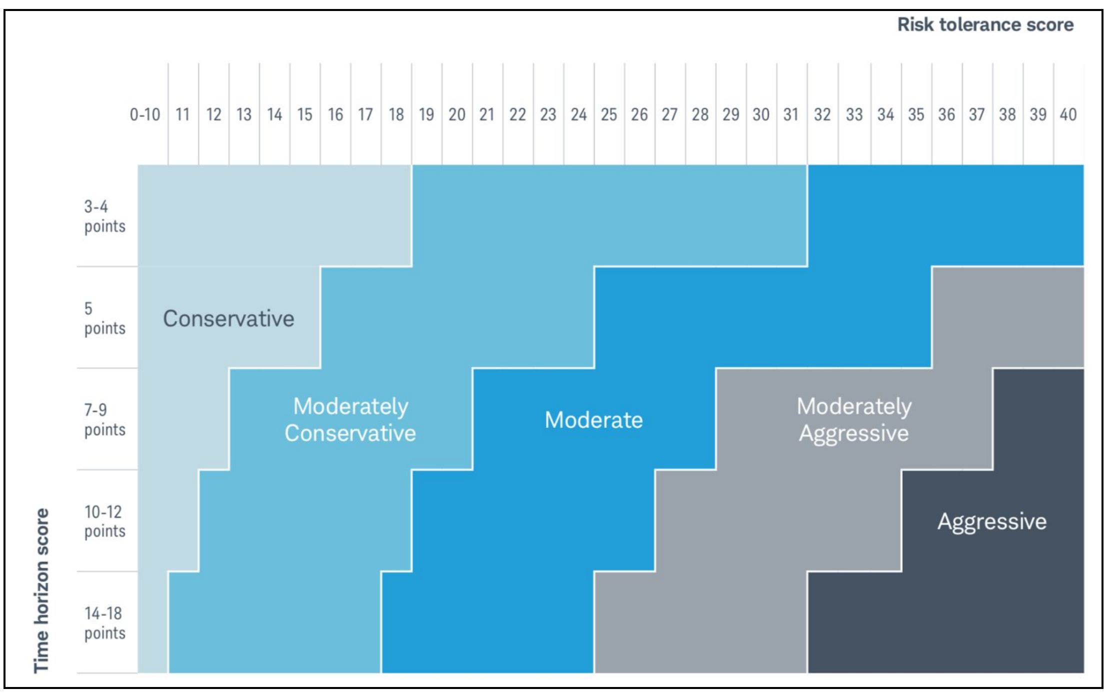


Figure 11. *Original Score Matrix from the Charles Schwab Questionnaire*

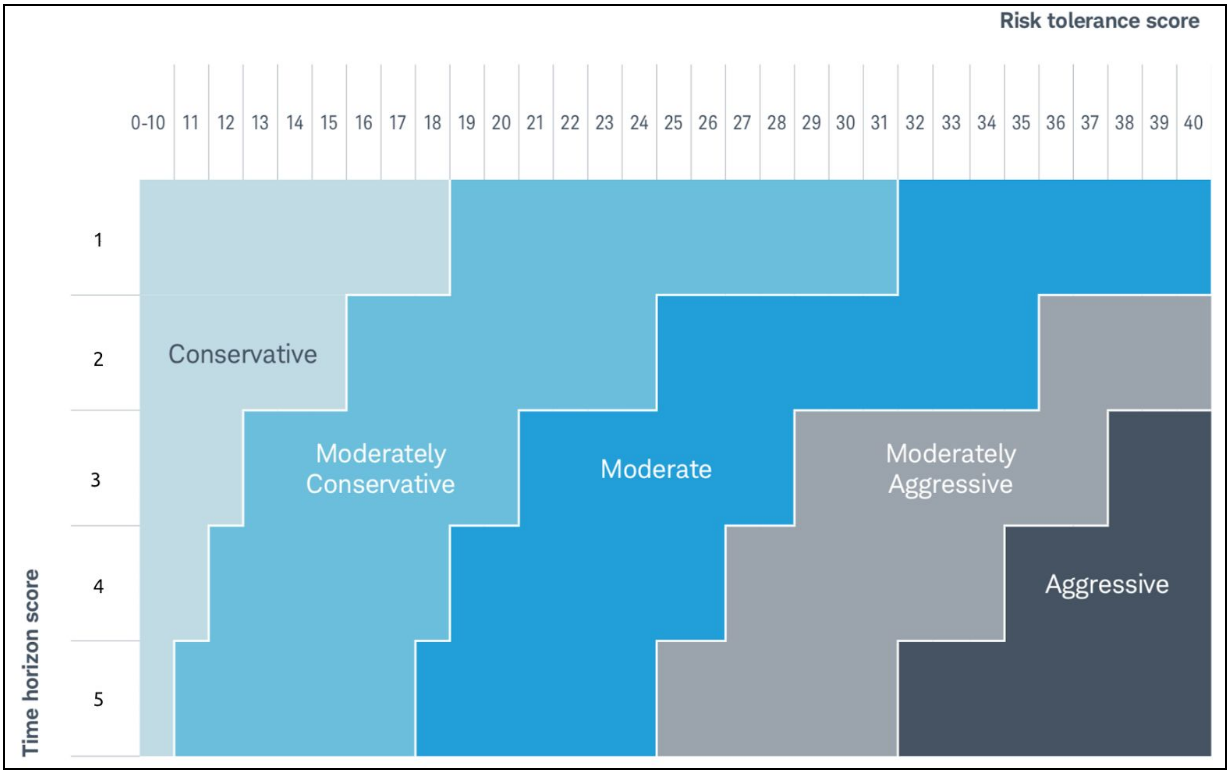


Figure 12. *Modified Score Matrix - Risk Tolerance and Time Horizon*

We have 5 questions in our risk profile, each going from a score of 1 to 4, for total of 20 points. This number was doubled to make it a total of 40 points for the *Risk Tolerance Score*, matching the original score matrix.

As for the *Time Horizon Score*, we followed the following formula to convert it to a 1-5 scale.

$$\textit{Time Horizon Score} = (6 - \textit{importance} + t)/2$$

where *importance* is the score of the "How important is it for you to achieve this goal on time?" question and *t* is calculated as follows:

Table 5. Corresponding value of *t* for a given time horizon

How long do you wish to save up for this goal?	t
<= 1 year	1
<= 2 years	2
2 - 5 years	3
5 - 10 years	4
10+ years	5

3.5.3 Other minor fixes and features added

Below is a list of some (not exhaustive) of the features added and bugs fixed, that were not mentioned already:

- Add markers to the line graphs when displaying portfolio historical data
- bokeh graphing library allows for graphs to be saved
- Automatic update of RSS feeds with ETF performance and daily news
- Ability for the user to change their password
- Editing goal feature
- Explanation behind the questionnaire questions
- Disable “Optimize” button when either goal is reached or time ends
- Custom logo and favicon made
- Error/ help text when users clicks to see their saved goals but has none yet

3.6 Limitations and Future Improvements

The limitations in our web app arise from the limited amount of time given for the project to be done but also that it took us longer at the beginning with a steep learning curve of front and back-end development to learn. Another reason for limitations that we discovered recently was that the online hosting platform, Heroku, did not support all library package versions. Listed below are the main areas to focus on for improvement.

1) Displaying multiple goal summaries - Either displaying just the progress bars of all goals in one place to get a snapshot view or displaying the net investment and net wealth across all goals
2) More effective communication with the user
    a) Right now we have errors that pop up, but these can be improved on. For example, for the incorrect password, user doesn’t exist error etc., a button can be added to go back to the appropriate login page. Or these errors can be displayed on the same page using pop-up windows.
    b) When the model detects an ambitious goal and changes the time horizon and disposable income for contributions, we need messages to explain to the user why the sudden change happened
3) To avoid errors in the model, we need to make sure that the form inputs are in the correct variable type and that all fields are filled out - add asterisks to indicate that all are mandatory fields to fill in.
4) Add data labels to the graphs - the pie chart with the portfolio allocations had percentages displayed earlier, but had to be deleted after because the version of bokeh with this feature was incompatible with deploying our app on Heroku.

4. Back-end Development

4.1 Technology Used

Python will be the language for our main infrastructure. Not only does it have many packages available which will shorten the code length, it is also good at integrating between different platforms. Plus, our team members are familiar with Python already and it is a very user-friendly language. We compared three different web framework available for python: Flask, Django, and Pyramid. Despite the fact that Django and Pyramid have a great community support, Flask coding is easy, simple, and tailored for quick implementation of relatively smaller projects, which make it perfect for our team since none of us have web application experience.

For our database selection, we had to choose between SQL and NoSQL databases. SQL databases have a rigid database structure that it must follow, and that takes away a lot of flexibility for our project. We want to have the option of expanding the application if time allows us to do so. NoSQL databases offer that kind of flexibility. Also, it does not require a strict table format so a lot of tables can be compressed to a few tables making a lot easier to work with. Among the few free options of NoSQL databases, we went with Mongo DB. The document structure that it provides gives us a lot of flexibility during integration and implementation of our application such as being able to store lists into certain fields for historical data or to quickly add a new field for testing.

For the host of our application, we compared Amazon Web Services, Google Cloud Platforms and Heroku. Amazon Web Services and Google Cloud platform scale better and are in general more efficient with big data. However, since we are implementing a small application, we chose to use Heroku for its ease of use, minimal configurations, smooth scaling and easy continuous deployment. Heroku also have a free addon called "MongoLab" that allowed us to have a small size database to store our data online.

4.2 Database

The data will be stored into the database in three separate Mongo DB collections: Users, Profiles and Portfolios. The primary key for Users collection is email, and the primary key for Profiles and Portfolios is port_id. To connect them together, Profiles and Portfolios have a foreign key user_email and Users have a list of port_ids to connect the Users with their respective Portfolios and Profiles.

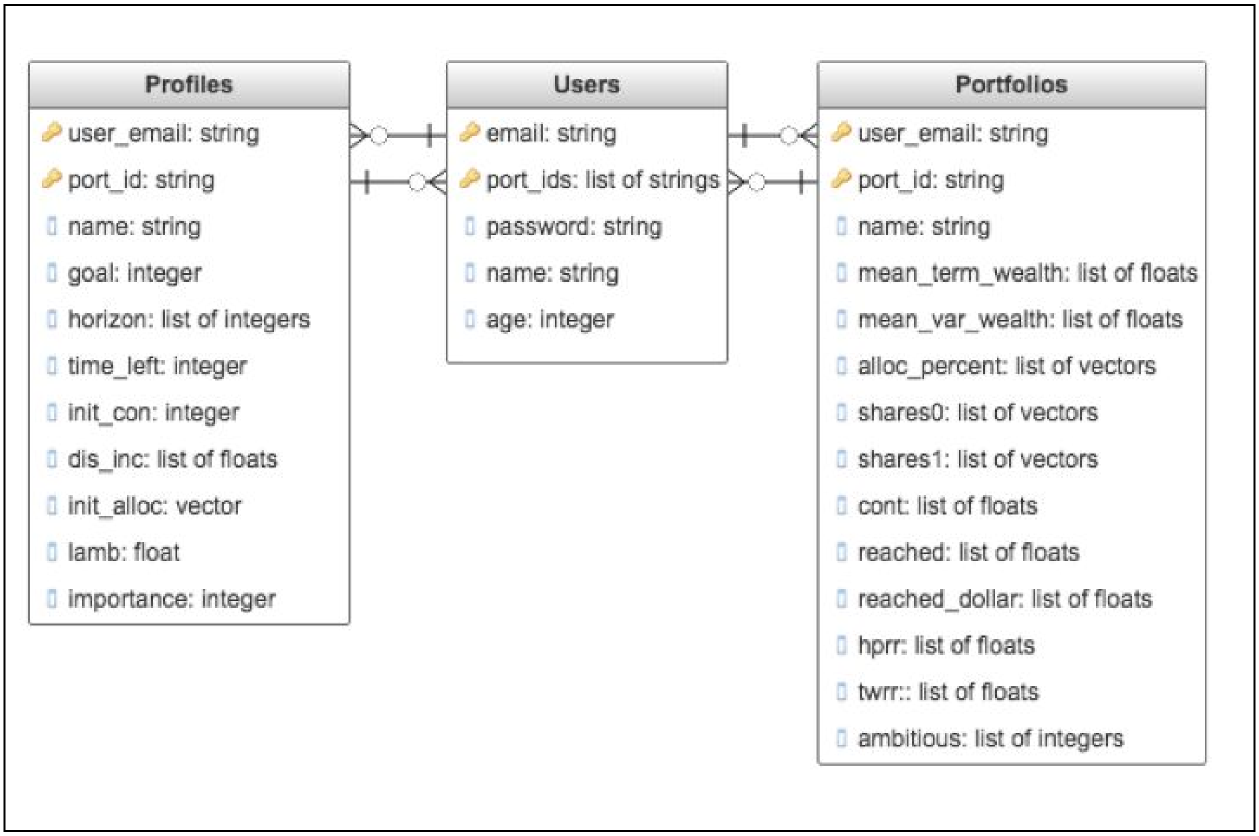


Figure 13. *New Database Schema*

4.2.1 Documentation of alternative designs

Our previous schema design had 5 collections and the Portfolios collection was storing the historical data with every field being a time increment. The same principle applies to asset returns. The design consists of 5 collections: User, Settings, Portfolios, Portfolio assets and assets. However, since the data for asset returns are different with every optimization, we decided to not store any asset returns into the database. Also because we decided to store historical data into a list in one single field, we are able to use the Portfolios collection much more efficiently and compress the two Portfolios collections into one and while being able to store more information. We changed the name “Settings” collection to “Profile” collection. Also, in the old design, only the User collection had a field containing email but we decided to put user_email field in both Portfolio and Profile collection so that it is very simple to track back from a profile or a portfolio to its user.

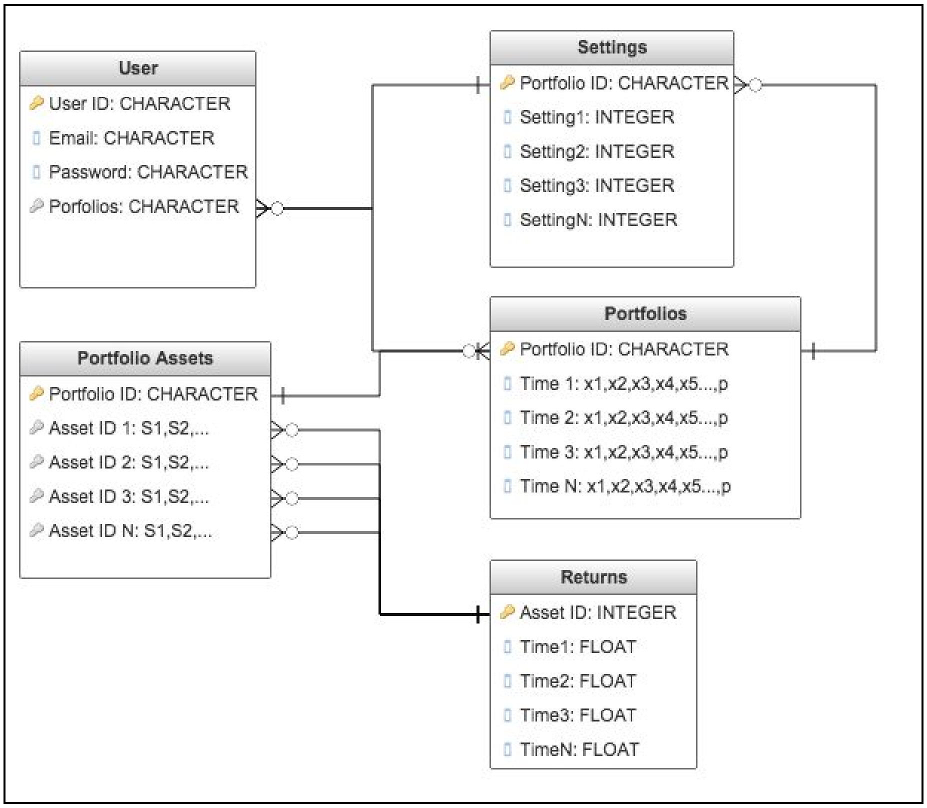


Figure 14. *Old Database Schema*

4.3 Collections

4.3.1 User collection

The User collection contains the basic login information of the user. It is the first collection created when the user register on our application.

Table 4. Description of the fields included in the *user* collection

Field	Description
email	It is the primary key of the collection. It is for login and also to identify and track the user within our application.
password	This key stores the login password of the user.
name	This field contains the full name of the user, and the value is used when displaying user information.
age	This field contains the age of the user, and the value is used when displaying user information

port_ids	It stands for Portfolio IDs. A user may have several profile/portfolios therefore we a using a list. The port_ids are used as connectors to link the users with their profiles and portfolios.

4.3.2 Profiles collection

Previously called "Settings", this collection contains all the necessary user input information needed by our optimization model. A document is generated whenever the user creates a new goal to reach. The answers of our new goal questionnaire will give information about the risk profile of this user as well as details of his/her goal. Most of the fields in this collection are numerical except horizon and dis_inc, which contains lists of numbers because they store historical data.

Table 6. Description of the fields in the *profiles* collection

Field	Description
port_id	port_id stands for portfolio ID. It is the primary key of the Profiles collection.
user_email	This field is a foreign key to the Users collection.
name	This field contains the name of the Portfolio associated with this profile.
goal	This field contains the total amount of this particular goal in dollars.
horizon	It stands for time horizon, and contains the time length of the goal in number of years. Due to the fact that the optimization might change the time horizon if it is not important to the user, we append the horizon of every optimization to keep track of the historical change of that variable.
time_left	It contains the time remaining to the end of the goal. This field is updated at every optimization.
dis_inc	dis_inc stands for disposable income. It represents the money injections that the user is able provides in order to make the optimization more feasible. It is the second field in Profiles collection that stores historical data. Therefore the field's value is a list of numbers.
init_con	It stands for initial contribution, which is the amount in dollars that the user is willing to contribute at the start of the optimization period.

init_alloc	It stands for initial allocation. This field contains the initial asset allocation and it is determined by the risk profile and time horizon questions answered by the user.
lamb	Stands for lambda, which is the risk attitude factor that we calculate based on the risk profile questions.
importance	This field contains an integer from a scale of 1-5 that indicates how important it is for the user to achieve his/her goal on time. This number is used in our optimization and for the initial asset allocation calculation.

4.3.3 Portfolio collection

This collection contains the results of our optimization model. It is the data source for our applications output (graphs and visuals of the optimization results). Every time a user creates a new goal, a Profile document is generated and populated. With every Profile document generated, there is a Portfolio document with the same port_id that is created to be populated later in the optimization stage. Other than the field port_id, user_email and name that remain constant through every optimization, every other field contains historical data and they are all in a list format.

Table 7. Description of the fields in *portfolio* collection

Field	Description
port_id	It is the primary key of the collection, same with Profiles.
user_email	It is the foreign key to the Users Collection
name	This field contains the name of the portfolio that the user set.
mean_term_wealth	It stands for mean terminal wealth; it represents the average value of the portfolio at the end of the optimization period.
mean_var_wealth	It stands for mean variance wealth. This field contains the variance of the user's wealth at the end of the optimization horizon
alloc_percent	It stands for allocation percentage, it contains the optimal weights of each assets at time=1. It is used to be the initial allocation of the next optimization run.
shares0	It stands for shares at time 0, similar to initial allocation in Profiles collection, it keep track of the number of shares at time zero for each asset.

shares1	It stands for shares at time 1. Similar to alloc_percent, it keeps track of the number of shares at time 1 for each asset.
cont	cont stands for contribution, it is the amount that the user will contribute according to the optimization model. This value's upper bound dis_inc in the Profile document with the same port_id.
reached	This contains the percentage of the target reached by the portfolio.
reached_dollar	This contains the dollar amount reached by the portfolio
hprr	It stands for holding period rate of returns. It contains the rate of return of the portfolio during the holding period.
twrr	It stands for time-weighted rate of returns from time. It contains the rate of return for a portfolio from time zero to now.
ambitious	It contains an indicator stating whether or not a goal is feasible. If it is not, (ambitious = 1), the model will either expand the time horizon or increase cash inflows or a combination of the two.

4.4 Asset Selection

For our asset universe, we decided to narrow it down to Exchange Traded Funds (ETFs). ETFs are priced and traded continuously throughout the day exactly like common stock whereas other assets like mutual funds are traded only once per day when markets close. This nearly instantaneous trading of ETFs makes portfolio management much more flexible. Also, ETFs offer diversification and risk management. ETFs give exposure to a group of equities across various industries or sectors and mimic the performance of an underlying index rather than a single asset's performance. They are a good choice for university and recently graduated students who want to quickly gain exposure to specific sectors or industries when they lack expertise in those areas. ETFs also tend to be low cost, having relatively lower fees in general and are more tax-efficient than mutual funds because they track an index without trying to outperform it. This can be extremely attractive to students with limited financial resources. Finally, ETFs are less computationally demanding to optimize. It is faster to compute optimization for a few ETFs than for hundreds of stocks that those ETFs encapsulate.

Using the Investor Profile Questionnaire from Charles Schwab as a reference, we divided our assets into 6 asset-class: cash investments, short-term fixed income, long-term fixed income, small-cap equity, large-cap equity, and international equity.

For cash investments, due to the higher fees of TFSAs (tax-free savings account) and the fact the student do not benefit as much of the tax-free account, we opted for a simple savings account at a regulated rate of 1%. The rest of them are ETFs on stocks and bonds. At some point, management fees and computational burden from incorporating additional assets outweigh the benefit of having more assets. Since ETF's are already diversified, we believe that one asset per class is sufficient for forming a diversified portfolio. Each asset we choose needs to be a representative of the whole asset class. That is why we picked the top asset by total assets. Total assets reflect the weight a particular ETF have on the market and they are also less likely to be affected by random economic pressures. Furthermore, ETFs with a high total asset also tend to have a high average volume, an indicator of greater liquidity.

Table 8. Asset Universe and Selected ETFs

Asset Class	Symbol	Name	Total Assets ($MM)	YTD	Average Volume
Large Cap	SPY	SPDR S&P 500 ETF	$255,164,614.91	20.00%	64,641,232.0
Small Cap	IWM	iShares Russell 2000 ETF	$46,578,195.68	14.57%	24,111,828.0
International	VEU	Vanguard FTSE All-World ex-US ETF	$22,374,340.64	24.48%	1,721,730.0
Short-Term Fixed Income	CSJ	iShares 1-3 Year Credit Bond ETF	$11,817,006.32	1.10%	470,261.0
Long-Term Fixed Income	BLV	Vanguard Long-Term Bond ETF	$2,341,500.00	9.43%	182,234.0

4.5 Data Flow

Below is the data flow diagram for our application. There are two external entities: the User and Yahoo Finance. We opted to use Yahoo finance to get our data because it has a very complete set of assets including the ETFs that we are using and it is a free service. There are other sources but they will usually charge a fee for importing ETF data.

The processes are in blue and they alter the data in one way or another. User email and port_id are flowing between the different processes since we are using them as keys to track different document in our database.

Finally the data stores are in yellow, they are the three collections. The Users collection is mainly used for the initial process of our application, login and registration. The Profiles collection is mainly used for goal setting and preparing for the optimization. Then the Portfolios collection is used at the final stage of our application, which is storing and displaying the optimization results.

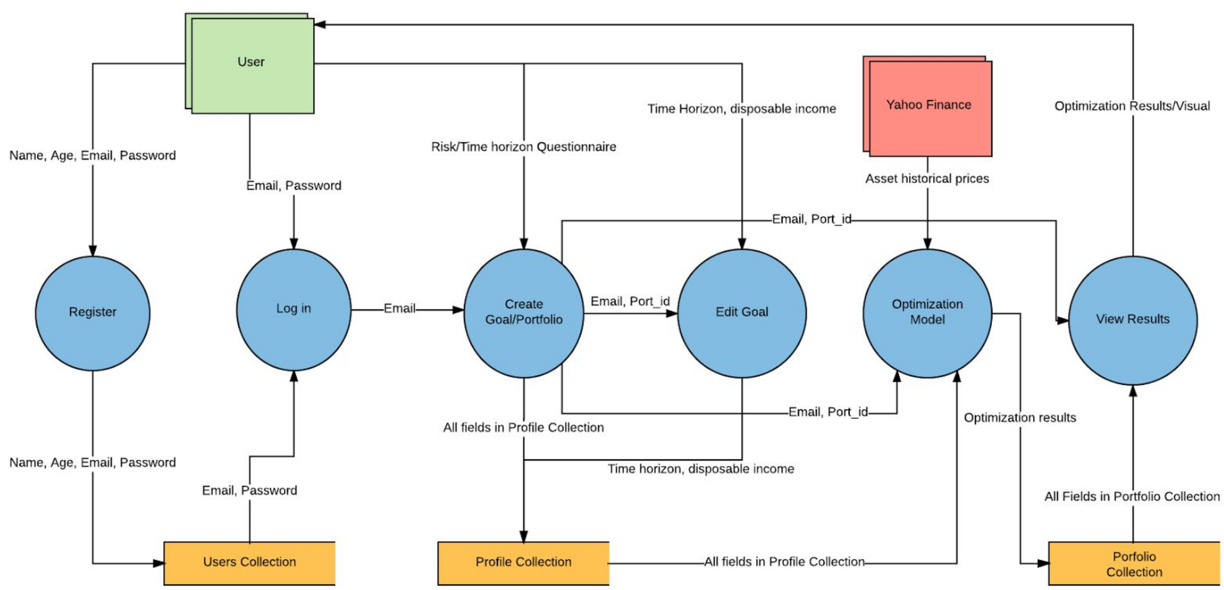


Figure 15. *Data Flow Diagram*

4.6 Future Improvements

One of the back-end decisions we made is to not store the Yahoo prices since they are only temporary data and they are not displayed to the user. The process of fetching historical prices from yahoo is one of the most computationally heavy operations that we have (sometimes the operation will run multiple time before one successful attempt). Another computationally heavy operation is our optimization process, and not having a data storage for Yahoo price data forces us to call both of the operations one right after the other. The problem with this process is that the user will wait a very longtime when they optimize their portfolio. Furthermore, Heroku will timeout if the request took more than 30 seconds to complete. This limits the maximum time horizon of the user's goal. To improve on our current application, we can create a temporary space in the database for Yahoo prices and call the fetch price operation when the user create his/her goal. That way, even though we are improving on the overall wait time by the user, we are decreasing the maximum wait time which can be useful to improve user experience and it can also allow for more computationally heavy optimizations on hosts such as Heroku.

5. Conclusion

Personal asset-liability management robo-advisor for inexperienced college students, aptly named “finewbie”, was designed to take on the challenge of recommending an optimal investment strategy for any type of goal given any risk profile and financial background in a way which makes the seemingly complicated world of finance more coherent. Our design process favored two values -- robustness and usability to ensure that once a goal is created, finewbie attempts to formalize a strategy which the investor is financially capable of following, and that the investor feels like he/she understands all financial concepts presented in our web application. Overall, finewbie demonstrates functional consistency, albeit with some potential improvements, with good satisfaction rates from usability testing on our real stakeholders -- students.

6. References

[1] B. Cude et al., "College Students and Financial Literacy: What They Know and What We Need to Learn," in Eastern Family Economics and Resource Management Association, 2006.

[2] M. Padula and T. Jappelli, "Investment in financial literacy and saving decisions," Journal of Banking & Finance, vol. 37, no. 8, pp. 2779-2792, 2013.

[3] R. Volpe and H. Chen, "An analysis of personal financial literacy among college students," Financial Services Review, vol. 7, no. 2, pp. 107-128, 1998.

[4] A. O'Shea, "Best Robo-Advisors: 2017 Top Picks," Nerdwallet, 23 June 2017. [Online]. Available: https://www.nerdwallet.com/blog/investing/best-robo-advisors/. [Accessed 6 November 2017].

[5] S. Elmblad, "2017: Top 9 Personal Budget Software Apps," The Balance, 21 September 2017. [Online]. Available: https://www.thebalance.com/top-10-budget-software-apps-1293609. [Accessed 6 November 2017].

[6] J. Mulvey and B. Shetty, "Financial planning via multi-stage stochastic optimization," Computers & Operations Research, vol. 31, pp. 1-20, 2004.

[7] E. A. Medova, J. K. Murphy, A. P. Owen and K. Rehman, "Individual asset liability management," Quantitative Finance, vol. 8, no. 6, pp. 547-560, 2008.

[8] K. Reddy and V. Clinton, "Simulating Stock Prices Using Geometric Brownian Motion: Evidence from Australian Companies," Australasian Accounting, Business and Finance Journal, vol. 10, no. 3, pp. 23-47, 2016.

[9] S. N. Z. Abidin and M. M. Jaffar, "Forecasting Share Prices of Small Size Companies in Bursa Malaysia Using Geometric Brownian Motion," Applied Mathematics and Information Sciences, vol. 8, no. 1, pp. 107-112, 20144.

[10] Developer.yahoo.com. *Yahoo! Finance Web Services - Industry News RSS Feed - YDN*. [online] Available at: https://developer.yahoo.com/finance/industry.html [Accessed 3 Nov. 2017].

[11] Elliot, D. A SIMPLE WAY TO ADD FREE NEWS CONTENT TO YOUR WEBSITE. [Blog] *DeveloperDrive*. Available: http://www.developerdrive.com/2012/03/a-simple-way-to-add-free-news-content-to-your-website/[Accessed 3 Nov. 2017].

[12] Usability Testing Basics - An Overview. (n.d.). [ebook] TechSmith. Available at: http://webservices.itcs.umich.edu/drupal/wwwsig/sites/webservices.itcs.umich.edu.drupal.wwwsig/files/Usability-Testing-Basics.pdf [Accessed 5 Nov. 2017].

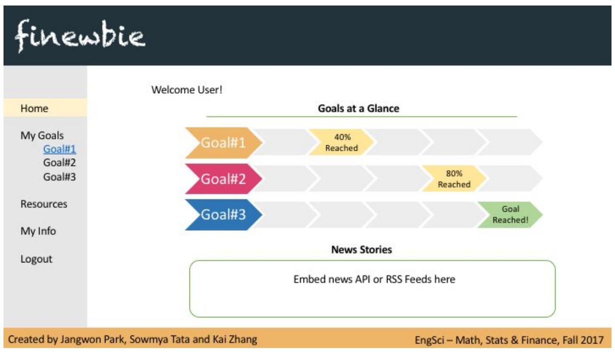
[13] Travis, D. (2013). The 1-page usability test plan. [Blog] *UserFocus*. Available at: https://www.userfocus.co.uk/articles/usability_test_plan_dashboard.html [Accessed 4 Nov. 2017].

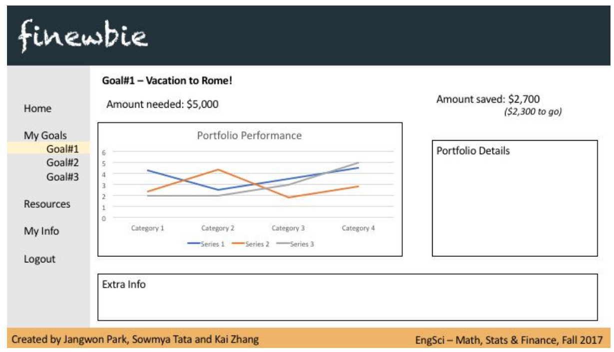
[14] Usability.gov. (n.d.). *Running a Usability Test*. [online] Available at: https://www.usability.gov/how-to-and-tools/methods/running-usability-tests.html [Accessed 4 Nov. 2017].

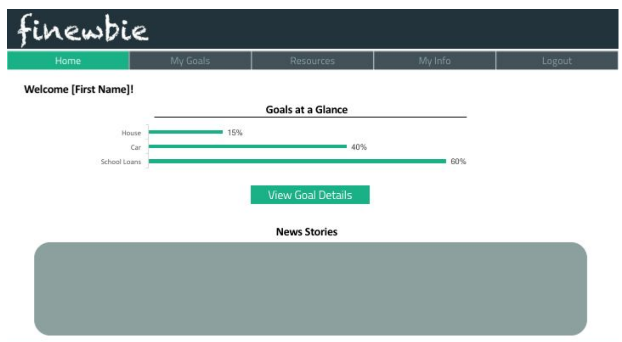
7. Appendices

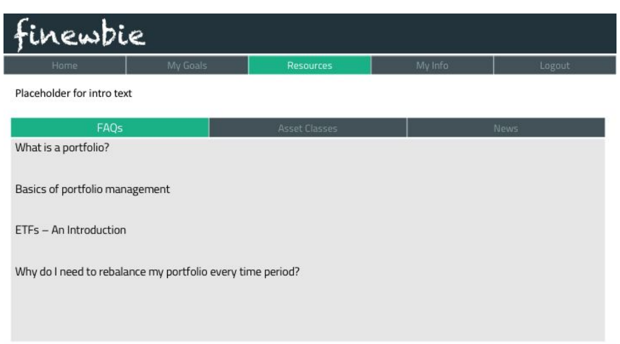
Appendix A: Wireframes and App Screenshots

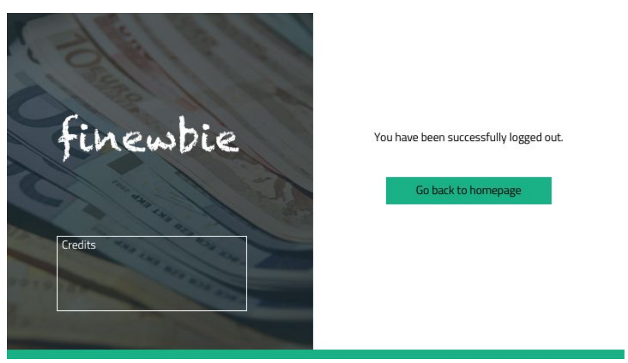
Old Design Prototypes and Templates



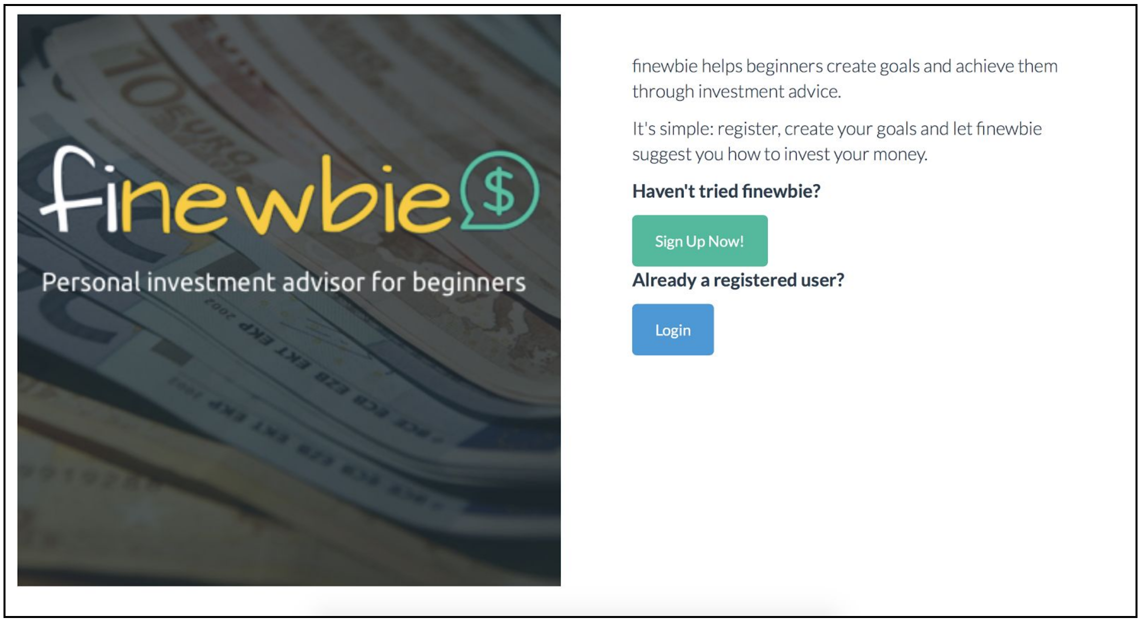


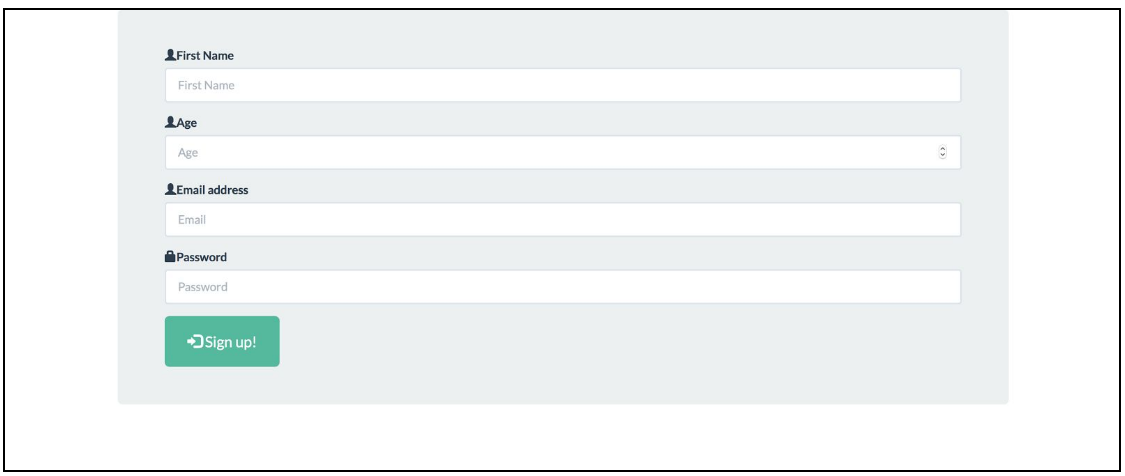


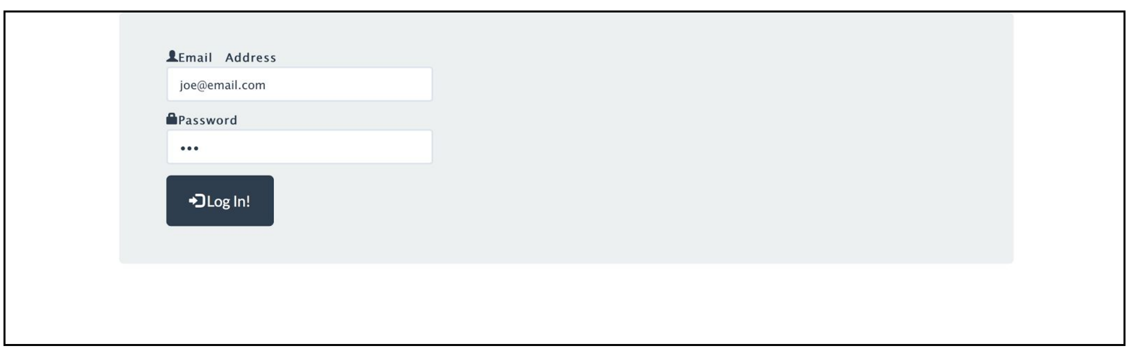


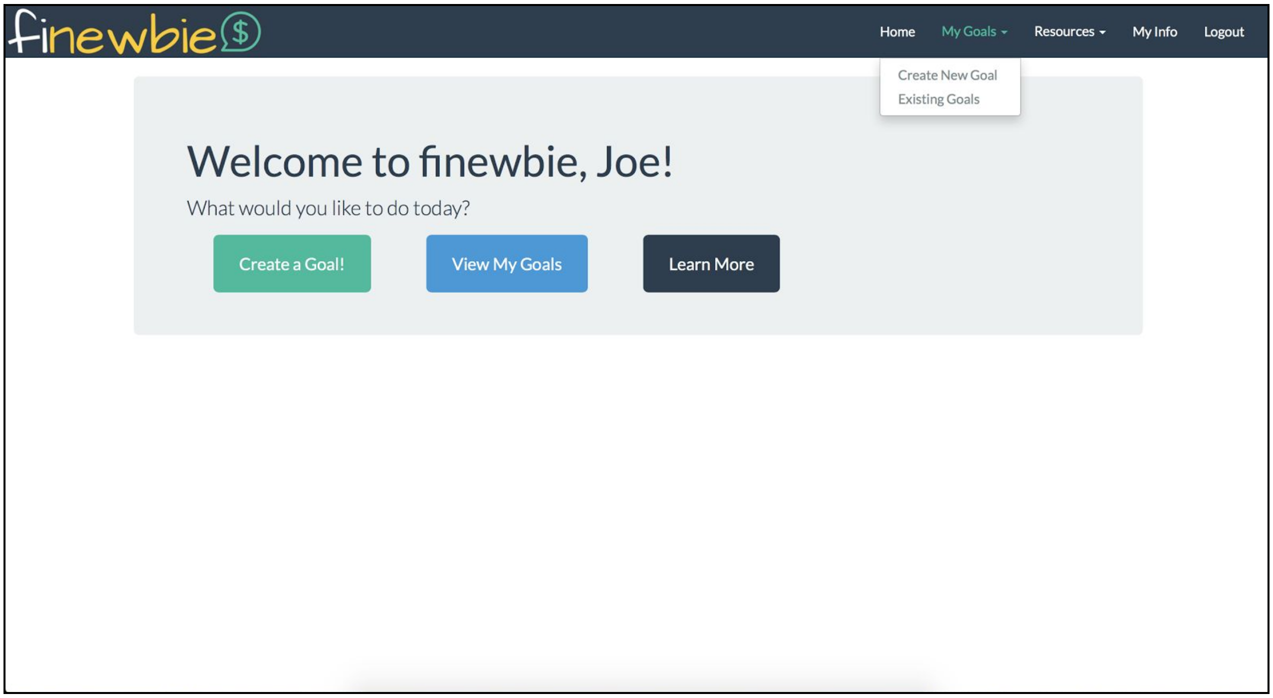


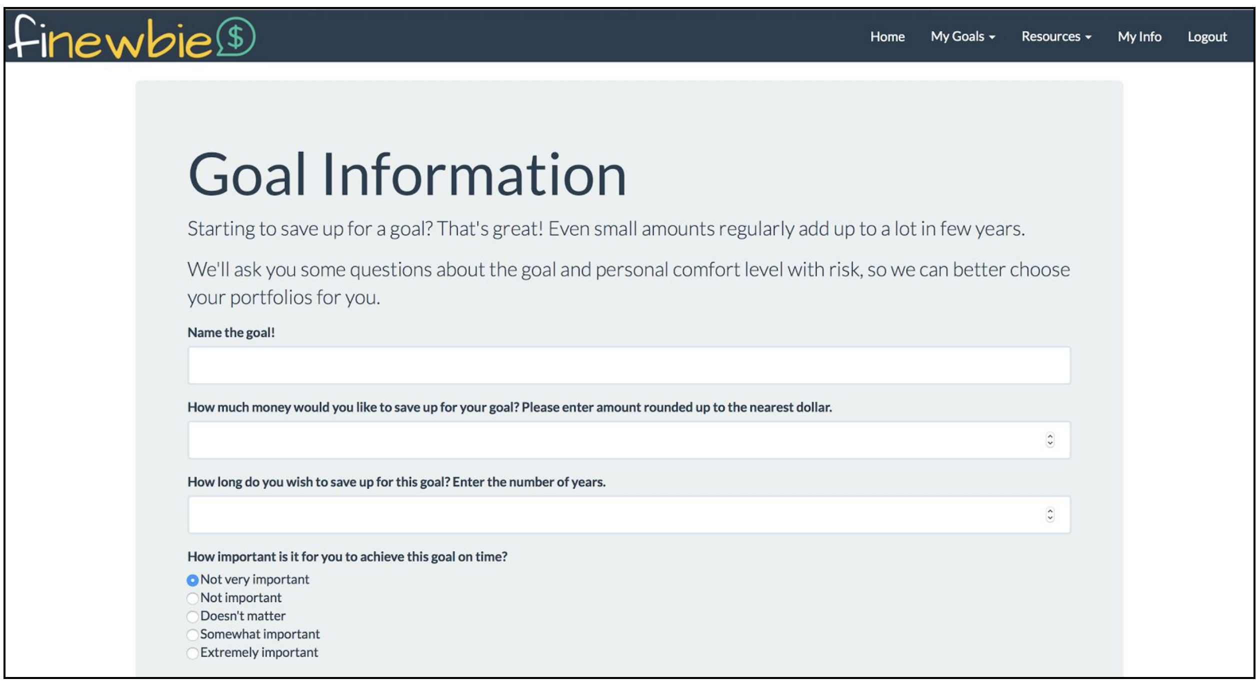
finewbie: App Screenshots








finewbie
Home
My Goals
Resources
My Info
Logout
Create New Goal
Existing Goals
Welcome to finewbie, Joe!
What would you like to do today?
Create a Goal!
View My Goals
Learn More


finewbie
Home
My Goals
Resources
My Info
Logout
Goal Information
Starting to save up for a goal? That's great! Even small amounts regularly add up to a lot in few years.
We'll ask you some questions about the goal and personal comfort level with risk, so we can better choose your portfolios for you.
Name the goal!
How much money would you like to save up for your goal? Please enter amount rounded up to the nearest dollar.
How long do you wish to save up for this goal? Enter the number of years.
How important is it for you to achieve this goal on time?
Not very important
Not important
Doesn't matter
Somewhat important
Extremely important

Goal Contribution

We'd like to know how much you can regularly contribute towards your goal.

Feel like you won't have any income left for your other needs? Don't worry, we will take other bills and payments you have to make into account.

What is the initial contribution you would like to make towards this goal? Please enter amount rounded up to the nearest dollar.

Enter the value of your monthly current assets (All sources of income basically - salary, savings account balance, existing investments.)

Enter the value of your monthly current liabilities (All expenses including rent, insurance, credit card bills, utilities etc.)

Risk Profile

What is your comfortable level of risk? Find out here!

Don't overthink the questions - just go with your instinct

You are on a TV game show and can choose only one of the following options. Which would you take?

- $1,000 in cash
- 50% chance at $5,000
- 25% chance at $10,000
- 5% chance at $100,000

Two weeks before you leave for your dream vacation, you lose your job. You would:

- Cancel your vacation
- Take a more modest vacation
- Proceed as scheduled
- Extend your vacation

When you think of the word 'risk', what first comes to mind?

- Threat
- Loss
- Uncertainty
- Opportunity

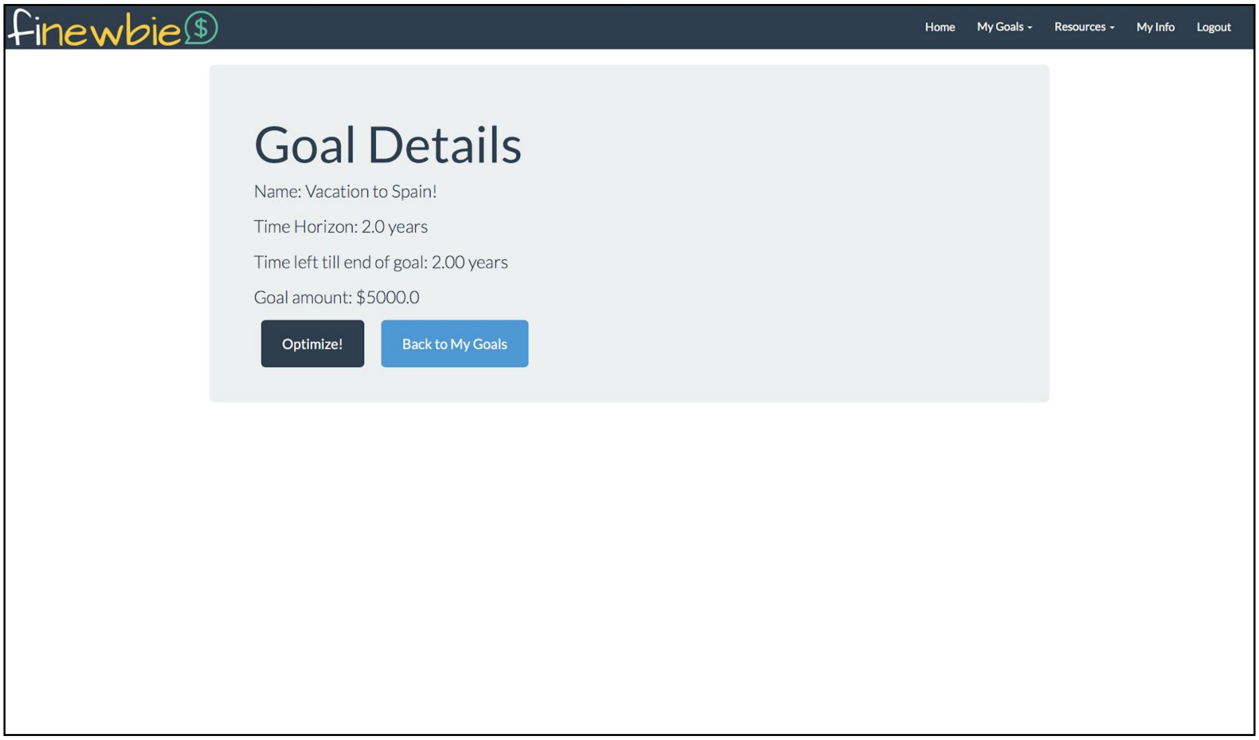
Given the best and worst case scenario, which of these investment choices do you prefer?

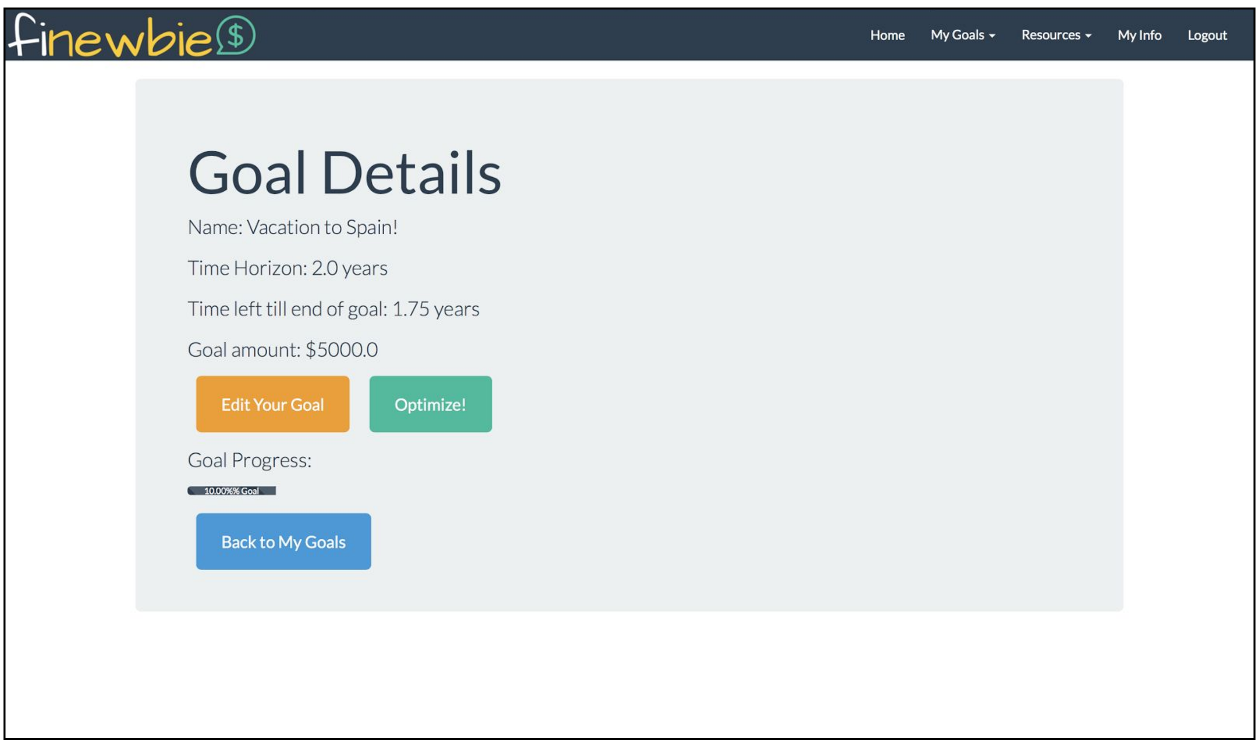
- $250 gain, $0 loss
- $750 gain, $200 loss
- $2,800 gain, $800 loss
- $5,000 gain, $2,500 loss

A good friend offers you an opportunity to invest in his new invention, which would double your investment if it passes a safety inspection. There's a 20% chance of success. How much would you invest?

- Nothing
- One month's salary
- Two month's salary
- Six month's salary

Create My Goal!


finewbie
Home
My Goals
Resources
My Info
Logout
Goal Details
Name: Vacation to Spain!
Time Horizon: 2.0 years
Time left till end of goal: 2.00 years
Goal amount: $5000.0
Optimize!
Back to My Goals


finewbie
Home
My Goals
Resources
My Info
Logout
Goal Details
Name: Vacation to Spain!
Time Horizon: 2.0 years
Time left till end of goal: 1.75 years
Goal amount: $5000.0
Edit Your Goal
Optimize!
Goal Progress:
10.00%% Goal
Back to My Goals

Home My Goals Resources My Info Logout

Portfolio Details - Vacation to Spain!

As of this time, you saved up 59.96% of your goal (inflation taken into account).

$ Translated to dollar value, your investment is now worth $3072.97.

Don't worry! You still have 0.51 years to reach your goal.

Back to Goal Summary

Important Statistics

Holding Period Rate of Return: -10.10%

Time-Weighted Rate of Return: -17.90%

Variance of Portfolio Value: $4.50

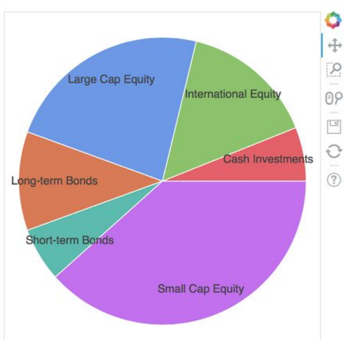
Investment Suggestion

finewbie suggests that you buy the following amounts of assets listed:

- -0.28 shares of SPY
- 7.07 shares of IWM
- 4.60 shares of VEU
- -0.99 shares of CSJ
- -0.20 shares of BLV
- $-99.14 added to your cash investments.

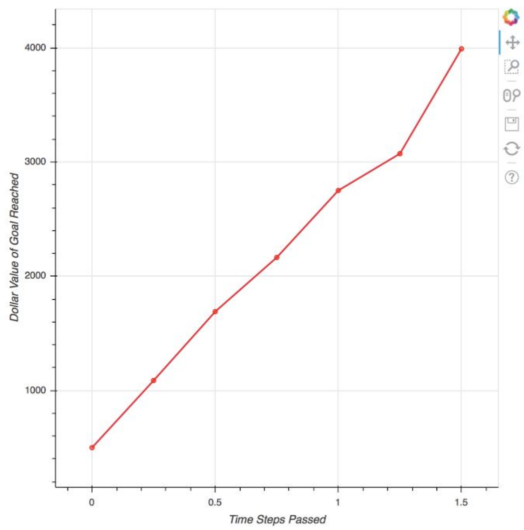
Asset Allocation within Portfolio

How is your investment split up into the different asset classes? This split keeps changing at every time period to be consistent with your risk profile, but adjusting for the returns of the assets.



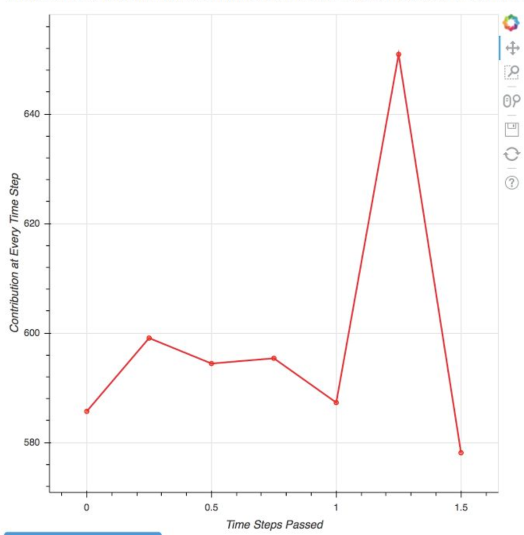
Market Value of Portfolio

This is how much your investment (initial contribution + added cash) is worth in the market today.

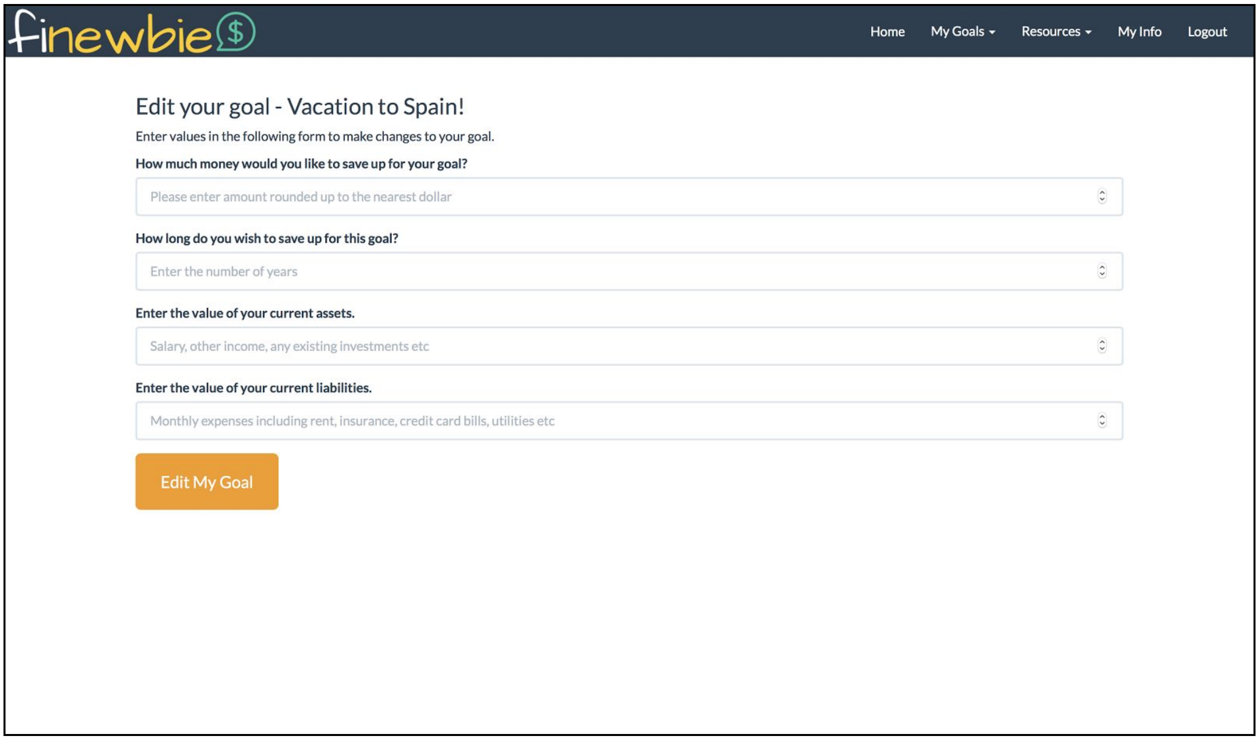


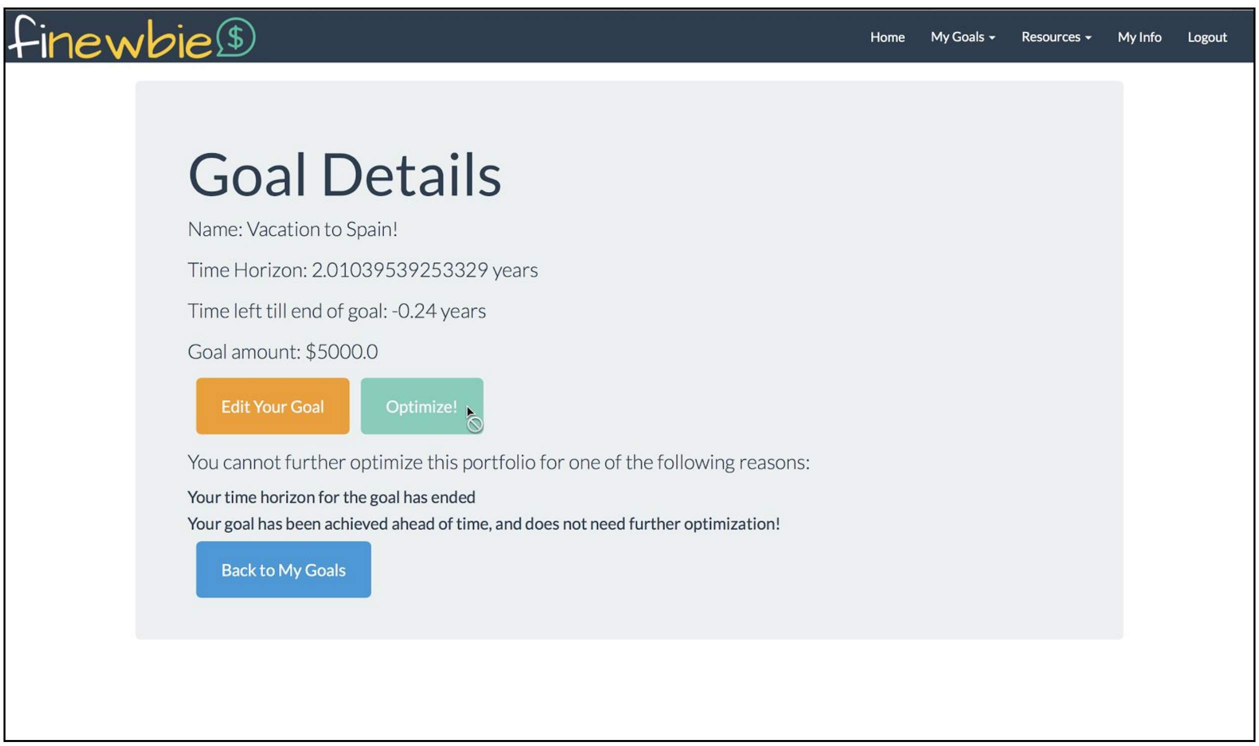
Additional Cash Inflow from Investor

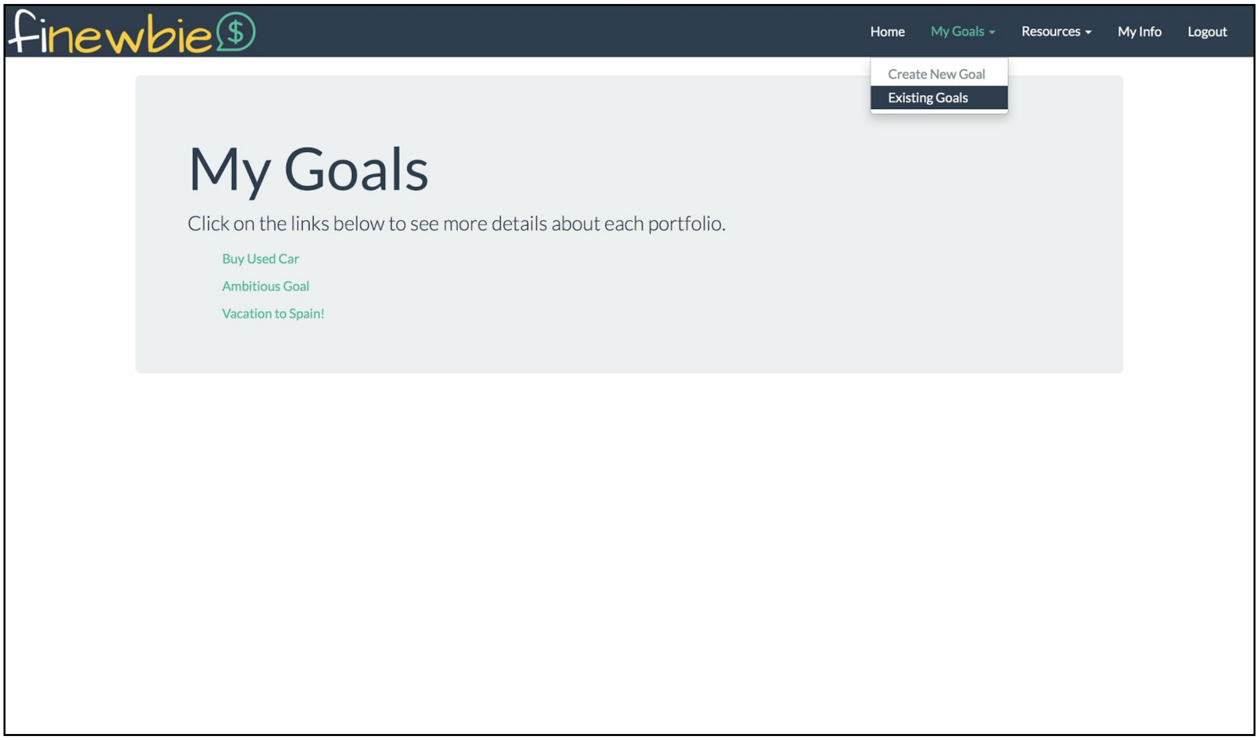
This is the money you put in to the portfolio as contribution towards the goal, at every time step.

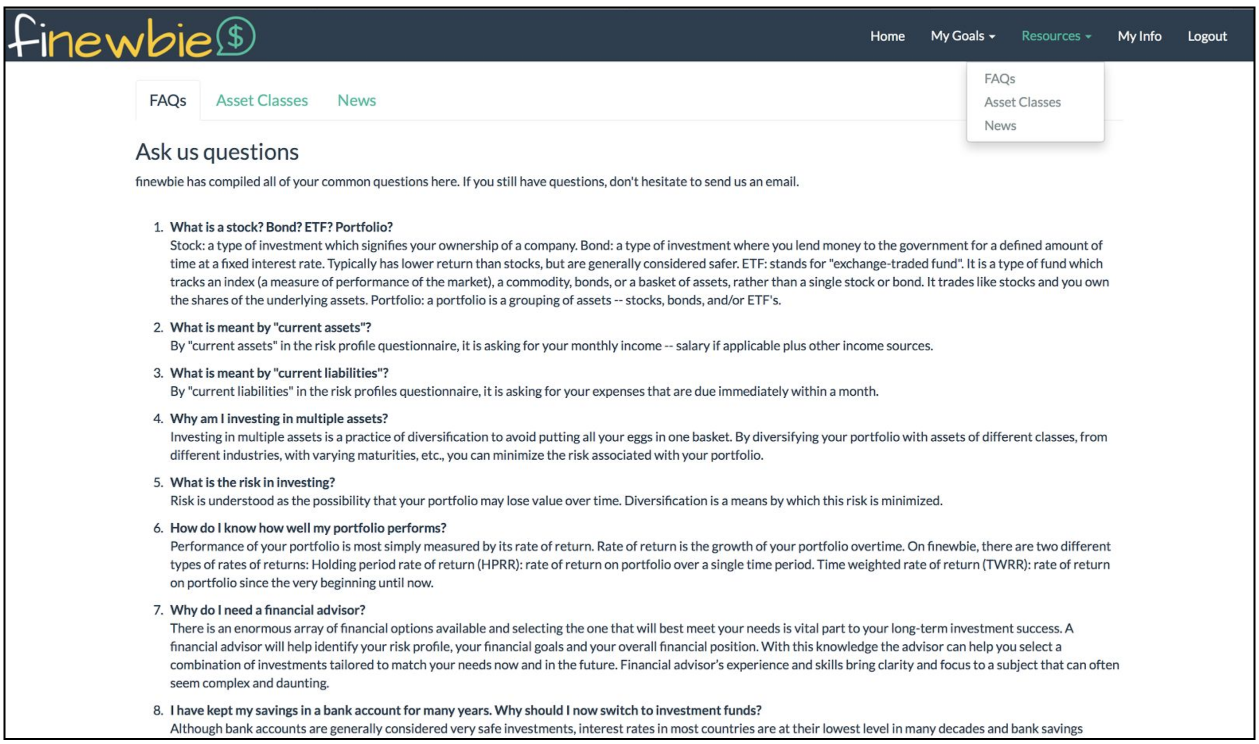


Back to Goal Summary


finewbie
Home
My Goals
Resources
My Info
Logout
Edit your goal - Vacation to Spain!
Enter values in the following form to make changes to your goal.
How much money would you like to save up for your goal?
Please enter amount rounded up to the nearest dollar
How long do you wish to save up for this goal?
Enter the number of years
Enter the value of your current assets.
Salary, other income, any existing investments etc
Enter the value of your current liabilities.
Monthly expenses including rent, insurance, credit card bills, utilities etc
Edit My Goal


finewbie
Home
My Goals
Resources
My Info
Logout
Goal Details
Name: Vacation to Spain!
Time Horizon: 2.01039539253329 years
Time left till end of goal: -0.24 years
Goal amount: $5000.0
Edit Your Goal
Optimize!
You cannot further optimize this portfolio for one of the following reasons:
Your time horizon for the goal has ended
Your goal has been achieved ahead of time, and does not need further optimization!
Back to My Goals





Ask us questions

finewbie has compiled all of your common questions here. If you still have questions, don't hesitate to send us an email.

1. **What is a stock? Bond? ETF? Portfolio?**
   Stock: a type of investment which signifies your ownership of a company. Bond: a type of investment where you lend money to the government for a defined amount of time at a fixed interest rate. Typically has lower return than stocks, but are generally considered safer. ETF: stands for "exchange-traded fund". It is a type of fund which tracks an index (a measure of performance of the market), a commodity, bonds, or a basket of assets, rather than a single stock or bond. It trades like stocks and you own the shares of the underlying assets. Portfolio: a portfolio is a grouping of assets -- stocks, bonds, and/or ETF's.
2. **What is meant by "current assets"?**
   By "current assets" in the risk profile questionnaire, it is asking for your monthly income -- salary if applicable plus other income sources.
3. **What is meant by "current liabilities"?**
   By "current liabilities" in the risk profiles questionnaire, it is asking for your expenses that are due immediately within a month.
4. **Why am I investing in multiple assets?**
   Investing in multiple assets is a practice of diversification to avoid putting all your eggs in one basket. By diversifying your portfolio with assets of different classes, from different industries, with varying maturities, etc., you can minimize the risk associated with your portfolio.
5. **What is the risk in investing?**
   Risk is understood as the possibility that your portfolio may lose value over time. Diversification is a means by which this risk is minimized.
6. **How do I know how well my portfolio performs?**
   Performance of your portfolio is most simply measured by its rate of return. Rate of return is the growth of your portfolio overtime. On finewbie, there are two different types of rates of returns: Holding period rate of return (HPRR): rate of return on portfolio over a single time period. Time weighted rate of return (TWRR): rate of return on portfolio since the very beginning until now.
7. **Why do I need a financial advisor?**
   There is an enormous array of financial options available and selecting the one that will best meet your needs is vital part to your long-term investment success. A financial advisor will help identify your risk profile, your financial goals and your overall financial position. With this knowledge the advisor can help you select a combination of investments tailored to match your needs now and in the future. Financial advisor's experience and skills bring clarity and focus to a subject that can often seem complex and daunting.
8. **I have kept my savings in a bank account for many years. Why should I now switch to investment funds?**
   Although bank accounts are generally considered very safe investments, interest rates in most countries are at their lowest level in many decades and bank savings

finewbie

Home | My Goals | Resources | My Info | Logout

FAQs | Asset Classes | News

Diversification is key

One of the basic rules of investing is to diversify your assets so that the risk is spread out and minimized. It is never wise to put all your egss in the same basket!

Here at finewbie, we invest your money into Exchange Traded Funds(ETFs). These are essentially collection of stocks, commodities or bonds that track and are representative of a larger group. You can buy ETFs of industries, by geography or by market indices.

Following are the ETFs your portfolio money is invested in. Look below for latest performance of these ETFs.

- SPDR S&P 500 Trust ETF (SPY) - Large Cap Equity
- iShares Russell 2000 Index Fund (IWM) - Small Cap Equity
- Vanguard FTSE All-World ex-US ETF (VEU) - International Equity
- iShares 1-3 Year Credit Bond ETF (CSJ) - Short-term Bonds
- Vanguard Long-Term Bond ETF (BLV) - Long-term Bonds
- Cash Investment - Savings Account

ETF Performance

05 Dec 2017 16:00:00 EST - The latest stock information is now available for your stocks

SPY

Last	263.19
Change	- 0.95
% Change	0.36%
Volume	77,974,820

As of: 5 Dec 2017 16:00:00 EST
View: Stock Quote | News

IWM

Last	150.93
Change	- 1.52
% Change	1%
Volume	29,657,353

As of: 5 Dec 2017 16:00:00 EST
View: Stock Quote | News

VEU

Last	53.7
Change	- 0.07
% Change	0.13%
Volume	1,713,475

finewbie

Home | My Goals | Resources | My Info | Logout

FAQs | Asset Classes | News

Keep up with the news!

A great way to learn more about investing and finance is to read the daily financial and economic news. Even if you don't understand anything at first, you'll get there soon. Here are the latest headlines from the financial world.

Business, Economy and Investing News Feed

Jobs Data To Look For

This is an important week for economic data in the U S but not quite yet This Friday morning we shall see the latest non farm payroll numbers and unemployment rate from the Bureau of Labor Statistics BLS We expect to see another strong month of jobs gains pretty much across the spectrum

Business planning is your business plan in motion

The Age of the Customer is disrupting and making obsolete many older practices, but not the requirement for business planning, especially cash flow. A business plan is the result of thinking, researching, strategizing and reaching conclusions about how to pursue opportunities. It may exist only in the head of the

Bite Into These Restaurant Stocks Ahead of Tax Overhaul

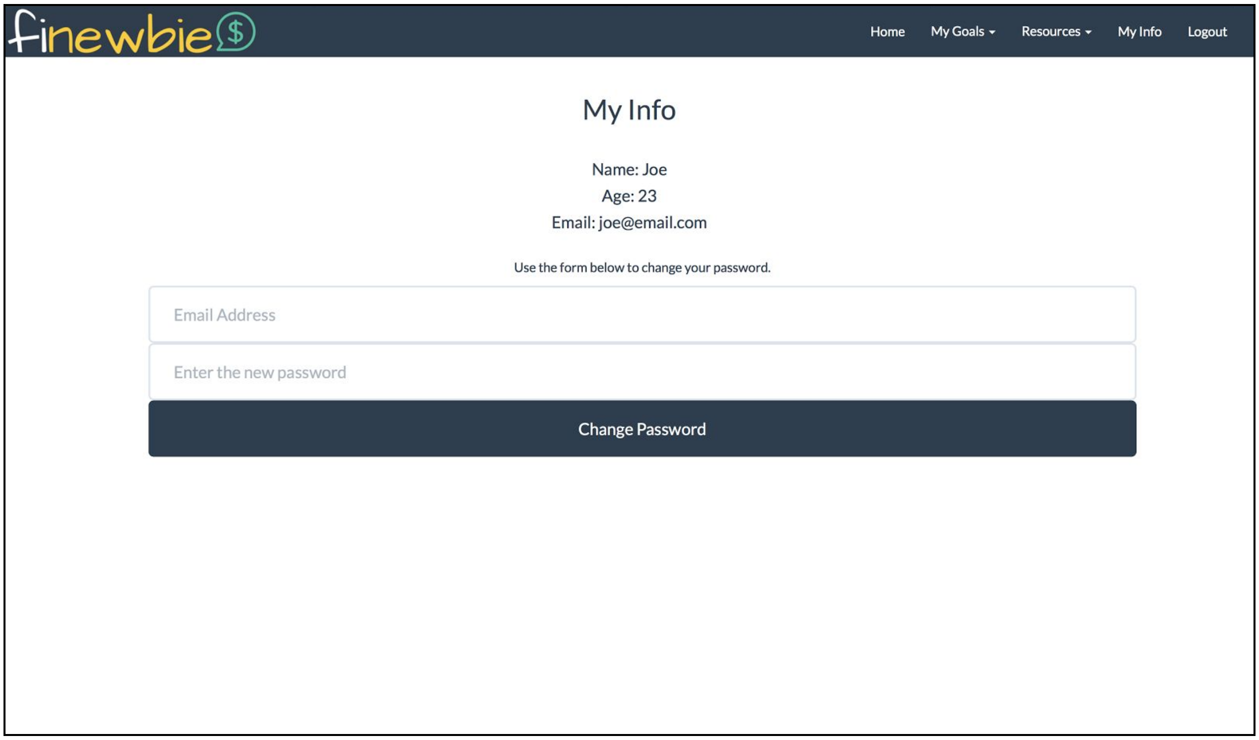
If you're looking for tasty returns in 2018 -- and why wouldn't you -- plenty of discounted restaurant stocks should be on your menu. On Monday, on the heels of the Senate Republicans passing a bill overhauling the federal tax code, known as the "Tax Cuts and Jobs Act," several analysts such as David Tarantino of

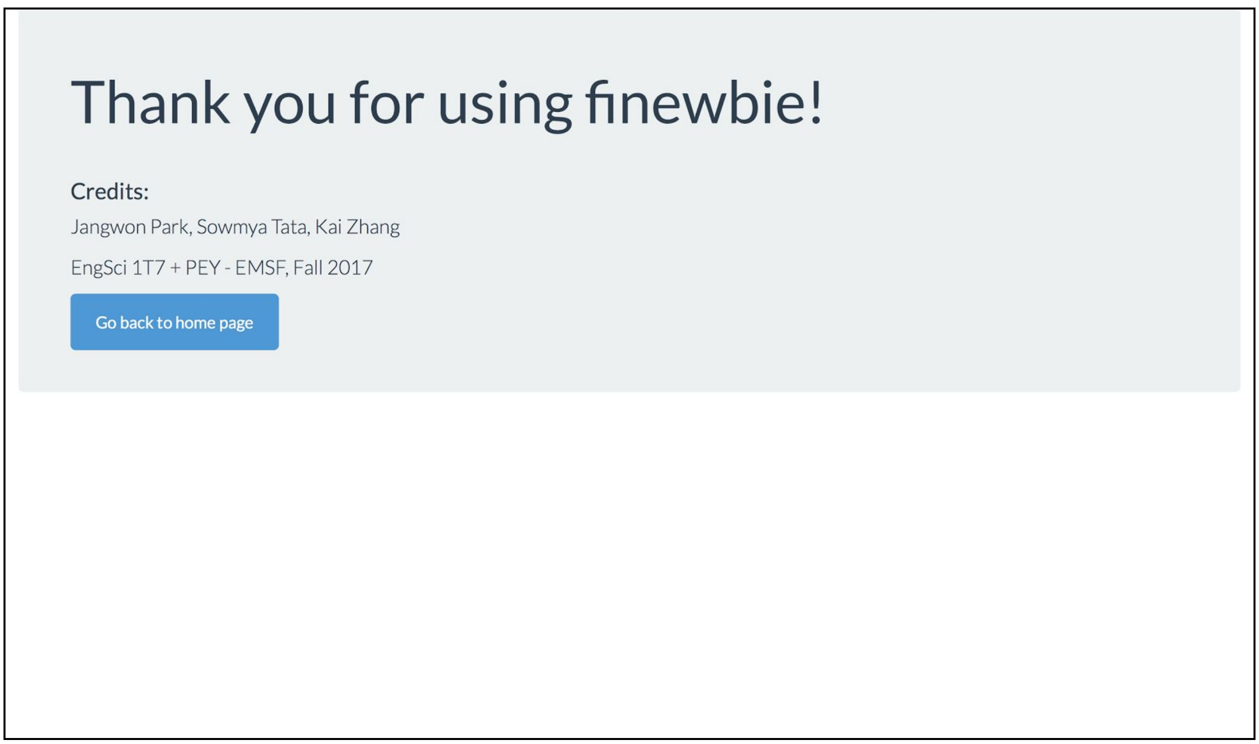
An Open Letter To BlackRock Regarding $7 Trillion Of Stock Buybacks

By Arne Alsin ByArne Alsin Dear Larry Dear Larry Are you doing everything possible to protect your investors from excessive stock buybacks Are you doing everything possible to protect your investors from excessive stock buybacks The bread and butter of BlackRock s

Dow Futures Up Above 200 Points In Pre-Market

Dow futures have rocketed up more than 200 points in this morning s pre market on news that the Senate has passed its version of a tax reform bill in the wee hours of Saturday morning The corporate tax rate shedding 15 percentage points 35 to 20 is one of the main items the Senate


finewbie
Home
My Goals
Resources
My Info
Logout
My Info
Name: Joe
Age: 23
Email: joe@email.com
Use the form below to change your password.
Email Address
Enter the new password
Change Password


Thank you for using finewbie!
Credits:
Jangwon Park, Sowmya Tata, Kai Zhang
EngSci 1T7 + PEY - EMSF, Fall 2017
Go back to home page

Appendix B: Usability Dashboard from UserFocus

USABILITY TEST PLAN DASHBOARD

AUTHOR
DAVID TRAVIS

CONTACT DETAILS
DAVID.TRAVIS@USERFOCUS.CO.UK +44 20 7917 9535

FINAL DATE FOR COMMENTS
SEPTEMBER 15TH

PRODUCT UNDER TEST
What's being tested? What are the business and experience goals of the product?
THE WEB SITE AT [TEST SITE TBA]

BUSINESS CASE
Why are we doing this test? What are the benefits? What are the risks of not testing?
THE TEST WILL ADDRESS SEVERAL KEY QUESTIONS THAT THE DESIGN TEAM NEED ANSWERS TO FOR THE NEXT ITERATION. FAILING TO ANSWER THESE QUESTIONS NOW INCREASES THE RISK OF DEVELOPING THE WRONG PRODUCT.

TEST OBJECTIVES
What are the goals of the usability test? What specific questions will be answered? What hypotheses will be tested?
DO PEOPLE UNDERSTAND THE VALUE PROPOSITION — THE CONCEPT OF AN ONLINE CONCIERGE SERVICE?
DO PEOPLE TRUST THE SERVICE?
DO THE EMAILS HELP PEOPLE PROCEED THROUGH THE VARIOUS STAGES?
DO PEOPLE UNDERSTAND HOW TO CHOOSE A TIME SLOT ON THE BOOKING SCREEN?

PARTICIPANTS
How many participants will be recruited? What are their key characteristics?
6-8 PARTICIPANTS RECRUITED VIA PANEL.
- ALL MUST BE IN FULL-TIME EMPLOYMENT
- ALL MUST OWN A SMARTPHONE
A MIX OF MEN AND WOMEN, HOMEOWNERS AND RENTERS.

EQUIPMENT
What equipment is required? How will you record the data?
LAPTOP WITH EYE TRACKING SOFTWARE AND MORAE TEST SOFTWARE.
ALL SESSIONS WILL BE RECORDED TO DIGITAL VIDEO.
WE WILL LOG USABILITY PROBLEMS AND MEASURE TASK COMPLETION RATE AND TIME ON TASK.

TEST TASKS
What are the test tasks?
FIND OUT MORE ABOUT THE SCHEME AND DECIDE IF YOU WOULD SIGN UP FOR IT.
SIGN UP FOR THE SERVICE.
FIND A TRUSTED PLUMBER WHO CAN FIT YOUR NEW DISHWASHER.
REVIEW THE OFFER AND ARRANGE A TIME FOR THE PLUMBER'S VISIT.
COMPARE 3 ALTERNATIVE DESIGNS OF THE TIME SLOT BOOKING SCREEN PAGE.

RESPONSIBILITIES
Who is involved in the test and what are their responsibilities?
DAVID TRAVIS (PM, DATALOGGER)
JANE HART (MODERATOR)
PETER HUNTER (EYE TRACKING)
JOHN KRAFT (CLIENT CONTACT)
LES HEASMAN (TECH SUPPORT)
LOUISE MANN (RECRUITMENT)

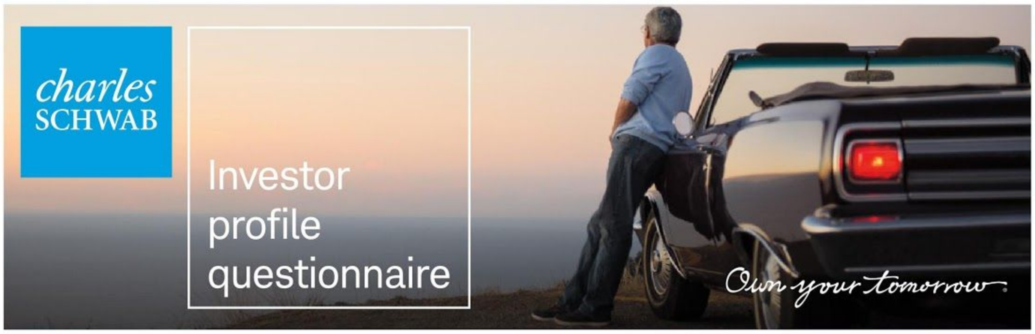
LOCATION & DATES
Where and when will the test take place? When and how will the results be shared?
SEP 23 @ USERFOCUS
180 PICCADILLY, LONDON, W1J 9HF
MAP: HTTP://GOO.GL/MAPS/87HKB
PHONE DEBRIEF ON SEP 27TH

PROCEDURE
What are the main steps in the test procedure?

0-5 MIN	5-10 MIN	10-45 MIN	45-50 MIN	50-55 MIN	55-60 MIN
WELCOME / CONSENT FORM	PRE-TEST INTERVIEW	CARRY OUT THE TEST TASKS	POST-TEST QUESTIONNAIRE	POST-TEST INTERVIEW	DEBRIEF / PAY INCENTIVE

Appendix C: Questionnaires

Charles Schwab Questionnaire



Find a suitable investment strategy

Your investing strategy should reflect the kind of investor you are—your personal investor profile. This quiz will help you determine your profile and then match it to an investment strategy that's designed for investors like you.

The quiz measures two key factors:

YOUR TIME HORIZON

When will you begin withdrawing money from your account and at what rate? If it's many years away, there may be more time to weather the market's inevitable ups and downs and you may be comfortable with a portfolio that has a greater potential for appreciation and a higher level of risk.

YOUR RISK TOLERANCE

How do you feel about risk? Some investments fluctuate more dramatically in value than others but may have the potential for higher returns. It's important to select investments that fit within your level of tolerance for this risk

How to make your choice

TIME HORIZON

Circle the number of points for each of your answers and note the total for each section.

1. I plan to begin withdrawing money from my investments in:

Less than 3 years	1
3–5 years	3
6–10 years	7
11 years or more	10

2. Once I begin withdrawing funds from my investments, I plan to spend all of the funds in:

Less than 2 years	0
2–5 years	1
6–10 years	4
11 years or more	8

Enter the total points from questions 1 and 2. **Time Horizon Score:** ______

If your Time Horizon Score is less than 3, stop here. If your score is 3 or more, please continue to Risk Tolerance.

A score of less than 3 indicates a very short investment time horizon. For such a short time horizon, a relatively low-risk portfolio of 40% short-term (average maturity of five years or less) bonds or bond funds and 60% cash investments is suggested, as stock investments may be significantly more volatile in the short term.

RISK TOLERANCE

3. I would describe my knowledge of investments as:

None	1
Limited	3
Good	7
Extensive	10

4. When I invest my money, I am:

Most concerned about my investment losing value	0
Equally concerned about my investment losing or gaining value	4
Most concerned about my investment gaining value	8

5. Select the investments you currently own :

Bonds and/or bond funds	3
Stocks and/or stock funds	6
International securities and/ or international funds	8

Example: You now own stock funds. In the past, you've purchased international securities. Your point score would be 8.

6. Consider this scenario:

Imagine that in the past three months, the overall stock market lost 25% of its value. An individual stock investment you own also lost 25% of its value. What would you do?

Sell all of my shares	0
Sell some of my shares	2
Do nothing	5
Buy more shares	8

7. Review the chart below.

We've outlined the most likely best-case and worst-case annual returns of five hypothetical investment plans. Which range of possible outcomes is most acceptable to you?

The figures are hypothetical and do not represent the performance of any particular investment.

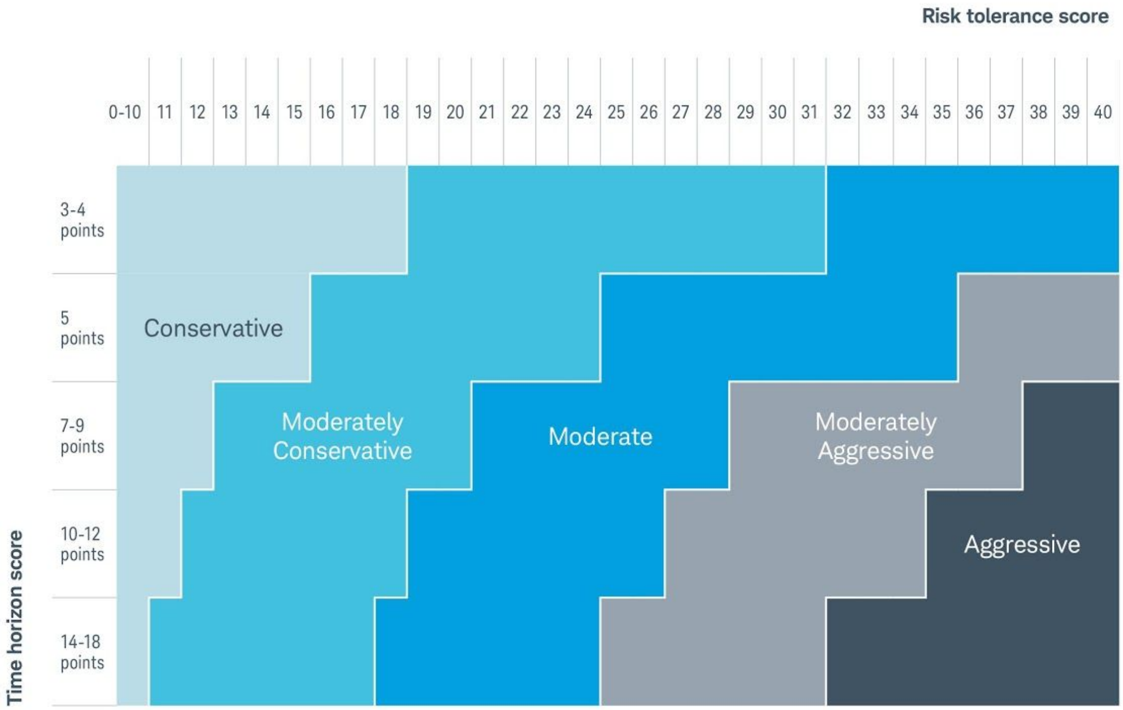
Plan	Average annual return	Best-case	Worst-case	Points
A	7.2%	16.3%	-5.6%	0
B	9.0%	25.0%	-12.1%	3
C	10.4%	33.6%	-18.2%	6
D	11.7%	42.8%	-24.0%	8
E	12.5%	50.0%	-28.2%	10

Enter the total points from questions 3 through 7. **Risk Tolerance Score:** ______

DETERMINE YOUR INVESTOR PROFILE

The chart below uses the subtotals you calculated in the preceding two sections.

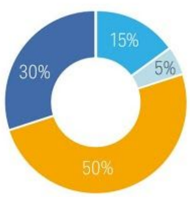
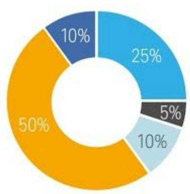
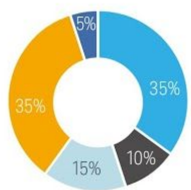
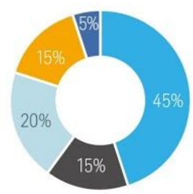
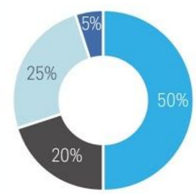
To determine your Investor Profile, find your Time Horizon Score along the left side and your Risk Tolerance Score across the top. Locate their intersection point, situated in the area that corresponds to your Investor Profile. On the next page, select the investment strategy that corresponds to your Investor Profile.



SELECT AN INVESTMENT STRATEGY

These investment strategies show how investors might allocate their money among investments in various categories. Please note that these examples are not based on market forecasts, but simply reflect an established approach to investing—allocating dollars among different investment categories. Keep in mind that it's important to periodically review your investment strategy to make sure it continues to be consistent with your goals.

If one of the investment strategies below matches your Investor Profile, you can use this information to help you create an asset allocation plan.

Conservative allocation	**Moderately conservative**	**Moderate allocation**	**Moderately aggressive**	**Aggressive allocation**
Average annual return: 7.6% Best year: 22.8% Worst year: -4.6%	Average annual return: 8.8% Best year: 27.0% Worst year: -12.5%	Average annual return: 9.4% Best year: 30.9% Worst year: -20.9%	Average annual return: 9.9% Best year: 34.4% Worst year: -29.5%	Average annual return: 10.1% Best year: 39.9% Worst year: -36.0%
For investors who seek current income and stability and are less concerned about growth.	For investors who seek current income and stability, with modest potential for increase in the value of their investments.	For long-term investors who don't need current income and want some growth potential. Likely to entail some fluctuations in value, but presents less volatility than the overall equity market.	For long-term investors who want good growth potential and don't need current income. Entails a fair amount of volatility, but not as much as a portfolio invested exclusively in equities.	For long-term investors who want high growth potential and don't need current income. May entail substantial year-to-year volatility in value in exchange for potentially high long-term returns.
				

■ Large-Cap Equity ■ Small-Cap Equity ■ International Equity ■ Fixed Income ■ Cash Investments

Brokerage Products: Not FDIC-Insured ▪ No Bank Guarantee ▪ May Lose Value

Source: Schwab Center for Financial Research with data provided by Morningstar, Inc. The return figures for 1970-2016 are the compounded annual average and the minimum and maximum annual total returns of hypothetical asset allocation plans. The asset allocation plans are weighted averages of the performance of the indices used to represent each asset class in the plans, include reinvestment of dividends and interest, and are rebalanced annually. The indices representing each asset class in the historical asset allocation plans are S&P 500® Index (large-cap stocks); CRSP 6–8 Index for the period 1970–1978 and Russell 2000® Index for the period 1979–2016 (small-cap stocks); MSCI EAFE® Net of Taxes (international stocks); Ibbotson Intermediate-Term Government Bond Index for the period 1970–1975 and Bloomberg Barclays U.S. Aggregate Bond Index for the period 1976–2016 (fixed income); and Ibbotson U.S. 30-day Treasury Bill Index for the period 1970–1977 and Citigroup 3-month U.S. Treasury Bills for the period 1978–2016 (cash investments). Indices are unmanaged, do not incur fees or expenses, and cannot be invested in directly. Past performance is no guarantee of future results.

Own your tomorrow.

Ontario Securities Commission Questionnaire

OSC ONTARIO SECURITIES COMMISSION | Get Smarter About Money.ca

Risk Profile

1

You are on a TV game show and can choose only one of the following options. Which would you take?

$1,000 in cash

50% chance at $5,000

25% chance at $10,000

5% chance at $100,000

2

Two weeks before you leave for your dream vacation, you lose your job. You would:

Cancel the vacation

Take a more modest vacation

Proceed as scheduled

Extend your vacation

3

When you think of the word 'risk', what first comes to mind?

Threat

Loss

Uncertainty

Opportunity

4

Given the best and worst case scenario, which of these investment choices do you prefer?

$250 gain, $0 loss

$750 gain, $200 loss

$2,800 gain, $800 loss

$5,000 gain, $2,500 loss

5

A good friend offers you an opportunity to invest in his new invention, which would double your investment if it passes a safety inspection. There's a 20% chance of success. How much would you invest?

Nothing

One month's salary

Two month's salary

Six month's salary

Appendix D: User Testing Survey - Risk Profile

Questionnaire Feedback!

Please take a look at the two questionnaires first - "Questionnaire - Ver 1" and "Questionnaire - Ver 2".

Questionnaire - Ver 1: https://drive.google.com/file/d/0BwPm_1xo_1KdcUhENTJxQ3NKZkU/view?usp=sharing

Questionnaire - Ver 2: https://drive.google.com/file/d/0BwPm_1xo_1Kdd2UwT296OExXR28/view?usp=sharing

Then, fill out the following questions about their structure and content. You can have the two questionnaires open for reference when answering this survey.

Thank you so much!! :)

*Required

How satisfied were you with the length of "Questionnaire Ver1"? *

- Very satisfied
- Somewhat satisfied
- Neither satisfied nor dissatisfied
- Somewhat dissatisfied
- Very dissatisfied

How familiar were you with the terms in "Questionnaire Ver1"? *

- Very familiar
- Slightly familiar
- Not at all familiar

How familiar were you with the terms in "Questionnaire Ver1"? *

- Very familiar
- Slightly familiar
- Not at all familiar

What are you overall thoughts about the first questionnaire? Please include any positive comments but also anything that can be improved on. *

Your answer

How satisfied were you with the length of "Questionnaire Ver2"? *

- Very satisfied
- Somewhat satisfied
- Neither satisfied nor dissatisfied
- Somewhat dissatisfied
- Very dissatisfied

How familiar were you with the terms in "Questionnaire Ver2"? *

- Very familiar
- Slightly familiar
- Not at all familiar

What are you overall thoughts about the second questionnaire? Please include any positive comments but also anything that can be improved on. *

Your answer

Which questionnaire took longer to fill in? Please take into account the time to read through the introduction and any instructions the questionnaire may have had. *

- ○ Ver 1
- ○ Ver 2

And lastly, which questionnaire would you personally prefer? *

- ○ Ver 1
- ○ Ver 2

SUBMIT