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MANGEMENT ENGINEERING CAPSTONE DESIGN PROJECT

TEAM 12

LUNAR
CRYPTO PORTFOLIO BUILDER

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Lunar – Crypto Portfolio Decision Support Tool

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Abstract – *In this report we will cover how we built a platform that utilizes a decision support tool for crypto portfolio diversification. We will discuss the history and fundamentals of cryptocurrency, as well as its potential to continue disrupting the global financial markets over the next several years. We will examine the current problems and risks with cryptocurrencies and the need for a decision support tool that assists with the process of allocating capital across various currencies. A list of functional and non-functional requirements of the platform is included as supplementary description for the main features of our initial design. At the end, we will talk about our design and why it is feasible for the problem we are tackling.*

Keywords: *cryptocurrency, blockchain, portfolio, risk tolerance, investment goals, capital, robo-advisor, decision support tool*

1. INTRODUCTION

Cryptocurrencies have experienced steady growth since early 2013; however, the past 5 years have been exceptionally significant. They are utilized and traded all around the world, notably in countries such as Japan, China, U.S., and Kenya [8]. The total cryptocurrency market cap has grown from 700 billion USD to 2.5 trillion USD in the past seven years. Cryptocurrency is incredibly secure when it comes to undertaking transactions since it uses blockchain technology. Cryptocurrency is independent of government regulation or banks, meaning that it is safe from possible manipulation. Currently, there are roughly 5300 cryptocurrencies; however, the most common and with the highest market cap are Bitcoin (BTC), Ethereum (ETH) and Tether (USDT). Together, they boast a tremendous market cap valued at 968.25 billion USD [1].

1.1. Market Overview

The current cryptocurrency market is a massive 1.6 trillion-dollar market and is expected to grow even larger in the future. With the recent uproar of crypto assets, there exists a need to research this seemingly profitable yet uncertain space. To participate in this volatile market, one must come up with a viable strategy that would minimize risk and maximize return. Whether cryptocurrencies offer legitimate investment opportunities or are a risky form of gambling is a question that needs to be answered by anyone that is looking to engage in this market. The uncertainty of the future of cryptocurrency is the main reason individuals are unwilling to step into this space. With confirmation of the future potential and more community adoption for this market, many would be more inclined to invest in crypto assets.

There is some competition in this field; however, since cryptocurrencies are quite new when compared to other forms of investments, there are few products that offer similar services. The top three products that are related this product are CoinTracker, Shrimpy and Panda Portfolio Builder. Out of these three, Shrimpy is the closest to what this team wants to achieve [14][15][16].

Figure 1 - BTC Market Cap

2. USER ANALYSIS

2.1. Target Audience

The target market is individuals that currently hold financial investments or have considered cryptocurrencies and understands the value of owning a long-term financial asset. User research revealed that many people currently hold investments, validating our target audience. Since this product will create a personalized portfolio based on investment goals, financial standing, habit/experience, an understanding of crypto and how it is traded will be beneficial when using the product and contribute to the customers success. There will be no limit for age as anyone with capital can invest. However, we foresee less users from the senior age group. Most individuals over the age of 65 enter retirement, according to average retirement ages around the world [7]. Instead of making more investments, they are at a stage in their life where they are withdrawing their savings made prior to retirement. The product should be used by someone who wants to grow their assets for a long period of time. Finally, customers can be located anywhere in the world because crypto is independent of any government or bank.

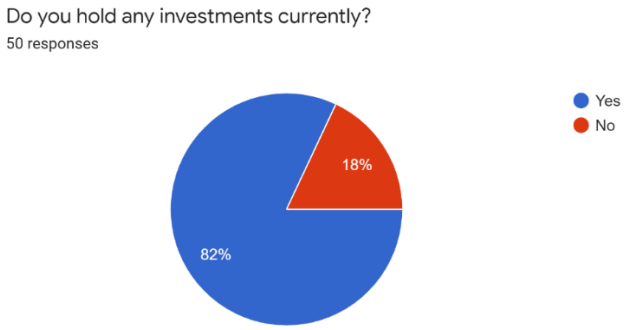

Figure 2 - Current Investment Holders

2.2. Current Investor Market

Of the respondents who currently hold investments, the majority own traditional assets such as mutual funds, ETFs, or stocks. A very small number of respondents hold guaranteed investment certificates (GICs) or cryptocurrencies. The low number of GIC owners reveals that many are not interested in assets with low levels of return relative to other asset classes and are willing to take on more risk for more gains. Alternatively, the public is also wary of taking on too much risk, hence the low number of crypto asset owners. Volatility is the number one reason why people have not entered the crypto space followed by a personal lack of understanding and fear of misinformation.

High levels of volatility instill fear in investors who risk losing their initial investment. Users reported they lack crypto related background knowledge that makes them comfortable with making an investment. 30% of respondents have not done any personal research and 38% report having a very basic understanding of the topic. Contributing to the slow acceptance of crypto is also the fact that the public does not trust the sources available. The most exposure to the topic is provided through social media outlets where credibility is not verified. This highlights a potential need for greater education on the topic to further growth and adoption.

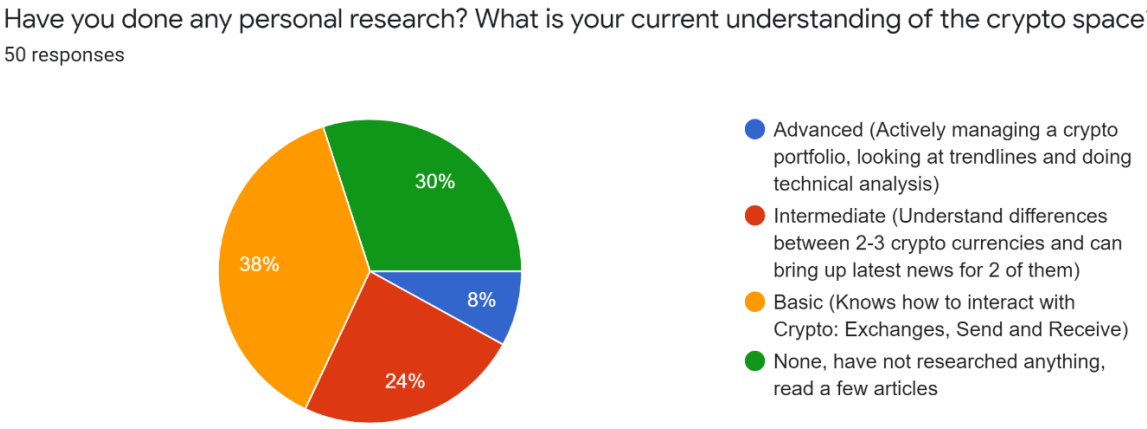

Figure 3 - Current Public Understanding of Crypto

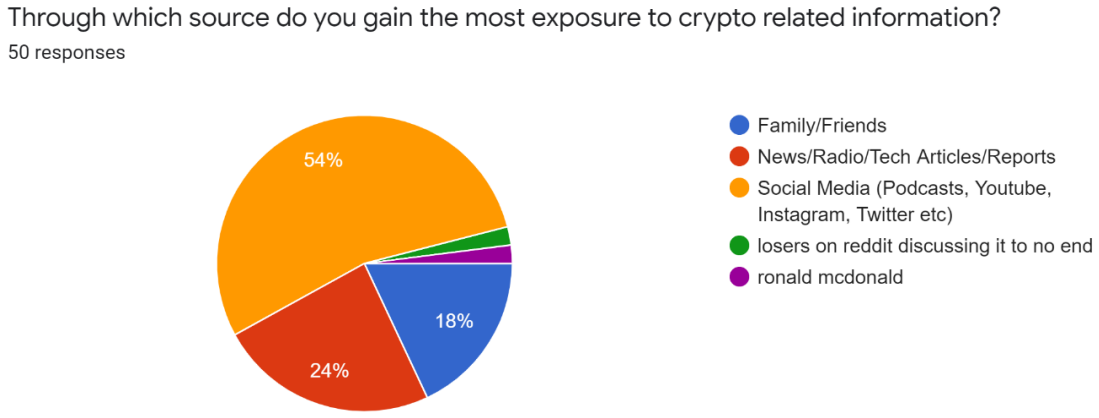

Figure 4 - Sources of Exposure to Crypto

2.3. Potential Roadblocks

The user survey revealed that there are less enthusiastic about the growth of cryptocurrencies. While most respondents appear to be thrilled and provided reasons for their excitement, the contrary also exist. In Appendix B-2, comments were left on the Reddit thread where the survey was posted, raising the issue of distrust between a user and a third-party platform. One individual wrote, “Nobody is going to trust them with their keys.” A sentiment like this will lead to some reconsiderations for certain features of the tool. Environmental concerns associated with the high energy usage by crypto miners will also cause potential users to hesitate before using the tool to invest in the asset.

2.4. Potential Outlook

Despite the negative attitudes of some respondents and the low level of crypto representation in current investment portfolios, there is still considerable potential for future growth and adoption in an investment sense. Many respondents have already considered entering the crypto market by citing reasons such as:

- “Hype and exponential growth”
- “Potential speed of the return”
- “Diversification and the opportunities associated with this newer investment”

If investments are to be made, over two thirds of potential customers will be saving for the long term and see a future where cryptocurrencies play a larger role. There appears to be a common understanding that crypto is and will continue to be a risky asset, but many are willing to accept the risk. These findings provide further support for a new platform that allows users to enter the crypto space. The interest in long term investing creates and maintains a market for said platform for as long as users remain invested.

3. PROBLEM ANALYSIS

3.1. Problem Overview

The use of blockchain ledger technology for monetary transactions is great as we can take advantage of the security and transparency of such innovation. However, what is not great is the large fluctuations in the price of a currency. As new endorsers of the technology, individuals are taking on massive risk by holding cryptocurrencies as its value depreciates and appreciates dramatically throughout the day.

3.2. Problem Breakdown and Causes

Like most new technology adoptions, lack of familiarity is one of the biggest problems that can cause massive overreactions in the market. As stated in a report written by The Economist Intelligence Unit, market trust or understanding of digital currencies/assets remains the main barrier to greater adoption among consumers (sited by 51% of survey-takers) [4].

Cryptocurrencies are currently used more like investable assets than payment mechanisms. Also stated in the same report by The Economist Intelligence Unit [4], the two primary roles of cryptocurrencies are capital appreciation and asset diversification. While it is normal to have active traders in the market inducing price fluctuations, it can be devastating to new investors that are unaware of the situation. Without proper risk management, new investors are prone to witnessing sudden changes in the value of their investments.

For new investors who understand risk management and diversification, the most common approach would be to create a portfolio that includes a variety of crypto assets. The problem arises as there are many cryptocurrencies to choose from; more than 5300 exist today. With the lack of fundamentals and familiarity with this volatile and emerging market, investors struggle to assemble an effective portfolio that is tailored to their risk preference in a time-efficient manner.

Additionally, the speculative nature of this new technology means participants can be easily manipulated by misleading information. For example, Dogecoin's (DOGE) value increased 38% in 30 minutes after Elon Musk, CEO of Tesla, Inc., tweeted about DOGE [3]. While it is a free market and such reaction is inevitable, each participant needs to understand the risks associated and make conscious investment decisions, which is often challenging to do especially with crypto assets, where utility and supply are the only real backings of the asset unlike the stock of a publicly traded company. Inexperience often leads to unwise decisions, which will deliver poor returns in the case of investments. New investors are especially susceptible to these undesirable consequences; this is a big concern that needs to be addressed.

3.3. Stakeholders and Impact

The true value of cryptocurrencies is not on short-term gain, but on providing a more stable, secure, and transparent financial system. Without a way for individuals to enter the market with calculated risk, cryptocurrencies will not be able to reach their full potential.

Solving risk-related issues for crypto can bring mass adoption faster, which can enable the participants to have freedom and control of their own money. Figure 3 shows the responses to one section of a user survey that was conducted. At least half of the participants responded by saying that they would be more comfortable with making a cryptocurrency investment if they gain a better technical understanding, see stronger community adoption, or observe positive historical performance. Three out of five participants stated that they would be more comfortable with making the investment if they see evidence of positive future potential.

The survey results show that many individuals are uncertain about the fundamentals of cryptocurrencies and want to see concrete evidence that their investments will be worth the risk. To improve the sentiment of the average stakeholder, the problem of uncertainty and risk associated with cryptocurrencies needs to be addressed.

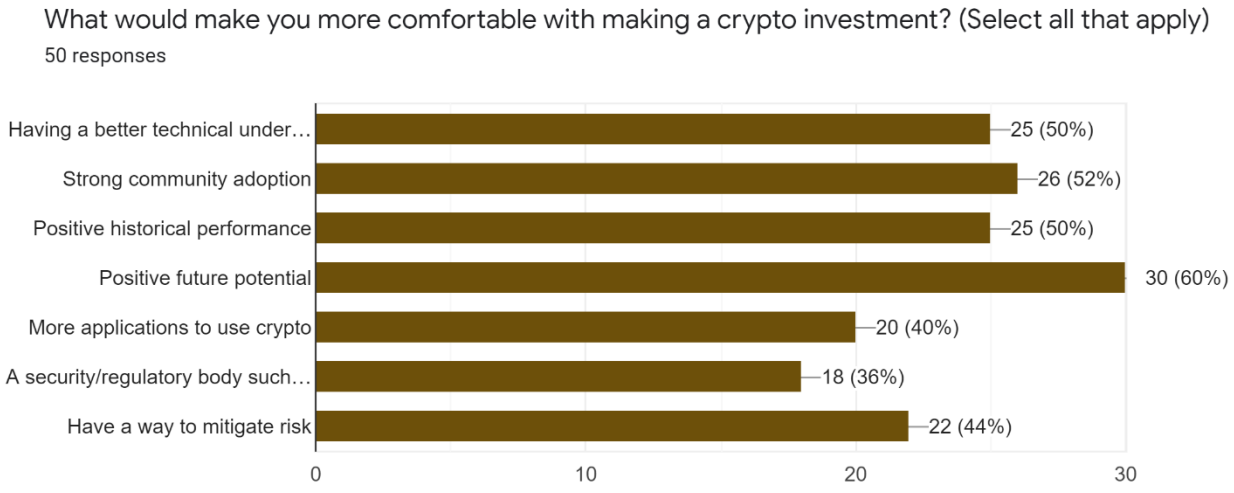

Figure 5 - Concerns with cryptocurrency investments

3.4. Prior efforts to Address Problems

Assets have traditionally been managed by legacy financial institutions like BlackRock, Inc. or The Vanguard Group with $7.4 trillion and $6.2 trillion AUM, respectively [2]. Investors would speak to financial advisors who would assist in choosing a product fit for the individual depending on risk, time horizon and capital. However, these financial institutions haven't provided users exposure to the crypto market yet.

Also coming from the traditional stock market background, exchange-traded funds (ETFs) and mutual funds are commonly employed to allow users to gain exposure to the market while diversifying risk with a basket of individual stocks or bonds [11]. On the same token, one survey suggested that around 50% of participants are more inclined to own cryptocurrency through an ETF than the underlying asset itself [12].

However, most cryptocurrency related ETFs focus largely on just Bitcoin or Ethereum, which are the two most liquid cryptocurrencies[13]. There have not been any services that provide a portfolio that exposes users to a basket of cryptocurrencies with respect to the user's risk tolerance. There exists a need to investigate the unexplored field of cryptocurrency portfolio diversification. The ideal solution will solve this issue by optimizing the projected portfolio return using technical analysis.

4. REQUIREMENT ANALYSIS

4.1. Design Objectives

The cryptocurrency investment decision support platform will aim to meet the following design objectives:

- Generate a portfolio with diverse crypto holdings that maximizes returns after considering a user's risk tolerance and investment goals
- Educate users on the potential of crypto and make it easier to get exposure to crypto market
- Display user's entire crypto asset portfolio if they choose to

4.2. Requirements

The growth of robo-advisors and cryptocurrencies presented an opportunity for the two to combine on a platform where crypto serves as a longer-term asset. In order to maximize reach and promote simplicity, the decision support tool will be a web application. There will be no interaction between users as portfolios are generated based on personal decisions. There will be a feature that enables user to share ideas around crypto or portfolio diversification in a token-gated community. Pulling inspiration from current, successful platforms who provide similar services such as Wealthsimple and Questrade, functional and non-functional requirements were established for the crypto portfolio decision support tool.

During the onboarding process, new users will be asked a series of questions to obtain their individual risk tolerance levels. The user can provide their API key and provides consent for the tool to read their current portfolio. This section will be optional as not all potential users will want to link their personal wallet. Using the users risk level, the tool will determine and suggest an optimal allocation of crypto assets with the potential to meet individual investment goals while minimizing risk.

When generating these portfolios, the system will be referencing Binance, the world's largest crypto exchange by volume for current and accurate pricing of each specific coin. [17] The tool

will display the percentage breakdowns of each coin as well as their respective dollar values and coin totals. Lastly, the tool will display a growth chart, visualizing the potential value of the optimized portfolios. The full list of functional requirements can be found in Table 1 of Appendix A.

Table 2 in Appendix A contains non-functional requirements for the product. The decision support tool should be web-based tool and must work on all browsers while maintaining performance. A web-based tool will ensure the product has maximum reach to potential users. The product should be secure in a sense that usernames, passwords and discrete information about the user's digital wallet such as portfolio value and API key should not be visible to any outside party or other users. The product must be user friendly since it is intended to reach a multitude of users differing in age, ethnicity and educational background. The product must be responsive in order to perform at high speeds. A user should not have to wait more than 5 seconds for data and pages to load. If the DST is slow, users will be deterred by the product and potentially seek alternatives. An intuitive product ensures that the onboarding process and extensive use is efficient and effective for all users. Assistance from the development team and/or a FAQ page should not be required when learning how to use the decision support tool.

The product will be educational in nature and provide the opportunity for users to learn about the crypto market and their chosen investment strategy. Upon consulting with the public, the need for a learning aspect on our platform has been amplified as most users report not entering the crypto market due to a lack of personal understanding. Finally, the product should stay running as long as a user is interacting with it, otherwise time-out after five minutes of inactivity to protect the customers information and make sure the servers are not overloaded.

The decision support tool aims to reach all individuals who have an intent to invest and grow their wealth. Whether they are experienced crypto traders or completely unfamiliar with the technology, the tool will be of value to everyone. For a detailed view of the target user groups, please refer to Appendix D. Target User Group.

4.3. Need Statement

"There exists a need for a tool that assists users with making safe and educated decisions for crypto portfolio creation and management"

5. SOLUTION DEVELOPMENT

5.1. Design Process

For our conceptual design we followed the design referenced in Appendix F-1, F-2, and F-3. Our team had bi-weekly sprints and a retrospective with our advisor to present the sprints' results and discuss any concerns. We then addressed our plans for the next sprint and updated the Jira board accordingly. After our first sprint we added a lot more key features that were presented in PPC and received positive feedback.

5.2. Final Design Front End

For our final design we took inspiration from existing successful portfolio builders and public feedback gathered through reviews. We each gave input on what type of design patterns we need to follow, and it was decided that our website will have a simple look with both dark and

light themes. The reason being the simple look offers more clarity when compared to our older glassy look, which did not receive positive feedback.

As a first-time user, the user will have to sign-up via three different sign-up options: email, Facebook and Google. Facebook and Google sign up were implemented to ensure a fast and common experience. Prior to completing sign-up, the user is encouraged to explore our website and learn how the product works with a link to our report. Once the user signs in for the first time, the site will prompt new users to fill out a mandatory survey that outputs one of five risk levels. To study how the survey resonates with each user, Google analytics tracks if the user stops the survey pre-emptively. The data gathered by Google will help us optimize our survey for future improvements. Finally, using the risk level assigned to the user, a portfolio is generated and redirects to the dashboard.

The dashboard is where our custom-tailored portfolio will be summarized for the user. They can view the generated portfolio's holdings in a pie chart with each coin's allocation and a graph that compares the portfolio's performance to the S&P 500's. The user can swap, delete or add new crypto assets to their portfolio, where our algorithm will then re-calculate and output new results. We also allow the user to re-take the survey and link them to the Learn page to view crypto fundamentals or explore new blockchain technologies.

The profile page allows the user to add their own crypto wallets (we support over 100). The API key we use is a read only key meaning we can only view their holdings and not make transactions. This feature helps our product stand out as it consolidates and summarizes all the users' assets across different exchanges. As a fun feature, the profile page the user also has the option to mint their own Lunar NFT via the step-by-step instructions on how exactly to mint an NFT on our platform.

5.3. Final Design Algorithm

The algorithm is designed with a focus on efficiency and simplicity. However, it is effective in determining the expected return and volatility of each portfolio. The initial step is to obtain the daily closing prices of each asset and aggregating the values to get monthly returns. We have set a monthly geometric decay of 5% to put more weight on recent data. Figure 2 is an overview of the past several years of daily returns for each of the 17 assets. The primary reason for putting less weight on older data is in consideration of the declining volatility and stabilizing conditions of the crypto market. However, it is important to note that fundamentals may change at any point and require a modification of the current model.

The weighted average return for each asset is obtained and used to derive additional measures such as standard deviation, correlation, and covariance. These measures are used as intermediate steps of the process of calculating expected portfolio return and standard deviation, which are the two attributes of a given portfolio that allow us to determine optimality.

Obtaining the optimal portfolio requires an iterative process through random number generation. Through a series of tests, we have decided to set the number of generated portfolios to 1000, in consideration of runtime. Our algorithm uses random numbers to produce allocation weights of assets in each iteration. In other words, a unique portfolio is created in every iteration. The unique weights of each portfolio's assets are then used to determine the associated risk and expected return of the portfolio.

One important point to consider is a specific user's risk tolerance. A risk-averse investor will likely favour a portfolio with minimal risk even though its expected return is comparably low. On the other hand, a risk-tolerant investor may prefer an aggressive portfolio with high risk and high

return. Taking this into account, we have decided to implement risk buckets that are separated by volatility ranges. Following the iterations, the randomly generated portfolios are assigned to one of the five risk buckets based on portfolio standard deviation.

The last step of the algorithm is the decision-making process. For each risk bucket, we obtain the Sharpe ratios of each portfolio within. The Sharpe ratio is a type of measurement using the excess return of an investment and the underlying volatility, indicating the relative performance of the given portfolio. The portfolios are then ranked based on Sharpe ratio in descending order to rearrange the choices in each bucket. Finally, the top portfolio in each risk bucket is selected as the optimal solution for the given risk level. On the application interface, the user will be suggested with one of the five portfolios depending on his or her risk preference.

5.4. Design Feasibility

The solution will be replacing existing implementation of financial analysis in Excel with a modern webpage solution that provides high accessibility to most users with computer devices and internet connection. The technical components of the solution delivery have three components: frontend, backend, and storage as seen in Figure 6.

Front end interfaces are built with ReactJS which has a community that offers libraries and tools for developers to build battle-tested chart visualization and input forms. Server-side rendering is achieved through NextJS which enhances ReactJS and deployed on Vercel which abstracts global Content Delivery Network and serverless compute. The design solution has a high feasibility since these technologies help the team iterate quick and deliver reliable interfaces for users efficiently.

The backend logical layer of the application will be implemented in NodeJS with GraphQL through serverless cloud function. The backend logical layer would interface with the PostgreSQL database and Redis cache components to query, update, and store user related information. Since sensitive API keys and secrets from exchanges could be gathered and stored, they will be protected with aes-256-ctr end-to-end encryption. Easter egg, Lunar NFT, implements ERC-721 contract on Ethereum blockchain and utilizes the browser extension Metamask to mint and display arts.

Storage component can be broken down into two categories: application and precomputed data. PostgreSQL database handles user and application related data such as user credential, basic information, risk preference survey inputs, and custom portfolios. The second static GCP bucket will store precomputed results for serverless function to load and serve. A cronjob will periodically update these assets with up-to-date candle data to ensure the freshness and accuracy of our portfolios.

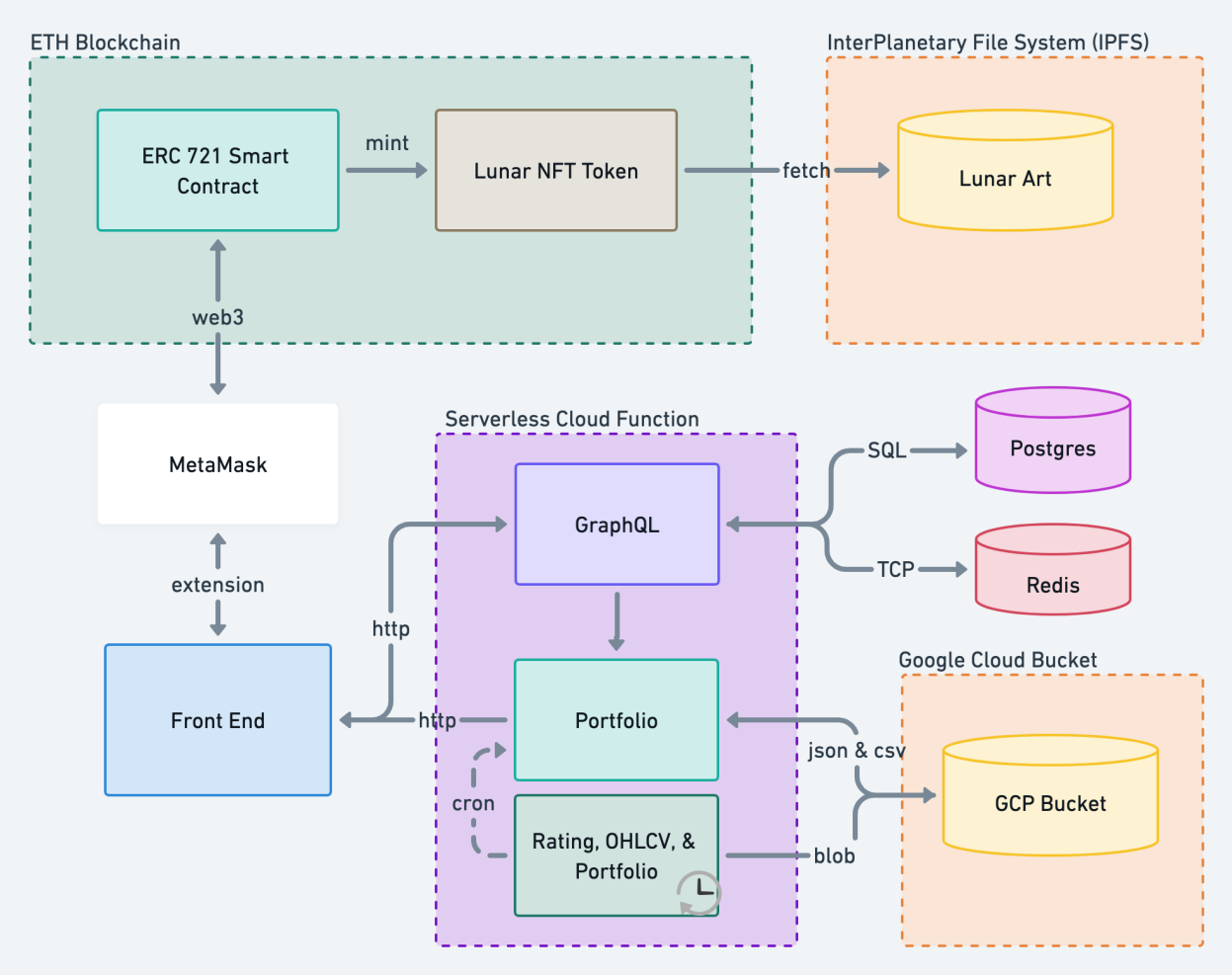

Figure 6 - System Diagram

5.5. Solution Evaluation

The full stack implementation involves CI/CD and monorepo to ensure an agile developer experience. Frontend components without the dynamic data are prerendered statically at build time for a faster load time and user experience. Backend GraphQL framework provides a high degree of flexibility. Google cloud and serverless functions offers high availability and allows elastic and dynamic adjustment of resources based on the traffic. Caching precomputed portfolios with static bucket and cronjob prevent servers from repeating heavy computation. The language choice, JavaScript, offers developers a better and faster experience for its dynamic typing. However, JavaScript could potentially slow down the development once the code base has grown to a certain size owing to its lack of static type definition and inherent freedom. Static languages such as Java or Golang could be considered to address the disadvantages. To find a middle ground, TypeScript has been used to supercharge the language with type safety.

While the current algorithm provides an in-depth analysis of the price fluctuations and interrelationships between the portfolio assets, it carries several drawbacks that should be brought to attention. First, the model does not offer any form of forecasting for future price action. This may not be appealing for investors because the application lacks a feature for price projections and

expected performance. The output of the algorithm is entirely based on historical data, meaning that it does not include any information on expected future return. Tied to this drawback is the model's inflexibility with varying investment time horizons. Currently, the algorithm relies on mean-variance analysis on monthly statistics for the given selection of assets. Therefore, it is unfit for investors who prefer to trade on momentum for short-term gains; the algorithm provides more value for medium to long-term investors.

Another disadvantage is the low amount of data on the crypto market. Most crypto assets that are analyzed by the algorithm are projects that have been initiated recently. Unlike the stock market, new data on crypto assets has a significant impact on the algorithm output. For this reason, there is a level of uncertainty that is attached to all generated portfolios formed by the current state of the market, which is continuously aiming to achieve stability and equilibrium.

5.6. Verification of Requirements

Internal, end-to-end testing verified all requirements listed in Appendix A. The functional requirements were laid out in high-fidelity prototypes in Figma such that none were overlooked. All inputs required from the user are handled by the user survey and sign-up portion of the user flow and descriptive features such as the performance chart are displayed in the dashboard portion of the product.

Of the non-functional requirements, the team was pleased to learn that the feedback received from outside parties is consistent with our own findings. It was noted that our new UI is superior to our initial "glossy" look and meets our goals of being a secure, responsive, intuitive and user-friendly web-based tool. Our learning pages also addresses the need for an educational component.

Lastly, our algorithm is discussed in detail in Appendix G, where we provide the user with an in-depth look at how and why our algorithm works. We ran a series of tests to confirm our assumptions of the relationship between volatility and return of portfolios. Figure 7 displays the complete set of results for each of the five risk levels over 20 iterations. For each iteration, we calculated the 1-year return, peak return, and drawdown for the corresponding portfolio in each risk bucket. The 1-year return is calculated by the percentage change between the starting and ending balances. The peak return is equal to the percentage change at the day of maximum portfolio balance. The drawdown column refers to the largest peak-to-trough decline in percentage over the observed past year.

Run	Risk Level 1			Risk Level 2			Risk Level 3			Risk Level 4			Risk Level 5		
	1Y	Peak	Drawdown	1Y	Peak	Drawdown	1Y	Peak	Drawdown	1Y	Peak	Drawdown	1Y	Peak	Drawdown
1	66.76%	155.93%	-54.73%	74.46%	208.78%	-54.18%	120.97%	260.22%	-49.66%	126.90%	312.23%	-54.18%	139.19%	272.71%	-53.28%
2	90.50%	233.24%	-50.34%	142.07%	223.34%	-50.60%	90.10%	227.55%	-49.94%	117.33%	266.67%	-52.95%	140.39%	309.32%	-51.97%
3	88.36%	193.93%	-52.52%	85.47%	214.69%	-55.63%	135.16%	259.23%	-51.79%	114.87%	254.04%	-53.22%	150.21%	333.14%	-53.41%
4	70.02%	202.46%	-52.66%	87.13%	219.80%	-56.39%	125.67%	237.81%	-56.41%	104.85%	208.00%	-54.07%	143.09%	328.22%	-54.02%
5	108.13%	212.47%	-52.82%	97.40%	221.30%	-54.80%	81.51%	187.31%	-54.37%	155.60%	302.72%	-54.46%	119.55%	284.99%	-55.99%
6	119.81%	249.08%	-49.48%	96.77%	203.86%	-52.03%	126.69%	265.68%	-51.06%	119.53%	253.72%	-54.10%	117.44%	265.86%	-59.40%
7	83.16%	217.86%	-55.40%	110.17%	227.88%	-51.55%	99.88%	188.30%	-54.09%	126.32%	256.53%	-51.90%	151.66%	331.96%	-56.11%
8	110.55%	243.83%	-55.76%	115.11%	225.56%	-53.46%	111.50%	239.83%	-52.66%	128.10%	273.35%	-51.06%	160.58%	335.52%	-54.61%
9	85.16%	189.92%	-52.65%	109.92%	227.97%	-52.75%	120.09%	258.36%	-51.23%	101.27%	219.86%	-53.48%	128.98%	244.34%	-52.67%
10	91.78%	184.16%	-57.38%	99.64%	242.76%	-54.16%	87.00%	217.07%	-54.22%	140.91%	322.39%	-52.91%	197.08%	386.93%	-52.75%
11	105.75%	208.70%	-53.40%	142.06%	265.68%	-53.48%	119.29%	226.67%	-50.52%	102.23%	252.44%	-53.65%	154.04%	321.74%	-53.64%
12	74.03%	193.24%	-54.97%	103.08%	228.23%	-55.53%	107.33%	223.64%	-53.05%	134.30%	255.64%	-55.62%	143.59%	338.34%	-51.58%
13	111.97%	258.76%	-49.28%	125.87%	263.88%	-52.45%	117.34%	246.36%	-50.69%	113.60%	230.23%	-51.87%	131.67%	274.37%	-52.64%
14	80.12%	173.76%	-55.15%	96.82%	246.90%	-55.17%	131.96%	263.78%	-53.24%	159.05%	295.11%	-53.41%	156.18%	326.15%	-53.05%
15	104.20%	253.17%	-55.84%	74.46%	227.08%	-56.14%	81.45%	195.55%	-55.41%	175.19%	324.48%	-51.00%	147.07%	263.68%	-54.10%
16	86.57%	206.40%	-56.00%	117.94%	249.35%	-53.11%	97.90%	221.45%	-54.04%	101.96%	245.89%	-55.18%	122.05%	282.04%	-54.95%
17	95.21%	221.45%	-50.11%	99.85%	226.46%	-53.65%	120.14%	275.27%	-54.71%	141.83%	300.80%	-52.87%	137.01%	306.56%	-55.12%
18	71.70%	191.43%	-54.50%	107.05%	225.62%	-52.39%	165.51%	297.85%	-53.93%	129.40%	236.97%	-51.40%	127.23%	270.03%	-55.04%
19	90.40%	224.54%	-57.85%	132.75%	238.88%	-53.20%	108.10%	241.16%	-51.68%	141.77%	246.10%	-54.69%	143.03%	282.52%	-52.10%
20	90.66%	202.60%	-53.32%	98.98%	244.81%	-51.98%	127.88%	289.95%	-55.87%	149.95%	252.72%	-53.84%	184.31%	336.70%	-51.98%
Average	91.24%	210.85%	-53.71%	105.85%	231.64%	-53.63%	113.77%	241.15%	-52.93%	129.25%	265.49%	-53.29%	144.72%	304.76%	-53.92%

Figure 7 - Test Run Statistics

Figure 8 shows a compiled and more comprehensive view of the test runs. One observation that can be made is the strictly increasing values of 1-year returns as risk level is increased. This is not taken by surprise because portfolios that are known to carry more risk tend to offer potentially higher return. The peak returns also show similar trends of increasing return. These values suggest the possible range of price movements on the upside over the past year. The drawdown, on the other hand, shows the possible change in the value of an investment. For each risk level, the decline appears to be in a tighter range compared to return. This outcome is generally ideal for an investor because it means that the downside of a risky portfolio is not as significant over the long run. The average drawdown of Risk Level 3 is -52.93%, meaning that the average peak-to-trough decline is less than the drawdowns of Risk Levels 1 and 2. This may entirely be a coincidence given the small difference between the values. However, it is important to keep note of this observation as it raises the question of whether a low-risk portfolio is always the safest option.

Risk Level	1Y			Peak			Drawdown		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
1	66.76%	119.81%	91.24%	155.93%	258.76%	210.85%	-57.85%	-49.28%	-53.71%
2	74.46%	142.07%	105.85%	203.86%	265.68%	231.64%	-56.39%	-50.60%	-53.63%
3	81.45%	165.51%	113.77%	187.31%	297.85%	241.15%	-56.41%	-49.66%	-52.93%
4	101.27%	175.19%	129.25%	208.00%	324.48%	265.49%	-55.62%	-51.00%	-53.29%
5	117.44%	197.08%	144.72%	244.34%	386.93%	304.76%	-59.40%	-51.58%	-53.92%

Figure 8 - Compiled Statistics

5.7. Design Impact

The existence of a crypto portfolio builder will have a major impact in the financial investment space. As discussed in Section 3.2, the erratic nature of the crypto market decimates the portfolios of many new investors who lack the ability to perform a risk assessment. Customers who use the tool get the opportunity to grow their wealth while experiencing the safety that a risk mitigating mathematical model provides. Customers are also at a lower risk of falling victim to the

many scam altcoins that exist with no intrinsic value. Following the accredited Weiss ratings system, the tool will only include legitimate coins with proven value in any given portfolio.

Survey results have shown that users are concerned about the environmental impact of the crypto space. Mining for these assets is very energy intensive as computers run around the clock at commercial scale farms or in individual living rooms. The tool does not directly contribute to the large use of energy since it is not actively mining; it will still be guilty by association when the usage of crypto grows as a result of the service being available.

One of the major appeals of crypto is that it is decentralized and unregulated as discussed in Section 1. Unfortunately, some government bodies are making attempts to control the growth and use of cryptocurrencies. Notable mentions include Turkey, whose central bank enacted a ban due to the risk that investors can not recover losses. Nigeria, the home to the largest cryptocurrency market in Africa, has had a ban on cryptocurrencies since 2017. [19][20] The most recent regulations that may have had the most impact on the global crypto market comes out of China when authorities banned crypto mining in June of 2021. This is significant because "over half of global Bitcoin production" comes out of China. [21][22] Our tool will have to abide by the regulations that each country has in place, meaning Lunar will not be available in the regions where crypto assets or access to exchanges are banned.

Should the tool be successful, cryptocurrency will become a more mainstream and widely accepted form of asset which in turn drives the growth and appeal of crypto mining. Global graphics processing unit (GPU) supply has already been tested in 2021 as prices skyrocketed, making the cards inaccessible. The mining boom has also driven manufacturers such as Nvidia to incorporate restrictions on cryptocurrency-mining capabilities in their RTX3000 series cards. [23] As crypto becomes more mainstream, we will also see an increase in applications where coins can be spent. Stepping away from the current popular use cases that are online casinos and illegal activities will further legitimize the asset.

Word count: 5000

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APPENDIX A: Requirements

Table 1: Functional requirements between customer and product

ID	Requirement	Description	Rationale	Specification target	Verification of requirement	Priority (High, Medium, Low)
1	Take in risk tolerance	Product should take in the risk tolerance of the customer through a list of options	Essential parameter in the model to output an optimal portfolio	N/A	The user will be allowed to continue in the portfolio development process	H
2	Take in time horizon/investment goals	The product will calculate the allocation based on investment time horizon	Essential parameter in the model to output an optimal portfolio	N/A	The user will be allowed to continue in the portfolio development process	H
3	Take in available capital ($) to invest	The capital available to the user will help determine portfolio allocations	Essential parameter in the model to output an optimal portfolio	N/A	The user will be allowed to continue in the portfolio development process	H
4	Take in a user's current crypto assets	The user's current crypto assets can be used to determine portfolio allocations. This can be done automatically via a user provided API key to their wallet or manually	Optional parameter in the model to output an optimal portfolio	N/A	The user's crypto holdings are accurately reflected in the DST. The user will be allowed to continue in the portfolio development process	H
5	Display % values of holdings	A list of currencies along with each of its	This would allow the user to see their	N/A	The customer will be able to efficiently look through their holdings	H

		allocations should be displayed.	personalized portfolio based on their inputs		and each of its allocations in % value	
6	Display $ values	A list of currencies along with the correspondin g dollar amounts should be displayed.	This would allow the customer to view their holdings in dollar amount	N/A	The customer will be able to efficiently look through their holdings and each of its allocations in $ value	H
7	Display coin quantities	A list of currencies along with the amount of each currency should be displayed.	This would allow the customer to easily track the number of coins owned by each customer	N/A	The customer will be able to efficiently look through their holdings and each of its allocations in coin quantities	H
8	Result History	The user should be able to check historical portfolio suggestion results along with their associated risk tolerance survey	This would allow the user to view and compare previously generated allocations and use them to make decisions for current and future portfolio diversificatio ns	N/A	In the users account page, there should be a list of historical records of previous portfolios that the user has built.	M
9	Email/Share /Export portfolio results	The user should be able to share their suggested portfolio with others via email, or as a picture	Sharing would encourage more user retention and grow user base of the tool	N/A	Once the suggested portfolio result is outputted, there should be a button that allow users to share the result through social media, email (image formats) or download in a spreadsheet format	M

10	Create account	The user should be able to login securely with username and password	This enables secure management of user's data and allow us to better manage data collected.	Password must be secure, with upper- and lower-case letters, at least 1 number, and 1 symbol	A new user should see prompts to create an account if they do not have login information There should be a sign-up page that makes sure user's username is unique and password comply with the rules	H
11	Delete Account	The user should be able to delete their account when they wish	Users should have the freedom to delete their account and all stored information	N/A	A user of the site, while logged in, should be able to delete their account from their account page.	H
12	Performanc e Chart	The user should be able to view historical performance, and future forecasted performance of the suggested portfolio	This provides a visualization of our suggestion, allowing the user to understand and comprehend the suggested portfolio much easier.	N/A	Along with the suggested portfolio, there should be a graph that show cases in different colors, the previous performance and the future performance of the suggested portfolio.	M
13	Portfolio Re-balancing	The user can implement the suggested portfolio in their current wallet with one click. Buying and selling of assets will be handled automatically	This will provide ease of use for the user and eliminate intermediate steps required to manually buy and sell assets	The user must be warned of what this action will do and should be required to confirm the action with a prompt	User's crypto wallets will accurately reflect the changes suggested by the DST.	L

Table 2: Non-Functional requirements between customer and product

ID	Requirement	Description	Rationale	Verification of requirement	Priority

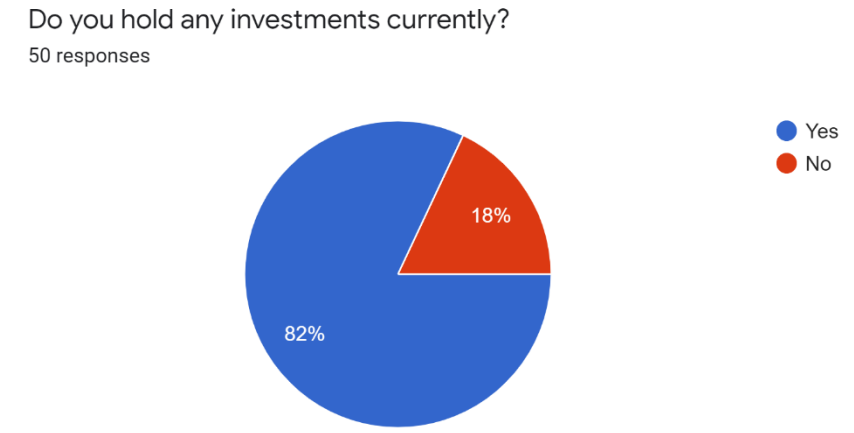
1	Web-based tool	The DST will be a web-based application and must work on all browsers. Performance should not be affected when accessed on different platforms	Users should not have to own a specific type of device (Android vs Apple). Web based makes the DST accessible	Users will view the same pages and results of the DST regardless of device	H
2	Security	Usernames, passwords and wallet information will not be visible to other users	Potential users trust a secure site, do not want personal information leaked. Financial information is especially sensitive	User generated usernames and passwords will only be visible in the master database, viewable by system admins	H
3	User friendly	The DST will be easy to use. All input instructions clearly laid out	A user-friendly system will appeal to more users and retain existing users	Users should be able to use tool to its full capacity (input parameters and view results) with minimal guidance every time they use the tool	H
4	System responsiveness	The user should not have to wait more than 5 seconds for the pages to load	A slow system is unattractive, and users will not be satisfied	Pages should load within 5 second time frame	L
5	Intuitive	A user should be able to learn how to use the tool without having to access additional resources	Asking for help (from support team or FAQ page) slows down the user experience. Financial situation can also be quite personal	Users will learn how to use the tool with	M
6	Learning	The system should provide users with learning opportunities	Users will feel a greater sense of attachment to system because it	System admins can view how many times the learning	H

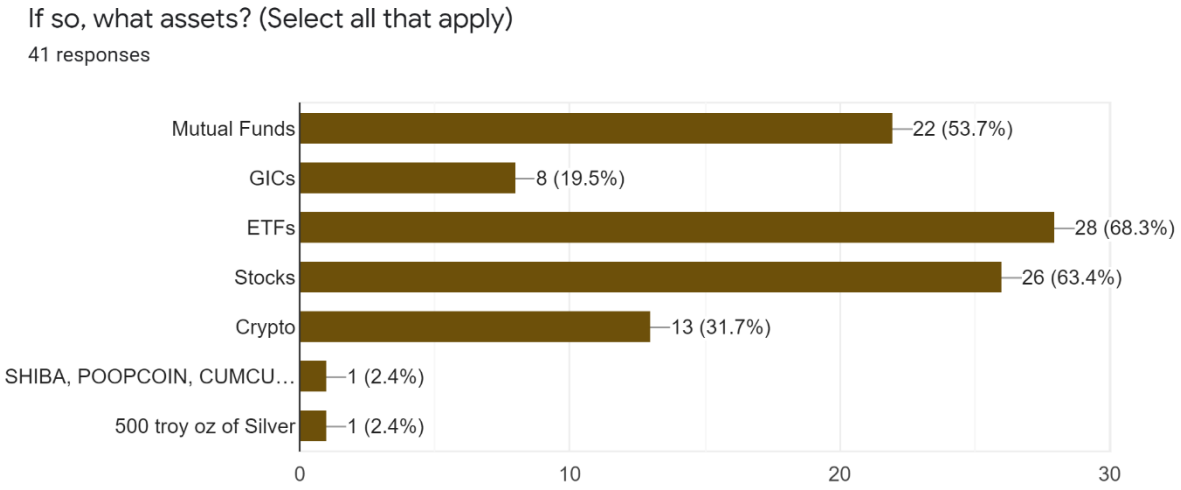
		about the crypto market and investment strategy	helps them expand their knowledge on an interesting topic	pages have been accessed	
7	User Sessions	If a user is active the page will not time out. The page will time-out and automatically sign out if the user has been inactive for over 5 min	Timing-out will protect the user's sensitive information (potential portfolio value) from any unauthorized viewers	User is logged out automatically after 5 minutes of inactivity	M

APPENDIX B: User Survey Summary

*** DISCLAIMER ***

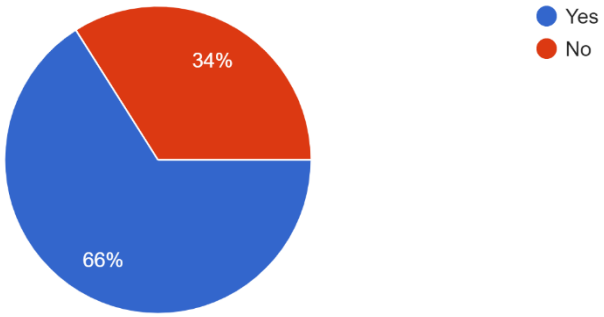
Certain segments of our survey allowed for customized user input in addition to set, multiple choice answers. As expected with asking strangers on the internet to provide their opinions, a small number of answers do not add any value to the survey but do provide some insight regarding the general public perception on the topic of cryptocurrencies. For this reason, all responses seen below are raw and unfiltered. Please excuse the obvious anomalous responses which may offend some audiences.





Have you considered purchasing or entering the crypto market in any way?

50 responses



If applicable, what made you consider buying into crypto currencies?

25 responses

- Enormous gains in a short period of time
- FREE MONEY, 2 THOUSAND CUMCUMCOIN IN CIRCULATION, BEST VALUE, FUTURE OF FINANCIAL TRANSACTIONS
- Hype and exponential growth.
- My friends told me I should get into it
- Growing popularity
- The fact that it is an investment market, so it is at least worth considering
- $$$$$$$$$$$$$$$$$$$$$$$$
- Michael Saylor and general internet influencers
- high-risk speculative investment

If applicable, what made you consider buying into crypto currencies?

25 responses

The potential speed of the return

hype

asset class price appreciation

$$$

The hype behind it

Diversification and the opportunities associated with this newer investment

Cash App

Excitement of something new

Listening to Podcasts/ Finance YouTube discuss advantages and disadvantages

If applicable, what made you consider buying into crypto currencies?

25 responses

Excitement of something new

Listening to Podcasts/ Finance YouTube discuss advantages and disadvantages

Potential for large gains.

safemoon moonpug shitandcum cockinmyass coins! very good investments!

High potential, high risk, so I don't have much in it.

Big crypto boom back in 2019-2020

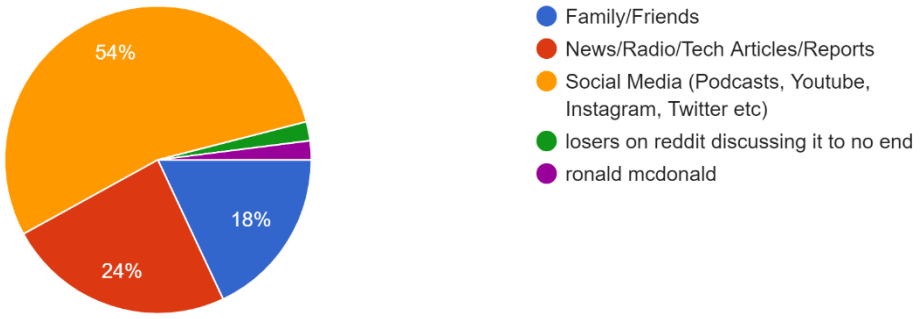
Functional technology

the hype

I saw a lot of people talking about it online (twitter) & read up on resources

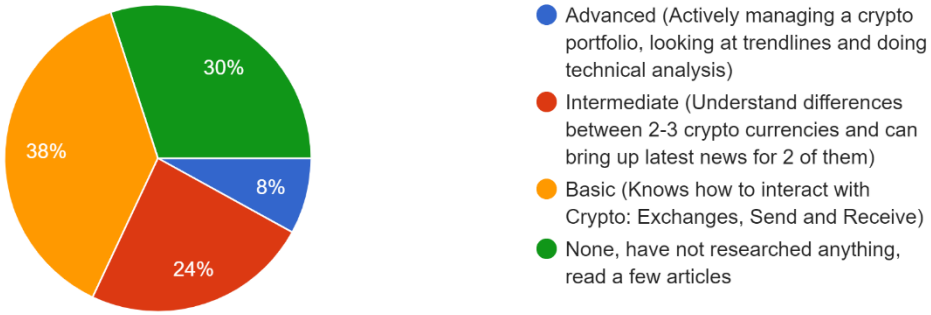
Through which source do you gain the most exposure to crypto related information?

50 responses



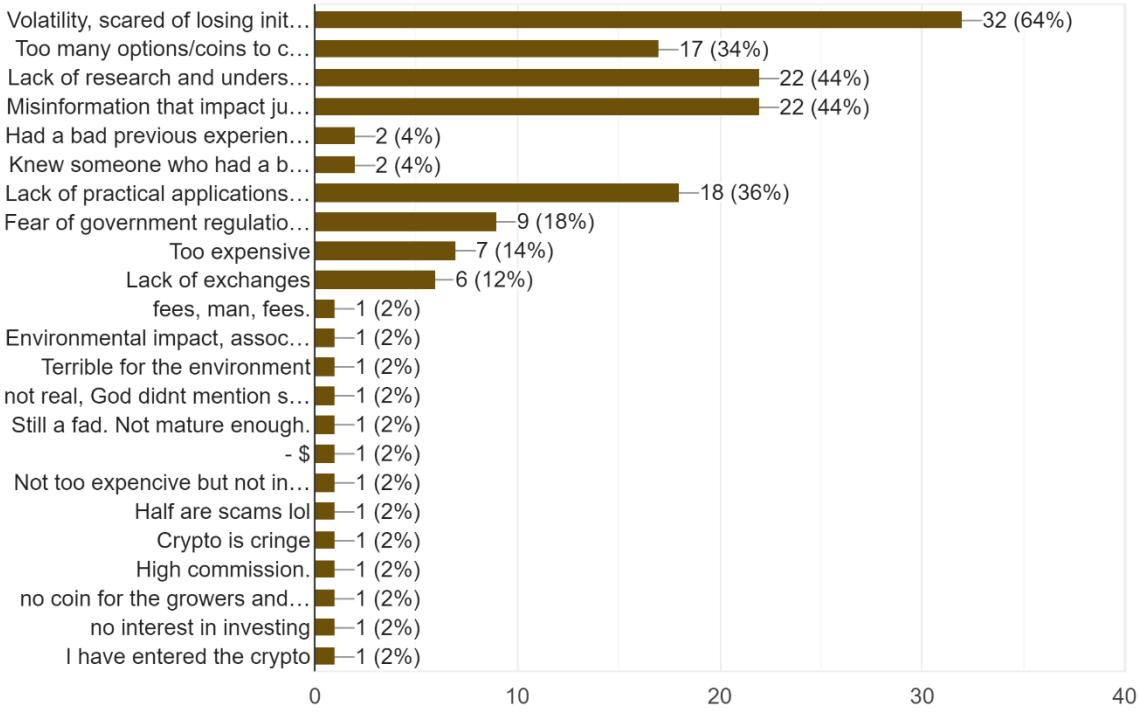
Have you done any personal research? What is your current understanding of the crypto space?

50 responses



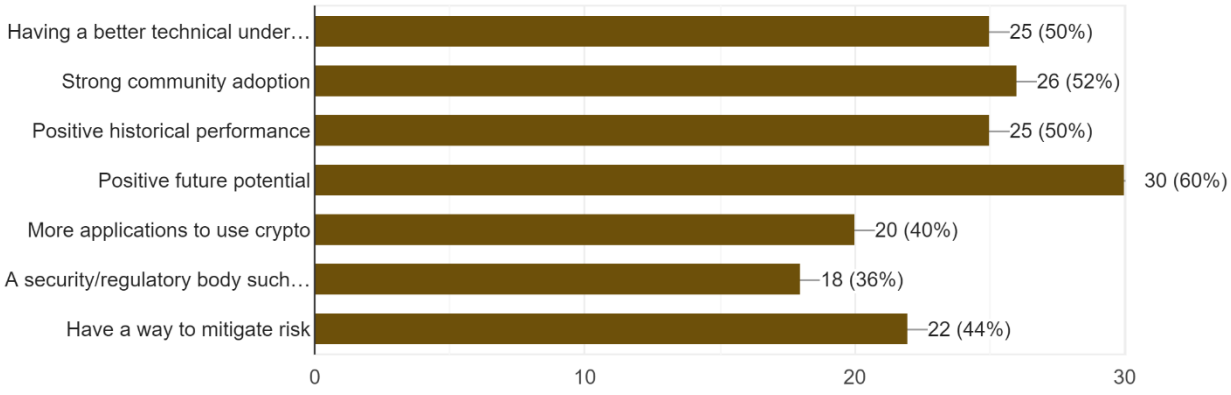
What has held you back from entering the crypto space or investing more? (Select all that apply)

50 responses



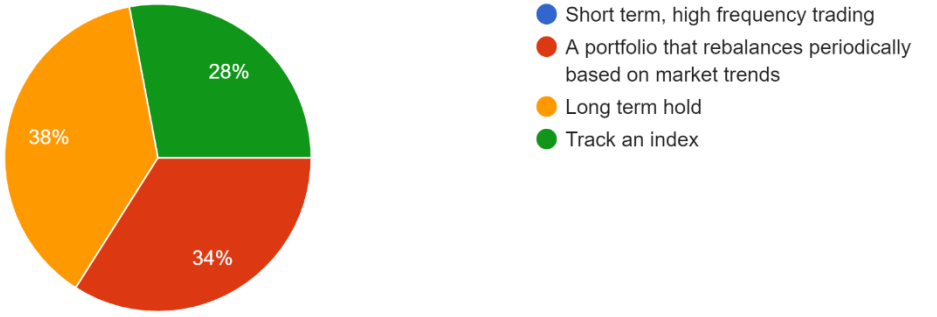
What would make you more comfortable with making a crypto investment? (Select all that apply)

50 responses



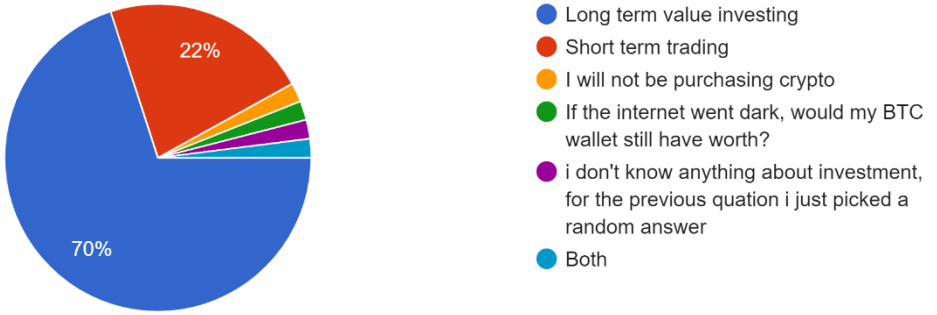
In your opinion, what is an effective way to mitigate risk?

50 responses



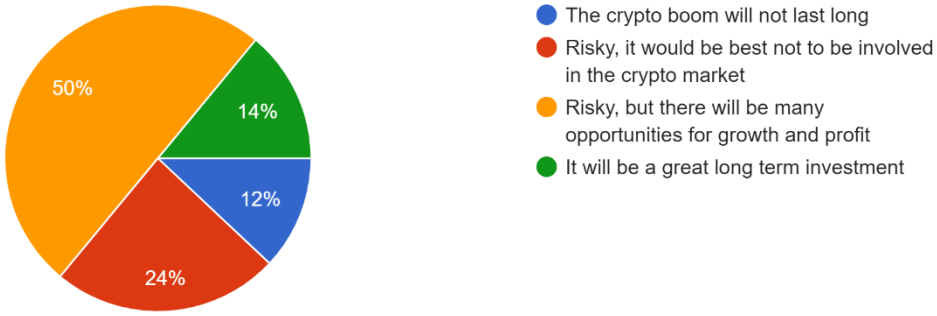
If you were to make an investment, what time horizon would you consider?

50 responses

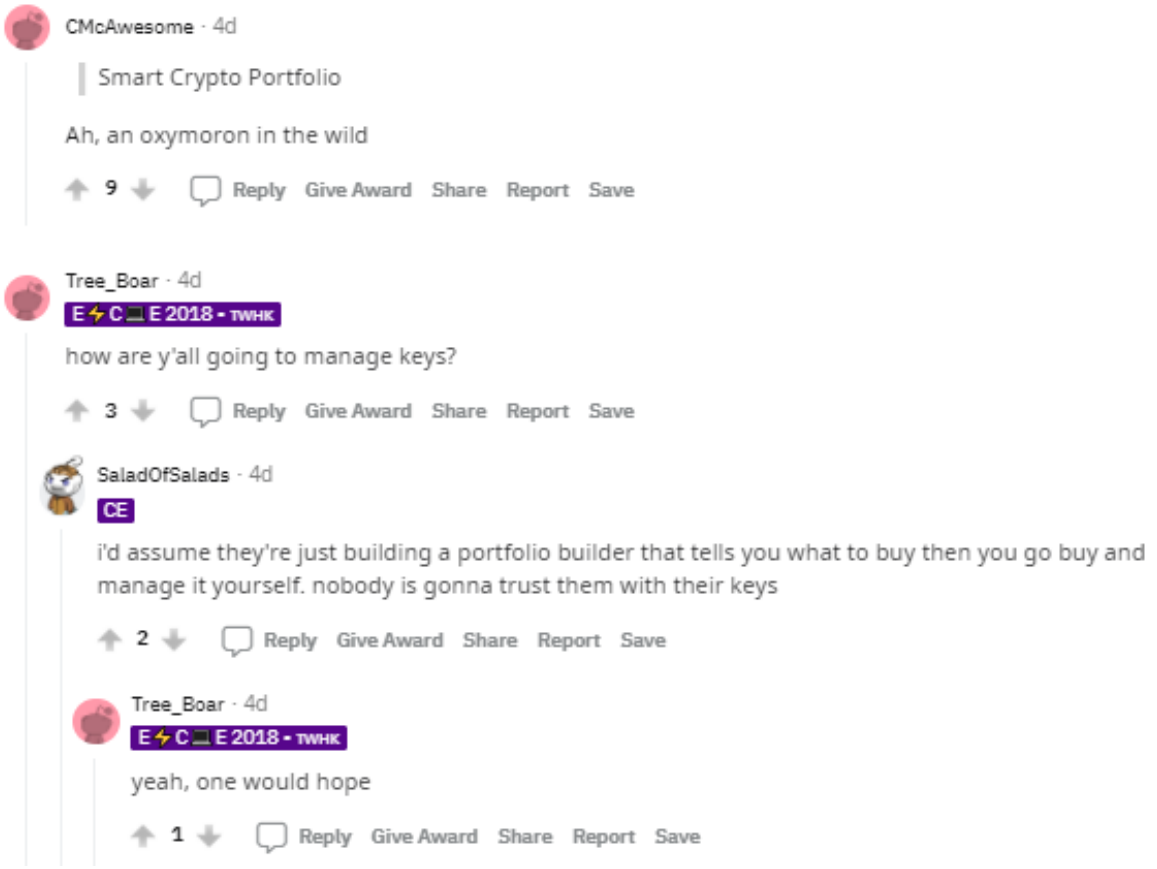


What do you think the future holds for cryptocurrencies?

50 responses



APPENDIX B-2: User Comments



CMcAwesome · 4d

> Smart Crypto Portfolio

Ah, an oxymoron in the wild

9 Reply Give Award Share Report Save

Tree_Boar · 4d

E⚡C💻E 2018 - TWHK

how are y'all going to manage keys?

3 Reply Give Award Share Report Save

SaladOfSalads · 4d

CE

i'd assume they're just building a portfolio builder that tells you what to buy then you go buy and manage it yourself. nobody is gonna trust them with their keys

2 Reply Give Award Share Report Save

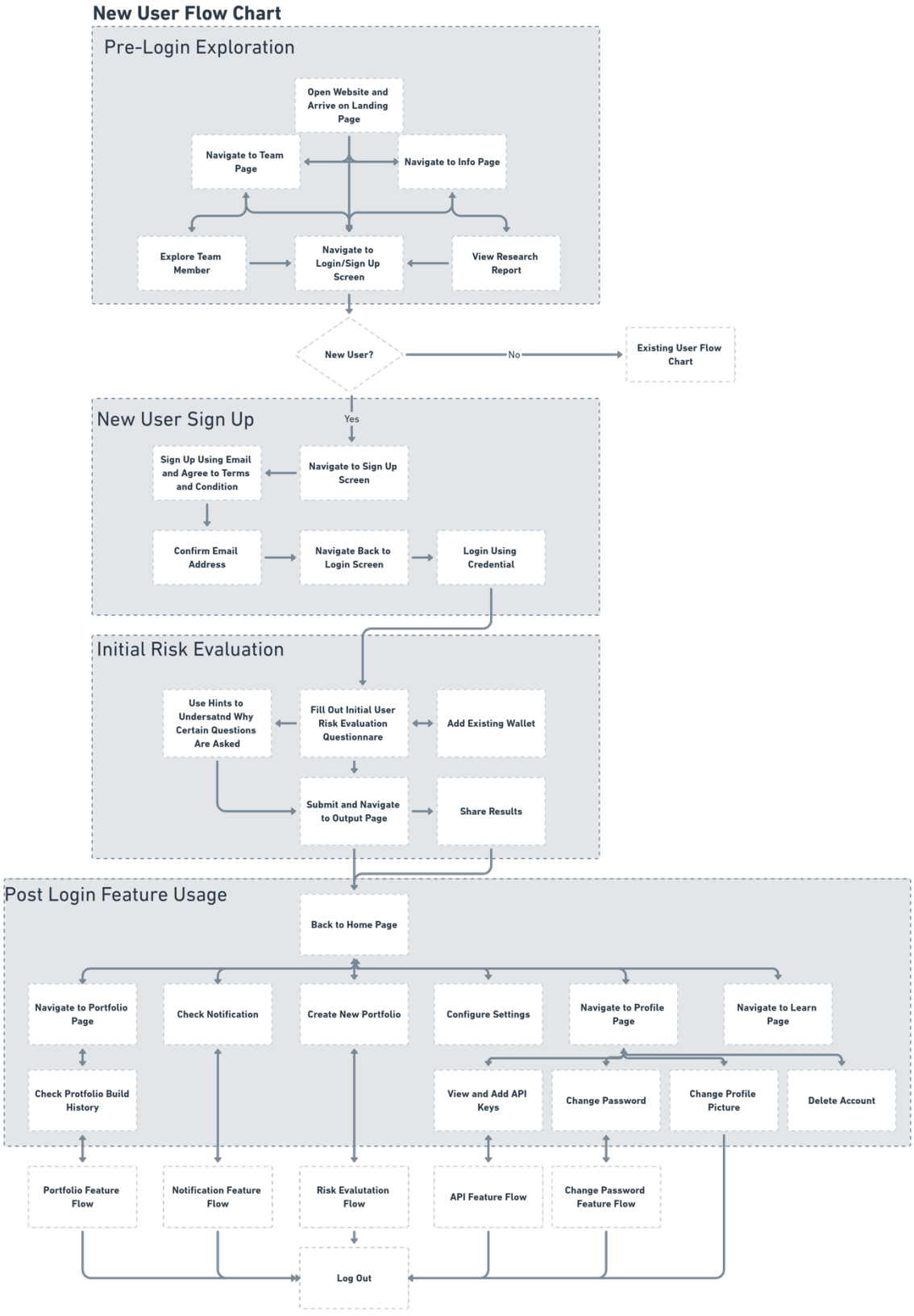
Tree_Boar · 4d

E⚡C💻E 2018 - TWHK

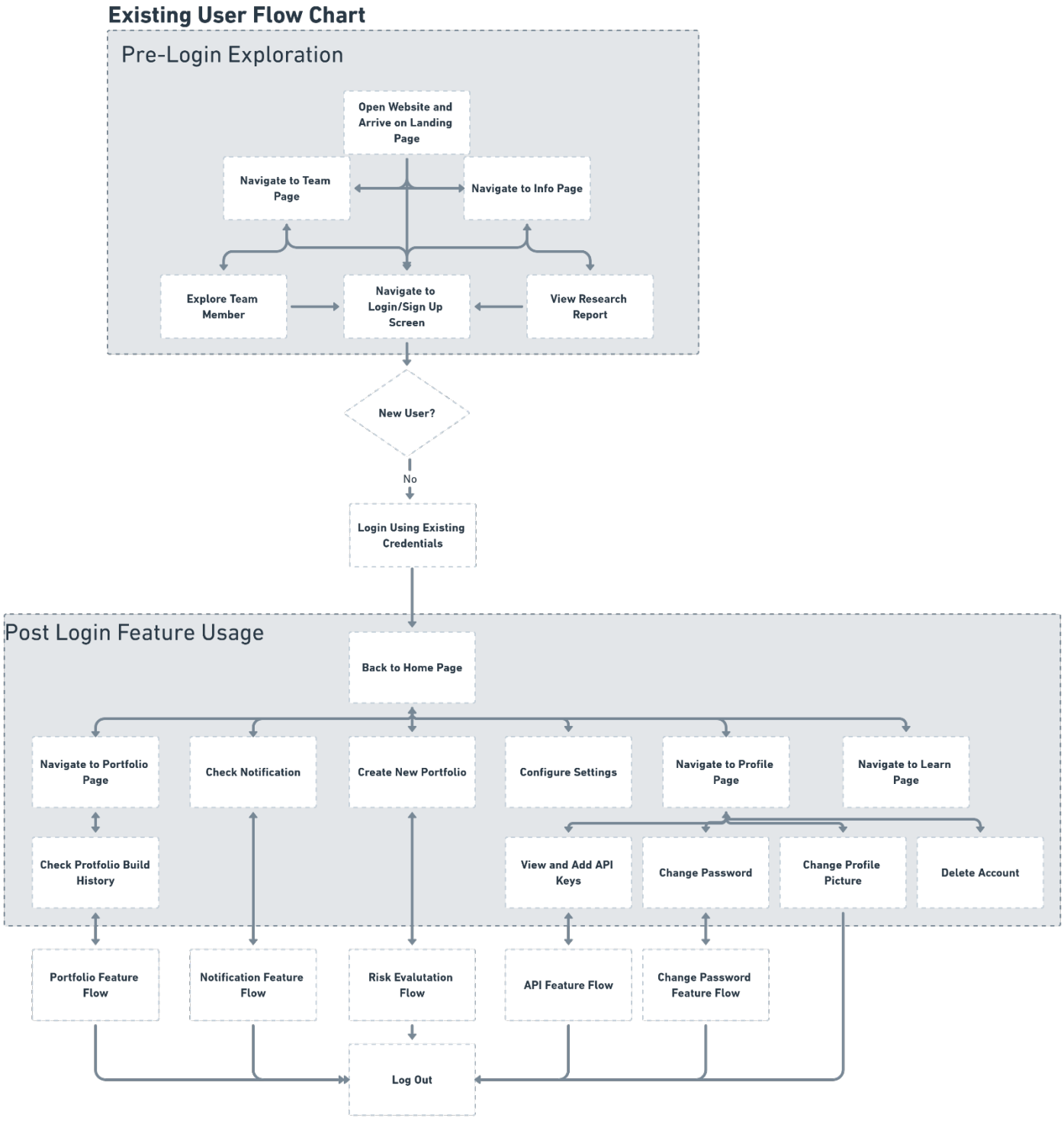
yeah, one would hope

1 Reply Give Award Share Report Save

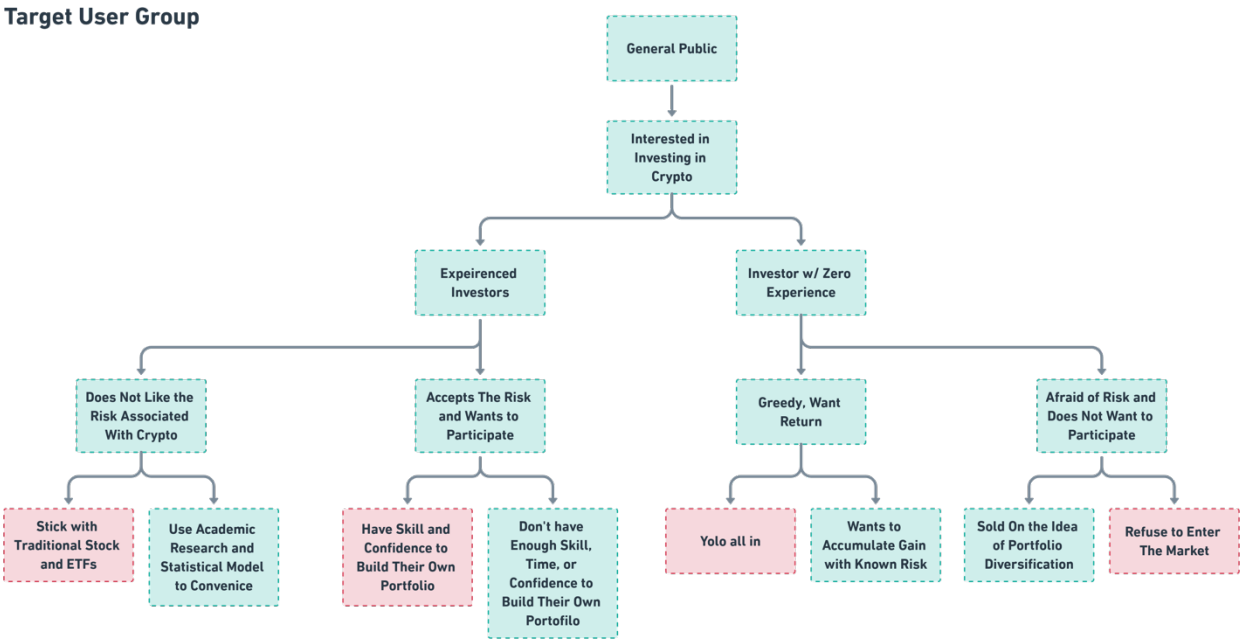
APPENDIX C-1: New User Flow Chart



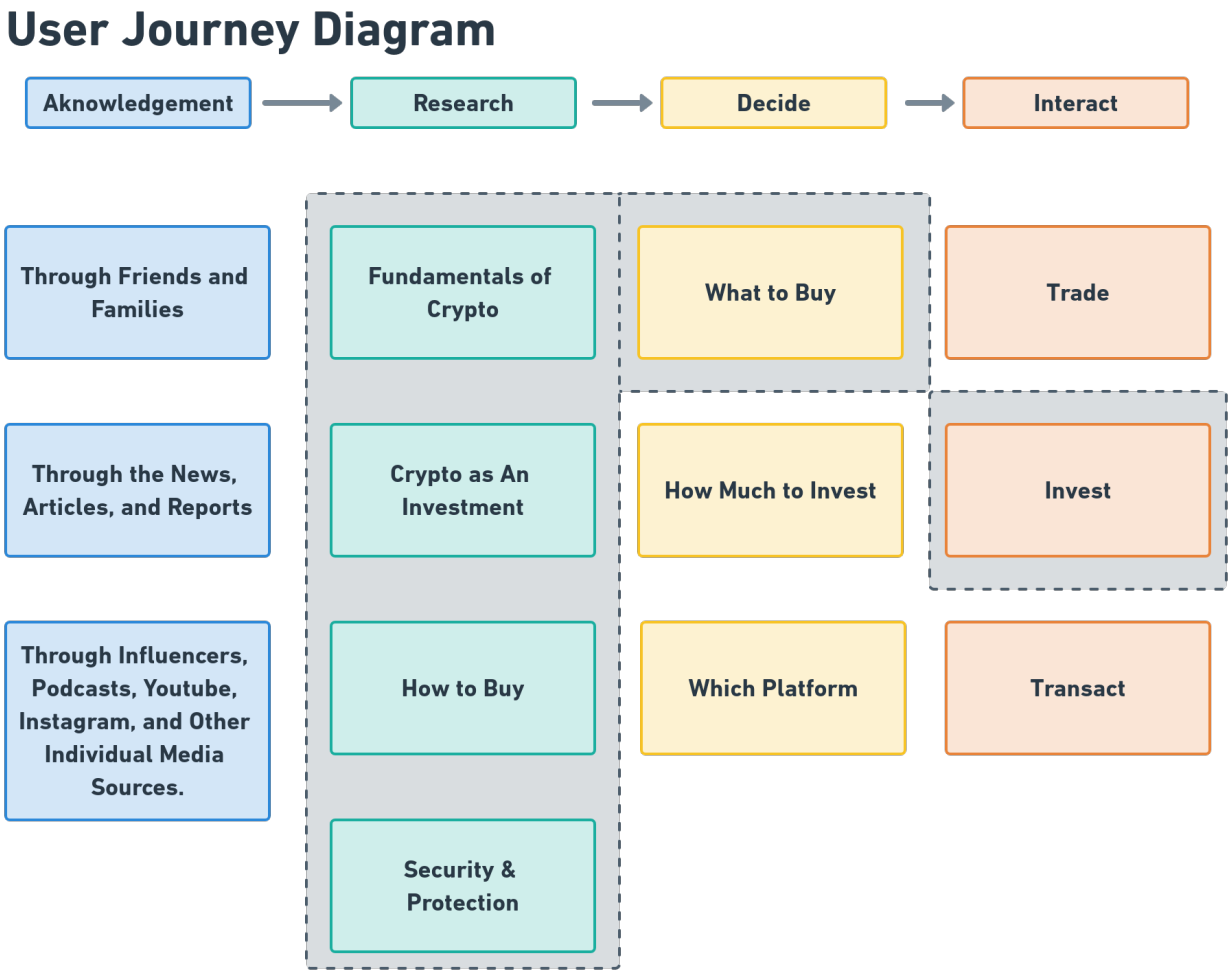
APPENDIX C-2: Existing User Flow Chart



APPENDIX D: Target User Group



APPENDIX E: User Journey Diagram



APPENDIX F-1: Product Prototype Design Iteration 1

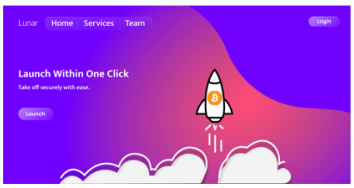


Figure 8 Iteration 1 - Landing Page

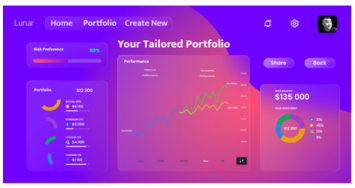


Figure Iteration 1 - Output Page

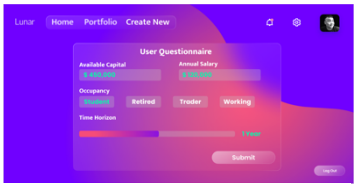


Figure 7 Iteration 1 - Input Page

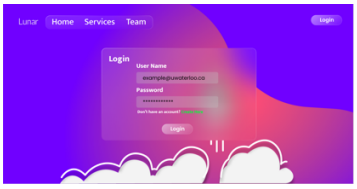


Figure 11 Iteration 1 - Login Page

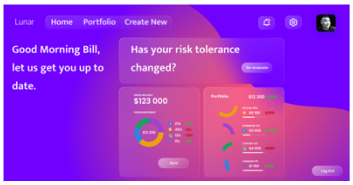


Figure 10 Iteration 1 - Home Page

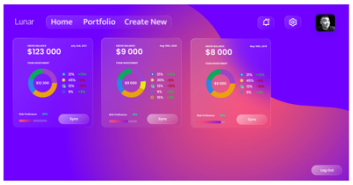


Figure 9 Iteration 1 - Portfolio Page

APPENDIX F-2: Product Prototype Design Iteration 2

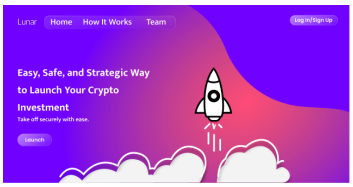


Figure 13 Iteration 2 - Landing Page

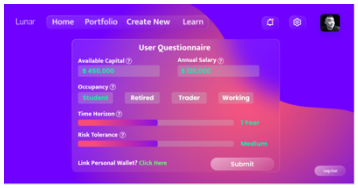


Figure 14 Iteration 2 - Input Page

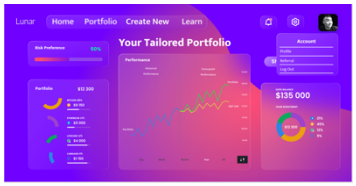


Figure 12 Iteration 2 - Account Menu

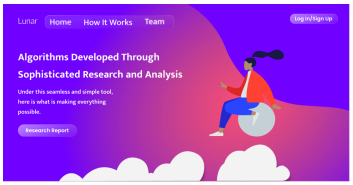


Figure 16 Iteration 2 - Info Page

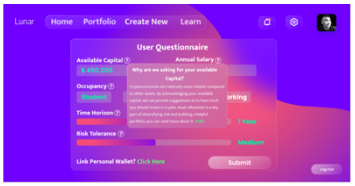


Figure 17 Iteration 2 - Help

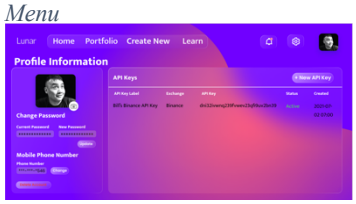


Figure 15 Iteration 2 - Portfolio Information Page

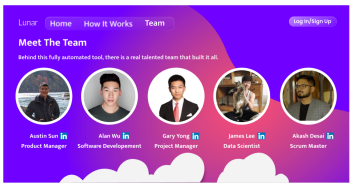


Figure 19 Iteration 2 - Teams Page.

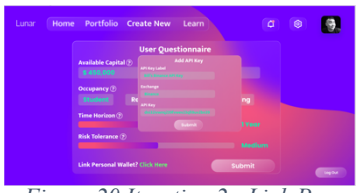


Figure 20 Iteration 2 - Link Personal Wal

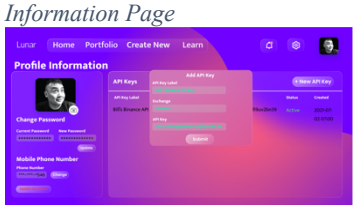


Figure 18 Iteration 2 - Add API Key

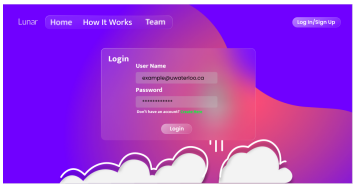


Figure 22 Iteration 2 - Login Page

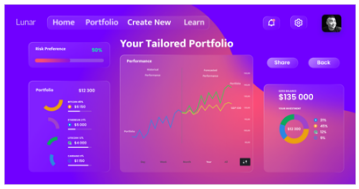


Figure 23 Iteration 2 - Output Page

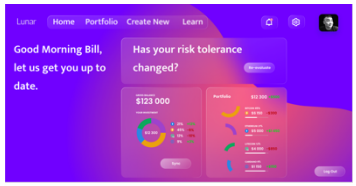


Figure 21 Iteration 2 - Home Page

Figure 25 Iteration 2 - Sign Up Page

Figure 26 Iteration 2 - Notifications

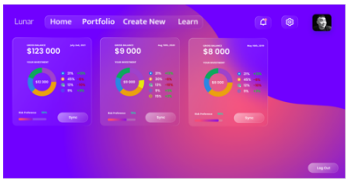


Figure 24 Iteration 2 - Portfolio Page

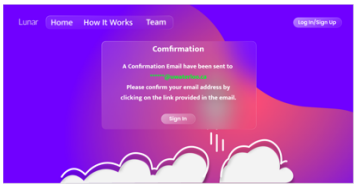


Figure 28 Iteration2 - Confirmation Page

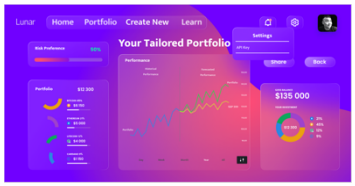


Figure 29 Iteration 2 - Settings

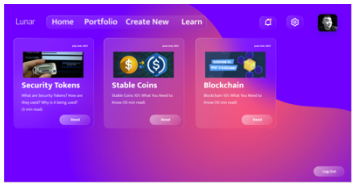


Figure 27 Iteration 2 - Learn Page

APPENDIX F-3: Product Prototype Design Iteration 3

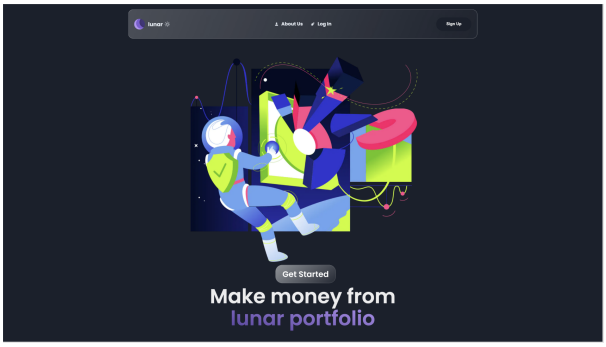


Figure 31 Iteration 3 - Landing Page

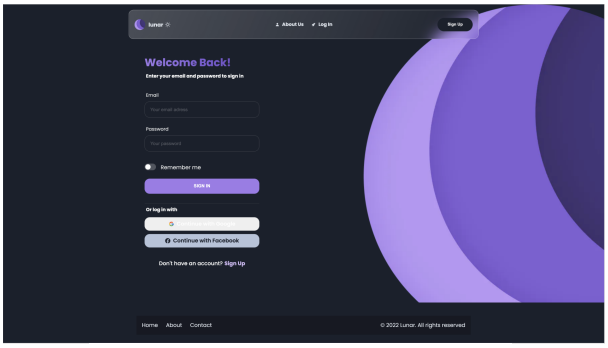


Figure 30 Iteration 3 - Login Page

Figure 33 Iteration 3 - Home Page

Figure 32 Iteration 3 - Home Page (without connection)

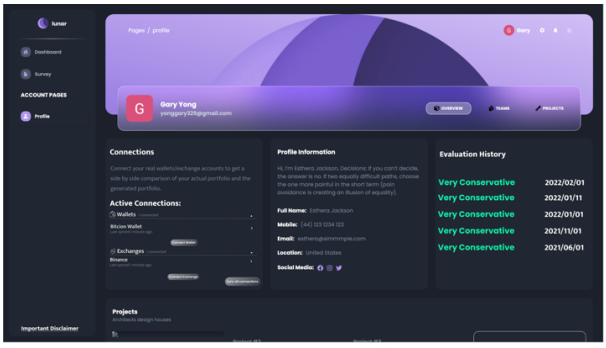


Figure 34 Iteration 3 - Profile Page

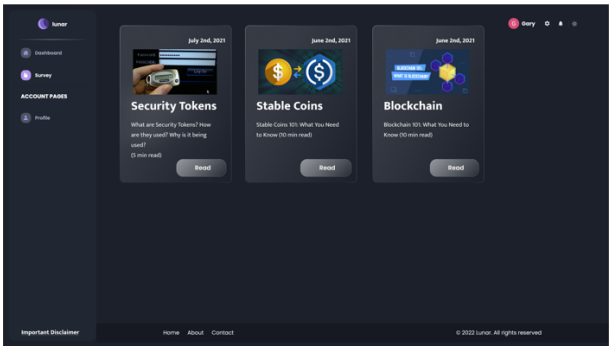


Figure 35 Iteration 3 - Learn Page

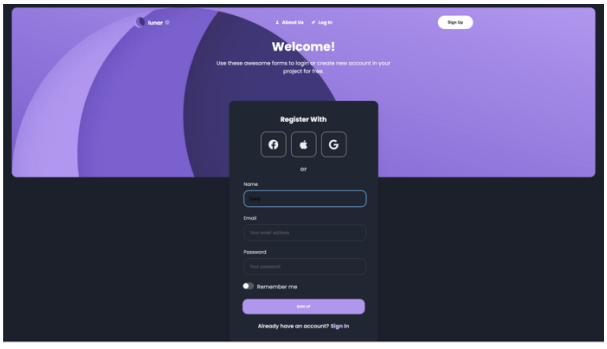


Figure 36 Iteration 3 - Login Page

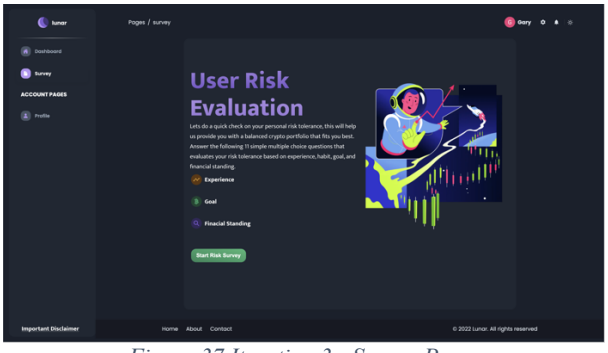


Figure 37 Iteration 3 - Survey Page

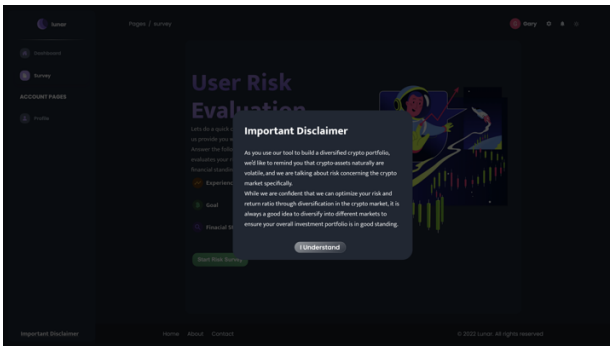


Figure 39 Iteration 3 – Important Disclaimer

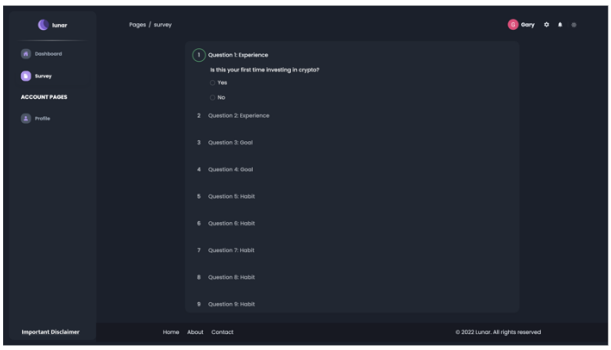


Figure 38 Iteration 3 – Survey Questions Page

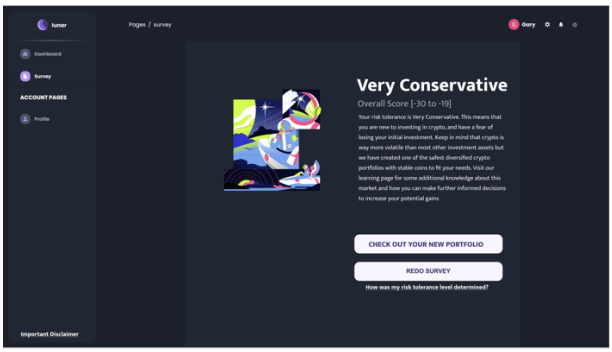


Figure 41 Iteration 3 – Survey Results Page (Very Conservative)

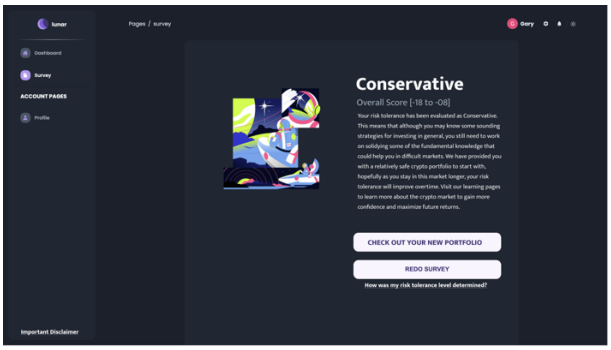


Figure 40 Iteration 3 - Survey Results Page (Conservative)

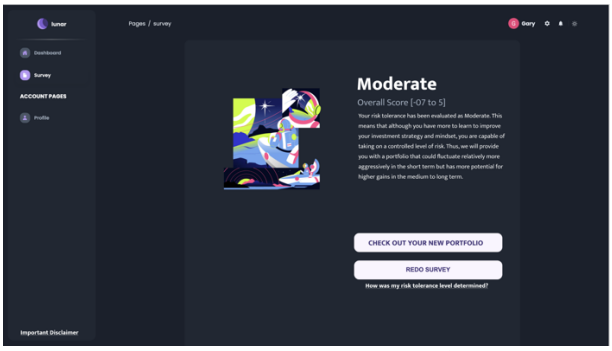


Figure 43 Iteration 3 - Survey Results Page (Moderate)

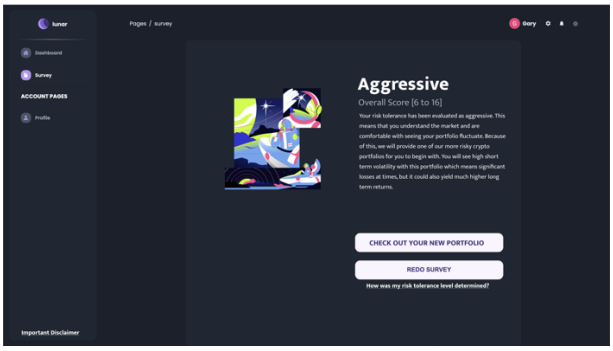


Figure 42 Iteration 3 - Survey Results Page (Aggressive)

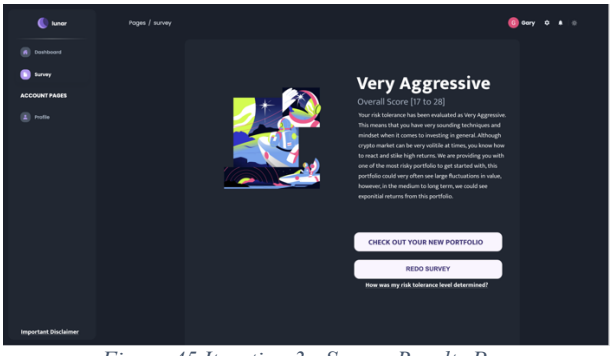


Figure 45 Iteration 3 - Survey Results Page (Very Aggressive)

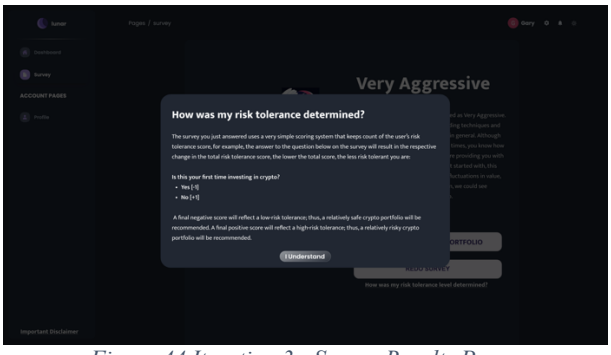


Figure 44 Iteration 3 - Survey Results Page (Info Note)

Figure 47 Iteration 3 – Output Page

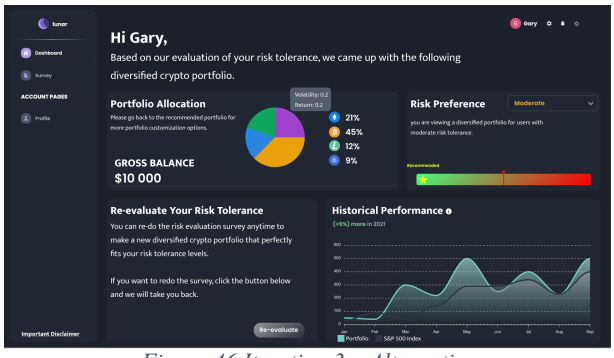


Figure 46 Iteration 3 – Alternative Portfolio Page

APPENDIX G: Detailed Lunar Algorithm Research Report (Available on website, user facing)

Lunar Capstone Research Report

Akash Desai, Alan Wu, Austin Sun, Gary Yong, James Lee

Table of Contents

Abstract

This study investigated the practicality of using multivariate statistical analysis for the development of a portfolio for crypto assets. The algorithm used in this experiment is an iterative process of creating 1,000 unique portfolios and returning the optimal set of solutions. The model considers the varying risk preferences of investors and returns the leading portfolio from each of the five risk levels. Because of the randomness occurring at each iteration, we conducted a series of tests to obtain the range of expected return and drawdown of portfolios at each risk level. After 20 trials, we observed that the drawdown over the past 12 months ranged between -59.40% and -49.28%, with the average drawdown equal to -53.50%. The historical 1-year return showed larger deviations, ranging between +66.76% and +197.08%, with average return of +116.97%. Peak return ranged between +155.93% and +386.93%, with average return of +250.78%. Observations show that there is more variability among 1-year and peak returns, while drawdown is generally consistent for all risk levels. The results of this study suggest that increasing volatility tends to amplify the magnitude of a portfolio's positive return but does not have a significant impact during periods of decline.

Introduction

This research report outlines the design approaches and methods used for implementing the cryptocurrency portfolio builder tool. There will be a brief explanation on the foundation of our research on risk analysis and portfolio diversification. Following the background, the algorithm design will go through a summarized flow of the entire process, starting with data gathering and ending on how the output of the algorithm will be presented to the user. The implementation section of the report contains a step-by-step walkthrough of the program and the techniques used for statistical analysis and data transformation. The report will be concluded by a visualization of the comparison between various portfolios and a discussion on the feasibility and efficiency of the presented algorithm.

Background

The fundamental basis of the solution utilizes modern portfolio theory (MPT), a mathematical algorithm that seeks to maximize the return of an investment portfolio with minimal risk. MPT was initially introduced in 1952 by American economist Harry Markowitz and has been widely used ever since due to its flexibility with balancing various portfolio asset types and interpretability of risk analysis.

MPT, also known as mean-variance analysis, analyzes the expected return and standard deviation of portfolios using historical data of the assets included. It allows investment decisions to be made by considering the risk and return of each portfolio and choosing on the optimal solution.

From a pool of over 10,000 assets, we use a ranking model that considers not only the historical returns of assets, but also the technology stack, general sentiment, market adoption, asset performance, and liquidity to rank and pick the candidates. The following experiment uses multivariate mean-variance analysis to analyze the historical daily returns and the interrelationship between 17 crypto assets that are currently the most highly rated on the ranking system. Namely, this study will analyze and generate a diversified portfolio of Aave (AAVE), Cardano(ADA), Axie Infinity (AXS), Bitcoin (BTC), Curve DAO Token

(CRV), Polkadot (DOT), Ethereum (ETH), FTX Token (FTT), Kyber Network Crystal v2 (KNC), Chainlink (LINK), Litecoin (LTC), Polygon (MATIC), The Sandbox (SAND), Uniswap (UNI), Stellar (XLM), XRP (XRP), and Tezos (XTZ).

Figure 1. Historical Prices of Crypto Assets

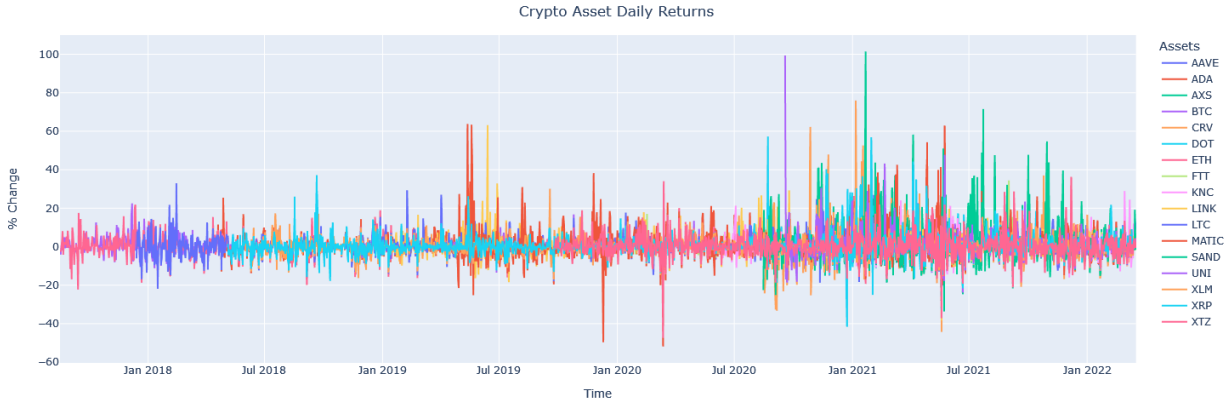


Figure 2. Historical Daily Returns of Crypto Assets

Algorithm Design

The algorithm is designed with a focus on efficiency and simplicity. However, it is effective in determining the expected return and volatility of each portfolio. The initial step is to obtain the daily closing prices of each asset and aggregating the values to get monthly returns. We have set a monthly geometric decay of 5% to put more weight on recent data. Figure 2 is an overview of the past several years of daily returns for each of the 17 assets. The primary reason for putting less weight on older data is in consideration of the declining volatility and stabilizing conditions of the crypto market. However, it

is important to note that fundamentals may change at any point and require a modification of the current model.

The weighted average return for each asset is obtained and used to derive additional measures such as standard deviation, correlation, and covariance. These measures are used as intermediate steps of the process of calculating expected portfolio return and standard deviation, which are the two attributes of a given portfolio that allow us to determine optimality.

Obtaining the optimal portfolio requires an iterative process through random number generation. Through a series of tests, we have decided to set the number of generated portfolios to 1000, in consideration of runtime. Our algorithm uses random numbers to produce allocation weights of assets in each iteration. In other words, a unique portfolio is created in every iteration. The unique weights of each portfolio's assets are then used to determine the associated risk and expected return of the portfolio.

One important point to consider is a specific user's risk tolerance. A risk-averse investor will likely favour a portfolio with minimal risk even though its expected return is comparably low. On the other hand, a risk-tolerant investor may prefer an aggressive portfolio with high risk and high return. Taking this into account, we have decided to implement risk buckets that are separated by volatility ranges. Following the iterations, the randomly generated portfolios are assigned to one of the five risk buckets based on portfolio standard deviation.

The last step of the algorithm is the decision-making process. For each risk bucket, we obtain the Sharpe ratios of each portfolio within. The Sharpe ratio is a type of measurement using the excess return of an investment and the underlying volatility, indicating the relative performance of the given portfolio. The portfolios are then ranked based on Sharpe ratio in descending order to rearrange the choices in each bucket. Finally, the top portfolio in each risk bucket is selected as the optimal solution for the given risk level. On the application interface, the user will be suggested with one of the five portfolios depending on his or her risk preference.

Implementation

A custom function is used to fetch the daily closing prices of all the assets. The resulting data frames is concatenated into one single data frame to be used for the remainder of the algorithm.

```
years = 5
start = datetime.today() - relativedelta(years=years)
dfs = []
for x in assets:
  try:
    dfs.append(ohlcv(start, x, '1d'))
  except:
    pass
data = pd.concat(dfs, axis=1)
data = data.reindex(sorted(data.columns), axis=1)
data = data[:-1]
```

Time	AAVE	ADA	AXS	BTC	CRV	DOT	ETH	FTT	KNC	LINK	LTC	MATIC	SAND	UNI	XLM	XRP	XTZ
2022-03-09	127.6	0.849	48.65	41941.71	2.156	17.86	2726.98	42.75	3.106	14.01	106.9	1.505	2.9619	9.21	0.1887	0.7658	3.174
2022-03-10	119.2	0.807	46.77	39422.00	2.041	16.96	2606.70	40.75	2.768	13.17	102.5	1.437	2.8266	8.68	0.1786	0.7361	3.053
2022-03-11	116.6	0.788	45.90	38729.57	1.970	17.69	2556.86	40.81	2.574	13.05	104.6	1.404	2.7750	8.51	0.1835	0.8029	2.985
2022-03-12	120.4	0.789	46.60	38807.36	1.977	18.14	2568.80	40.93	2.748	13.15	105.6	1.396	2.7790	8.46	0.1850	0.7857	3.024
2022-03-13	115.7	0.786	45.19	37777.34	1.919	17.22	2515.65	39.80	2.583	12.70	101.7	1.360	2.7136	8.19	0.1763	0.7602	2.905
2022-03-14	118.4	0.802	47.84	39671.37	1.952	17.70	2589.41	41.47	2.895	13.41	105.6	1.379	2.7490	8.49	0.1800	0.7748	2.997
2022-03-15	122.1	0.800	46.90	39280.33	1.952	17.81	2617.73	41.02	3.058	13.69	106.8	1.378	2.7337	8.72	0.1827	0.7657	2.969
2022-03-16	141.7	0.838	50.42	41114.00	2.090	19.05	2773.81	42.72	3.062	14.66	111.4	1.467	3.2589	9.10	0.1893	0.7919	3.099
2022-03-17	155.6	0.835	50.26	40917.90	2.126	18.75	2811.92	43.06	3.113	14.40	110.2	1.446	3.2062	9.22	0.1896	0.7935	3.081
2022-03-18	160.1	0.851	50.46	41757.51	2.243	18.95	2938.92	44.58	3.386	15.01	111.9	1.497	3.2103	9.63	0.1928	0.7965	3.151

Figure 3. Recent Closing Prices of Assets

With the closing prices saved to the data frame, the daily and monthly returns are calculated with the respective decay rates.

```
# Monthly decay rate
m_decay_rate = 0.05

# Get number of months since start_date
def get_months(start_date):
  end_date = date.today()
  years = end_date.year - start_date.year
  months = end_date.month - start_date.month
  return years * 12 + months

monthly_closes = data.resample('M').last() # Resample daily returns to monthly
monthly_returns = monthly_closes.pct_change() # Monthly returns
monthly_returns = monthly_returns.apply(lambda x: x * (1-
m_decay_rate) ** get_months(x.name), axis=1) # Monthly returns with decay
```

Time	AAVE	ADA	AXS	BTC	CRV	DOT	ETH	FTT	KNC	LINK	LTC	MATIC	SAND	UNI	XLM	XRP	XTZ
2021-06-30	-0.216477	-0.127697	0.092824	-0.037368	-0.045432	-0.185900	-0.100254	-0.121230	-0.004467	-0.247050	-0.146556	-0.236599	-0.168347	-0.199995	-0.185647	-0.202595	-0.098365
2021-07-31	0.211434	-0.031607	4.307185	0.121474	-0.037649	0.015451	0.074447	0.185089	-0.020128	0.108678	0.000506	-0.048997	1.064837	0.085655	0.000771	0.037290	-0.001679
2021-08-31	0.127814	0.766303	0.487347	0.094978	0.213336	0.606052	0.247807	0.264688	0.128957	0.122585	0.131231	0.163569	0.345343	0.244243	0.135333	0.411514	0.489676
2021-09-30	-0.216568	-0.173213	0.025474	-0.051140	0.033219	-0.064013	-0.091874	0.048683	-0.166357	-0.074335	-0.078010	-0.114445	-0.217814	-0.146368	-0.131290	-0.144030	0.129396
2021-10-31	0.106139	-0.055244	0.659124	0.308560	0.690308	0.382565	0.331781	0.114989	0.256891	0.193445	0.194833	0.556327	1.038013	0.047683	0.260426	0.129464	0.035548
2021-11-30	-0.149058	-0.170034	-0.007130	-0.057789	0.110014	-0.091791	0.065174	-0.119514	-0.020465	-0.127334	0.067486	-0.064690	2.707330	-0.121622	-0.080248	-0.083807	-0.111943
2021-12-31	-0.009352	-0.135723	-0.273839	-0.161592	0.051610	-0.255066	-0.176656	-0.209900	-0.290358	-0.196475	-0.253747	0.354958	-0.120104	-0.171475	-0.176939	-0.144800	-0.178235
2022-01-31	-0.342659	-0.177326	-0.395551	-0.151339	-0.347324	-0.246783	-0.242867	0.125760	0.422761	-0.109170	-0.227013	-0.315732	-0.269858	-0.277651	-0.226556	-0.230928	-0.177173
2022-02-28	-0.070571	-0.080447	0.036455	0.115903	-0.240984	-0.021089	0.082737	0.051664	0.282378	-0.111895	0.036438	-0.015631	-0.205179	-0.100085	-0.009995	0.251579	0.012801
2022-03-31	0.098080	-0.115385	-0.072256	-0.032495	-0.081491	0.000528	0.006152	-0.029815	0.385434	-0.007931	-0.015831	-0.072491	0.000062	-0.085470	-0.023797	0.019977	-0.108628

Figure 4. Recent Monthly Returns

There are two methods of determining the monthly standard deviation of a portfolio. The first method uses daily returns to initially obtain the daily standard deviation and then scale and transform the result into monthly standard deviation. The second method uses monthly returns to directly calculate the monthly standard deviation. To improve the accuracy and precision of standard deviation estimations, the first method is chosen.

```
# Daily decay rate
d_decay_rate = 1 - (1-m_decay_rate)**(1/30)

# Get number of days since start_date
def get_days(start_date):
  end_date = date.today()
  diff = end_date - start_date.date()
  return diff.days

daily_returns = data.pct_change() # Daily returns
daily_returns = daily_returns.apply(lambda x: x * (1-d_de-
cay_rate) ** get_days(x.name), axis=1) # Daily returns with decay
```

Time	AAVE	ADA	AXS	BTC	CRV	DOT	ETH	FTT	KNC	LINK	LTC	MATIC	SAND	UNI	XLM	XRP	XTZ
2022-03-09	0.048589	0.057709	0.047306	0.081642	0.058552	0.051645	0.057727	0.052914	0.013173	0.070015	0.060629	0.039471	0.047026	0.044710	0.088125	0.061622	0.053653
2022-03-10	-0.064936	-0.048798	-0.038118	-0.059260	-0.052615	-0.049707	-0.043508	-0.046148	-0.107343	-0.059143	-0.040601	-0.044569	-0.045060	-0.056764	-0.052797	-0.038256	-0.037604
2022-03-11	-0.021553	-0.023264	-0.018380	-0.017356	-0.034373	0.042530	-0.018892	0.001455	-0.069253	-0.009003	0.020244	-0.022691	-0.018038	-0.019352	0.027109	0.089669	-0.022008
2022-03-12	0.032257	0.001256	0.015095	0.001988	0.003517	0.025178	0.004622	0.002910	0.066909	0.007585	0.009463	-0.005640	0.001427	-0.005815	0.008091	-0.021204	0.012932
2022-03-13	-0.038704	-0.003770	-0.030000	-0.026316	-0.029088	-0.050285	-0.020514	-0.027373	-0.059533	-0.033929	-0.036617	-0.025568	-0.023333	-0.031643	-0.046627	-0.032179	-0.039017
2022-03-14	0.023177	0.020217	0.058242	0.049795	0.017079	0.027685	0.029121	0.041674	0.119967	0.055524	0.038087	0.013875	0.012956	0.036380	0.020844	0.019075	0.031454
2022-03-15	0.031090	-0.002481	-0.019548	-0.009807	0.000000	0.006183	0.010881	-0.010796	0.056016	0.020773	0.011305	-0.000721	-0.005537	0.026952	0.014923	-0.011685	-0.009295
2022-03-16	0.159976	0.047338	0.074797	0.046522	0.070455	0.069386	0.059421	0.041302	0.001304	0.070613	0.042924	0.064366	0.191465	0.043429	0.036001	0.034100	0.043636
2022-03-17	0.097927	-0.003574	-0.003168	-0.004762	0.017195	-0.015721	0.013716	0.007945	0.016627	-0.017705	-0.010754	-0.014290	-0.016143	0.013164	0.001582	0.002017	-0.005798
2022-03-18	0.028920	0.019162	0.003979	0.020519	0.055033	0.010667	0.045165	0.035300	0.087697	0.042361	0.015426	0.035270	0.001279	0.044469	0.016878	0.003781	0.022720

Figure 5. Recent Daily Returns

The following code snippet uses the information on daily and monthly returns to generate the weighted average monthly return and monthly standard deviation of all 17 assets. Using these two values and a risk-free rate of 0.1%, the Sharpe ratio can be determined.

Monthly Standard Deviation (30-day approximation):

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{N}} \cdot \sqrt{30}$$

x_i = Individual daily return

μ = Average daily return

N = Number of data points

Sharpe Ratio:

$$S = \frac{E[R_p - R_f]}{\sigma_p}$$

R_p = Portfolio return

R_f = Risk-free rate

σ_p = Standard deviation of portfolio

```
avg_return = monthly_returns.mean() # Average monthly return
std_dev = daily_returns.std()*np.sqrt(30) # Monthly standard deviation

risk_free_rate = 0.001 # risk-free rate (0.1%)

ret_vol_sr = pd.concat([avg_return, std_dev], axis=1)
ret_vol_sr.columns = ['return','volatility']
ret_vol_sr['sharpe_ratio'] = ret_vol_sr.apply(lambda x: (x['return'] - risk_free_rate)
/x['volatility'], axis=1) # Calculate Sharpe ratio
ret_vol_sr = ret_vol_sr.applymap(lambda x: round(x,6))
```

	return	volatility	sharpe_ratio
AAVE	0.094706	0.254948	0.367549
ADA	0.052682	0.144722	0.357112
AXS	0.460164	0.376987	1.217985
BTC	0.021261	0.088869	0.227992
CRV	0.082040	0.319267	0.253833
DOT	0.063860	0.245021	0.256549
ETH	0.034104	0.113529	0.291593
FTT	0.079711	0.167896	0.468804
KNC	0.073537	0.238893	0.303636
LINK	0.048228	0.178289	0.264898
LTC	0.010973	0.128737	0.077466
MATIC	0.177395	0.240925	0.732158
SAND	0.341892	0.367587	0.927378
UNI	0.060114	0.267496	0.220989
XLM	0.022310	0.152623	0.139628
XRP	0.044962	0.163174	0.269417
XTZ	0.026338	0.210980	0.120099

Figure 6. Weighted Return, Volatility, and Sharpe Ratio of All Assets

To begin the iterations, there is one more piece of information that is required. The covariance matrix allows us to calculate portfolio variance. It will be used in conjunction with randomly generated weights on each iteration.

Covariance:

$$Cov(X,Y) = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{N}$$

X_i = Individual return of asset X

$\bar{X}$ = Average return of asset X

Y_i = Individual return of asset Y

$\bar{Y}$ = Average return of asset Y

N = Number of data points

```
cov_matrix = daily_returns.cov()
```

	AAVE	ADA	AXS	BTC	CRV	DOT	ETH	FTT	KNC	LINK	LTC	MATIC	SAND	UNI	XLM	XRP	XTZ
AAVE	0.002167	0.001099	0.001467	0.000748	0.001750	0.001404	0.001182	0.001054	0.001128	0.001433	0.001133	0.001612	0.001033	0.001651	0.001051	0.001156	0.001282
ADA	0.001099	0.000698	0.001161	0.000296	0.001139	0.001093	0.000408	0.000625	0.000893	0.000612	0.000452	0.000778	0.000824	0.001102	0.000536	0.000456	0.000753
AXS	0.001467	0.001161	0.004737	0.000904	0.001746	0.001420	0.001216	0.001166	0.001246	0.001456	0.001240	0.001632	0.002394	0.001528	0.001280	0.001409	0.001618
BTC	0.000748	0.000296	0.000904	0.000263	0.000809	0.000759	0.000272	0.000513	0.000596	0.000421	0.000316	0.000496	0.000655	0.000717	0.000324	0.000307	0.000503
CRV	0.001750	0.001139	0.001746	0.000809	0.003398	0.001488	0.001153	0.001130	0.001319	0.001620	0.001148	0.001626	0.001550	0.001573	0.001160	0.001220	0.001508
DOT	0.001404	0.001093	0.001420	0.000759	0.001488	0.002001	0.001066	0.001044	0.001092	0.001376	0.001125	0.001422	0.001056	0.001388	0.001070	0.001079	0.001343
ETH	0.001182	0.000408	0.001216	0.000272	0.001153	0.001066	0.000430	0.000699	0.000778	0.000614	0.000411	0.000717	0.000861	0.001103	0.000430	0.000412	0.000698
FTT	0.001054	0.000625	0.001166	0.000513	0.001130	0.001044	0.000699	0.000940	0.000767	0.000789	0.000672	0.000885	0.000871	0.001013	0.000651	0.000644	0.000733
KNC	0.001128	0.000893	0.001246	0.000596	0.001319	0.001092	0.000778	0.000767	0.001902	0.001047	0.000867	0.001157	0.001189	0.001094	0.000948	0.000857	0.001111
LINK	0.001433	0.000612	0.001456	0.000421	0.001620	0.001376	0.000614	0.000789	0.001047	0.001060	0.000641	0.000883	0.001066	0.001351	0.000652	0.000625	0.000968
LTC	0.001133	0.000452	0.001240	0.000316	0.001148	0.001125	0.000411	0.000672	0.000867	0.000641	0.000552	0.000734	0.000845	0.001079	0.000484	0.000489	0.000762
MATIC	0.001612	0.000778	0.001632	0.000496	0.001626	0.001422	0.000717	0.000885	0.001157	0.000883	0.000734	0.001935	0.001029	0.001497	0.000772	0.000758	0.000980
SAND	0.001033	0.000824	0.002394	0.000655	0.001550	0.001056	0.000861	0.000871	0.001189	0.001066	0.000845	0.001029	0.004504	0.000995	0.000893	0.000895	0.001106
UNI	0.001651	0.001102	0.001528	0.000717	0.001573	0.001388	0.001103	0.001013	0.001094	0.001351	0.001079	0.001497	0.000995	0.002385	0.001043	0.001106	0.001150
XLM	0.001051	0.000536	0.001280	0.000324	0.001160	0.001070	0.000430	0.000651	0.000948	0.000652	0.000484	0.000772	0.000893	0.001043	0.000776	0.000606	0.000818
XRP	0.001156	0.000456	0.001409	0.000307	0.001220	0.001079	0.000412	0.000644	0.000857	0.000625	0.000489	0.000758	0.000895	0.001106	0.000606	0.000888	0.000806
XTZ	0.001282	0.000753	0.001618	0.000503	0.001508	0.001343	0.000698	0.000733	0.001111	0.000968	0.000762	0.000980	0.001106	0.001150	0.000818	0.000806	0.001484

Figure 7. Covariance Matrix of Assets

Portfolio variance:

$$\sigma_p^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j Cov(a_i, a_j)$$

w_i = Weight of Asset i

a_i = Asset i

Before running the iterations, we first initialize empty lists to store the associated measures for each portfolio created in the loop.

```
port_weights = [] # Asset weights
port_returns = [] # Portfolio return
port_std_dev = [] # Portfolio standard deviation
port_sharpe_ratio = [] # Portfolio Sharpe ratio

num_ports = 1000 # Number of iterations
```

Data preparation is now complete and the algorithm now proceeds to the iteration stage.

```
for port in range(num_ports):
  weights = np.random.random(len(assets)) # Generate 10 random numbers between 0 and 1
  weights = weights/np.sum(weights) # Divide each random number by sum to make 100% co
mposition
  port_weights.append(weights)

  curr_return = np.dot(weights, avg_return) # Portfolio average return
  port_returns.append(curr_return)

  var = cov_matrix.mul(weights, axis=0).mul(weights, axis=1).sum().sum() # Portfolio v
ariance
  std_dev = np.sqrt(var) * np.sqrt(30) # Portfolio standard deviation
  port_std_dev.append(std_dev)

  sharpe_ratio = (curr_return - risk_free_rate)/std_dev # Portfolio Sharpe ratio
  port_sharpe_ratio.append(sharpe_ratio)
```

The results are concatenated into one large data frame as shown below. Each row displays the precise allocations for each asset, as well as the portfolio's expected return, volatility, and Sharpe ratio.

```
df = pd.DataFrame(port_weights, columns=assets)
df['return'] = port_returns
df['volatility'] = port_std_dev
df['sharpe_ratio'] = port_sharpe_ratio
df = df.applymap(lambda x: round(x, 6))
```

	AAVE	ADA	AXS	BTC	CRV	DOT	ETH	FTT	KNC	LINK	LTC	MATIC	SAND	UNI	XLM	XRP	XTZ	return	volatility	sharpe_ratio
0	0.062402	0.057640	0.066888	0.051177	0.016340	0.052098	0.080022	0.106883	0.068769	0.054971	0.064566	0.061181	0.071861	0.031067	0.066572	0.075271	0.012290	0.107630	0.170651	0.624844
1	0.095227	0.070427	0.001873	0.132015	0.079172	0.000709	0.017756	0.087062	0.054951	0.015549	0.086203	0.029303	0.116859	0.031794	0.037306	0.096978	0.046815	0.089709	0.167505	0.529586
2	0.036288	0.033236	0.094062	0.078325	0.107818	0.026112	0.042837	0.045700	0.090581	0.090893	0.087371	0.002754	0.021154	0.057523	0.064431	0.070687	0.050227	0.094875	0.178838	0.524915
3	0.069736	0.077032	0.003886	0.085820	0.032080	0.077241	0.074959	0.014699	0.043589	0.013104	0.025190	0.104383	0.070215	0.099761	0.041883	0.097244	0.069178	0.085331	0.172635	0.488490
4	0.056734	0.107871	0.032675	0.074476	0.033048	0.108715	0.080831	0.031288	0.050733	0.050430	0.022028	0.062481	0.108542	0.007898	0.072627	0.021230	0.078393	0.102292	0.173631	0.583375
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
995	0.005048	0.012031	0.071350	0.052796	0.082772	0.031306	0.067499	0.107483	0.097217	0.100655	0.010776	0.045615	0.123833	0.025565	0.096603	0.032671	0.036780	0.123407	0.181751	0.673489
996	0.031558	0.069321	0.050971	0.064215	0.092882	0.064114	0.074349	0.060099	0.086984	0.065514	0.060673	0.081667	0.051996	0.028071	0.088625	0.022938	0.006022	0.097843	0.174725	0.554257
997	0.010609	0.085974	0.057523	0.083039	0.089535	0.083612	0.062914	0.067406	0.042436	0.056070	0.106236	0.058218	0.030564	0.021650	0.049546	0.008533	0.086136	0.086800	0.171430	0.500496
998	0.107199	0.116120	0.004087	0.088147	0.122123	0.021665	0.116353	0.049043	0.042336	0.013783	0.055691	0.098053	0.055988	0.031689	0.000135	0.000836	0.076752	0.084197	0.175598	0.473792
999	0.011581	0.105564	0.001890	0.023761	0.088104	0.099040	0.065887	0.116603	0.075091	0.060506	0.093729	0.002721	0.111518	0.019365	0.069991	0.043866	0.010781	0.086188	0.171480	0.496779

1000 rows × 20 columns

Figure 8. Portfolio Allocations, Expected Return, Volatility, and Sharpe Ratio

The following scatterplot shows the distribution of the randomly generated portfolios across varying ranges of standard deviation and expected return on the monthly scale.

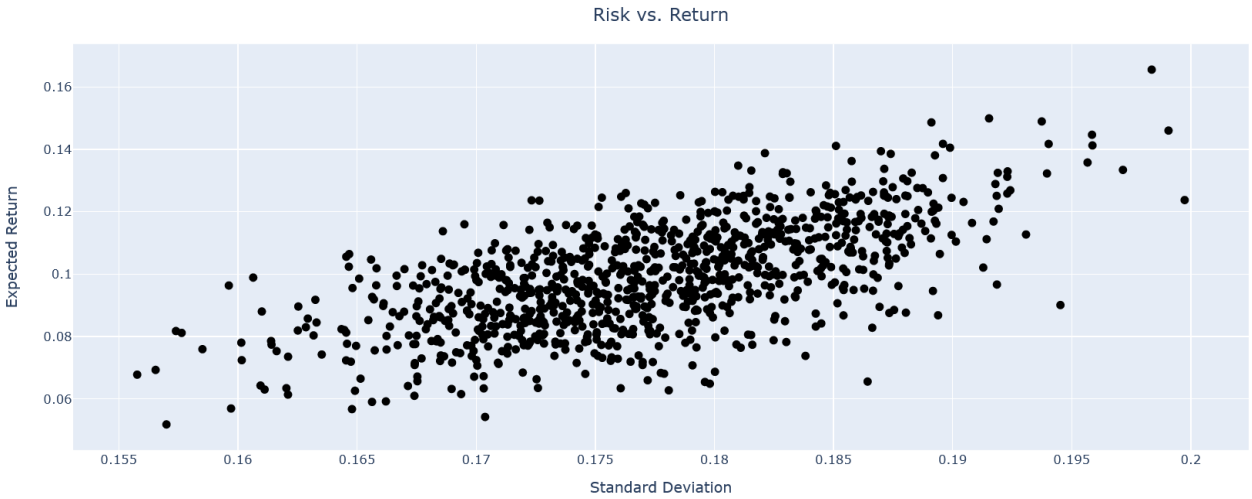


Figure 9. Risk vs. Return (Monthly Standard Deviation vs. Expected Return)

The default number of risk buckets that we have chosen is 5. Portfolios are ordered in ascending standard deviation and evenly distributed among the five risk buckets.

```
num_buckets = 5
df_sorted = df.sort_values(by=['volatility']) # Sort portfolios in increasing order of
 standard deviation
risk_buckets = np.array_split(df_sorted, num_buckets) # Split into 5 risk buckets
```

From each bucket, we pick out the portfolio with the highest Sharpe ratio and store other details about the assets that make up the portfolio such as allocation and expected return.

```
portfolios = [] # Store for top portfolios in each bucket

for i in range(num_buckets):
  bucket_df = risk_buckets[i]
  max_sr = bucket_df.loc[bucket_df['sharpe_ratio'].idxmax()] # Max Sharpe ratio

  assets_info = []

  # Asset Information
  for a in assets:
    assets_info.append({
      'asset': a,
      'allocation': max_sr[a],
      'return': ret_vol_sr['return'][a],
      'volatility': ret_vol_sr['volatility'][a],
      'sharpe_ratio': ret_vol_sr['sharpe_ratio'][a]
    })

  # Portfolio Information
  obj = {
    "risk_level": i+1,
    "portfolio": {
      "return": max_sr['return'],
      "volatility": max_sr['volatility'],
      "sharpe_ratio": max_sr['sharpe_ratio']
    },
    "assets": assets_info
  }

  portfolios.append(obj)
```

The details of each portfolio suggestion are summarized into a table below.

```
result = pd.DataFrame(columns=['return','volatility','sharpe_ratio'])
for i in range(num_buckets):
  bucket_port = portfolios[i]['portfolio']
  result = result.append({
      'return': bucket_port['return'],
      'volatility': bucket_port['volatility'],
      'sharpe_ratio': bucket_port['sharpe_ratio'],
  }, ignore_index=True)
result.index.name = 'Risk Level'
result.index += 1
```

Risk Level	return	volatility	sharpe_ratio
1	0.115977	0.169506	0.678308
2	0.123653	0.172326	0.711750
3	0.126002	0.176279	0.709113
4	0.138772	0.182119	0.756492
5	0.165540	0.198352	0.829534

Figure 10. Summary of Leading Portfolios

Results

The results table from Figure 10 is extended to show the exact allocations of assets in each portfolio. Figure 11 shows the complete information that will be used on the application interface to provide users with details of the portfolio of interest.

```
result_cols = assets + ['return','volatility','sharpe_ratio']
result = pd.DataFrame(columns=result_cols)
for i in range(num_buckets):
  bucket = portfolios[i]
  bucket_port = bucket['portfolio']
  allocations = [x['allocation'] for x in portfolios[i]['assets']] + [bucket_port['ret
urn'], bucket_port['volatility'], bucket_port['sharpe_ratio']]
  result.loc[len(result)] = allocations
result.index.name = 'Risk Level'
result.index += 1
```

Risk Level	AAVE	ADA	AXS	BTC	CRV	DOT	ETH	FTT	KNC	LINK	LTC	MATIC	SAND	UNI	XLM	XRP	XTZ	return	volatility	sharpe_ratio
1	0.030006	0.041275	0.106063	0.062303	0.007636	0.003677	0.110834	0.112589	0.054480	0.045750	0.078855	0.094400	0.049981	0.024980	0.077354	0.023916	0.075900	0.115977	0.169506	0.678308
2	0.058692	0.108393	0.082667	0.079666	0.027437	0.025974	0.094425	0.084720	0.007342	0.041215	0.038171	0.103280	0.090938	0.024134	0.004826	0.079202	0.048918	0.123653	0.172326	0.711750
3	0.006172	0.026386	0.079499	0.055089	0.000870	0.090964	0.059152	0.077966	0.001132	0.139274	0.078888	0.101260	0.122948	0.003400	0.070278	0.023656	0.063066	0.126002	0.176279	0.709113
4	0.038616	0.092368	0.096553	0.032131	0.042828	0.017095	0.032053	0.113418	0.074317	0.000318	0.072384	0.109989	0.114482	0.014336	0.030803	0.043185	0.075124	0.138772	0.182119	0.756492
5	0.014601	0.091695	0.152795	0.014685	0.031495	0.066722	0.003593	0.009280	0.005766	0.091605	0.137774	0.070131	0.162982	0.067822	0.024784	0.022553	0.031718	0.165540	0.198352	0.829534

Figure 11. Optimal Portfolios with Asset Allocations

The first observation is an important point to consider when comparing portfolios. Return seems to hold a strong positive correlation with volatility. This makes it difficult to choose because of the risk-reward trade-off that is set in place. Having access to the Sharpe ratios suggests one way to decide between

several different portfolios. The decision that an investor makes will ultimately depend on his or her risk tolerance and investment goals. Another observation of the data frame above is the varying composition of assets in each portfolio. Assets like BTC and ETH are known to be less volatile than assets like LTC and SAND. Assets with low volatility tend to hold more weight in low-risk portfolios than assets with high volatility. In high-risk portfolios, assets with high volatility appear to take more space. This is a natural consequence and a direct connection of the risk-reward trade-off mentioned above.

To gain more insight from our results, we decided to modify our results for a comparison with a benchmark in broader markets such as the S&P 500 index.

```
start = datetime.today()-relativedelta(years=1, days=2) # Analyze 1-year histori-
cal data
end = datetime.today()

sp500 = web.DataReader(['sp500'], 'fred', start, end)
sp500 = sp500.pct_change() # Daily returns

performances = [sp500] # Track performances

data_hist = data[data.index > start].pct_change() # Crypto assets historical prices

for ind, p in enumerate(portfolios):
  p_assets = p['assets']
  p_weights = [x['allocation'] for x in p_assets]

  dcopy = data_hist.copy()

  for i, col in enumerate(dcopy.columns):
    dcopy[col] = dcopy[col].apply(lambda x: x*p_weights[i])

  dcopy['risk_level_'+str(ind+1)] = dcopy.apply(lambda x: np.nansum(x)/sum([y if not m
ath.isnan(float(x[i])) else 0 for (i, y) in enumerate(p_weights)]), axis=1)

  performances.append(dcopy['risk_level_'+str(ind+1)])

index_ports_returns = pd.concat(performances, axis=1)
```

	sp500	risk_level_1	risk_level_2	risk_level_3	risk_level_4	risk_level_5
2021-03-18	NaN	NaN	NaN	NaN	NaN	NaN
2021-03-19	-0.000603	0.016841	0.020334	0.016346	0.019503	0.021884
2021-03-20	NaN	-0.020814	-0.023859	-0.024713	-0.033097	-0.044844
2021-03-21	NaN	-0.009864	-0.006742	-0.007434	-0.006508	0.000360
2021-03-22	0.007025	-0.054686	-0.055308	-0.055096	-0.050945	-0.057279
...	...	...	...	...	...	...
2022-03-14	-0.007421	0.038626	0.031277	0.033679	0.036147	0.033449
2022-03-15	0.021408	0.003569	-0.000105	0.001778	0.001927	0.001927
2022-03-16	0.022384	0.060150	0.072176	0.073621	0.069002	0.080609
2022-03-17	0.012348	0.001801	0.002995	-0.006889	0.001725	-0.005693
2022-03-18	0.011662	0.028356	0.024083	0.022377	0.026621	0.019457

Figure 12. Daily Returns of S&P 500 and Portfolios (03/18/2021 – 03/18/2022)

A starting balance of $10,000 is used to transform the daily returns into account balances. The historical performance tracks the price changes of the S&P 500 index alongside all five portfolios starting from March 18, 2021 and ending on March 18, 2022. Using daily returns, the closing balance at the end of each day is calculated in succession as seen below.

```
index_ports_returns.iloc[0] = 10000 # Starting balance
for enum, z in enumerate(index_ports_returns.columns):
  for i in range(1, len(index_ports_returns)):
    if np.isnan(index_ports_returns.iloc[i,enum]):
      index_ports_returns.iloc[i,enum] = index_ports_returns.iloc[i-
1,enum] # Take previous day balance if no data
    else:
      index_ports_returns.iloc[i,enum] = index_ports_returns.iloc[i-
1,enum] * (1+index_ports_returns.iloc[i,enum])

index_ports_returns = index_ports_returns.applymap(lambda x: round(x, 2))
```

	sp500	risk_level_1	risk_level_2	risk_level_3	risk_level_4	risk_level_5
2021-03-18	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
2021-03-19	9993.97	10168.41	10203.34	10163.46	10195.03	10218.84
2021-03-20	9993.97	9956.77	9959.90	9912.29	9857.60	9760.59
2021-03-21	9993.97	9858.56	9892.76	9838.60	9793.45	9764.10
2021-03-22	10064.18	9319.43	9345.61	9296.53	9294.52	9204.82
...	...	...	...	...	...	...
2022-03-14	10658.03	17598.34	18946.96	17706.30	21500.67	21113.97
2022-03-15	10886.20	17661.15	18944.97	17737.78	21542.10	21154.65
2022-03-16	11129.88	18723.46	20312.35	19043.66	23028.55	22859.90
2022-03-17	11267.31	18757.18	20373.18	18912.46	23068.27	22729.75
2022-03-18	11398.71	19289.05	20863.84	19335.66	23682.38	23172.00

Figure 13. Historical Performance With $10,000 Initial Balance

The data points from Figure 13 are plotted as shown. As expected, aggressive portfolios like Risk Level 4 and Risk Level 5 outperformed the other portfolios for most sessions over the past 12 months. In periods of high inflow and positive uptrend, the relative performance of these aggressive portfolios is much greater. However, the drawdown on these portfolios is typically worse during periods of decline.

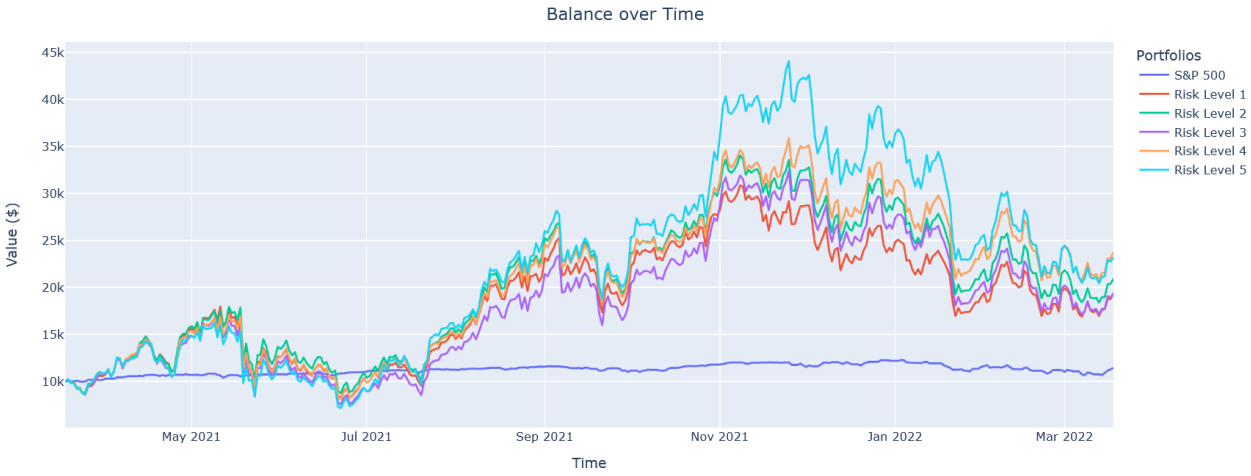


Figure 14. Historical Performance Comparison

Testing

We ran a series of tests to confirm our assumptions of the relationship between volatility and return of portfolios. Figure 15 displays the complete set of results for each of the five risk levels over 20 iterations. For each iteration, we calculated the 1-year return, peak return, and drawdown for the corresponding portfolio in each risk bucket. The 1-year return is calculated by the percentage change between the starting and ending balances. The peak return is equal to the percentage change at the day of maximum portfolio balance. The drawdown column refers to the largest peak-to-trough decline in percentage over the observed past year.

Run	Risk Level 1			Risk Level 2			Risk Level 3			Risk Level 4			Risk Level 5		
	1Y	Peak	Drawdown	1Y	Peak	Drawdown	1Y	Peak	Drawdown	1Y	Peak	Drawdown	1Y	Peak	Drawdown
1	66.76%	155.93%	-54.73%	74.46%	208.78%	-54.18%	120.97%	260.22%	-49.66%	126.90%	312.23%	-54.18%	139.19%	272.71%	-53.28%
2	90.50%	233.24%	-50.34%	142.07%	223.34%	-50.60%	90.10%	227.55%	-49.94%	117.33%	266.67%	-52.95%	140.39%	309.32%	-51.97%
3	88.36%	193.93%	-52.52%	85.47%	214.69%	-55.63%	135.16%	259.23%	-51.79%	114.87%	254.04%	-53.22%	150.21%	333.14%	-53.41%
4	70.02%	202.46%	-52.66%	87.13%	219.80%	-56.39%	125.67%	237.81%	-56.41%	104.85%	208.00%	-54.07%	143.09%	328.22%	-54.02%
5	108.13%	212.47%	-52.82%	97.40%	221.30%	-54.80%	81.51%	187.31%	-54.37%	155.60%	302.72%	-54.46%	119.55%	284.99%	-55.99%
6	119.81%	249.08%	-49.48%	96.77%	203.86%	-52.03%	126.69%	265.68%	-51.06%	119.53%	253.72%	-54.10%	117.44%	265.86%	-59.40%
7	83.16%	217.86%	-55.40%	110.17%	227.88%	-51.55%	99.88%	188.30%	-54.09%	126.32%	256.53%	-51.90%	151.66%	331.96%	-56.11%
8	110.55%	243.83%	-55.76%	115.11%	225.56%	-53.46%	111.50%	239.83%	-52.66%	128.10%	273.35%	-51.06%	160.58%	335.52%	-54.61%
9	85.16%	189.92%	-52.65%	109.92%	227.97%	-52.75%	120.09%	258.36%	-51.23%	101.27%	219.86%	-53.48%	128.98%	244.34%	-52.67%
10	91.78%	184.16%	-57.38%	99.64%	242.76%	-54.16%	87.00%	217.07%	-54.22%	140.91%	322.39%	-52.91%	197.08%	386.93%	-52.75%
11	105.75%	208.70%	-53.40%	142.06%	265.68%	-53.48%	119.29%	226.67%	-50.52%	102.23%	252.44%	-53.65%	154.04%	321.74%	-53.64%
12	74.03%	193.24%	-54.97%	103.08%	228.23%	-55.53%	107.33%	223.64%	-53.05%	134.30%	255.64%	-55.62%	143.59%	338.34%	-51.58%
13	111.97%	258.76%	-49.28%	125.87%	263.88%	-52.45%	117.34%	246.36%	-50.69%	113.60%	230.23%	-51.87%	131.67%	274.37%	-52.64%
14	80.12%	173.76%	-55.15%	96.82%	246.90%	-55.17%	131.96%	263.78%	-53.24%	159.05%	295.11%	-53.41%	156.18%	326.15%	-53.05%
15	104.20%	253.17%	-55.84%	74.46%	227.08%	-56.14%	81.45%	195.55%	-55.41%	175.19%	324.48%	-51.00%	147.07%	263.68%	-54.10%
16	86.57%	206.40%	-56.00%	117.94%	249.35%	-53.11%	97.90%	221.45%	-54.04%	101.96%	245.89%	-55.18%	122.05%	282.04%	-54.95%
17	95.21%	221.45%	-50.11%	99.85%	226.46%	-53.65%	120.14%	275.27%	-54.71%	141.83%	300.80%	-52.87%	137.01%	306.56%	-55.12%
18	71.70%	191.43%	-54.50%	107.05%	225.62%	-52.39%	165.51%	297.85%	-53.93%	129.40%	236.97%	-51.40%	127.23%	270.03%	-55.04%
19	90.40%	224.54%	-57.85%	132.75%	238.88%	-53.20%	108.10%	241.16%	-51.68%	141.77%	246.10%	-54.69%	143.03%	282.52%	-52.10%
20	90.66%	202.60%	-53.32%	98.98%	244.81%	-51.98%	127.88%	289.95%	-55.87%	149.95%	252.72%	-53.84%	184.31%	336.70%	-51.98%
Average	91.24%	210.85%	-53.71%	105.85%	231.64%	-53.63%	113.77%	241.15%	-52.93%	129.25%	265.49%	-53.29%	144.72%	304.76%	-53.92%

Figure 15. Test run statistics

Figure 16 shows a compiled and more comprehensive view of the test runs. One observation that can be made is the strictly increasing values of 1-year returns as risk level is increased. This is not taken by surprise because portfolios that are known to carry more risk tend to offer potentially higher return. The peak returns also show similar trends of increasing return. These values suggest the possible range of price movements on the upside over the past year. The drawdown, on the other hand, shows the possible change in the value of an investment. For each risk level, the decline appears to be in a tighter range compared to return. This outcome is generally ideal for an investor because it means that the downside of a risky portfolio is not as significant over the long run. The average drawdown of Risk Level 3 is -52.93%, meaning that the average peak-to-trough decline is less than the drawdowns of Risk Levels 1 and 2. This may entirely be a coincidence given the small difference between the values. However, it is important to keep note of this observation as it raises the question of whether a low-risk portfolio is always the safest option.

Risk Level	1Y			Peak			Drawdown		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
1	66.76%	119.81%	91.24%	155.93%	258.76%	210.85%	-57.85%	-49.28%	-53.71%
2	74.46%	142.07%	105.85%	203.86%	265.68%	231.64%	-56.39%	-50.60%	-53.63%
3	81.45%	165.51%	113.77%	187.31%	297.85%	241.15%	-56.41%	-49.66%	-52.93%
4	101.27%	175.19%	129.25%	208.00%	324.48%	265.49%	-55.62%	-51.00%	-53.29%
5	117.44%	197.08%	144.72%	244.34%	386.93%	304.76%	-59.40%	-51.58%	-53.92%

Figure 16. Compiled statistics

Conclusion

The MPT algorithm is an effective approach of analyzing the risk and return associated with a given portfolio. It relies on calculations using historical data and is flexible with the study timeframe and risk measure types. For the problem that we are attempting to solve, which mainly concerns the development of a balanced portfolio of crypto assets, the current model is suitable. This is because the directional movement of assets in the crypto market has a strong positive correlation. In other words, it is not common for two portfolios to behave differently in terms of direction. As shown in Figure 14, all five portfolios display similar trends, only differentiating in magnitude.

There are some disadvantages to the current model. First, there is no regard for forecasting in the algorithm design. One of the ways an investor makes investment decisions is to look at a particular asset and choosing to buy, hold, or sell it based on its current state and an approximate prediction on its future price. By only using historical returns as the main source of data, it is not possible to make any statement on what will happen to a basket of assets within the next few months or years. Another problem with the current model is its inflexibility with varying investment time horizons. Because our algorithm currently uses monthly returns, it is most appropriate to use as a decision support tool for medium to long-term investors.

This research used mean-variance analysis on the historical data of crypto assets to produce multiple portfolios for various risk tolerance levels. The current baseline model provides well-diversified investment ideas for all types of investors. The results generated are strongly supported by a sturdy mathematical model of multivariate analysis. There are ideas such as the points described above that will help to solidify the algorithm even further and allow expansion of our platform to offer a wider variety of features to investors.

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