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Metrics That Matter: A Tool for Risk-Return Trade-offs in Portfolio Analysis

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Abstract: Financial literacy is essential for military service members, particularly those in the blended retirement system, who must actively manage their Thrift Savings Plan (TSP) investments alongside traditional pensions. They face complex financial decisions requiring understanding of risk-return relationships and portfolio management. We developed an Excel-based educational tool that bridges theoretical finance concepts with practical application, enabling hands-on learning of modern portfolio theory and asset allocation strategies. The tool integrates a mean-variance portfolio optimizer using current market data, a risk assessment module translating user preferences into investment parameters, and dynamic visualizations illustrating allocation effects. Designed for the Air Force Academy's finance curriculum, the tool allows students to conduct sensitivity analyses and build intuition about risk-return trade-offs. Beyond the classroom, it serves as a resource for military personnel financial planning, with applications for Air Force Services and support organizations. Preliminary testing indicates improved comprehension of portfolio theory and engagement with financial decision-making.

Keywords: Financial literacy, Portfolio optimization, Military retirement planning, Risk-return analysis

1. Introduction

1.1 Context and Motivation

The customer for this project is the Department of Management at the United States Air Force Academy (DFMA), specifically the finance courses offered by DFMA. The mission of DFMA is to teach the next generation of officers to manage complex systems of resources, technology, and people. The finance group within DFMA teaches financial literacy and investments concepts. Teaching future officers these topics enable them to be better leaders and share this knowledge with their operational units. Currently the finance classes within DFMA use an Excel workbook as a teaching tool to demonstrate concepts of risk, reward, and asset allocation. However, the tool is currently not intuitive to use, and it over-simplifies some financial concepts. This project aims to enhance and refine the tool to better support financial education. The goal of this project is to take an analytical approach, with some human factors' elements, to enhance the capabilities of this tool for the benefit of students in the USAFA Investments course – limiting to USAFA keeps the scope realistic and manageable. The ultimate objective of our work is to create a tool that is implemented in and out of the classroom and demonstrates measurable improvements in student understanding of risk, reward, and asset allocation concepts.

1.2 Problem Statement

Problem: The current investments tool that cadets use in Management courses is difficult to use, is limited in teaching capabilities, and lacks the complexity that is required of a digital tool to be successful in today's market. Students in the investments class are unable to navigate the tool without instructor guidance. The tool has many features which have zero explanation on how to use them. With these limitations, cadets cannot fully grasp the concept of diversification, risk-return tradeoff, and capital market assumptions.

1.3 Research Question

How can an enhanced financial modeling tool, leveraging Capital Market Assumptions and publicly available data, be developed to optimize the tradeoff between risk and return while ensuring usability and interpretability for cadets and educators in the United States Air Force Academy's finance curriculum?

1.4 Project Goals

The primary goal of this project is to revise and update the existing Excel-based investment portfolio model to improve its functionality and alignment with a risk-reward trade-off approach, rather than solely maximizing returns. The project will evaluate whether the current model should be upgraded or fully redesigned. Specifically, the project will involve enhancing the Expected Return Model and Volatility & Correlation Estimates, with a focus on recovering the lambda, or risk coefficient. The current approach, which prioritizes return maximization, will be adjusted to account for an optimal balance between risk and reward, thereby improving decision-making for investment managers.

In addition to improving decision-making, the overall objective is to develop a portfolio analysis tool that not only enhances educational experience but also equips future officers with the financial acumen required in today's complex economic landscape. The tool will emphasize visualizations and forecasts to better represent portfolio risk and performance, providing cadets with a hands-on understanding of investment strategies. Furthermore, the customer's requirement to maintain an Excel front-end will be strictly adhered to, ensuring that the final model remains both accessible and easily understandable for cadets and other users.

2. Related Work

The insights from Alnes's (2016) thesis on Conditional Value-at-Risk (CVaR) are fundamental to refining our portfolio optimization approach. Alnes addresses the limitations of mean-variance optimization, emphasizing CVaR's ability to capture tail-end risks and model extreme financial downturns. His use of linear programming to minimize severe losses informs our strategy for constructing a resilient, risk-aware portfolio.

Building on Alnes's foundation, Zhou and Xu (2024) introduced a distributionally robust reward-risk model integrating CVaR with standard deviation, offering a computationally efficient framework for managing volatility. Their semi-definite programming approach validates the robustness of combining these risk measures, which we plan to incorporate into our model.

De Giorgi, Hens, and Mayer (2008) highlight investor behavior in portfolio selection, applying prospect theory to explain deviations from traditional models. This perspective allows us to factor in investor-specific preferences, improving utility and customization.

Michaud and Michaud's (2007) Resampled Efficiency (RE) optimization addresses the sensitivity of mean-variance models to estimation errors. Their Monte Carlo-based framework stabilizes portfolio outcomes, while Jorion (1992) emphasizes robust estimation techniques using simulations for more reliable risk assessments.

Geambaşu et al. (2013) compare Modern Portfolio Theory (MPT) and Post-Modern Portfolio Theory (PMPT), advocating for downside risk measures over standard deviation. PMPT's focus on minimum accepted return rates aligns with real-world investor expectations, enhancing optimization methods.

Buraschi, Porchia, and Trojani (2010) explore stochastic correlations in portfolio optimization, presenting a novel approach to managing volatility and correlation risks. Their findings suggest that incorporating covariance hedging improves robustness under fluctuating market conditions.

Finally, Pedersen, Fitzgibbons, and Pomorski (2021) examine ESG integration in portfolio construction, demonstrating its impact on the efficient frontier. Incorporating these factors enhances the applicability of our model to socially responsible investment strategies.

In summary, these sources collectively inform our approach by combining advanced risk measures like CVaR, behavioral insights, robust estimation techniques, and practical enhancements to portfolio optimization models. Together, they provide a comprehensive framework for achieving our project's goal of developing a more resilient, risk-aware, and adaptable investment tool.

3. Data and Methodology

3.1 Data and Relevance

Our model uses a 15x15 Risk-Return correlation matrix based on JPMorgan's Capital Market Assumptions (CMAs) to evaluate relationships among 15 diverse asset classes. In Table 1, we include the full 15x15 matrix which shows the risk and return of each asset class along with its correlation factor with each of the other asset classes. Furthermore, approximately 150 responses were collected from cadets in USAFA investment course to create a risk distribution. This distribution of risk was used to map individual scores to a starting portfolio with the appropriate amount of risk

The 15x15 matrix incorporates historical return data, volatility metrics, and correlation figures to simulate realistic portfolio scenarios. These values are obtained from JPMorgan's annually published capital market assumptions, providing a foundational source for understanding long-term expectations of risk and return across assets.

The use of JPMorgan's assumptions ensures that the data reflects realistic, forward-looking market conditions, essential for modeling risk-return tradeoffs accurately. JPMorgan's assumptions are well-known and often referred to as a benchmark for investment funds. This approach allows cadets to see the effect of diversified asset allocation on portfolio performance, blending theoretical learning with practical application.

Table 1. Risk-Return Correlation Matrix

Weight	Asset Class	Return	Risk	Cash	Inter Treasury Bonds	TIPS Bonds	US Aggregate Bonds	US Investment Grade Corporates	Junk Bonds	Emerg Mkt Bonds	US Large Stocks	US Small Stocks	Intl Developed Stocks	Intl Emerging Stocks	REITs	Commodities	Gold	Hedge Funds
0.0%	Cash	3.10%	0.65%	1.00	0.17	0.02	0.08	0.01	(0.05)	0.03	(0.00)	(0.05)	0.03	0.03	(0.06)	(0.03)	0.10	0.04
0.0%	Inter Treasury Bonds	3.85%	3.34%	0.17	1.00	0.62	0.84	0.52	(0.02)	0.31	(0.06)	(0.13)	(0.04)	(0.05)	0.10	(0.17)	0.36	(0.30)
0.0%	TIPS Bonds	4.26%	5.78%	0.02	0.62	1.00	0.76	0.72	0.48	0.62	0.31	0.22	0.32	0.33	0.38	0.26	0.47	0.20
3.2%	US Aggregate Bonds	4.70%	4.52%	0.08	0.84	0.76	1.00	0.87	0.38	0.66	0.26	0.18	0.30	0.29	0.39	(0.01)	0.39	0.04
3.2%	US Investment Grade Corporates	5.25%	7.28%	0.01	0.52	0.72	0.87	1.00	0.66	0.82	0.49	0.40	0.54	0.53	0.53	0.19	0.36	0.35
0.0%	Junk Bonds	6.44%	8.52%	(0.05)	(0.02)	0.48	0.38	0.66	1.00	0.75	0.74	0.71	0.77	0.72	0.67	0.44	0.13	0.61
0.0%	Emerg Mkt Bonds	6.24%	9.71%	0.03	0.31	0.62	0.66	0.82	0.75	1.00	0.62	0.53	0.70	0.70	0.61	0.33	0.33	0.46
0.0%	US Large Stocks	7.91%	16.26%	(0.00)	(0.06)	0.31	0.26	0.49	0.74	0.62	1.00	0.90	0.88	0.74	0.77	0.44	0.04	0.68
0.0%	US Small Stocks	8.82%	20.73%	(0.05)	(0.13)	0.22	0.18	0.40	0.71	0.53	0.90	1.00	0.80	0.68	0.76	0.38	(0.03)	0.64
49.7%	Intl Developed Stocks	9.49%	17.61%	0.03	(0.04)	0.32	0.30	0.54	0.77	0.70	0.88	0.80	1.00	0.86	0.71	0.52	0.13	0.70
0.0%	Intl Emerging Stocks	9.18%	21.08%	0.03	(0.05)	0.33	0.29	0.53	0.72	0.70	0.74	0.68	0.86	1.00	0.59	0.56	0.25	0.68
43.9%	REITs	9.33%	17.22%	(0.06)	0.10	0.38	0.39	0.53	0.67	0.61	0.77	0.76	0.71	0.59	1.00	0.30	0.09	0.42
0.0%	Commodities	5.32%	18.10%	(0.03)	(0.17)	0.26	(0.01)	0.19	0.44	0.33	0.44	0.38	0.52	0.56	0.30	1.00	0.35	0.51
0.0%	Gold	5.31%	16.76%	0.10	0.36	0.47	0.39	0.36	0.13	0.33	0.04	(0.03)	0.13	0.25	0.09	0.35	1.00	0.12
0.0%	Hedge Funds	5.06%	5.80%	0.04	(0.30)	0.20	0.04	0.35	0.61	0.46	0.68	0.64	0.70	0.68	0.42	0.51	0.12	1.00

3.4 Methodology

The current investments tool used in Management courses fails to meet educational and practical needs due to its oversimplified approach and limited functionality. It does not effectively model real-world investment scenarios, such as dynamic risk-return tradeoffs or advanced portfolio diversification techniques, which are critical for understanding modern financial markets. These limitations hinder its ability to prepare cadets for the complexity of financial decision-making in professional environments.

The updated 15x15 Risk-Return Matrix is designed to be easily usable by cadets with little to no background in investments or finance. It features a model with clear inputs and constraints, aiming to optimize the portfolio toward the "northwesterly" direction on the matrix—meaning higher returns with lower risk. This approach takes into account each cadet's approximate risk tolerance and seeks the point that offers the best possible trade-off: maximizing return while minimizing risk.

The team used a pre-existing and trusted finance questionnaire developed from the Wall Street Journal and Investment Technologies to poll students on their risk tolerances, scores ranged from 0 to 111, 111 being the riskiest. Using data from student scores, we created a distribution to map these scores to corresponding levels of risk tolerance ranging from 0 to 111. This mapping establishes a personalized risk metric, which is complemented by a reward value to pinpoint the user's optimal position on the efficient frontier. Based on individual questionnaire results, each user's risk tolerance is matched to a specific stock-to-bond ratio. From this, the risk metrics for pure stock and bond portfolios are used to calculate a personalized lambda, or risk aversion coefficient. Using the implied lambda from the 2-asset allocation derived from the q-mapping score, the efficient frontier is constructed. Our model then optimizes the 15-asset allocation to match this lambda, aiming for greater efficiency and diversification compared to the stock-and-bond combination.

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3.5 Model

The project employs risk-return optimization techniques and recovery of the lambda risk aversion coefficient for portfolio analysis. Based on user's preferences, models will adjust to maximize northwesterly risk-return for the user's risk tolerance.

The resulting model uses Excel as the front-end interface and integrate simulations to represent portfolio risks and tradeoffs visually. It includes tools for visualizing volatility, expected returns, and CVaR, providing a comprehensive view of the portfolio's risk-return dynamics.

4. Results and Conclusions

In order to quantify our project, we used data from a risk questionnaire that approximately 150 students completed in their Finance and Investments class. This questionnaire helped quantify tolerance for risk relative to investments. Though this data collection wasn't randomized, and only draws from one sample, it is still sufficient to estimate the riskiness of cadets in general. From this data, we found that the median cadet scored a 68 on the risk quiz. Since most target date funds for 20-year-olds approximately use an 80/20 stock/bond split we decided to use this mix for our average cadet. Using this asset ratio will serve as a baseline for results to compare to later on.

Using risk and return data for two asset classes, 80% stocks and 20% bonds, we found that this would yield approximately 7.26% in returns with a risk of 13.27%. Although this is a respectable return for the risk, when we use our optimizer, we are able to find a better asset mix for the user. Using the same "riskiness" score of 68, we can run the optimizer tool with 15 asset classes. Doing so yields 8.58% in returns at 15.22% risk. In this example, using the optimizer tool yields an extra 1.32% in return. However, the risk increases by 1.95%, which isn't desired. Going back to a baseline of 13.27% risk for an 80/20 stock-bond split, we used our optimizer tool to find a greater return for the same amount of stock (i.e., "moving north). Optimizing this same amount of risk, we yielded approximately 8.10% in returns, an .84% increase in returns for no additional cost in risk.

While a 0.84% or 1.32% increase in returns may appear negligible, time value of money calculations reveals a significant long-term impact. Assuming a 7.26% annual return and a 3% inflation rate, consistent annual contributions of $7,000 to a Roth IRA over 40 years would accumulate to $713,370.92. At an 8.10% return, the final value increases to $878,982.75, a difference of approximately $165,000. These results demonstrate the effectiveness of our optimizer tool and highlight the benefits of portfolio diversification. For an investor with similar risk tolerance, optimizing the portfolio based on risk rather than relying on baseline returns yields an additional $280,000.

5. Next Steps and Future Work

In Operations Research, we often assert that a model is only as good as its assumptions. This principle is particularly relevant to our project, as the foundation of our tool relies on the accuracy of JP Morgan's capital market assumptions. While predicting the future is inherently uncertain, we trust JP Morgan as a reputable source for these assumptions. A logical next step would be to enhance the tool by incorporating alternative CAPM assumptions, which would require deeper research into how these matrices are constructed and how they affect our results.

Looking ahead, the most impactful way to improve the tool would be to expand its applicability beyond cadets in an investments course. Currently, USAFA finance instructors plan to utilize our optimized tool for future core and specialized finance classes, which highlights the tool's practical value in an academic setting. Enhancing the user interface to improve ease of use and providing additional explanations on the tool's functionality would make it more accessible to individuals with limited financial literacy or those eager to learn more about investing. Because of its wide applicability, this tool can effectively serve other college students with a tendency toward high-risk investing.

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6. Figures and Graphs

Below are the Risk Mix and Asset Mix pie charts currently used in the 15x15 Matrix Portfolio (Figure 1). These visuals, while functional, highlight some limitations of the current tool. For instance, the Risk Mix chart does not provide a detailed breakdown of how individual assets contribute to portfolio volatility, and the Asset Mix chart includes an unclear category labelled "N/A" which may confuse users. Furthermore, the charts lack interactivity and dynamic features that could help cadets explore the effects of adjusting asset allocations on both risk and return. The updated version of the Risk-Reward Portfolio aims to address these shortcomings by introducing more intuitive and visually engaging charts, potentially integrating interactive components to better demonstrate asset and risk allocation.

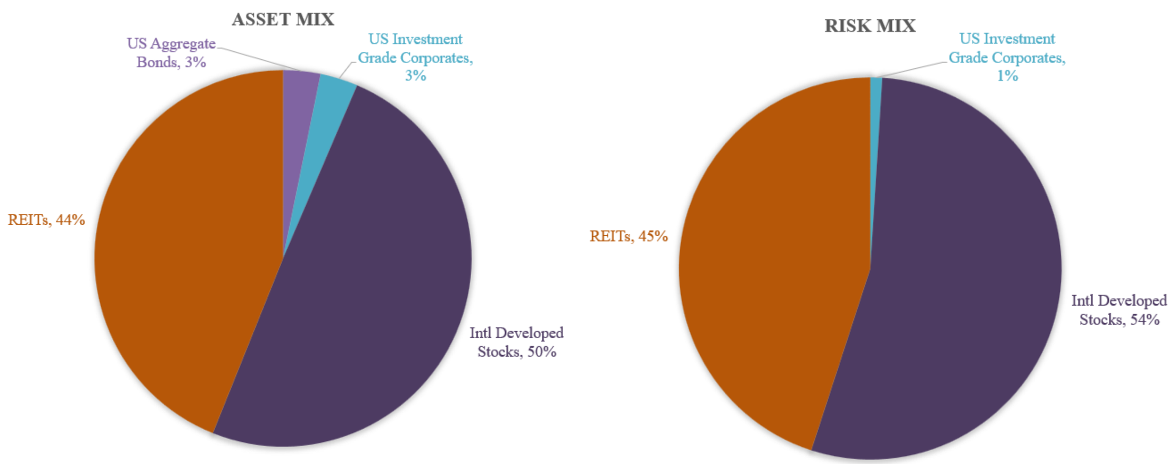

Figure 1. Asset (Left) and Risk (Right) Pie Charts from the Excel Tool

Our team developed a visual representation (Figure 2) to illustrate the impact of utilizing the Northwest optimizer tool, comparing the performance of a two-asset portfolio against a fifteen-asset portfolio. We assessed the risk and return for 30 distinct scores within each portfolio, evenly distributed across the 111 possible scores. These data points were then plotted, and a smooth line of best fit was generated in Excel, resulting in the efficient frontier for both portfolios. Notably, while the curves are not perfectly smooth, as one might expect from a typical "efficient frontier" found through a Google search, the fundamental principles remain intact. The graph clearly demonstrates that the Northwest optimizer tool effectively enhances returns while simultaneously reducing risk.

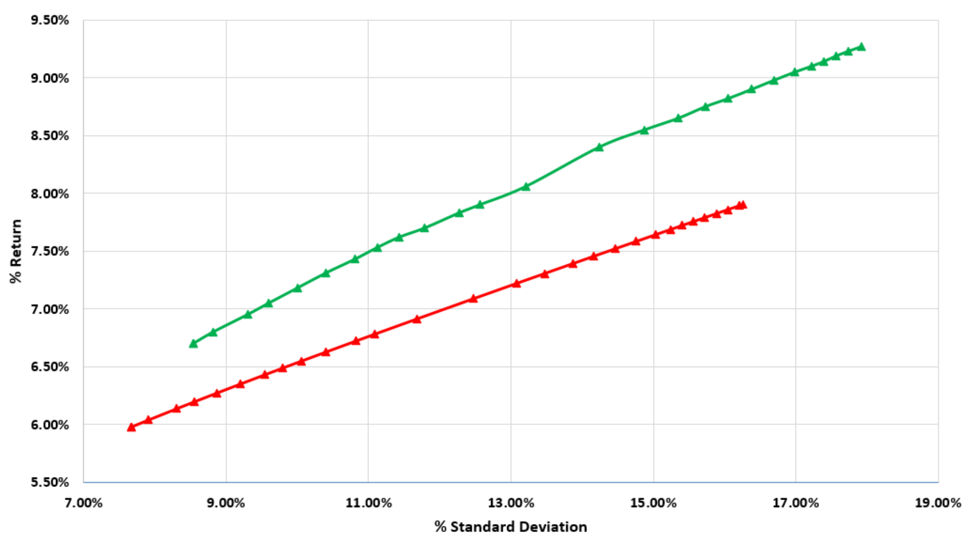

Figure 2. Efficient Frontier Visual

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