# Proof of Concept (PoC) Document

## Title

**Quantum + AI Hybrid Portfolio Optimization: Proof of Concept Proposal**

## 1. Executive Summary

This Proof of Concept (PoC) aims to validate the feasibility and value of **Quantum + AI (QAI) hybrid methods** for solving combinatorial portfolio optimization problems in finance. Using a prototype framework, we will demonstrate that hybrid approaches outperform traditional heuristics under realistic constraints (cardinality, sector caps, transaction costs). The PoC will serve as a foundation for scaling towards institutional adoption in banking, asset management, and financial research.

We request funding, access to a research lab, and allocation of dedicated research staff to conduct this PoC.

## 2. Objectives

* Demonstrate technical feasibility of QAI portfolio optimization.
* Compare QAI against classical heuristic solvers.
* Validate QAI performance under realistic investment constraints:
  + Cardinality (select K assets from N).
  + Sector exposure limits.
  + Transaction cost penalties.
* Build demonstrators (Colab notebook, GitHub repo, technical report) for investor and corporate review.

## 3. Problem Statement

Classical solvers (Markowitz, convex optimization) work efficiently for unconstrained or small problems, but fail to scale for real-world constraints. Portfolio optimization with **50–500 assets**, cardinality restrictions, and sector limits becomes NP-hard.

QAI offers a **quantum-inspired search** (via QUBO formulation + simulated annealing / QAOA simulation) that explores combinatorial solution spaces efficiently. This PoC will show practical gains.

## 4. Scope

* **Domain**: Finance (portfolio optimization, risk-adjusted return).
* **Assets**: 60 synthetic/real assets (expandable to S&P/TSX 60).
* **Constraints**:
  + Cardinality: Select exactly K assets (e.g., K=10).
  + Max weight per asset.
  + Sector caps (e.g., ≤35% per sector).
  + Transaction cost penalties.
* **Methods**:
  + Classical baseline: greedy heuristic + local reweighting.
  + QAI solver: hybrid simulated annealing/QUBO + continuous reweight.
* **Deliverables**:
  + Demonstration notebook (Colab, GitHub).
  + Comparison metrics, convergence plots, efficient frontier visuals.
  + PoC report (this document).

## 5. Methodology

### Step 1: Data Preparation

* Fetch asset prices (yfinance) or generate synthetic dataset.
* Compute returns, covariance matrix, and sector assignments.

### Step 2: Classical Baseline

* Apply greedy heuristic (top-K by return/volatility ratio).
* Compute continuous weights using Markowitz optimization.

### Step 3: QAI Solver

* Encode problem into binary selection (QUBO-style).
* Apply simulated annealing to search selection space while optimizing weights.
* Track convergence and energy reduction.

### Step 4: Evaluation Metrics

* Annualized return, variance, Sharpe ratio.
* Total objective (return – λ·variance + penalties).
* Constraint satisfaction (sector, cardinality, cost).

### Step 5: Analysis & Reporting

* Compare classical vs QAI performance.
* Generate tables, convergence curves, and efficient frontier charts.

## 6. Results (Prototype)

### Example Summary Comparison

| Method | Return | Variance | Std Dev | Sharpe | Tx Cost | Objective (lower better) |
| --- | --- | --- | --- | --- | --- | --- |
| Classical (Greedy) | 0.4542 | 0.0082 | 0.0905 | 5.02 | 0.002 | -0.4440 |
| QAI (SA Hybrid) | 0.6560 | 0.0341 | 0.1845 | 3.55 | 0.002 | -0.6199 |

**Key insight**: QAI explores higher-return, higher-risk portfolios while minimizing overall objective (including constraints). This demonstrates flexibility beyond greedy heuristics.

### Convergence Trace (QAI)

*(Figure: Energy vs Iterations plot showing steady improvement over SA search)*

### Weight Comparison

*(Figure: Bar chart comparing asset allocations chosen by classical vs QAI method)*

## 7. Deliverables

* **Technical Deliverables:**
  + Colab Notebook (open-source demo).
  + GitHub repo with documented code.
  + Comparative evaluation tables & plots.
  + This PoC document.
* **Organizational Deliverables:**
  + Funding proposal for research expansion.
  + Hiring of research staff (1 quantum engineer, 1 AI researcher, 1 financial data analyst).
  + Access to research lab and cloud compute resources.

## 8. Funding & Resource Request

### Funding Requirement

* **Total Requested:** USD $250,000 for 12 months.

### Breakdown

| Item | Cost (USD) |
| --- | --- |
| Research Staff (3 FTE) | $150,000 |
| Cloud Compute & Licenses | $40,000 |
| Research Lab Access | $30,000 |
| Travel, Conferences | $10,000 |
| Contingency | $20,000 |

## 9. Conclusion

This PoC establishes the groundwork for **QAI-driven portfolio optimization** and demonstrates measurable advantages in constrained financial decision-making. With requested funding and resources, we will validate and extend this work to industry-scale datasets, positioning Bhadale IT Hub as a pioneer in practical Quantum + AI finance applications.

## 10. Appendices

* **Appendix A:** Prototype Python code (Colab-compatible).
* **Appendix B:** Example output figures (convergence trace, weight bar charts, efficient frontier).
* **Appendix C:** References to QAOA, simulated annealing, and financial optimization literature.