QIntern 2025 Detailed Research Plan

Project Title: Quantum Computing for Civil Site Design Optimizations

Duration: 6 weeks (Mid-June/July to August 15th)

Mentor: Dr. Gueorguiev

Objective: This research project investigates how quantum computing (QC) can support real-world civil engineering challenges, specifically optimizing building layouts, pipe networks, and grading plans in early-stage civil site design. The focus is on evaluating whether quantum algorithms, such as QAOA or quantum annealing, can provide improvements over classical heuristics like A* in scenarios with multiple competing constraints.

Project Timeline

Week 1: Onboarding and Foundations

- **Goal:** Ensure interns understand the problem domain, classical approaches, and QC foundations.

- **Activities:**
    - **Monday:** Onboarding to Runopt's current site design challenges; introduction to the civil engineering context and typical constraints.
    - **Wednesday:** Intro to the A* algorithm and its application in routing and layout optimization. Interns will reproduce a simple A*-based layout optimizer in Python.
    - **Friday:** Intro to QC optimization (QAOA, MaxCut, quantum annealing). Assign readings and Qiskit or D-Wave tutorials.

Week 2: Classical Benchmarking

- **Goal:** Benchmark classical A* performance across civil layout test cases.
- **Activities:**
    - Implement and run A* on test scenarios (e.g. pipe routing or zoning layouts).
    - Generate runtime, accuracy, and complexity plots and tables.
    - Begin early-stage ideation for translating the problem into a quantum-compatible format (e.g., graph for MaxCut).
    - Optional: Start encoding problems in Qiskit or D-Wave hybrid solvers.

Week 3: Quantum Prototype Implementation

- **Goal:** Implement quantum analog of A* and compare.
- **Activities:**
    - Model the same layout/routing problems using MaxCut, QUBO, or constraint satisfaction forms.
    - Use QAOA on Qiskit or quantum annealing on D-Wave to approximate solutions.
    - Run simulations and compare outcomes (accuracy, runtime) with A* benchmarks.

    - Generate comparative graphs and tables to visualize findings.

Week 4: Reporting

- **Goal:** Summarize and submit an internal report to Runopt.
- **Activities:**
    - Interns write a mid-term report detailing results, insights, and gaps.
    - Discuss challenges encountered with quantum approaches.
    - Propose future directions (e.g., scaling strategy, hybrid quantum-classical solvers, roadmap).

Week 5: Codebase and Documentation

- **Goal:** Deliver clean, well-documented code.
- **Activities:**
    - Refactor and document all code into a GitHub repo.
    - Include sample datasets, README, and experiment scripts.
    - Tag releases with explanations of functionality and usage.

Week 6: Presentation and Wrap-up

- **Goal:** Prepare interns for final presentation and project conclusion.
- **Activities:**
    - Prepare slide deck and walkthrough of GitHub repo.
    - Final presentation to Runopt team and optionally QWorld/QIntern showcase.
    - Collect feedback and reflect on potential long-term contributions (e.g., internships, continued collaborations).

Intern Support and Resources

- Weekly check-ins for technical guidance and progress review.
- Access to Runopt datasets and simplified design models.
- Mentorship support in both classical CS algorithms and quantum computing.
- Suggested QC learning resources (Qiskit tutorials, QBronze, D-Wave docs).