1. Context and Relevance

Efficient snow plowing in cities is crucial during the winter months to ensure safety, reduce traffic disruptions, and minimize fuel costs. As cities grow, optimizing snow plowing routes becomes increasingly complex due to numerous variables, such as road lengths, traffic, snow accumulation, and the number of snow plows available.
In Canada, snow plowing is a critical municipal service. Snow accumulation on roads reduces traction, increasing the likelihood of accidents due to slippery conditions, which raises serious safety concerns. Even slight delays in snow plowing can lead to thick ice sheets, further endangering drivers. In extreme cases, blocked storm drains for melting snow and ice may cause traffic to halt. Traffic accidents can increase by up to 75% in the wors t conditions.

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2. Challenge Overview

Traditionally, optimizing snow plow routes has been tackled using classical algorithms like the **Travelling Salesman Problem (TSP)** or the **Chinese Postman Problem (CPP)**, which aim to find the most efficient route for clearing all city streets. However, these problems are NP-hard, making them computationally intensive—especially for large cities—and often requiring heuristic solutions for classical computers.

In this challenge, participants are tasked with optimizing snow plow routes using a **graph-based abstraction** of a city street network. Roads and intersections are represented as **nodes and edges** in a graph, and the goal is to find the most efficient route. Participants are encouraged to:

- Model this problem using either the **Travelling Salesman Problem (TSP)**, where the snow plow clears each node once and returns to the starting point, or
- The **Chinese Postman Problem (CPP)**, where the snow plow must clear all streets with the least amount of travel.

The quantum solution should demonstrate if and how quantum computing—running on **Alice & Bob platform**—can provide a solution to this problem.

The challenge includes creating a project that:

- Proposes a business idea with a clear business plan for municipal snow plowing or similar optimization problems.
- Implements a quantum algorithm to enhance routing, with potential extensions to include more realistic models and forecasts.

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3. Problem Statement

- How can quantum computing be used to optimize snow plowing or similar problems?
- Which details of a city grid and the environment should be considered for the algorithm?
- Can you come up with metrics (classical and quantum) to assess the quality and scalability of your solution?

- What advantages can quantum technology provide to future customers and citizens in this context?

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4. Use Case Details

a. **Generate Graphs to Model a City Street Network**:
   - Represent the city's streets as edges and intersections as nodes in a graph. You can start with smaller graphs and increase their size once you are more familiar with the problem.

b. **Quantum Computing's Role**:
   - Investigate and choose the optimization approach that can find the shortest path (TSP) or the shortest closed path that visits every edge at least once (CPP) so every part of the city is connected.
   - Leverage a suitable quantum algorithm to solve the chosen approach and run it in a quantum computing simulator first.
   - Test your solution under real conditions on the Alice & Bob platform, adjusting the solution accordingly and leveraging the strengths of Alice & Bob's platform.

c. **Target Users**:
   - Identify the target users of your solution. Would it be solely for municipalities, or could it also be applied to the private sector?
   - How does your solution help them deliver better services to their customers or target audience?

d. **Business Potential**:
   - How can your solution be used in traditional or new business models? Is it transferable to other optimization problems?

e. **SDG Impact**:
   - How does your solution contribute to **SDG 9: Industry, Innovation, and Infrastructure**, and which other Sustainable Development Goals (SDGs) might it impact?

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5. Expected Deliverables

a. **Optimizing Algorithm**:
   - A working prototype demonstrating how quantum computing can improve snow plowing routes.

b. **Technical Documentation**:
   - A detailed explanation of the quantum algorithms used, including how they optimize snow plowing routes.

c. **Business Case**:
   - A clear business plan demonstrating the commercial viability of the solution, identifying target users, interaction models, and potential regions for deployment.
   - A strategy for turning the algorithm into a product that can reach real institutions, city management, or the private sector.

- Distribution models for bringing the platform to market, whether through partnerships, SaaS models, or direct-to-consumer platforms.

d. **Impact Case**:
   - An analysis showing how the solution contributes to supporting **SDG 9**.

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6. Judging Criteria

a. **Innovation**:
   - Novel use of quantum computing to optimize snow plowing routes.
   - Distribution models and ideas for integrating these algorithms into new platforms and business models that optimize city infrastructure or other applicable projects.

b. **Impact**:
   - The solution's potential to significantly enhance city infrastructure and positively impact **SDG 9**.

c. **Feasibility**:
   - The practicality and potential for real-world implementation of the algorithm.

d. **Technical Merit**:
   - The level of quantum computing skill and sophistication demonstrated.

e. **Presentation**:
   - The clarity and effectiveness of the final pitch, explaining the solution, its impact, and its technical details.

Appendix:

Classical Optimization Approach to Snowplowing:
https://www.iaarc.org/publications/fulltext/054%20ISARC%202021%20Paper121.pdf

Generating graphs in Qiskit:
https://medium.com/@shoaib6174/how-to-solve-qubo-problems-using-qiskit-f4eab6cc3061
https://qiskit-rigetti.readthedocs.io/en/v0.4.1/examples/qaoa_pyquil.html

Formulating TSP as a Quadratic Unconstrained Binary Optimization (QUBO):
https://arxiv.org/abs/2110.12158
https://arxiv.org/abs/2106.09056

Formulating CPP as a Quadratic Unconstrained Binary Optimization (QUBO):
https://www.arxiv.org/abs/2008.02768

Useful quantum algorithms explained:
https://learning.quantum.ibm.com/tutorial/grovers-algorithm
https://learning.quantum.ibm.com/tutorial/variational-quantum-eigensolver

Grover search to solve QUBO:
https://arxiv.org/abs/1912.04088

Variational Quantum Eigensolver for QUBO:
https://medium.com/@shoaib6174/how-to-solve-qubo-problems-using-qiskit-f4eab6cc3061

The advantage of Alice & Bob's cat qubits:
https://felis.alice-bob.com/docs/getting_started/why_cat_qubits/