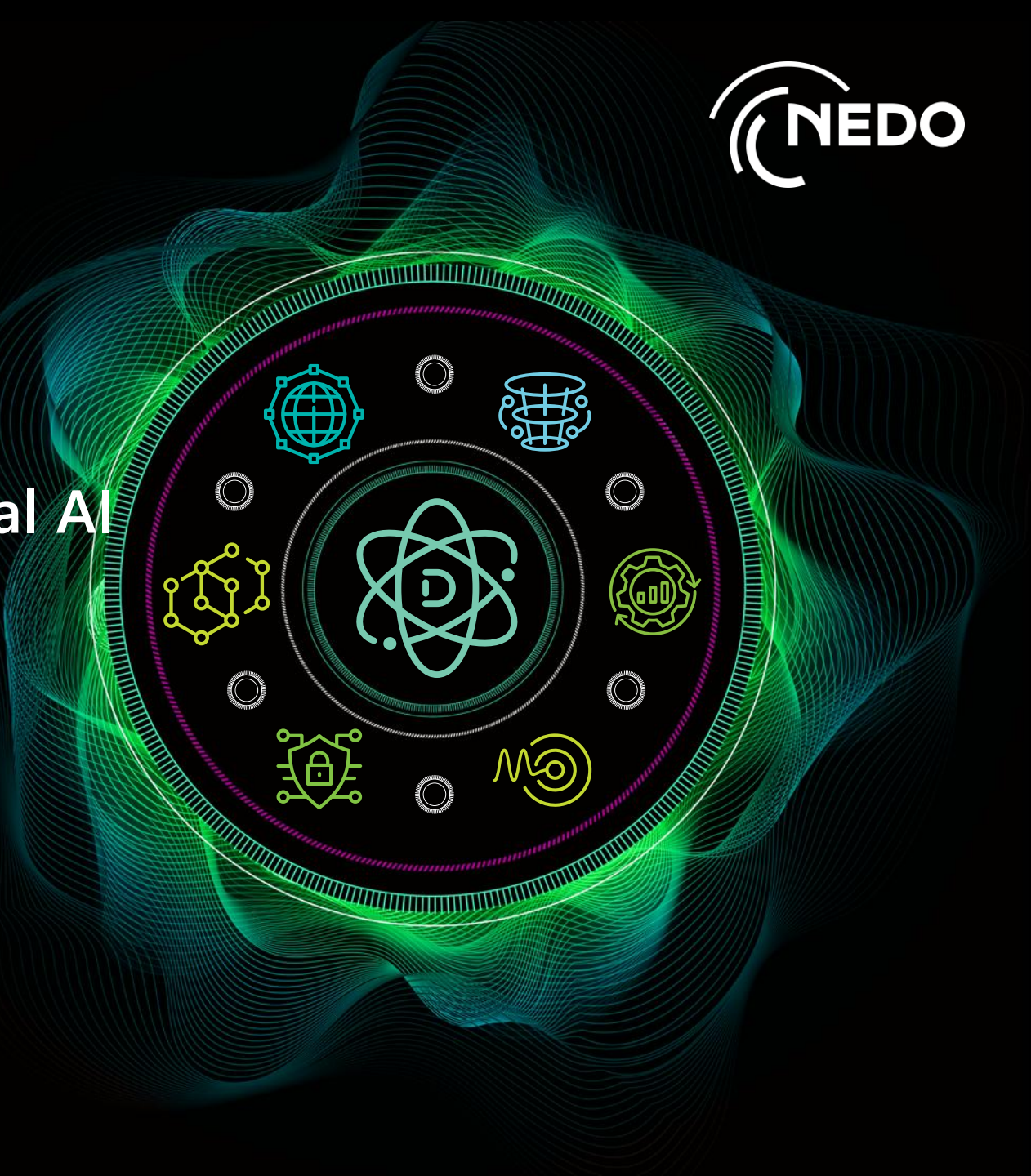
Quantum Computing Use Cases

Improving Logistics Operations Efficiency with Quantum + Classical AI

BIPROGY



New Energy and Industrial Technology Development Organization (NEDO)

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Validation

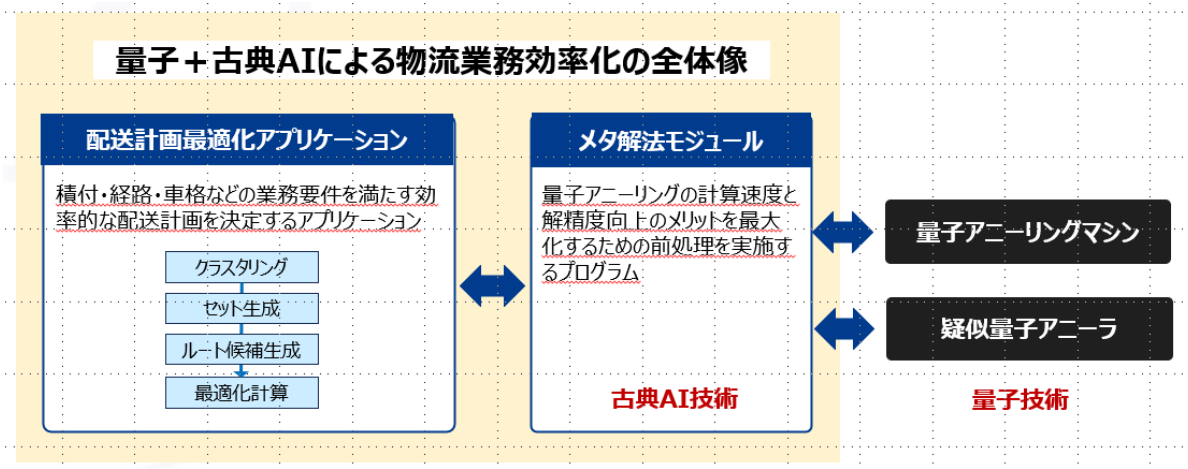
Industry	Transportation
Means	land transportation
Method	combinatorial optimization
Category	Ising*

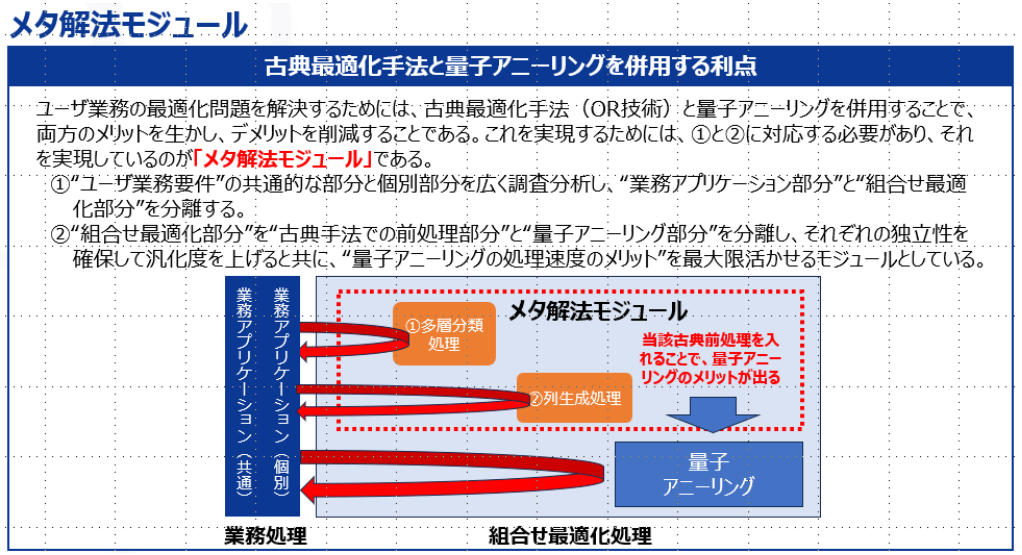
Background

- Due to the 2024 logistics issue, **responding to upper limits on driver working hours and shortages in transport capacity have become management challenges**
- In delivery planning, **it is necessary to handle the packing problem, the vehicle routing problem, and the matching problem simultaneously, and there are many constraints and a wide solution space**
- **With conventional general-purpose classical solvers, it is difficult to create delivery plans at practical business scale within a practical timeframe**
- **By combining quantum annealing and classical AI**, the aim is to rapidly generate optimal delivery plans that satisfy operational requirements

Issues and motivation to be solved

- A "**delivery planning application**" was developed to create delivery plans for manufacturers and others operating nationwide in a short time while satisfying complex operational constraints
- The improvement KPIs are **planning time, number of trucks, total travel distance, transportation cost, and CO2 emissions**
- A "**metaheuristic module**" was developed to reduce the search space in preprocessing and to execute combinatorial optimization at high speed using quantum annealing
- An optimization model is constructed that can also handle complex delivery conditions in which there are many possible combinations of delivery destinations and pickup locations and costs vary depending on transport volume





Reference: AI and Robot Department, New Energy and Industrial Technology Development Organization (NEDO), "Cyber-Physical Development Project for Quantum-Classical Hybrid Technologies" (https://www.nedo.go.jp/content/800030349.pdf)
*Ising: A computing approach, mainly associated with quantum annealers and simulators specialized for the Ising model, in which a problem is first formulated as an Ising model and then solved computationally. It is particularly well suited to problems that involve finding the optimal combination from a vast number of possibilities.

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Problem formulation for quantum computer

- **Target Problem:**

A combinatorial optimization problem that seeks a delivery plan based on delivery instructions while satisfying constraints such as loading capacity, vehicle availability, and time

- **Objective Function:**

Minimize the number of trucks, total travel distance, transportation cost, and penalties for congestion, overcapacity, and other violations

- **Main Constraints:**

Loading capacity, package type and weight, prohibition of mixed loading, warehouse operating hours, waiting time, vehicle class, and N-to-N delivery

- **Formulation:**

Candidates are narrowed down through clustering and column generation using classical AI, and the problem is then solved as a QUBO using quantum annealing

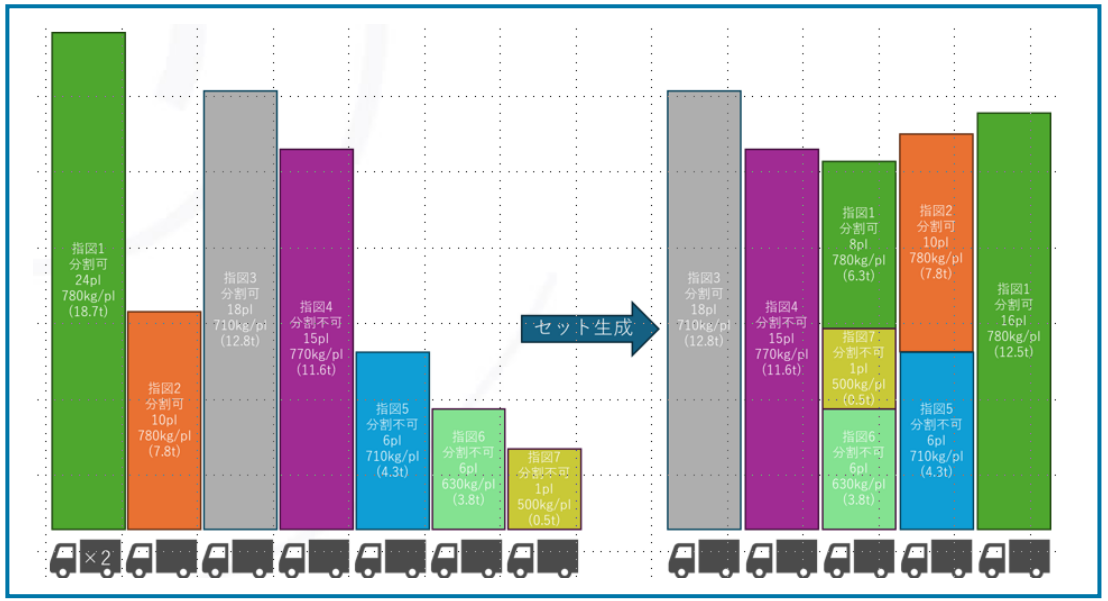
- **Why It Is Difficult with Classical Methods Alone:**

Computation time tends to grow substantially when trying to simultaneously satisfy operational constraints and perform large-scale search

Expected business benefits

- **Reduced the number of trucks from 1,541 to 1,116 (a 27.6% reduction)**
- **Reduced total travel distance by 30.0%**
- Reduced CO2 emissions and driver workload
- Achieved faster delivery planning and lower logistics costs

Illustration of optimization results



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More use cases are available on our website. We invite you to explore them.
https://www.quantum-computing-use-cases.nedo.go.jp/english/

More Use Cases

New Energy and Industrial Technology Development Organization (NEDO)
AI and Robotics Department (e-mail: quantum_ai@ml.nedo.go.jp)

This collection of use cases was obtained as a result of the work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) "Cyber-Physical Development Business of Quantum/Classical Hybrid Technology/Study of Use Case of Quantum Technology" and the “Post-5G Information and Communications System Infrastructure Reinforcement R & D Project (Quantum Industrialization)/Comprehensive Study for Promoting the Industrialization of Quantum Computers”.