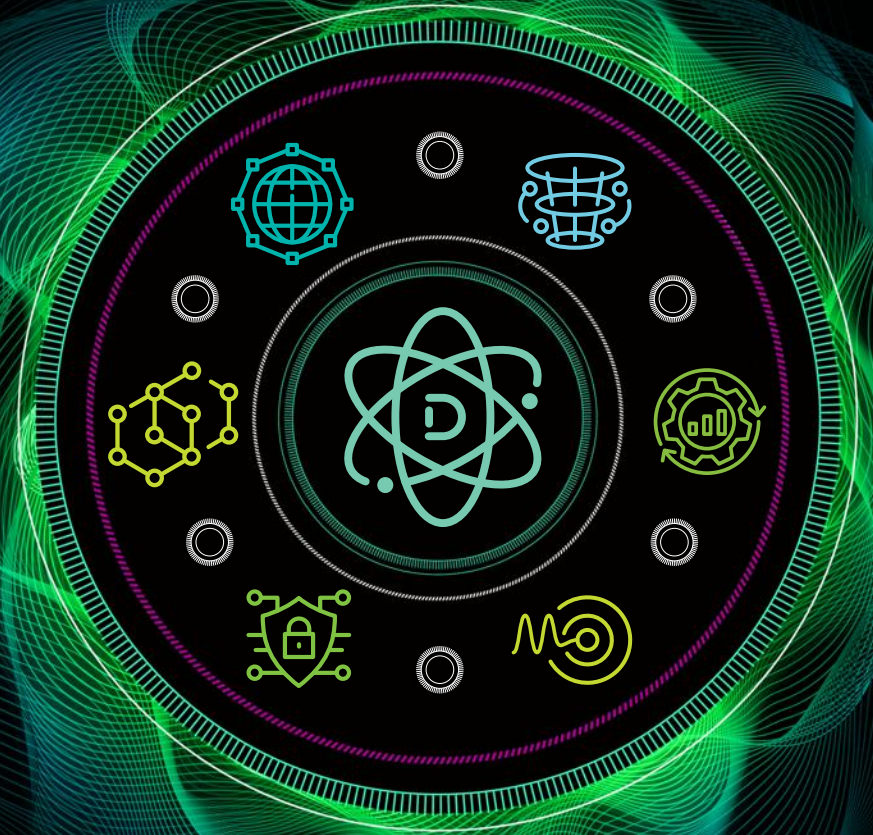
Quantum Computing Use Cases

Digital Twin Quantum Optimization for Human–Machine Collaborative Operations in Logistics Settings

Tokai National Higher Education Research System



New Energy and Industrial Technology Development Organization (NEDO)

Tokai National Higher Education Research System: Digital Twin Quantum Optimization for Human–Machine Collaborative Operations in Logistics Settings [2026/3] 1/3

Validation

Industry	Transportation
Means	land transportation
Method	combinatorial optimization
Category	Ising*

Background

- **Workloads in logistics warehouses are increasing** due to the spread of e-commerce, growth in small-lot, multi-item logistics, and rising demand for same-day shipping and short delivery times
- **Labor shortages at logistics sites in Japan are becoming more serious, and there is a need to maintain high shipping quality and processing capacity with limited personnel**
- In large-scale logistics warehouses, many processes such as receiving, inspection, temporary storage, put-away, picking, sorting, and shipping are interrelated, while the status of workers, cargo, transport equipment, storage areas, and truck berths changes continuously
- In such environments, **it is difficult to improve efficiency across the entire site using only conventional experience-based operating rules or mathematical optimization based on limited assumptions**
- In warehouses handling a wide variety of items, cargo shape, size, weight, receiving frequency, storage location, and work order are diverse, **making it difficult to model all cargo and operations in advance**
- When considering efficiency measures such as area layout, workforce allocation, temporary storage locations, transport routes, work order, and robot introduction, **direct trials in an actual warehouse carry risks** such as work stoppages and increased operational burden
- For this reason, **it is important to build a digital twin that reproduces the state of the real environment in digital space and allows measures to be evaluated in advance**

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)
[1] N. Kawaguchi et al., “Digitization Methods for a Logistics Warehouse Towards Digital Twin-Driven Optimization,” IEEE SmartComp 2025
[2] K. Higashiura et al., “Semi-Automated Framework for Digitalizing Multi-Product Warehouses with Large-Scale Camera Arrays,” PerCom 2024
[3] Y. Mori et al., “Multi-Camera Worker Tracking in Logistics Warehouse Considering Wide-Angle Distortion,” arXiv:2510.19432 (2025)
[4] K. Kano et al., “CorVS: Person Identification via Video Trajectory–Sensor Correspondence in a Real-World Warehouse,” IPIN 2025
*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.

Tokai National Higher Education Research System: Digital Twin Quantum Optimization for Human–Machine Collaborative Operations in Logistics Settings [2026/3] 2/3

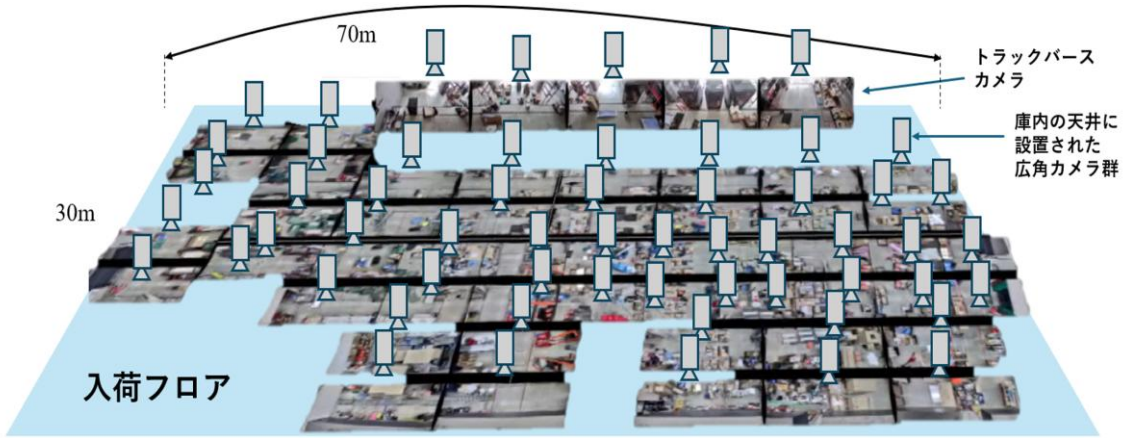
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Issues to be solved and motivation

- To obtain the basic data needed for efficiency improvement, a digital twin of the logistics warehouse was constructed. A camera platform was built by installing more than 60 network cameras on the ceiling, creating a framework to understand the status of workers and cargo in the warehouse [1]
- Building the digital twin required object recognition and tracking across multiple cameras, and accuracy was improved through technology development in AI training annotation, multi-camera tracking, and person re-identification [2][3][4]
- In this project, **the aim was to create use cases for warehouse operational issues of a scale and complexity difficult to address with conventional technology, by combining quantum technology and AI in a quantum-AI hybrid approach**
- By connecting a digital twin based on real site data with quantum-classical hybrid optimization, the project aimed to develop and demonstrate practical optimization applications beyond theoretical verification

Figure: Developed camera platform



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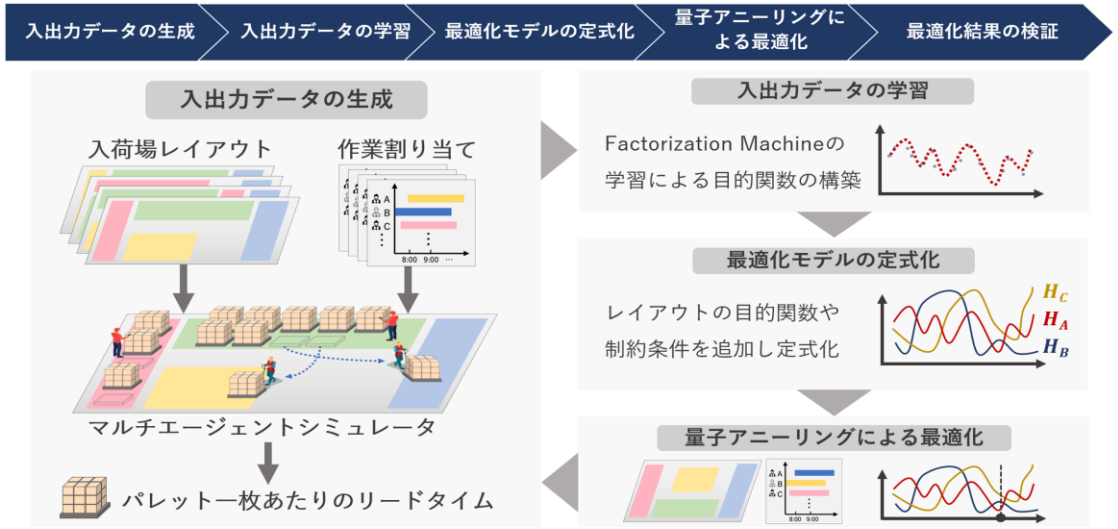
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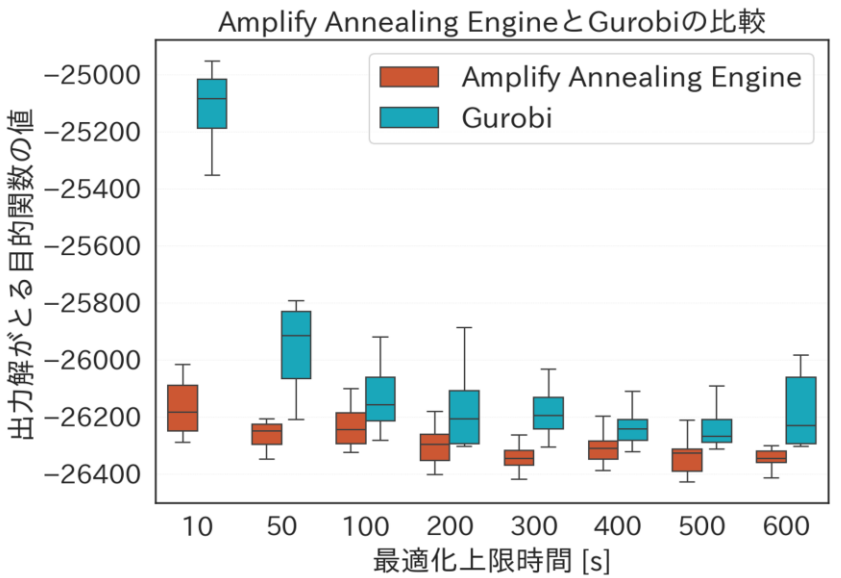
Problem formulation for quantum computer

- At the receiving area of a logistics warehouse, shifts and layouts must be determined for tasks such as inspection, sorting, transport, and storage, and these need to be optimized simultaneously. In this R&D project, **the black-box optimization shown below was carried out.** In addition, **the effectiveness of simulated quantum annealing was evaluated by comparison with Gurobi, a classical optimization engine** [5]

Black-box optimization for warehouse layout and shift planning



Comparison of pseudo-quantum annealing and classical optimization (Gurobi)



Expected business benefits

- As a result of the black-box optimization approach, **the optimization of worker shifts and task assignments produced solutions that reduced average processing time by about 23.5% and total labor hours by about 15.2% compared with the baseline. It was also confirmed that simultaneously optimizing receiving-area layout together with shift and task assignment can reduce average processing time by about 21.4% to 26.5% and total labor hours by about 8.7% to 21.7%**

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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)
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