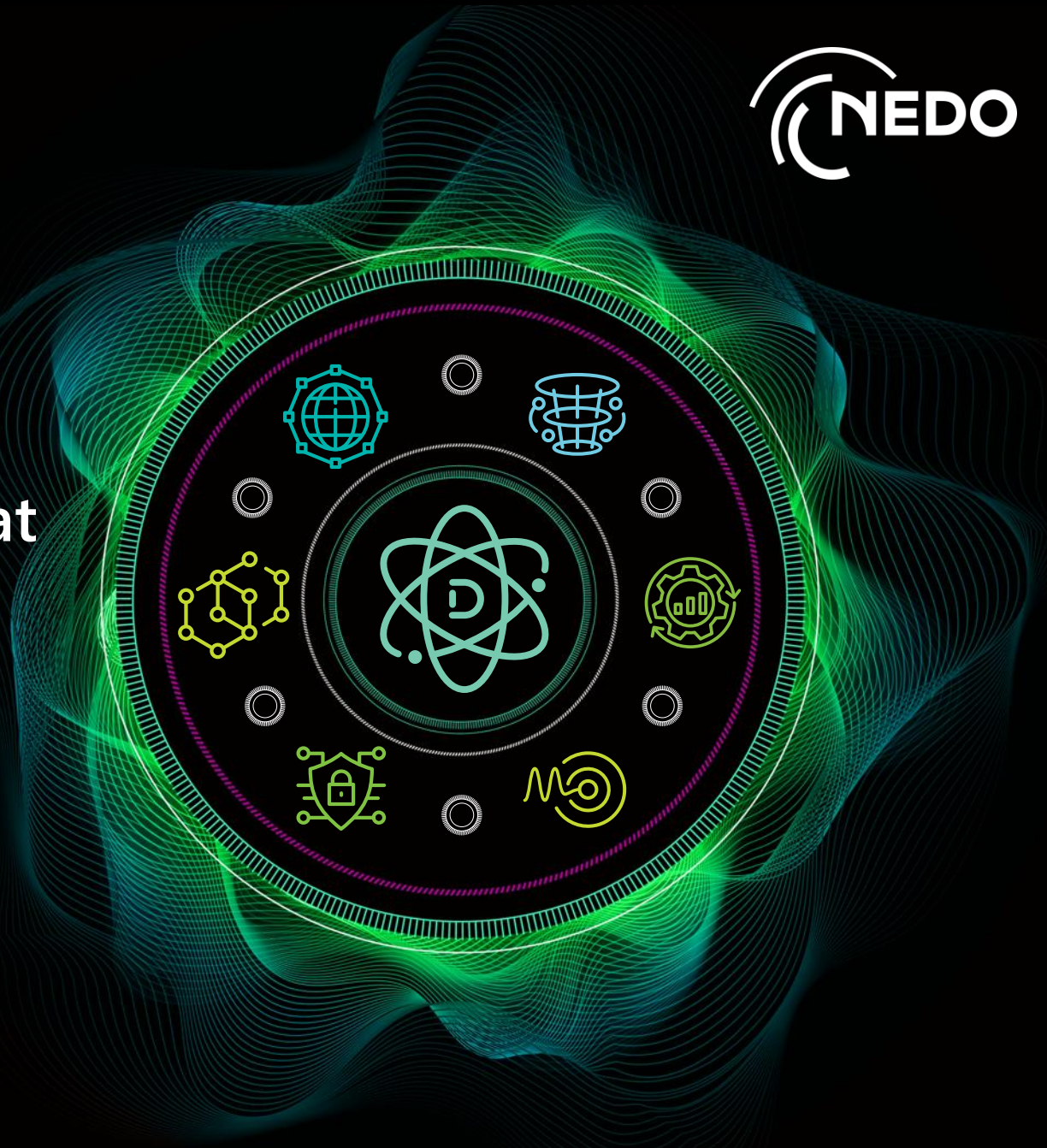
Quantum Computing Use Cases

Improve the availability rate of automated guided vehicle (AGV) at factories

DENSO / Tohoku University



New Energy and Industrial Technology Development Organization (NEDO)

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Validation

Industry	Discrete Manufacturing
Process	Shipping and sales
Method	combinatorial optimization
Category	Ising*

Background

- **For the manufacturing industry, improving productivity in factories is a priority, and output (quantity and quality) and costs are directly linked to corporate performance.**
- **In the future, with the advancement of smart factories, it will be important to interconnect facilities in factories and IoT, and to visualize in real time the operation status of equipment/production lines, the entire factory, and the entire supply chain including outside the factory, and to manage and control the entire Process.**
  - ✓ At factories, production stoppage, which lasts from several minutes to several tens of minutes, often occurs on a daily basis on each production line. After the production stoppage occurs, workers manually take time to decide whether or not to switch production.
  - ✓ For switching decisions, it is necessary to consider a combination of various parameters, such as the order of assembly of parts and materials, tasks before and after delivery, and milestones. However, classical computers have too many problem scales to optimize them instantaneously.
- The computation time is expected to **slow down the flow of inventory/products and reduce the efficiency of production lines, resulting in significant economic losses**. Specifically, if it is difficult to forecast demand or if a sudden change in the production plan is required, if the production process is not optimized on an ad hoc basis, intermediate inventories tend to increase, which may lead to an increase in costs.

Issues and motivation to be solved

- **The utilization of automated guided vehicles (hereinafter referred to as AGV) is attracting attention for the improvement of production efficiency in factories.** AGVs are automated vehicles for automatically transporting parts and goods within factories and warehouses, **and are an important means of solving problems such as labor shortages.**
  - ✓ AGV contributes to the efficiency of processes between processes and **contributes significantly to the improvement of overall productivity in the plant.**
- On the other hand, since AGVs are usually simple based on predetermined routes and rules, **multiple AGVs trying to travel on the same route may cause congestion,** resulting in **reduced AGV availability.**
- In order to manage and control automated guided vehicles (AGV) and prevent traffic jams, it is necessary to adjust the movements of multiple AGVs traveling simultaneously. Therefore, it is important to provide real-time integrated control of AGVs and **verify the effectiveness of combinatorial optimization to select the optimal path.**
- DENSO and Tohoku University conducted a demonstration to improve the availability of AGVs using quantum computers.

Reference: Nikkei BP "DENSO's factory AGV route optimization utilization rate increased from 80% to 95%" (https://xtech.nikkei.com/atcl/nxt/column/18/01755/00011/), Business +IT "Why DENSO won an acclaim at the world's largest international conference on quantum computers" (https://www.sbbit.jp/article/cont1/35565), Tohoku University "Tohoku University and DENSO used quantum annealing machines
Announced efficient delivery technology for automated guided vehicles in factories "(https://www.tohoku.ac.jp/japanese/newimg/pressimg/tohokuuniv-press20191125_01web_Com.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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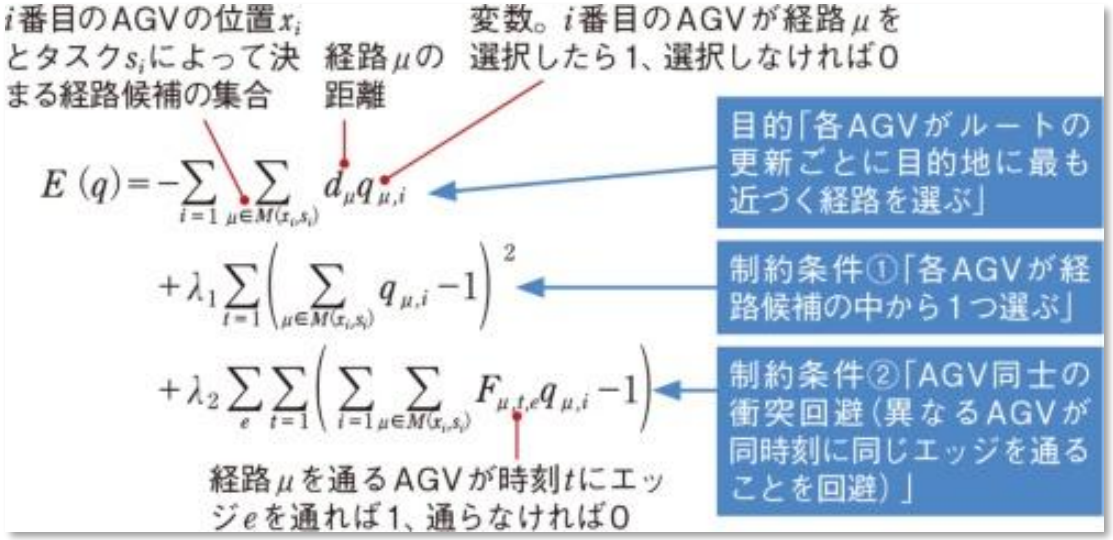
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Problem setting as a quantum computer

- In this demonstration, we focused on the management and control of the Automated Guided Vehicle (AGV) **and utilized D-Wave's Quantum Annealing Machine as a means of combinational optimization** (instead of optimizing the entire production process in the plant), using an AGV simulator.

Problem setting as a quantum computer (Advanced)

problem setting	• Improvement of operation rate of automated guided vehicles (AGV, Automated Guided Vehicle) at factories
quantum computer Hardware	• D-wave2000Q (2000 qubits)
Implementation	• Update AGV plans with the following optimizations every hour:
objective function	• Reduce AGV downtime as much as possible (i.e. improve utilization)
Constraints	• AGVs must not collide with each other
Variables	• Speed of each AGV (conducted from 10 to 10,000 units) (Select one of three ways: stop, one step forward or two steps forward.)→ Number of combinations is raised to the N-th power of 3 N: Number of AGVs



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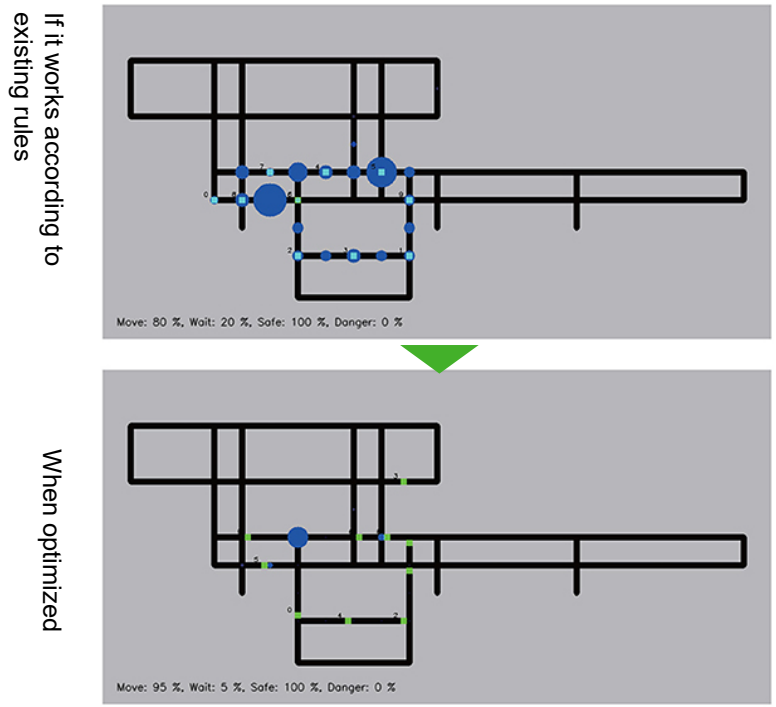
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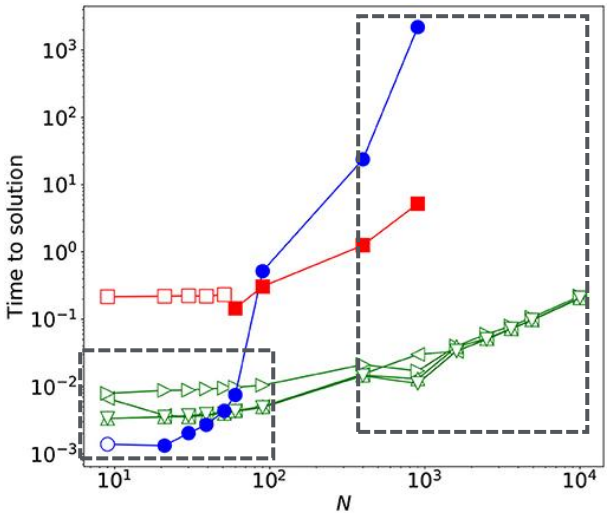
Expected business benefits

- Effect measurement using AGV simulator was verified. The size of the blue circle indicates the number of times the AGV stopped at that point. In other words, **The fewer the blue circles, the higher the utilization rate.**
- **Increased capacity utilization from 80% to 95%** of AGVs. Note that this is a comparison between the no-optimization state (80%) and quantum optimization (95%).



Comparison with classical computers

(Comparison based on computation time to find the best solution with 99% probability)



N: Number of AGVs
Above N=60, D-Wave does not work on its own, resulting in hybrid calculations that are dramatically slower due to the overhead involved.

○:D-Wave
□:Digital Annealer
△: Gurobi (done with three options)
Filled means the time to find the best solution with 99% probability;
Time taken to complete solution without fill

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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

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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”.