Quantum Computing Use Cases

Traffic flow optimization (congestion reduction)

Volkswagen



New Energy and Industrial Technology Development Organization (NEDO)

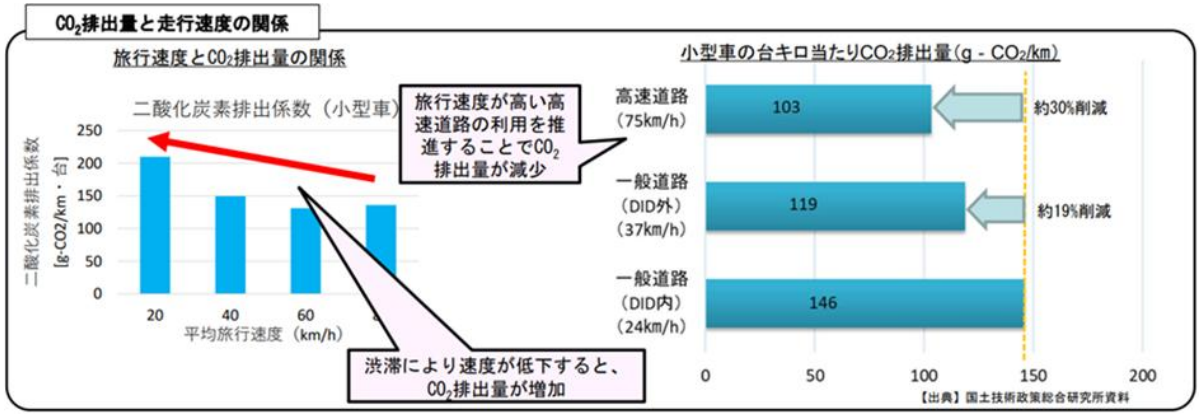
Volkswagen: Traffic flow optimization (congestion reduction) [2019/11] 1/4

Validation

Industry	Transportation
Means	Human Movement _ Land Transport
Method	combinatorial optimization
Category	Ising*

Background

- **Traffic congestion in urban areas with a high density of vehicles on the road is one of the causes of global warming due to emissions of air pollutants such as NOX (nitrogen oxides) and carbon dioxide, as well as economic losses caused by longer travel times for passengers.**
  - ✓ CO2 emissions increase due to slower speeds and longer driving times caused by traffic jams
- **By developing means and technologies to "avoid traffic congestion before it becomes apparent," it will be possible to reduce exhaust gas emissions from low-speed driving and wasteful fuel consumption such as idling.**
  - ✓ It is important not only to solve environmental problems but also to improve convenience by shortening travel time for vehicle users.



Reference: the Ministry of Land, Infrastructure, Transport and Tourism "Contribution to Carbon Neutrality in the Road Sector" (https://www.mlit.go.jp/policy/shingikai/content/001470072.pdf) and D-WAVE"How Volkswagen is using real quantum computers for transportation optimization research" (https://dwavejapan.com/app/uploads/2019/12/Final_Dwave_VW_Case_Study_2019_11_13.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.

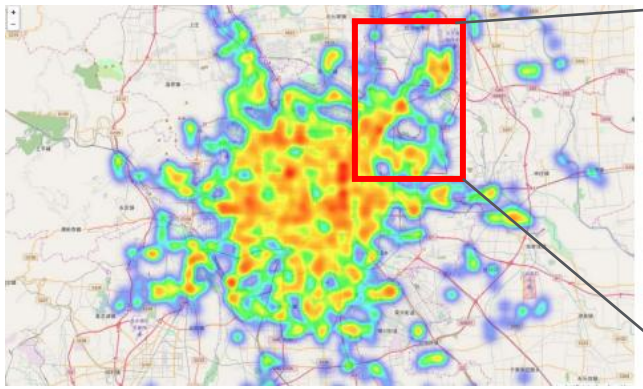
Volkswagen: Traffic flow optimization (congestion reduction) [2019/11] 2/4

Validation

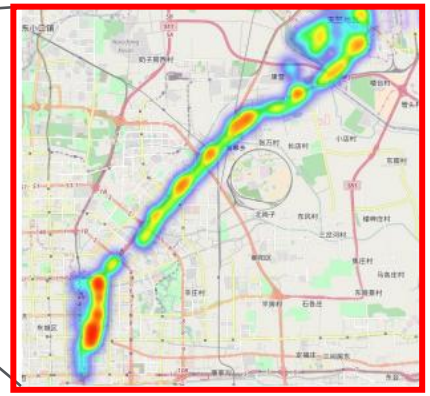
Industry	Transportation
Means	Human Movement _ Land Transport
Method	combinatorial optimization
Category	Ising*

Issues and motivation to be solved

- **Solving congestion in urban areas To solve the traffic flow optimization required, it is necessary to solve the route optimization problem considering millions of vehicles and billions of routes and destinations.**
  - ✓ In particular, when handling a plurality of vehicles connecting two points, all vehicles tend to take the same (shortest) route connecting the two points, resulting in congestion.
- Therefore, it is necessary to control the travel route of multiple vehicles traveling at the same time in order to solve the congestion. Therefore, it is important to verify the effectiveness of the combinatorial optimization that selects the optimal route including the route which is not congested from the location data collected in real time.
  - ✓ On the other hand, computation with a large number of parameters is difficult with classical computers.
- Volkswagen has demonstrated how to use quantum computers to improve utilization.



large cities with heavy traffic jams (e.g. Beijing)
(High vehicle density in red)



Traffic congestion on the route between two points (between Beijing City and Beijing International Airport)

Reference: D-WAVE"How Volkswagen is using real quantum computers for transportation optimization research" (https://dwavejapan.com/app/uploads/2019/12/Final_Dwave_VW_Case_Study_2019_11_13.pdf), VOLKSWAGEN"Quantum Computing at Volkswagen: Traffic Flow Optimization using the D-Wave Quantum Annealer" (https://www.dwavesys.com/media/erzjluvs/qubits-day-2-morning-5-vw.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.

Volkswagen: Traffic flow optimization (congestion reduction) [2019/11] 3/4

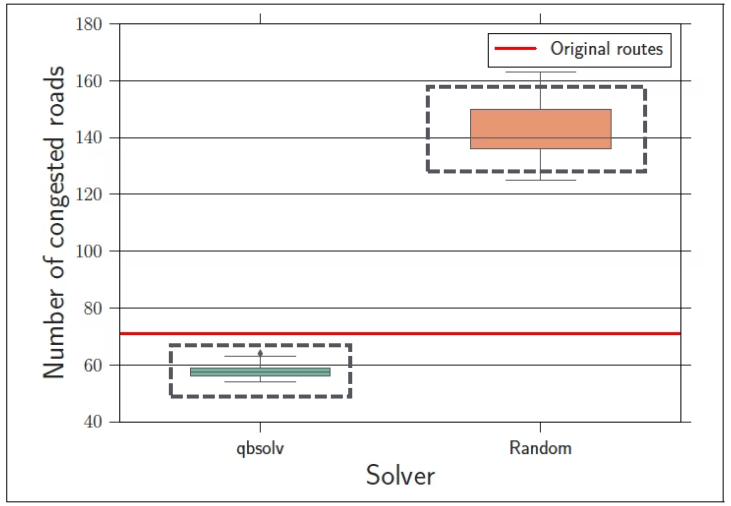
Validation

Industry	Transportation
Means	Human Movement _ Land Transport
Method	combinatorial optimization
Category	Ising*

Problem setting as a quantum computer

- The demonstration will focus on optimizing the traffic flow of taxis between Beijing and Beijing International Airport in China, which is the most congested city in the world (instead of alleviating the congestion of the entire city), and will **derive an optimized route for eliminating congestion by collecting travel data from moving vehicles**.
- The machine is powered by a **quantum annealing machine** from D-Wave.

problem setting	• Elimination of traffic jams by taxis connecting the congested city center and Beijing Airport (= optimization of traffic flow by distributing routes)
quantum computer Hardware	• D-wave2000Q (2000 qubits)
Implementation	• Update the taxi route by executing the following optimization calculation 50 times
objective function	• Reduce route overlap as much as possible for the 418 optimized taxis (allowing longer routes)
Constraints	• Each taxi must choose one route
Variables	• **418 taxis x 3 possible routes =1,254 variables** • (Since it exceeds the logical variables that can be solved by a D-Wave machine with limits between qubits, it is calculated by a hybrid classical/quantum computer tool.)→ **The number of combinations is 3 ^ 418**



Solver:
qbsolv is a quantum algorithm, Random is a random route assignment to a taxi
Number of congested roads

Reference: D - WAVE "How Volkswagen is using real quantum computers for transportation optimization research" (https://dwavejapan.com/app/uploads/2019/12/Final_Dwave_VW_Case_Study_2019_11_13.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.

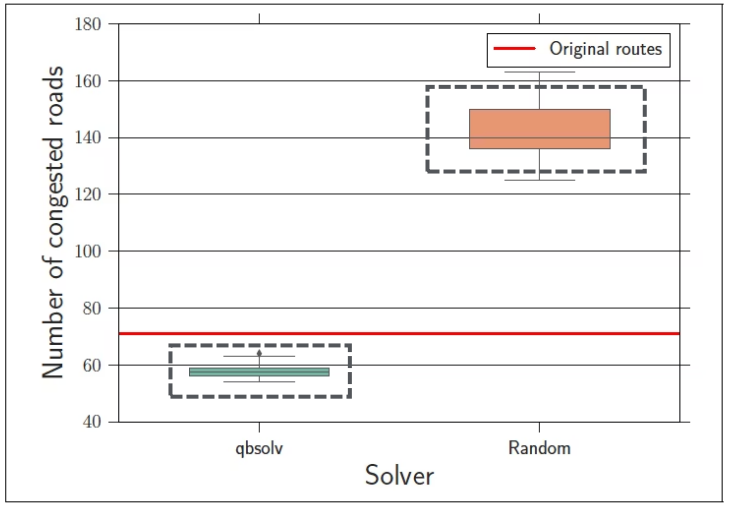
Volkswagen: Traffic flow optimization (congestion reduction) [2019/11] 4/4

Validation

Industry	Transportation
Means	Human Movement _ Land Transport
Method	combinatorial optimization
Category	Ising*

Expected business benefits

- The effect of a quantum annealing machine (D-wave2000Q) and a classical/quantum hybrid algorithm for route optimization on reducing taxi congestion was measured using open maps.
- Using GPS data from 418 Beijing taxis (updated every 1 to 5 seconds) to calculate optimized routes in real time, **we demonstrated that we could distribute routes for each vehicle and reduce congestion.**



Solver:
qbsolv is a quantum algorithm, Random is a random route assignment to a taxi
Number of congested roads



If all taxis take the same route, there are many congested roads (red areas on the map) where taxis are concentrated.



Quantum-Computer Algorithms Allocate Alternate Routes to Taxis and Eliminate Congested Areas

Reference: D - WAVE "How Volkswagen is using real quantum computers for transportation optimization research" (https://dwavejapan.com/app/uploads/2019/12/Final_Dwave_VW_Case_Study_2019_11_13.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.

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".