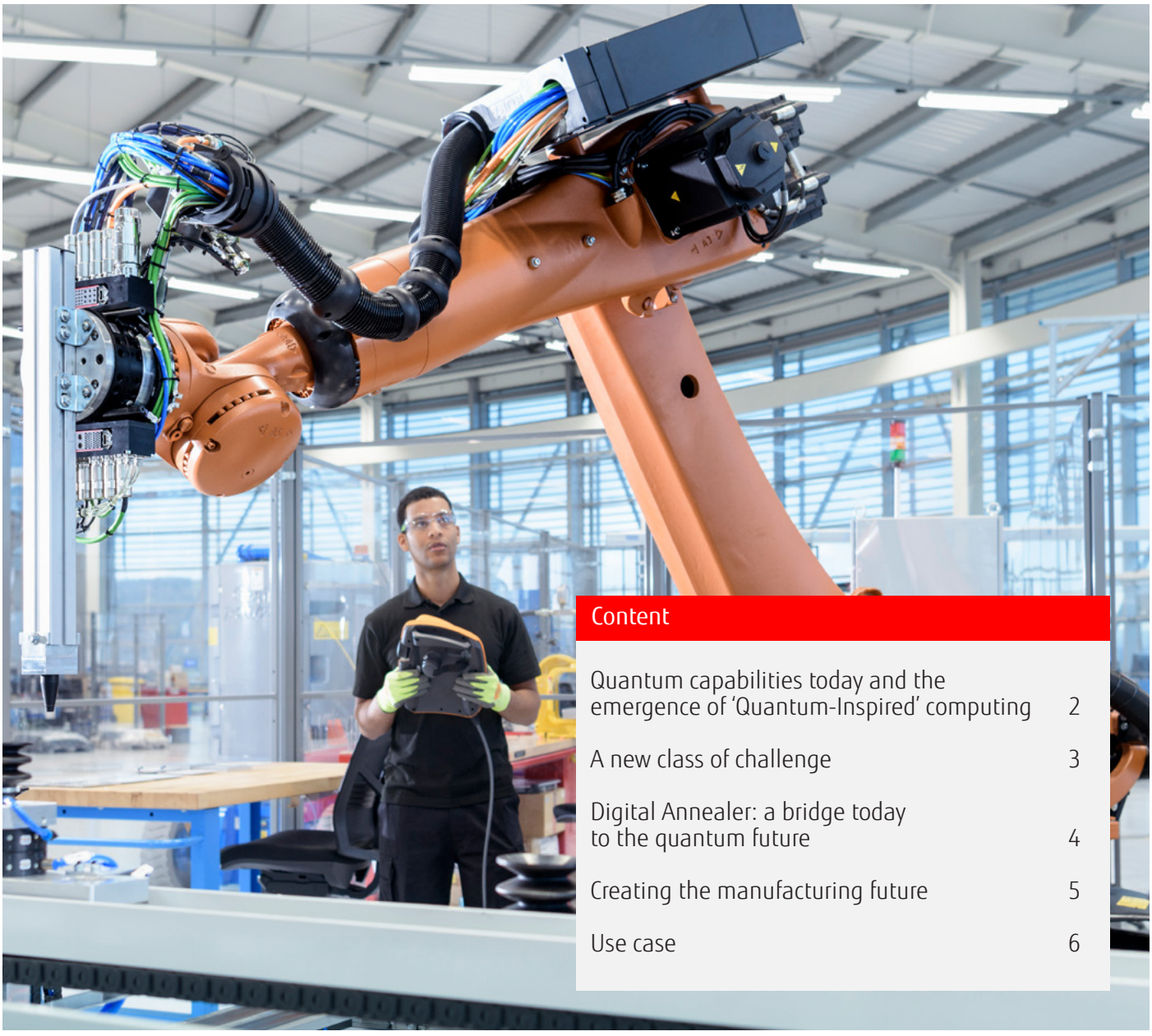
FUJITSU

White Paper
Manufacturing gets ready for quantum computing

How to build a bridge to the quantum future



Content

Manufacturing leaders and thinkers are looking hard at quantum computing to transform the industry. Alliances and projects are already in place as the major players jockey for position – knowing that this technology changes the game and the prospect of being left behind is a risk not worth taking.

In automotive, the touch paper was lit when major OEMs considered the implications of optimizing traffic across a city or country for autonomous cars and mobility platforms. The calculations were just too big to handle quickly enough for real time traffic conditions.

Quantum computing is eventually expected to have the potential to solve these real-world problems, however today it is still in research phase. 'Quantum-Inspired' computing, on the other hand, is available today and solves optimization challenges with the acceleration, precision and scale promised by quantum computing.

Quantum capabilities today and the emergence of 'Quantum-Inspired' computing

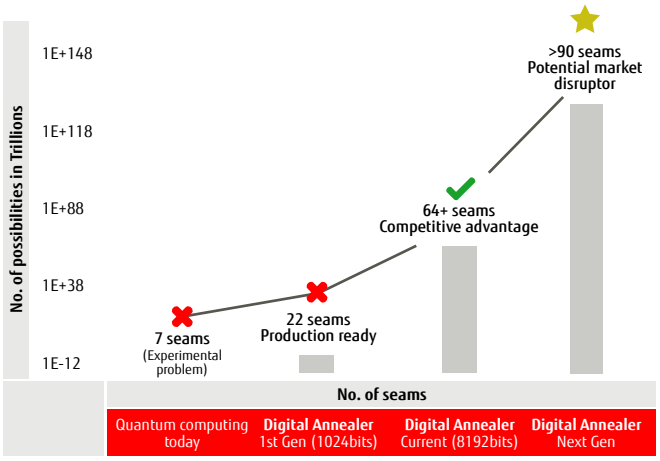
In 2018, for the first the time in public, Fujitsu demonstrated some very concrete results from proof of concepts using its new 'Quantum-Inspired' computing with automotive OEMs. Fujitsu experts supported customers at that event to explore real-world complex optimization problems. These were problems the customers described as "unsolvable with linear upgrades of the technology we have today". Some of them described how – some years earlier – the research and investigation of traffic optimization for autonomous cars quickly made it clear that the calculations involved surpassed the abilities of currently available computing power.

That was the starting point for the OEMs to start exploring quantum computing – an emerging branch of computing that can process billions if not quintillions of calculations simultaneously. However, quantum computers are not a state where practical problems can be resolved. It is still in research or testing phase. Once they are mainstream, then optimizing today's challenges, such as city-wide, even countrywide road traffic routing, may become routine.

Under discussion was the co-creation with Fujitsu of solutions for manufacturers using Fujitsu's new Digital Annealer – a quantum-inspired computing technology that is ready to solve practical, real-world problems today. The combined customer-Fujitsu teams have already solved optimization challenges including job shop scheduling, engineering design customization, route optimization and manufacturing optimization for robot positioning for chassis seaming, which, as we will see, has a significant impact on manufacturing efficiency and cost.

The task for an automotive manufacturer is to calculate the best possible path for production seaming robots setting out from and returning to their base positions. Solving this optimization challenge has resulted in a higher vehicle throughput without investment in additional resources.

In the 'paint shop', which is one of the costliest processes in car manufacturing – contributing to an average of 40% of the total cost of manufacturing – PVC seam-sealing by robots has been a particular focus of optimization efforts. Currently, prototype quantum computing solutions addressing this challenge are able to compute optimization routes for about seven seams. The Digital Annealer is already fully handling 64 seams today, with even higher capabilities already in sight. This increase from seven to 64 seams isn't just nine-times the number of seams. The number of possible trip combinations to choose from increases by a factor of 10^{100} which is far beyond the assumed number of atoms in the whole universe.



This has resulted in production of more vehicles with the same resources and hence a reduction in paint-shop costs – which account for between 30 and 50 percent of automotive OEM's manufacturing costs.[1] Optimization in these areas can provide significant cost benefits and will be truly transformational for the industry. This is just the tip of the iceberg.

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1. Assessment of Automotive Coatings Used on Different Metallic Substrates, W. Bensalah, N. Loukil, M. De-Petris Wery, and H. F. Ayedi, https://www.hindawi.com/journals/ijc/2014/838054/

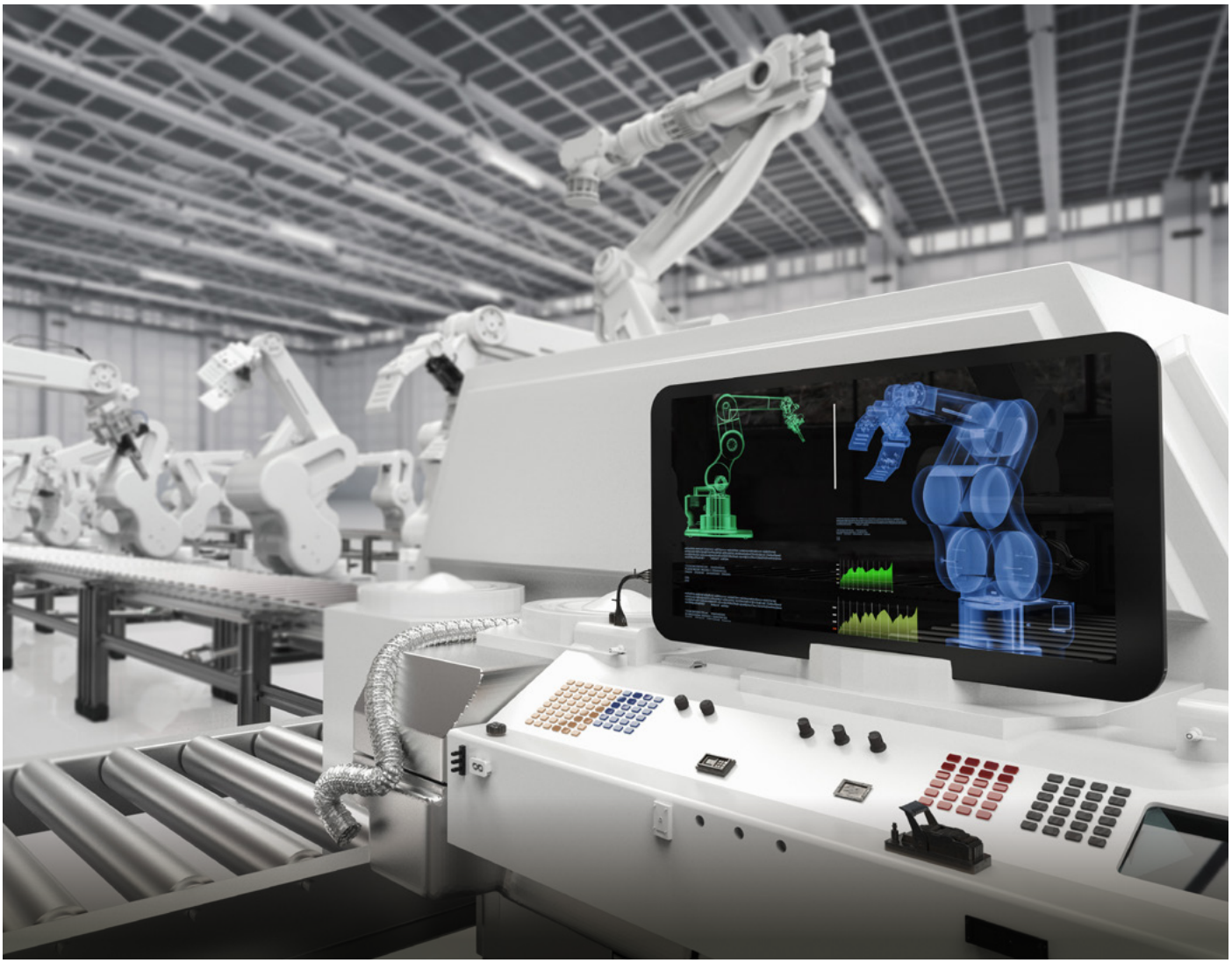
A new class of challenge

The automotive industry is reaching for the ability to improve business processes by solving a class of problems known as "combinatorial optimization". This addresses problems where the set of possible solutions is finite. The main goal is to find ways to search efficiently for answers that are optimal, without having to try every possible one – in other words, taking a series of educated guesses.

In tackling any optimization process, there is a trade-off between precision and risk. Until now, seeking high precision implied the need for more time to calculate the answer, while accepting an answer that is 'good enough' introduced an increasing amount of risk and the need for a security buffer. The more precise the calculation you can achieve, the less waste there is in the process.

It's a bit like old-school sailing calculations before the advent of sonar and GPS. When calculating the clearance under the ship at any point in a tidal pattern, it was wise to leave a margin of error, even at the expense of a slightly longer journey, just in case the calculation was not precise enough – because the risk, cost and inconvenience of running aground was far higher.

With the advent of quantum computing, the balance in this equation shifts – because it's possible to get a precise enough view to remove the need to build in this margin of error – and it's in this area that savings are achieved. The time, practicality and cost advantages of high precision – through optimization – are possible when you can make calculations even when based on mind-boggling numbers of variables. For example, when calculating the most valuable combination of just 40 from 100 items that could be carried on a trek in a knapsack, this could result in a number of possibilities exceeding one million times the number of stars in the universe.[2]



2. Single items have interdependencies. For example, as a stand-alone item such as a box of nails has a low value, but this increases when combined with a hammer. The number of stars is assumed as being 10^{22}.

Digital Annealer: a bridge today to a quantum future

The distinction between true quantum and quantum-inspired computing needs explanation.

The idea of a quantum computer goes back 40 years, when physicists familiar with quantum theory began to speculate whether it might provide the basis for encoding information. Whereas in traditional computing a bit can be either ‘0’ or ‘1’, in quantum computers it can be anywhere in between at once – an effect which is known as ‘quantum superposition’. If this superposition of states could be harnessed in a computer, you would have the ability to calculate all possible combinations of results simultaneously.

Despite initial skepticism, we now see various kinds of quantum computers being used for experimental testing – and the potential is awe-inspiring. The only problem is, it remains some distance in the future. Optimists think perhaps five years – a more realistic assessment could be 10, 15 even 20 years away.

Quantum computing remains experimental, expensive, complicated and temperamental, and requires very specific operating conditions in order to compute and provide output – including power and cooling requirements. As MIT professor Isaac Chuang puts it: “The thing driving the hype is the realization that quantum computing is actually real. It is no longer a physicist’s dream—it is an engineer’s nightmare.”

In order to get the correct output for a problem, quantum bits must remain in superposition at near absolute-zero temperatures, free from any outside interference, including cosmic or magnetic rays. Get this wrong and the qubits collapse out of their parallel superpositioned state, losing all quantum acceleration and of course also rendering any calculation impossible. To emphasize just how difficult this is, when an IT company recently unveiled a 50-qubit quantum computer to great acclaim, it featured the ability to preserve a quantum state for an industry-record time: 90 microseconds.

But what if it were possible to harness quantum-like simultaneous calculation capabilities on existing computer architectures today? Fujitsu’s scientists were first in the world to react to the realization that some of the principles of quantum computers could be emulated within existing digital architectures. Fujitsu created the Digital Annealer incorporating quantum-inspired simultaneous data processing capabilities to almost instantly find the optimal combination of massively complex, previously unmanageable data variables, accurately and cost effectively. The underlying technology processes quantum algorithms, and hence organizations already evaluating quantum computing were able to quickly comprehend the power Digital Annealer provides to make progress at a larger scale than is possible with current ‘true quantum’ devices.

In a short time, the first proof of concepts with Digital Annealer have shown immense potential in optimizing manufacturing and logistics control, for portfolio optimization in finance or for molecular design in material discovery. In addition, new business areas are opening up - for example in the field of smart mobility. Digital annealing technology currently has a unique proposition.

FUJITSU Quantum-Inspired Computing Digital Annealer has been described by independent analysts as a unique opportunity to pre-empt quantum computing and achieve the benefits of optimization today, working within current data center constraints. They talk about creating a “bridge” to the quantum future – getting the benefits of combinatorial optimization today while also learning how true quantum computing can be applied to operations in the future.

Creating the manufacturing future with quantum-inspired computing

Engineer's nightmare or not, manufacturers are finding plenty to dream about. The potential of quantum and quantum-inspired computing to overturn manufacturing paradigms that stretch back decades has really gripped the imagination of industry visionaries.

In aerospace, a manufacturer established a research team in 2015 tasked with the study of potential applications of quantum technologies and has recently launched an open competition, inviting proposals for the application of quantum computing.

Other aerospace and defense manufacturing companies known to be investigating quantum computing include Lockheed Martin and Raytheon. And when investment bank Morgan Stanley recently evaluated the potential of quantum computing, it identified major opportunities in aerospace for data storage and sorting, satellite imagery analysis and the development of new ultra-durable materials for aircraft. Other candidate uses cases include optimizing the loading, routing and scheduling of aircraft, with enormous potential commercial benefits for time and costs.

As we have seen in the automotive sector, OEMs began with traffic optimization but have quickly branched out from there as they gain experience with quantum computing and the quantum-inspired Digital Annealer. Battery development is in the spotlight, with the search on for high-density designs that could dramatically expand the capacity of batteries used in everything from portable electronics to vehicles. The time is right: Improvements in battery density have been running at just 5 to 8 percent annually.

At Daimler, the Mercedes-Benz automotive research and development division they are also researching how quantum computers could help discover new materials that might "...unlock a billion-dollar opportunity", according to Benjamin Böser, quoted in the Wall Street Journal, director of open innovation at Mercedes-Benz Research and Development North America. That opportunity is battery innovation: "We could simulate the actual behavior of a battery with a quantum computer, which is currently not possible with existing computer power."

At Ford Motor Company, Dr. Ken Washington, Vice President, Ford Research and Advanced Engineering, and Chief Technology Officer recently said: "...while we're still in the discovery phase when it comes to quantum computing, we know enough to believe that its potential can help us solve real problems that affect the people and businesses using our vehicles."

One of those challenges is exploring how to help commercial fleet owners manage the total energy consumption of their large number of vehicles more efficiently. Ford's scenario entails finding the optimal route for a single delivery vehicle carrying out a specific task by making stops at multiple locations, then applying that to all vehicles in the fleet. Using traditional computing methods, it is only possible to model these options for a limited number of vehicles and locations, since it quickly becomes unmanageable as soon as you increase the number of vehicles, relevant locations and potential routes.

The prospect of quantum computing has thrown the deck of cards available to manufacturers into the air. Creative thinkers are exploring the new opportunities. The availability of the Quantum-Inspired Digital Annealer has suddenly changed the game again – from a theoretical, experimental mode of thinking, to practical applications for combinatorial optimization challenges in real-world use cases.

What's on offer is the ability to apply creativity and innovative thinking that can transform production processes and leapfrog competitors. There are few limits here, and imagination will be a valuable resource. As Ford's Ken Washington says: "Once we understand the right way to ask questions in a quantum framework, there's no telling the power we'll have to solve potential problems in the future...".

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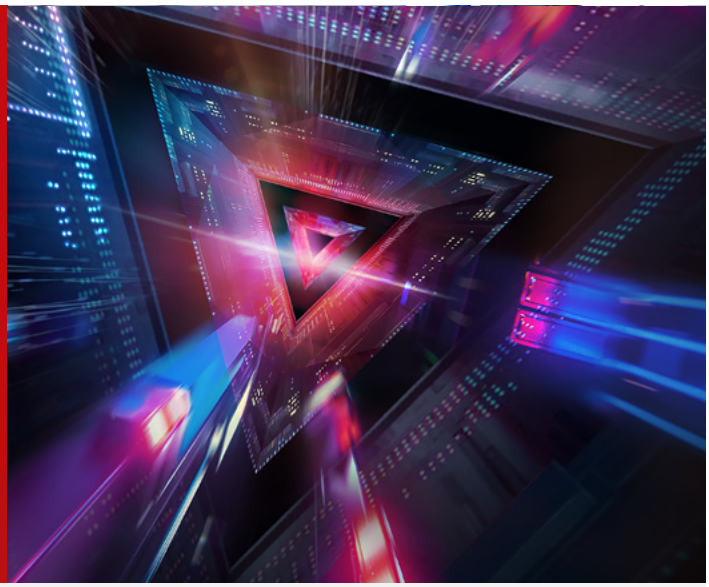
Use case:

Manufacturing in the data age



Quantum-inspired computing is disrupting the manufacturing industry

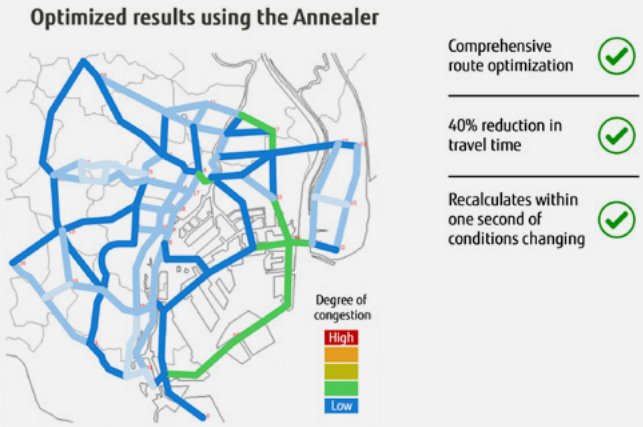
What is a manufacturer? The organizations we conventionally thought of as producers of vehicles, aircraft or machines are rapidly morphing into something new - mobility service providers, logistic enablers or robotics-on-demand providers.

In the automotive sector, author and economist, Jeremy Rifkin, puts it like this: "25 years from now, car sharing will be the norm and car ownership an anomaly." In the aerospace industry, airlines are less interested in the price of an engine than the number of hours the aircraft is carrying passengers in the air. The major engine manufacturers now price on that basis – fully aligning customers' commercial imperatives with the manufacturing offer.

Competitive advantage, in other words, now rests on processes spanning the entire value chain and optimization within that chain is where to find the disruption necessary to lead an industry.

To differentiate their mobility platforms, vehicle manufacturers must seek the ability to bring insight via traffic real-time optimization. Although this is beyond the capabilities of conventional computing, quantum-inspired computing with the Digital Annealer puts these calculations within practical reach.

The potential benefits of traffic optimization are high: better air quality means lower levels of respiratory and other diseases, plus increased citizen well-being. Lower carbon emissions feed through to climate reduction targets, enabling governments to focus their spending on other vital policy areas. With whole cities' traffic light networks optimized to minimize red light waiting time, more efficient journeys will raise productivity, reduce frustration and encourage economic growth.



The Digital Annealer's ability to perform successive, real-time calculations on unbelievably complex challenges stands head and shoulders above today's computers. These struggle to perform the calculations at all. Early modeling suggests that digital annealing holds the potential to reduce traffic congestion by up to 40 percent, by dispersing traffic to less congested routes.

The potential for digital annealing to impact new battery technologies holds tremendous excitement as well. The capability of Digital Annealer to identify molecular similarity provides the opportunity to manage battery lifecycles resulting in a faster shift to electric vehicles (EVs) as 'range anxiety' becomes less of an inhibitor to adoption.

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According to website The Drive, "The development of high-performance batteries for electric vehicles is a tedious and complicated affair. And the automaker that produces the longest lasting batteries, not counting Energizer and its famous bunny, will have the biggest advantage in this long and challenging race for EV dominance. Having identified all these hurdles Volkswagen Group, much like Daimler, is now using quantum computing to push the envelope of new battery technology."

Not only will the winners here have the "biggest advantage": they will also have contributed to a massive reduction in pollution and opened up many new potential products or even industries involving other battery-driven devices, for example hearing aids, smart watches – the list would be continually expanding with new disruptive applications.

Data stands at the fulcrum of manufacturing's services-oriented future. Achieving a new era of data insight in manufacturing will depend on real-time prioritization of data, finding the relationships and dependencies hidden within it, and using these to optimize processes across the entire value chain. Quantum-inspired optimization with the Fujitsu Digital Annealer will accelerate these breakthroughs. For manufacturers seeking new, disruptive opportunities and differentiation, Digital Annealer is the bridge to the quantum future.

Fujitsu

Web: www.fujitsu.com/DigitalAnnealer