

White Paper

How to transform manufacturing production to become Always Optimal

Taking a leap beyond optimization.



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The optimization imperative

The topic of manufacturing optimization is suddenly on everyone's lips again. It's hardly a new idea – the concept of Lean Manufacturing focuses on eliminating waste through organizational optimization and dates back to the 1930s.

The goal is to minimize resources such as energy, operating costs, time, space, investment, pollution – in fact, any factor that creates a competitive edge, while maximizing customer satisfaction. It's especially pertinent as business – and society generally – reconsiders how to operate while recovering from the current pandemic. However, the number of options that must be considered to solve certain classes of optimization challenges is simply out of reach – even for today's fastest computers. There can be more possibilities in these calculations than there are atoms in the universe. Even if you could calculate an answer, by the time you have it, the opportunity to profit from it has gone. As a result, businesses have had to accept a sub-optimal status quo.

What is new is the emerging ability, driven by disruptive new technologies, to optimize much more complex manufacturing scenarios. Greater depth of analysis and optimization is not the end of the story. The new capabilities also provide much greater accuracy and speed than previously possible, giving organizations the flexibility to assess and reassess optimizations strategies as often as they want and to achieve optimal efficiency and productivity – no matter how often circumstances change.

Demonstrating the performance breakthroughs that have only recently become possible, a global car manufacturer is now using near-real-time quantum-inspired computing for process optimization. This has cut the distance robots have to move to complete the automated underbody sealing on a vehicle by 40% (see 1.3 A., on page 4).¹

With the automotive sector blazing a trail, early adopters can now refine factory processes to reach substantially better performance in any given situation. This saves time, space and capital, and reduces waste, energy and operating costs. And optimization can be updated as often as needed – even in near-real-time, which means in a few seconds.

This advance is largely down to the inspiration of experimental quantum computers. Although quantum computing is – by some years – still unable to deliver solutions to practically relevant solutions, it has provoked new approaches on classical digital architectures, allowing us to analyze and resolve far more complex optimization models. These radical new technologies¹ are opening up a new realm of optimization possibilities for manufacturers that until now was simply out of reach.

The timing could not be better. According to analyst firm SITS, manufacturing process industries in particular lag in the drive towards digital performance breakthroughs: something usually described in shorthand as 'digital transformation' (or, even shorter, 'DX').²

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Any breakthrough in optimization promises a new DX agenda for manufacturing, focused on indisputable operational benefits such as reducing waste, energy, space and cash burn – and delivering a business advantage over competitors. This is music to the ears of senior manufacturing managers. Research commissioned by Fujitsu³ confirms that manufacturers well understand the impact of optimization, with 87% agreeing that process optimization has the potential to create the next wave of digital disruption. What seems to have been missing until now is the availability of ready-to-use solutions: 77% of manufacturers in the study demand proven, tangible optimization services today – and spurn experimental technology. “We know optimization is powerful and it can be done,” is the clear message from manufacturing to solution providers, “but you're making it much too complex for us to use.”

That usability gap between laboratory-based quantum computing devices and highbrow mathematical models on the one hand, and, on the other, things that manufacturers might actually want to do and be prepared to pay for today, has now been filled with the factory deployment of quantum-inspired computing. This technology applies the learning from software developed for experimental quantum computers but running on the established silicon-based processors already in widespread use today. The result is the practical ability today (we will look at use cases later in this paper) to solve optimization problems related to applications in manufacturing.

82% of business leaders feel that quantum-inspired computing could speed up new product development.⁴ By removing this computational roadblock, quantum-inspired computing has opened up new classes of optimization for manufacturers to explore today, with profound, new business advantages that truly deserve the DX label. Four out of five business leaders state that quantum-inspired computing could open the door to radical new possibilities.⁵

1. For a discussion about quantum computing and the new, digital architecture quantum-inspired computing, see Fujitsu's The White Book of Quantum Computing.

2. Digital CX & IoT, Worldwide, 2019 Manufacturing Industry: CxO Priorities and IT Investment Trends by Sub-Verticals SITS, Market Analysis, InSight Analysis.

3. “Is business ready to make the quantum leap”, teknowlogy Group, May 2019. The study is based on a survey of 350 business leaders at large and medium-sized businesses in Canada, Finland, Germany, Ireland, Spain, Sweden, UK and USA.

4. A commissioned study conducted by Forrester Consulting on behalf of Fujitsu, May 2020.

5. A commissioned study conducted by Forrester Consulting on behalf of Fujitsu, May 2020.

What is optimization and is it possible?

Optimization comes in many different flavors in manufacturing – for example, production efficiency.

This isn't the end goal, of course. For manufacturers, the most direct route to increase profitability is any opportunity to increase output to meet new orders without increasing the marginal cost of production. This is why production efficiency is one of the most closely observed optimization targets.

Through adopting Lean Manufacturing principles, production line managers are constantly looking to squeeze extra output from their processes, for example to pave the way for 24x7 production.

"There used to be limits to how far you could push this approach," says Walter Graf, Fujitsu Distinguished Engineer. "Manufacturers have long harvested the low-hanging productivity gains, leaving only more and more complex possibilities to pursue. These tend to be cases where optimization is theoretically possible, but what has been lacking until now is the ability to compute answers quickly enough to be practically useful."

Manufacturing output is currently limited by numerous processes currently too complex to optimize. One goal is the optimized production (and maximum throughput) of an array of different products with a given set of machinery. This task, commonly called 'job shop scheduling', optimizes multiple jobs, with different operation sequences to a given set of machines. For example, 40 different production jobs running on 20 machines, each job requiring a different amount of machine time.

By calculating the optimal sequence of jobs to maximize production, a manufacturer could expect to increase the output possible from existing capital plant, all without the need for costly capital investment. In this example, a slower production job may be embedded in the general flow of faster processes so that it doesn't become a bottleneck. This will have a positive effect on machine utilization as well as total throughput.

The challenge for COOs is that deciding what is optimal can be very complex in certain classes of so-called 'combinatorial optimization' problems. Even with just a few product variables, the calculations of different combinations have become so complex, it has been beyond the capability of conventional computing to evaluate the most profitable solution.

From optimized to Always Optimal

In the examples of production line output and profit maximization, a crucially important factor is the speed of calculation. It's easy to assume that modern computers are now so powerful they can handle almost any task. Given enough time, that may be true. However, with combinatorial problems there is not usually enough time. As soon as you introduce too many variables, it becomes impossible to use conventional computing power to reach a workable answer quickly enough to gain any practical benefit.

To grasp the challenge, consider that calculating the most valuable combination of just 40 out of 100 items could result in a number of possibilities exceeding one million times the assumed number of stars in the universe.

This is why optimization – if attempted at all – has been limited to one-time calculations where speed or constant repetition is not the most crucial factor. By enabling repeated, on-the-fly optimization, solutions such as Fujitsu's Quantum-Inspired Optimization Services allow constant re-evaluation of the optimal state for any of these processes, at any given time. This creates a huge increase in agility, in terms of being able to better cope with delays caused by unplanned maintenance – let alone an emergency shutdown – priority orders or the flexibility to produce units in smaller lot sizes, for example.

Close to 75% of business leaders feel that quantum-inspired computing would avoid the need for large scale production investment.⁶ For 81% of businesses this would play a key role in reducing costs.⁷

Standard production in large lot sizes is clearly efficient but excludes the potential of additional revenue from product variants that may be more attractive to customers, as limited or customized editions. Real-time optimization enables manufacturers to plan in more diversified products for segments they were not previously able to address. This means the creation of more differentiated and therefore more attractive products which can retail for a higher margin.

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6. Quantum-Inspired Computing: Today's Solutions To The Hardest Business Operations Challenge, a commissioned study conducted by Forrester Consulting on behalf of Fujitsu, May 2020.
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This is what being Always Optimal looks like

This approach to optimization challenges is already happening in automotive manufacturing, in job shop scheduling, engineering design and JIT manufacturing optimization for robot positioning for chassis welding. Other proven deployment opportunities include logistics and warehousing optimization, plus workforce planning and scheduling.

Robot positioning optimization


One 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 speeds up the production line, resulting in higher throughput without the need for investment in additional resources.

Right now, Fujitsu is optimizing the routines of robotic PVC sealing of vehicle sub-frames for weather protection in a global-scale German automotive OEM. The takt time needed by the robots to complete this routine puts a significant brake on the total output of any manufacturing plant, particularly as the number of PVC seam welds increases with every new generation of vehicle.

Currently, prototype quantum computing solutions addressing this challenge can compute optimization routes for about seven seams only. The auto manufacturer is now calculating 64 seams per trip. This increase from seven to 64 seams is not just nine times the number of seams. The choice of possible trip combinations increases to more than 10^{100} , a number so big that it is far beyond the number of atoms thought likely to exist in the whole universe.

This has resulted in the manufacturer being able to produce more vehicles with the same resources, as well as reducing costs. By deploying Quantum-Inspired Optimization Services to re-map its robots' paths between and around vehicles, Fujitsu's customer has reduced robot movement in the PVC sealing of car underbodies by 40% and has side-stepped the need to build a new, capital-intensive plant – which could result in capital expenditure savings of more than €50 million.

A further compelling aspect of this use case is that the optimization can be repeated, as often as needed, to meet changing requirements throughout the day. This would be a breakthrough.



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The total number of combinations involved in mapping an optimized route is so large that conventional techniques simply cannot provide solutions fast enough to accommodate the real-time, on-the-fly changes necessitated by unplanned machinery downtime or smaller lot sizes.

Beyond spraying, other robot positioning applications in automotive are likely to emerge involving assembling and welding. There are further optimization criteria for robot movement besides the time and distance factors discussed here so far. Other possibilities include the optimization of energy consumption or reducing robotic movement types known to increase wear-out. In short, the potential for a total re-imagining of production line optimization now exists.

Job shop scheduling

Deciding what to make and in what order to produce it impacts manufacturers' revenue potential and therefore profit. Production jobs are sequential operations on machines, such as drilling, milling and shaping. They require multiple operations running on multiple machines. Very often multiple machines offering the same operation are available in parallel and each job may require different sequencing of operations. Every product also requires a different duration and order of use of machine tools.

Even in the example discussed earlier, of 40 different production jobs running on 20 machines, determining the best sequence of jobs for the circumstances pertaining at a moment in time – urgent orders, unscheduled machine downtime, specialist staff availability – is massively complex and has been beyond conventional solutions.

Another global vehicle OEM has optimized its job shop scheduling to identify the most efficient use of machine tools for different order quantities of each product.

In terms of agility, it is now possible to reduce the optimization effort to only a second. This ability to optimize and re-optimize in seconds is a fundamental requirement for application in factory environments. In this case, it enables the OEM to deal more effectively with unscheduled events such as machine downtime or sudden, high-priority sales orders, through creating the ability to re-plan and optimize for the new circumstances. Taking only a second, these new plans propel a higher level of efficiency and flexibility, regardless of the circumstances. They can also, of course, help reconfigure entire factories and supply chains in the face of a lengthy shutdown, such as generated by the COVID-19 pandemic.

In the future, this solution could also drive higher profitability by creating latitude in the production schedule for new products, more revenue and making possible a differentiated, higher margin mix of products.

Components logistics

Fujitsu has applied this optimization solution in its own factories, with the result that workers' traveling distances during warehouse component picking has reduced by 45% a month, with a consequent reduction in non-productive time.

Having components available at precisely the right time is a crucial aspect of widely used manufacturing Operational Excellence methodologies, such as Lean Manufacturing, Six Sigma⁸ and Just-in-Time (JIT).⁹

However, many optimization problems in Operational Excellence have solution spaces so vast that no current computer can come close to finding an optimal solution within a reasonable time frame. Conventional models are therefore often limited to purely heuristic approaches, the results of which usually differ significantly from the optimum. On the other hand, Fujitsu Quantum-Inspired Optimization Services can evaluate massive amounts of alternatives in parallel and deliver much better results within seconds.

This capability opens up possibilities to maximize efficiency by identifying and picking components from internal and external suppliers and components warehoused within the factory, then routing and delivering them the correct production line at precisely the right time.

Another opportunity for manufacturers to optimize components logistics was demonstrated when Japan Post cut the size of its delivery vehicle fleet in Tokyo from 52 to 48 trucks, simply by optimizing transportation route combinations, truck types and cargo loads. The result achieved the seemingly impossible – both shrinking the size of the delivery fleet, reducing costs and ensuring improved truck loading efficiency and resulting in faster delivery times.

Each of these logistics optimization steps, on its own, builds significant improvements and business advantage. Combined into an optimized whole, with the added ability to accommodate near real-time job re-planning and scheduling, the cumulative effect is substantially greater than the sum of its parts.

“ Workers' traveling distances during warehouse component picking has reduced by 45% a month. ”

8. A six-sigma process is one in which 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects.

9. A methodology often used synonymously with Lean Manufacturing, aimed primarily at reducing times within production system as well as response times from suppliers and to customers.



Deploying optimization in manufacturing

Achieving these business outcomes involves much more than pressing the 'on' switch. It is very unlikely that many manufacturing organizations yet understand the potential of quantum-inspired optimization or have the experience and internal skills to make the unassisted move toward being Always Optimal.

Any manufacturer making a move to investigate quantum-inspired optimization, especially the capability to be Always Optimal, is ahead in the adoption curve. "This won't always be the case," according to Jouko Koskinen, Manufacturing CTO, Fujitsu Finland. "Many manufacturing competitors have declared an interest in quantum and quantum-inspired optimization and are starting to investigate the possibilities – which means there is no time to lose."

The scope for optimization is vast. Many manufacturers will already have a wish list of use cases with the potential for investigation. Others may be curious but feel inhibited by the novelty of the technology and the sheer range of possibilities. Reijo Sihvonen, Sales Director (Private Sector), puts it like this: "Remember when music streaming services first became available – at first the choice felt overwhelming and we didn't really know where to look. It's the same with optimization. At first you probably look at the things you already know about. But over time you begin to see new opportunities that hadn't previously occurred to you."

Arriving at the best targets for optimization is the first step. No one has all the answers, and this puts a premium on a culture of co-creation, where a team that understands optimization and the capabilities of the technology works jointly with people who understand current operational challenges. "This means either adapting existing optimization solutions for new customers or working creatively with them to understand how to overcome current sub-optimization situations in their operations," says Paul Bresnahan, Head of Manufacturing, Fujitsu North America.

Building trust internally is vital too. Once ideation is in place, a Proof of Business (PoB) can achieve that while limiting financial risk. This approach is a low-risk method to scale possible business outcomes with minimum investment in time, materials and recruitment of specialized know-how.

Partner choice should focus on access to deep expertise and experience provided by a team of mathematicians and physicists who can translate real-world problems into the appropriate quantum algorithm. That team should also know how to optimize and fine-tune each run of the algorithm and be aware of how to deliver and explain results.

The fastest progress is possible when a company's data scientists evaluate cases beyond normal operational tasks. Although shop floor personnel should be involved at a later stage, they usually do not have time or the scope to proactively seek out new and disruptive solutions. The most rapid results come from external experts working with a manufacturer's data scientists to co-create a solution. Then, once early results come through from running the algorithm, it's time to bring in production specialists to jointly refine the process.

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Key areas Quantum-Inspired Optimization Services is helping today:



Robotic Optimization



Job-Shop Re-scheduling



Component Logistics



Workforce Optimization

3. Summary

Quantum-inspired computing is opening a door to a new level of manufacturing efficiency. This is not a theoretical possibility – this paper discusses real examples, happening today. Quantum-inspired computing is a key organisational priority for 82% of businesses.¹⁰

We started out by noting that optimization itself is nothing new in manufacturing. That has always been the goal. However, with quantum-inspired computing there are two new, fundamentally different options:

First, the pool of opportunities available for optimization has suddenly deepened and broadened. Modelling of variables at a scale that was previously beyond the limit of practical exploitation is now within scope. This demands a new way of thinking – a creative way of thinking where ‘anything is on the table’.

Second, the speed at which these calculations can be performed has jumped to warp speed – moving from ‘way-too-long to be useful’ to near-instant. This radically disrupts the old way of thinking about optimization – which was a one-off calculation that defined a new status-quo. The new optimization paradigm is about being Always Optimal. Unthinkable until a couple of years ago, this is already happening today.

The necessity of reactions agile enough to respond at the speed of Always Optimal has only been reinforced by the COVID-19 pandemic,

which has unearthed fundamental vulnerabilities in many business and social systems and processes. Getting the old systems restarted efficiently is proving difficult enough, when what is really needed is root and branch reoptimization to adjust to today’s radically changed circumstances. Quantum-inspired optimization can deliver the ad hoc optimizations necessary to resume operations quickly and effectively after a process interruption – be that for a day or several months.

There is one more thing to consider. True quantum computers, for all the excitement they are generating, are still five, perhaps 10 years from even early-stage commercial deployment. When they do arrive, they are likely to be massively temperamental and equally expensive. As MIT professor Isaac Chuang put 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.”

Solutions such as Fujitsu’s Quantum-Inspired Optimization Services provide the opportunity to work with and understand the quantum algorithms that underly these exotic new devices now. This gives internal teams the time to understand quantum and get ready from a position of knowledge, rather than be blind-sided by the new technology, when that time comes. Quantum-inspired computing means the chance to become Always Optimal today and is an opportunity to create a bridge to the quantum future.

Get ahead by transforming your manufacturing operations to Always Optimal. [Contact us today.](#)

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10. Quantum-Inspired Computing: Today’s Solutions To The Hardest Business Operations Challenge, a commissioned study conducted by Forrester Consulting on behalf of Fujitsu, May 2020.