FUJITSU

White Paper
Mobility in Smart Cities/Regions powered by Quantum-Inspired Optimization

How a public administration optimizes intermodal mobility to maintain resilience, sustainability and safety, and to foster a human-centric intelligent society.

Content

The urban challenge – and opportunity

The current dominance of urban areas

More than four billion people – over half the world's population – now live in cities.[1] In Europe, the figure is even more startling: 80% of the European population lives in urban areas, and cities generate about 85% of the EU's GDP.[2]

We should hardly be surprised by this. Rapid urbanization has been a dominant characteristic of human society since the industrialization of early 19th century Britain. At that time, just three percent of the world's population is estimated to have been urban dwelling. By the 1950s that had risen to 29%, climbing to 50% in 2008. The number continues to grow and is expected to reach 65% of the global population by 2040.[3]

The complex, wide-ranging impact of such intense urbanization is occasionally thrown into sharp relief. Now is such a moment, with the COVID-19 pandemic shockwave requiring wholly-new approaches to the proximity and density of people. The impacts are multi-faceted but have particular relevance in transport and mobility, with new ways urgently needed for travelling through urban spaces for work, leisure, tourism, to protest and a host of other purposes.

However, the urban experience is not restricted to people living in cities. As cities grow larger with denser populations, so does their gravitational pull. They suck in a wider and wider circumference of suburbs and formerly rural areas, increasingly bound together in an extended ecosystem. Economic ties and transport infrastructure mean that people living 50km, even 100km, from major urban centers are likely to identify more with the city than the dormitory town or village where they happen to sleep. It is no longer adequate to talk about the urban challenges - **we must consider entire regions.**

Is city dominance a blight or a blessing?

From Charles Dickens to Karl Marx to Batman, the portrayal in literature of cities as dirty, desperate and degrading has left an indelibly negative image of the urban experience. However, in many areas of the world that has now been turned on its head, with cities likely to be the best opportunity for high-income, low carbon-footprint living.

During the worst phases of urbanization, which started in Europe in about 1800 and which continues today in various areas of the world, migration to cities was and remains a desperate survival gamble rather than a lifestyle option. Too rapid growth initially causes even higher levels of poverty and degradation of the environment. The very success of cities in attracting and retaining citizens creates its own problems. Insufficient water availability and poor water and air quality, issues with waste disposal, or a significant increase in energy usage are all concerns. Other potential negative effects include increased urban crime, worsening traffic, disease spread and inadequate housing.

> "...theorists of human geography have concluded that people elect to remain in cities for a variety of positive reasons: more job opportunities with higher wages, better living conditions, better education and health services, better facilities, less chance of being impacted by natural disasters."

Over time, however, as cities develop and overcome many of their negative side-effects, theorists of human geography have concluded that people elect to remain in cities for a variety of positive reasons: more job opportunities with higher wages, better living conditions, better education and health services, better facilities, less chance of being impacted by natural disasters.

Intense population densities and highly concentrated economic activity can still make cities and the economies they serve vulnerable to shocks, such as the Kobe earthquake in 1995 and the more recent COVID-19 pandemic. It is a matter for debate whether governments, worldwide, have done enough to promote the resilience of cities, arming them with the ability to function efficiently and effectively in a society experiencing some form of crisis.

1. https://ourworldindata.org/urbanization
2. Managing Urban Freight to Smart City Logistics Networks, Tolga Bektas, Teodor Gabriel, Crainic Tom Van Woensel, May 2015.
3. https://www.visualcapitalist.com/anatomy-smart-city/

Solving the interlocked challenges in urban areas

The challenges facing urban regions are highly interrelated – transport, congestion, pollution and health, for example, are all closely locked together in a complex tangle of cause and effect that has so far defied the efforts of planners. Often the inability to break through this complexity has been a failure of technology.

Through the combination of different approaches such as Stream Data Utilizer, Over the Air updates and Quantum-Inspired Optimization Services under the umbrella of Fujitsu's Future Mobility Accelerator, this is no longer a barrier that should hold us back.

This paper therefore focuses on mobility as a valuable prism through which to look at the urban experience and looks at how smart regions can optimize their data ecosystems to benefit citizens, commuters and visitors. We then illustrate how the concept of always optimal could be the next step in the mobility revolution.

The mobility revolution, Mobility-as-a-Service (MaaS) & sustainability

Since the Industrial Revolution, companies and public entities in the automobile and railway sectors have provided transportation modes with growing speed and capacity. Now, digital transformation is changing this landscape significantly - the automobile sector, to take one example, is experiencing a radical shift to connected, autonomous, shared, on-demand and electricity-powered modes of vehicles. At the same time, automotive providers are also having to face society's expectation to meet environmental sustainability standards.

What do these changes mean to us? What people really need is not necessarily a product in the form of an automobile, but to experience the value of mobility and to experience Mobility-as-a-Service (MaaS).

They want to move from Point A to Point B in the most convenient, flexible, comfortable, efficient and still affordable manner – ideally being able to shift seamlessly between different modes of transport -so-called 'intermodal mobility'.

The transport problems in cities today

In cities all over the world, there has been a consequent rapid rise in vehicle-dispatch applications and ride-sharing services, as well as services that provide information to users on the status of taxis in operation in big cities. Although these do help enhance mobility experience, it is still difficult for many people to move comfortably within cities and between different modes of transport.

As cities grow and become wealthier, increasing demand for transport leads to problems such as traffic congestion. Intel estimates that more integrated digital capabilities – so called 'smart city' initiatives - could save each global citizen 125 hours a year, or almost two and half hours a week. A lot of this would come from reductions in traffic and congestion: the average peak-time vehicle speed in cities is currently 4 mph, causing drivers to lose up to 70 hours per year. Smart cities with integrated infrastructures, creating better traffic management and quicker and safer roads, could give drivers up to 60 hours back annually.

There are other urban transport problems too. These include a local level imbalance of demand for human movement and supply of various transport modes. While large cities are crowded and have multiple mobility options – including public transport, cycling, taxis and car sharing platforms – people living further out in the suburban or rural zones of an urban region can have a radically different experience, with few mobility options beyond the household car.

Safety is a massive challenge too. In the USA, according to the Federal Highway Administration (FHWA), between 2013 to 2017 just under 4,000 cyclists (3,958) died on US roads. That's 792 for each year on average, with 777 of those (98%) killed as a result of accidents with motor vehicles.[4] The trend is getting worse. US cyclist fatalities have increased 30% in the last 10 years, from 785 in 2009 to 1,024 in 2018.[5]

> "This will allow people to freely select the most suitable combinations of services through networks, anytime and anywhere – being constantly updated and optimized in near real-time."

4. https://bayareabicyclelaw.com/safety-laws/bike-stats/
5. https://injuryfacts.nsc.org/home-and-community/safety-topics/bicycle-deaths/

The shift towards a mobility revolution

Responding to these challenges, we are living through a mobility revolution. Soon, we will see a substantial shift from vehicle ownership to shared usage and intermodal mobility, together with the spread of connected cars and self-driving vehicles, while Mobility-as-a-Service will become a reality.

Automobiles will be integrated into the public transportation service system – along with buses and trains – to form an integral part of urban infrastructure. Eventually, perhaps relatively soon, robo-taxis and ridesharing using autonomous-driving technology will enable on-demand services – while being barrier free and accessible for everyone. In addition, mobility management – the real-time monitoring of traffic conditions to deliver effective traffic control – will realize both smooth transportation without traffic jams and highly utilized mobility infrastructure, at the same time.

This will shape a human centric intelligent society, where all mobility services need to be orchestrated using digital information in an integrated manner. MaaS will allow people to freely select the most suitable combinations of services through networks, anytime and anywhere – being constantly updated and optimized in near real-time.

Some cities have already begun to implement intermodal mobility projects, field testing and implementing public transport systems that feature modal mixes and ride-sharing services that incorporate self-driving vehicles. Fujitsu has established a Centre of Excellence in collaboration with Singapore's Agency for Science, Technology and Research (A*STAR) and Singapore Management University. The joint team is conducting collaborative research aimed at easing traffic congestion and improving pedestrian flows in cities as well as developing solutions to optimize logistics, harbor and marine traffic.

The key point is that, by using these new mobility services, communities will have the opportunity to boost urban sustainability and re-invent their cities for the future. This will have at least two dimensions. Some cities will use new mobility services to lift traditional constraints and significantly expand the area that anyone can move around easily. Others, with Mannheim and Berlin's 'Urban Tech Republic' as current examples, preferring to bring more aspects of people's living needs within smaller urban areas, or quarters, reducing the need for many journeys in the first place. Under either scenario, digital mobility will allow contemporary designs for both downtown and suburban areas, as well as working and living areas.

What will future mobility mean for business?

Start-up companies in various parts of the world already offer vehicle dispatch and ride-sharing services using digital technology. The democratization of mobility service provision has already begun. Mobility platforms will also accelerate the development of new services in adjacent industries, such as logistics, entertainment, healthcare, and welfare. These will shape cross-industrial ecosystems. This is a new world, where anyone with an innovative idea and determination to carry it through can innovate and co-create.

In an intermodal revolution, traditional barriers between industries are disappearing as diverse information relating to mobility and adjacent activities can now be handled in real time in the form of digital data. As a result, the industrial landscape will be reorganized into business ecosystems that encompass multiple sectors. Organizations that are traditionally segregated into different industries and which are strongly relying on co-creation – automobile, railway, taxi, electric utilities, and the like – will form new autonomous, distributed ecosystems connected via digital technologies, together creating a society focused on human-centric mobility. And, as we will see in part 3 (Opening public data for development of mobility solutions), city-municipalities and citizens are an integral part of the co-creation processes that are creating intermodal mobility: silos are crumbling and collaboration is rising.

Such transformation will provide huge growth opportunities for a range of businesses, while also posing a threat to businesses that remain in the existing industrial framework and inside an outdated mindset. This is because start-up companies and enterprises from completely unrelated industries will now be able to enter the new mobility services sector.

The Smart City & Region opportunity

If the challenges are complex, the opportunity to resolve them by driving intelligence into our planning and operating systems and processes is equally exciting. This is the goal of protagonists of 'smart cities' or, more accurately, 'smart regions'.

A smart region describes the meaningful linking of people, technology and design based on the collection, processing, analysis and visualization of immense amounts of data with the aim of making cities and regions more livable, sustainable, cleaner and safer. This is connectivity between digital devices (phones, connected cars and homes), people and a city's physical infrastructure, intended to cut costs and improve sustainability.

Smart city and region investments can trigger a robust cycle of economic growth by unlocking savings and attracting businesses, residents, and talent, according to a benchmarking report of 136 cities from ESI ThoughtLab. The "catalytic impacts" associated with becoming a smarter city have the potential to increase GDP per capita by as much as 21 per cent and population growth by 13 per cent over the next five years for cities beginning their smart city journey.

This is no longer a sci-fi film script. Cities and regions are increasingly underpinned by technology in data ecosystems and advances in wireless networks and the Internet of Things (IoT). Smart regions have already gone beyond an interesting optional extra for politicians and planners to trial; they are a requirement to effectively service the population.

The initial experiments in this area focused on linking individual data sets to solve a limited challenge, but breakthrough advance comes with connecting a broad range of data sets and sources to resolve large, complex challenges.

We at Fujitsu are committed to the Sustainable Development Goals (SDGs) of the UN. There is no fundamental reason we can't use these capabilities to cut congestion, minimize CO2 emissions and pollution, slash energy consumption, streamline waste management, and even improve air quality with help from the IoT.

There is also the potential to help address the challenges of interlocked rural areas with their diminishing and aging populations. More elderly people in a population creates distinct pressures on transport systems, which need to be reconfigured to permit autonomous, barrier-free, on-demand services, such as Deutsche Bahn's ioki.

At the top level, the potential gains are enormous. A 2019 report on the economic development of smart cities estimates the concept could boost the economic development of global cities by more than 5%, delivering at least $20 trillion in additional economic benefits by 2026.[6]

However, just putting a monetary value on the benefits is missing the point. Although based on connecting innovative technologies in mobility, energy and data management, the smart region concept has now developed from a pure technology and infrastructure topic to a social concept of citizen involvement, collaboration and co-creation. To have a meaningful future, it is vital that smart regions benefit people, not just cities. Practicing human-centricity and civic-participation is central.

6. Role of Smart Cities for Economic Development.

Combinatorial optimization and the opportunity to enhance mobility

The main challenge facing smart regions today is that the potential on offer from data and technology is not being fully harnessed. This is because smart region initiatives often suffer from constrained ambitions. They are often limited to a small number of potential users, seeking unambitious benefits or based on a single data set or technology.

There are many reasons for this, but one is the sheer complexity of the task.

Consider one of the most well-known examples of this type of conundrum. The travelling salesperson problem. When a salesperson must visit several cities and then return to the original city, which order of visits minimizes the salesperson's total travelling distance? If the number of cities is five, there are 120 combinations. However, if the number of cities is 30, the number of combinations jump to 10 quadrillion x 10 quadrillion.

Finding the best combination from among multiple choices by evaluating the results of the possible combinations is termed combinatorial optimization.

> "The travelling salesperson problem is an issue that is a key conundrum for 80% of organizations.[7]"

When it comes to the cities and regions of today, the unique needs of the people, the landscape, current services and any manner of factor will play its part. And every city will be different.

Imagine the potential scale of a region-wide data set and then the task of finding meaningful, actionable interrelationships with other, equally large data sets – including consolidating different data-formats and creating suitable APIs. Then consider processing that vast amount of information to extract the optimal next-action and doing that sufficiently quickly to make a difference that improves outcomes in a meaningful way. And then imagine recalculating everything instantly to take account of the changing situation on the ground, including the adjustments you have just implemented. Let alone the challenge to overcome data-silos and to encourage a huge variety of stakeholders sharing their data – this requires a fundamental cultural shift and a new mindset.

Solving this problem through combinatorial optimization can be extremely challenging. With such a large quantity of combinations, it takes an enormous amount of time for classical computers to solve these problems with their brute-force approach.

Confronted with this seemingly unmanageable tangle of combinations, clearly beyond the capabilities of conventional computing, new initiatives are now taking place based on the emerging classes of quantum and quantum-inspired computing.

Fujitsu has worked with the Hamburg Port Authority to cut traffic congestion and speed up journey times by optimizing traffic light sequencing in the port area and on roads into the city of Hamburg. It has also enabled modelling for Japan Post for delivery truck fleet reduction in Tokyo.

As these examples show, quantum and quantum-inspired computing isn't just focused on the future. The capabilities are being harnessed today. Solving traffic flows and reducing congestion is one of the top two reasons for the application of quantum-inspired technology.[8]

Fujitsu, for example, is now becoming a Future Mobility Accelerator, using and embedding the Digital Annealer platform and associated Quantum-Inspired Optimization Services for the advantage of business critical combinatorial optimization.

The technology bridges the gap to the quantum world and sifts through a multitude of options so complex they are beyond conventional computers – then finds the best possible operational decision. The process is fast, low-risk and results-orientated – in other words, transformational. For MaaS to be useful it needs to be real-time or near real-time. This will involve a huge volume of calculations, ensuring that always optimal Quantum-Inspired Optimization Services is essential.

7. A commissioned study conducted by Forrester Consulting on behalf of Fujitsu, May 2020.
8. 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.

Optimizing towards smart mobility – becoming always optimal

Cities and regions are alive. They continue to grow, evolve, and move with (or sometimes against) the needs of their residents. What was once the best course of action, may now prove to be inefficient and ineffective.

The use of quantum-inspired computing for combinatorial optimization gives you the ability to determine the optimal solution to large-scale, complex problems by searching through quintillions of options in seconds. But it also provides the opportunity to re-optimize as often as required. We term this "always optimal".

For smart cities and regions this promises greater efficiency, flexibility and sustainability, as well as increased trust from citizens and residents. In many cases, we're getting closer to smart, efficient and sustainable cities. Becoming always optimal can provide the essential next step.

4 in 5 business leaders believe that quantum-inspired computing and combinatorial optimization could open the door to radical new possibilities, while 82% believe it would greatly benefit citizens.[9]

Ensuring optimal services

The pressure for a new way of organizing mobility has been growing for some time. If the pace of change sometimes feels too slow for the magnitude of the challenge, the recent pandemic shows how easily our assumptions, needs and solutions can be ruptured. What exactly is the correct balance today between mobility for a physical presence and digital connectivity for a virtual presence? How will people's feelings about public transport change when it can also be perceived as a health risk?

When it comes to reconfiguration, outside of a few utopian experiments, no one starts planning new Smart Region mobility solutions from a blank canvas. The task is to optimize what is already there.

That infrastructure will not be optimal for the task ahead. It was designed to shift hundreds of thousands of people into city centers for commuting or leisure, or to bypass cities altogether to avoid congestion and pollution. Within a typical urban area too, the infrastructure sometimes seems to have evolved in a way not designed for humans. Between 25% and 40% of a city's topography is comprised of roads, according to Gil Penalosa of urban reform group 8 80 Cities[10] – and for the last century virtually all of that has been given over to cars and trucks. That is a massive public space overhead, with citizens now increasingly questioning the right of the car to "own" it. Imagine if 40% of every city suddenly became available for Human-Centric mobility – walking, bikes, electric scooters - and leisure.

"4 in 5 business leaders believe that quantum-inspired computing and combinatorial optimization could open the door to radical new possibilities, while 82% believe it would greatly benefit individuals."

People are trying to find solutions. In the pre-pandemic world, before the idea of cutting cars and trucks out of the equation seemed politically feasible, there was already a pronounced shift away from private vehicle usage towards car sharing technologies, such as Journify in Spain or Zipcar. As Carlo Ratti, Director of MIT's Senseable Lab, notes, "cars are idle 95% of the time", meaning that every shared car could effectively replace between 10-30 privately owned cars. Self-driving vehicles also might make vehicle-usage more efficient, creating a city with up to one-fifth of the number of cars in use today, although MIT researchers also acknowledge the opposite outcome is possible.[11]

A cocktail of environmental, health and mental well-being issues are forcing a radical change of agenda. People are increasingly unwilling to tolerate the mobility overhead of the road transport sector, which account for 72% of the CO2 transport related emissions in the EU.[12] In terms of traffc congestion, in Europe every year nearly 100 billion Euros, or 1% of the EU's GDP, are lost to the European economy as a result of this phenomenon.[13]

Transport is responsible for nearly 30% of the EU's total CO2 emissions, of which 72% comes from road transportation. As part of efforts to reduce CO2 emissions, the EU has set a goal of reducing emissions from transport by 60% by 2050 compared to 1990 levels.

9. 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.
10. https://www.bbc.co.uk/news/av/business-52670597/coronavirus-lockdown-is-opportunity-of-a-lifetime-for-bike-lanes
11. http://senseable.mit.edu/papers/pdf/20180727_Duarte-Ratti_ImpactAutonomousVehicles_JUT.pdf
12. https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics
13. Managing Urban Freight to Smart City Logistics Networks, ibid

Optimizing the first and last mile

In the public mobility space, often it is the 'first mile' and the 'last mile' (i.e. getting to and from the main transport hubs) that cause the greatest difficulty. There might be a good, regular, fast train connection from a suburban town to the urban center, but if it takes 45 minutes or more just to get to the station, and the same again at the end of the day, that's simply adding too much time to the total journey.

This lack of integration between modes of transport often forces people to select private cars as the fastest and cheapest option. Improving citizens' experience in the first and last mile has the benefit of reducing the number of private cars heading into a city or travelling within it. This means adjusting the entire existing mobility infrastructure system to reduce car traffic and support pedestrians, bikes and public transport. It means creating real options to interconnect all the different mobility options, such as walking, bikes, e-scooters, bike and car sharing platforms, trams, metro, buses, trains, cars. It's a long list. Mobility stations which integrate Park & Ride options for private cars are an integral part for connecting different modes of transport.

Citizens stand to benefit financially from optimization, which is one way to encourage people to use intermodal mobility apps. By demonstrating time savings, more convenience and flexibility, as well as smarter, greener modes of transport (such as cycling and electric car sharing), and technologies that make journeys more efficient (such as Waze and Citymapper), people will save both time and money.

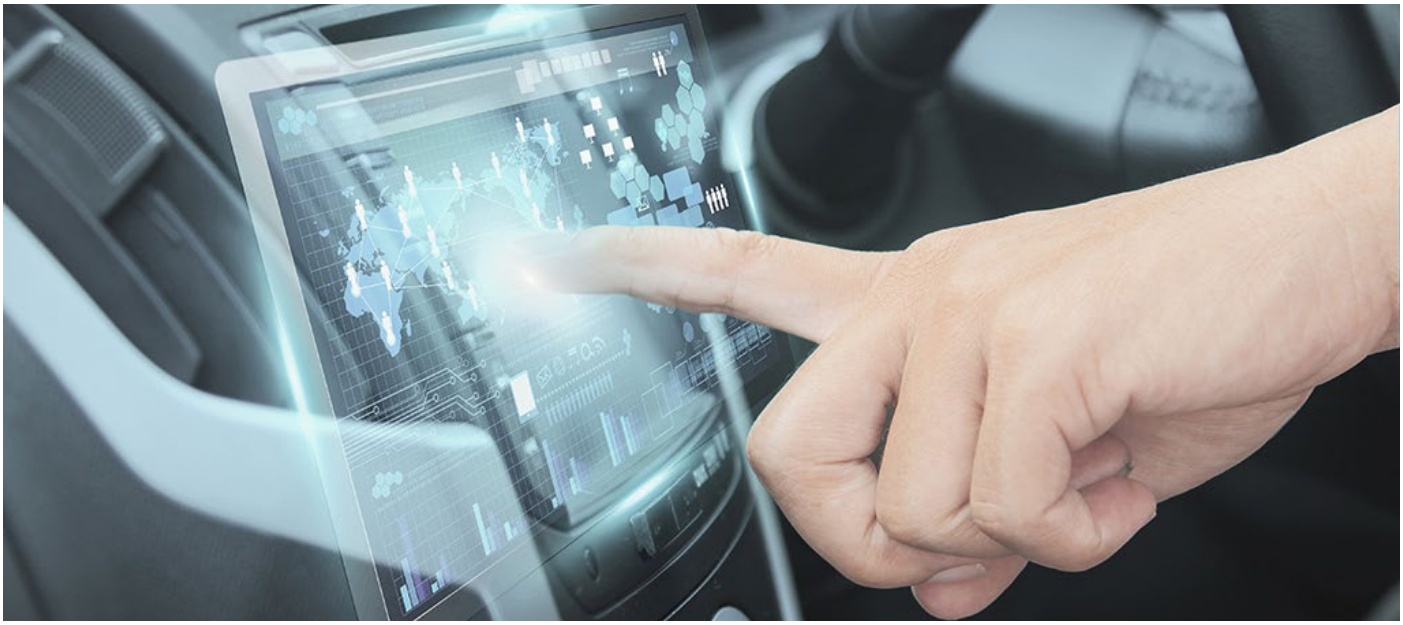
However, trust is a vital component too. Creating these options is a function of information and then optimization of the choices for hundreds of thousands of uses so that each citizen can be confident that they will not be routed onto a new bottleneck created by the mobility optimization app.

Optimization of delivery services

In terms of transport of commercial goods, there is massive scope for mobility optimization using services such as Fujitsu's Mobility Accelerator. On average, in the EU in 2018, 12.3 % of road freight journeys in international transport were performed by empty vehicles[14] and in 2015 24% of goods vehicles operated empty. Smaller vehicles had an average load capacity of just 57%. By addressing these inefficiencies, policymakers and private companies have an enormous potential upside: a 30% increase in effciency would create an estimated economic value of 22 billion euro.[15]

Recently, we have seen explosive growth in home delivery services due to the rise of online shopping and peer-to-peer marketplace transactions between individuals. But this is problematic for the logistic sector. Significantly more workers are required to fulfill small-lot home deliveries, and food deliveries require a complicated mix of ambient, cool and frozen storage capabilities, making managing costs to keep healthy margins a challenge. Delivering goods to a destination also requires a complex arrangement that connects the trunk-line logistics network (base to base) with the "last mile" transport (base to final destination). Innovations such as platooning of autonomous trucks will allow the trunk-line networks to carry large a quantity of cargo more efficiently. At the logistics base, the items can then be transferred to a drone, a self-driving delivery truck, or to another vehicle for the last mile. This will enable the transporting of goods with minimal human involvement.

What will happen when the entire distribution process is automated? We will be able to collect real-time data about the exact location of goods as well as the detailed status of system operation throughout the end-to-end delivery processes. This data will be analyzed by AI and a new type of computers using quantum principles to optimize complex end-to-end delivery operations.



14. https://ec.europa.eu/eurostat/statistics-explained/index.php/Road_freight_transport_by_journey_characteristics#Average_vehicle_loads
15. Managing Urban Freight to Smart City Logistics Networks, ibid

The need to be always optimal is more than a financial cost/benefit calculation

Because the potential savings from smart region optimization are so eye-watering, there is a risk that we look at the benefits in purely economic terms, from the top down. The perspective of the individual citizen (or someone visiting the region) is just as important - possibly more so, as it is individuals who make decisions about behavior.

If we think about mobility in the widest context, for example, to include aspects of urban road usage such as garbage collection, there are all sorts of ways that quantum-inspired optimization - and the sharing of the data that results in those optimizations – could change city life for the better:

- What if we could optimize waste collection, by identifying and cutting out stops where bins are still nearly empty, and take garbage trucks off the roads at school times? How would that improve traffic flow and help reduce accidents?
- What if people could get a day-specific route suggestion to minimize congestion, combining inter-modal connections such as car, park and ride, train, bike?
- What if traffic lights gave priority to pedestrians, bikes and public transport, or to the prevailing traffic flow for the time of day?
- Recognizing that personal car journeys are unlikely to suddenly cease, what if people know where they are most likely to find free parking spots when they arrive?
- What if traffic lights could "get informed" about arriving emergency cars and adjust the lights so that crossings can be cleared more easily?

As with travel route optimization, these initiatives rely on presenting transparent, trustable data to the citizen. A scheme in Seattle, the Trash Track project, shows how sharing information can raise awareness and stimulate behavioral change, leading to greater civic climate action. The project attaches tags to waste and then gives citizens the capacity to 'follow' it as it moves through the city's street sanitation system. Many participants in the project say that watching trash move from their home directly to landfill has helped them realize that their habits, such as buying plastic water bottles, result in direct environmental degradation.

The benefits of an optimized city are that it becomes faster to navigate, safer and more livable for people. It also increases cities' competitiveness and potential to create wealth by attracting a talent pool for startups and larger businesses alike.

Always optimal provides essential flexibility for when challenges hit

Optimizing cities for everyday life is one thing. Does optimization have a role to play when challenges hit?

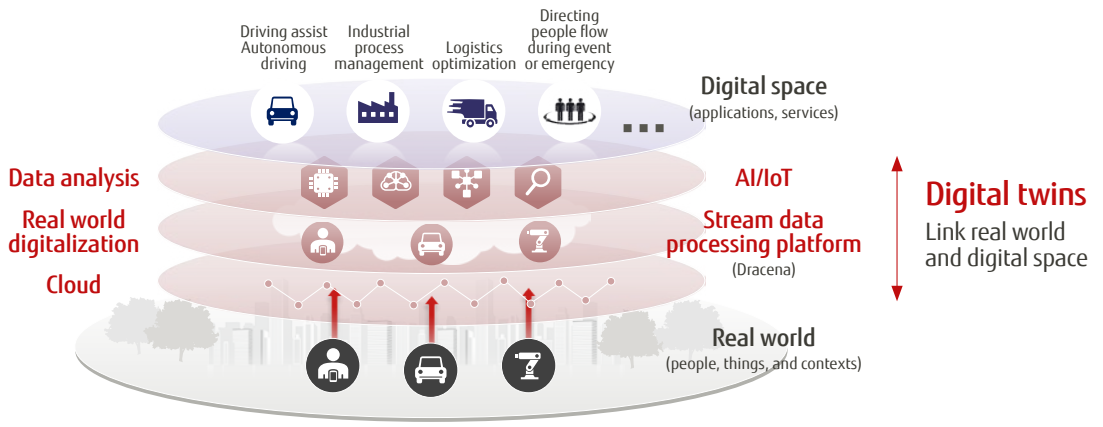
These could be caused by natural phenomena, such as hurricanes, snow, floods and earthquakes, or human-caused incidents, such as accidents or terrorism. The objective is to ensure the flow of life gets back on track quickly by rerouting people quickly and safely, quite possibly when the disturbance or obstacle is still in place, in as short a time as possible to avoid knock on impacts.

For example, if a train is delayed it can have knock-on effects for the timetable for the rest of the day – harming the citizen's onward journey and therefore experience. However, in a smart environment an optimal solution can be re-established in minutes.

Any optimization capability that aspires to deliver real-world improvements for citizens will need the speed to handle optimization assessments on massively large data sets to be able to respond immediately to major disruption. This combination of speed and scale can only be achieved with quantum or quantum-inspired computing and the ability to be always optimal.

Once in place, the aim is for predicative optimization that triggers early intervention, by slowing the flow of traffic to reduce bottlenecks and NOx emissions or dynamically re-routing trains when a signaling fault occurs.

We're creating a new tech ecosystem - the relevance of Quantum-Inspired, 5G, AI, IoT in the solution and how they will help



The ongoing challenges posed by increasingly complex infrastructures

Complexity is not suddenly going to disappear from our lives. Quite the opposite is more likely – as the number of people living in cities grows still larger, citizens' needs for flexibility and conveniences rises, and as data proliferates, the options available to us become exponentially larger.

Nor is it likely that any single actor in government or business can wave a wand and resolve this complexity. Optimizing increasingly complex infrastructures will work best when public and private sectors come together within the data ecosystem – the whole is greater than the parts.

In 2018, a pick-up/drop-off service was field-tested using idle vehicles of residents in Japan's Date City in Fukushima Prefecture. This service, developed with the participation of the local administration, uses Fujitsu's location information cloud platform service. It identifies a vehicle based on the availability and current location of local resident drivers, as well as the intended destinations of each user. The service makes effective use of idle vehicles while offering an efficient and safe pick-up/drop-off service for residents. This may evolve into a new type of sustainable mobility that does not depend on existing public transport infrastructure and has the potential to dramatically reduce costs that individuals and the community must bear, delivering more equitable access to transport.

When cross-sector co-creation like this works, the benefits are loud and clear. A recent report found that even in relatively unsophisticated smart cities mobile apps can save riders 10.3 hours annually per capita in waiting time and increase transit ridership, while smart traffic signals can offer per capita annual personal time savings of 9.7 hours and fuel savings of 3.3 gallons [15 liters] per capita.

The ever-changing challenge of complex human needs

People's needs and expectations evolve and grow as well. Earlier we looked at the issues created in mobility by the 'first and last mile', but these can be particularly acute for people with disabilities. For example someone travelling by wheelchair from one suburban address in a city region to another via the city and home again in a day sometimes requires military style planning by the wheelchair user and what happens if things go wrong?

Patrick Stephenson, Director of Innovation and Health, who is Fujitsu's UK employee disability network Exec Sponsor is passionate that mobility needs to be inclusive for all of society. With current technology, pinpointing the optimum journey is a time-consuming and often frustrating exercise for a wheelchair user. With a quantum-inspired solution, on the other hand, this would be a matter of seconds, including the ability to re-optimize the journey if circumstances change. "We need to make smart regions inclusive by design," says Patrick, "either for people without a disability, who perhaps want to ride their bike to work, and for people with both physical and hidden disabilities. Both are complex use cases to simulate and optimize in a city. Ultimately, making progress comes down to the priorities of the city administration and better understanding citizens' needs."

Pressure is growing on politicians and administrators to find new ways of operating in cities. The growing backlash against the way cars have been allowed to take over cities, discussed earlier, is just one. Responses are taking many different forms, including greater emphasis on cycling lanes and public transport.

Scrutiny of air quality is another, with transport often the main cause of urban air pollution. 'Breathe London', which claims to be the world's most advanced and comprehensive network of air quality monitors, launched in 2019 to investigate and improve the quality of the UK capital's toxic air. The initiative uses a range of fixed and mobile sensors to build up a real-time, hyperlocal image of London's air quality, taking readings approximately every 30 meters at tens of thousands of locations. The data generated by this new network will be available for the public to view on an interactive online map on the Breathe London website. Such initiatives are crucial and interwoven with new mobility: they show us if those concepts contribute significantly to sustainability goals, such as better air quality.

A 2018 report benchmarking 136 cities by ESI ThoughtLab, found that city leaders see the environment as the top challenge to address through smart city programs, and improved public safety and health as the main benefits. For example, environment investments in smart grid technology generate annual per capita savings of $229.86 and reduce CO2 emissions by over 100kg per person annually, even in cities that are just beginning their moves towards being smart. It also found that pollution reduction has positive effects on health, particularly for sufferers of chronic obstructive pulmonary disease (COPD), for whom treatment with smart public health technologies such as telemedicine can reduce annual healthcare costs per capita by $24.83.

The journey to becoming always optimal: opening public data for development of mobility solutions

The smart city future

Unsurprisingly, with so many potential financial benefits and public goods on offer, administrations and cities around the world are ramping up their smart city and smart region capabilities, with mobility often in the forefront.

They are expanding their use of data about everything from transport to movement of people, energy usage, crime, infrastructure, weather etc. The collection, storage, analysis and use of this type of data is not new, but smart technologies (such as data analytics tools, artificial intelligence, IoT sensors, apps or tech-enabled services) enable it to happen at a far greater speed and scale than ever before.

The benchmarking report referred to already[16] shows that almost all cities will draw on IoT and real-time data by 2021. Predictive data, which is already employed by about 40 per cent of cities, will rise in usage by 63 per cent. As you would expect, the report finds that spending is rising in step: as cities move up the smart city maturity curve, so does their spending on smart city projects as a proportion of their operating and capital budgets.

By benefiting society and environment for citizens, we are indirectly benefiting businesses in our city-regions. For example, giving talent reason to want to live in the area. Citizens themselves fuel smart city development, saving each other money through exchange apps and platforms founded on the sharing/circular economy concept - such as Olio and Depop in the UK, Wallapop in Barcelona, and Jaspr in Berlin.

How open data can enhance mobility and smart city initiatives

We can take this a step further and open public data for use by citizens and businesses to develop innovative products and services themselves, creating a virtuous circle that is enhancing a city region.

According to several studies, there is a substantial economic benefit to adopting open data. In Germany, it has been estimated that the national economy could be increased by at least €12 billion per year over the period to 2026 (Konrad Adenauer Foundation 2016) or by 10 billion euros for transport data alone in the EU28+ in the period to 2020 (European Commission 2015).[17]

Understandably, the EU has recognized the significance of open data for intermodal transport. To promote the development of intelligent transport systems (ITS) it has created an ITS directive and regulations, which stipulate there should be a 'national access point' for mobility data in every EU member state. In Germany, the Mobilitäts Daten Marktplatz (MDM) performs that role.

Open Data can facilitate innovations and new business models, for example the development of information apps for public transport users. The German Federal Ministry of Transport and Digital Infrastructure (BMVI) acknowledges the federal authorities will "benefit from open data through more efficient internal processes as well as a higher degree of public confidence, who will enjoy greater transparency and more possibilities of participation." Indeed, municipalities in Germany are often required by law when developing new mobility concepts to work with open data.

Elsewhere, Barcelona has already implemented a radical open data policy in relation to smart city initiatives. In the UK, Bristol is Open, is driving cross-society collaboration, knowledge, data sharing and analytics management across the digital landscape to deliver services to the public authorities, residents, businesses, students and visitors to Bristol and the West of England.

Connectivity between citizens and governments is more fluid in the smart city, where feedback apps, such as Ctzen Inc, allow citizens to report incidents and issues in their local area to the municipality through their smartphones, and civic forums, like 'Better Rekjavik', give citizens a direct line of communication with their local authority, improving citizen-institution relations and social cohesion.

Smart city initiatives that prioritize people - both residents and visitors – primarily will improve quality of life for everyone in the city. More efficient transport services, smart parking apps, digitalized government services, and even simple things like public Wi-Fi and smart street furniture with charging points, for example, often have a direct positive impact on citizens' lives because they are created specifically with people's needs and experiences in mind.

16. https://www.smartcitiesworld.net/news/news/how-smart-city-investment-can-unlock-economic-growth-3566
17. https://www.bmvi.de/SharedDocs/EN/Articles/DG/open-data.html

A smart city relies on a human-centric intelligent society and enables its citizens to live and work smarter, bringing people together with data and physical things. It needs to focus on the pains and needs of citizens and business, not create a digital 'field of dreams' and expect human behavior to conform to a sterile digital environment.

It must be human centric, organic and data-driven to be sustainable and resilient, requiring co-creation and enormous amounts of data collected every second of the day with what appears to be an infinite array of possible outcomes. Optimizing city life by leveraging this plenitude of data will make for a better life for urban and regional citizens as well as for a sustainable future for the upcoming generations.

Co-creating with Fujitsu as a Future Mobility Accelerator supports you in enabling your Always Optimal smart region. Together we will build the future of how people navigate through our regions and cities. Contact us today.

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