

FUJITSU

Fujitsu Future Insights
**The Future of
Mobility**

shaping tomorrow with you

Foreword:

Future Mobility



Jack is a manager at a manufacturing company with its headquarters in a metropolitan area. He lives together with his wife Anna, daughter Lucy, and son Oliver in the suburbs and he has a one-hour commute to and from work.

Jack usually works from home, but today happens to be a commuting day for him. From his registered pick-up/drop-off point, he boards a self-driving bus to a location nearer his company, then changes to a different self-driving bus that circles the vicinity of his office. His AI agent arranges a Robo-Taxi to take him to a client meeting scheduled for the afternoon. The taxi conveniently arrives just as he exits the building. With the destination already set, the Robo-Taxi begins moving autonomously. While en route, Jack accesses his company's conference system from a device fitted inside the taxi and conducts a meeting with his team members. Since the road system is designed to dynam-



cally optimize traffic and autonomous vehicles communicate with each other, the taxi is able to travel smoothly without encountering traffic jams. After the client meeting, Jack's AI agent recommends the train is the quickest way for him to get home and directs him to a nearby next-generation train station.

After authenticating himself with his hand, Jack boards the train. Shortly, the train stops automatically at his destination, and his fare is deducted in real time.

On Sunday morning, the family leaves for a seaside town Lucy has wanted to visit for some time. The reserved share car arrives at their house, the family get in and Jack logs into his account to receive information on points of interest to see during the journey and at the destination. The car drives autonomously and the family talk happily, without anyone having to pay attention to the road. Arriving at the destination at noon, the family



leave the car and follow a walking trail to a restaurant they wanted to visit. During the walk, Oliver accidentally runs onto the road and into the path of a moving vehicle, but the vehicle stops instantly, so any harm is avoided. After enjoying a swim in the sea, the family arrange for another share car to take them to their home. The family has had a fun-filled day out, but is not at all tired from the traveling.

Jack's parents are elderly and live in a rural town which is about an hour away by car from his home. They have spent their later years in a community surrounded by countryside. After driving became too difficult, they initially relied on buses for shopping and hospital visits. The buses come only three times a day. However, things have changed for the better. There is now a remote healthcare system in place, so the couple do not need to visit the hospital every time they need to speak to a doctor. Even better, when they do need face to face care, the hospital sends a

self-driving car to pick them up from their house. And, thanks to the VR-based online supermarket, they can purchase everything they need as if visiting a real store but buying from the comfort of their own home.

Tonight, Jack's parents are enjoying dinner with their friends. The restaurant is a short 15-minute walk away, however a two-seater personal self-driving mobility vehicle¹ takes them there. They all enjoy a wonderful time together, and after returning home, they receive a video-call from their grandchildren. They said "we will visit you next week". So they instantly make a reservation for the autonomous vehicle to pick up the grandchildren. They look forward to seeing their grandchildren.

¹ A "personal mobility device" is a compact mobile support vehicle with capacity for one or two passengers. It is a personal movement tool developed to fill a niche between pedestrians and existing vehicles. It has been proposed as a form of transport distinct from conventional automobiles and is aimed at reducing per capita energy consumption during the process of moving people.

Fujitsu Future Insights The Future of Mobility First edition March, 2019

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Fujitsu Future Insights

Every year, Fujitsu publishes the Fujitsu Technology and Service Vision. This is the company's global vision for the future, looking at how businesses and society will use technologies to drive innovation. Fujitsu Future Insights looks at specific fields in order to provide a deeper analysis of challenges and the impact of technologies. It also offers suggestions for possible future scenarios and strategies related to those fields.

[Website]

Fujitsu Technology and Service Vision

<http://www.fujitsu.com/vision/>

Fujitsu Future Insights The Future of Mobility

<https://www.fujitsu.com/global/vision/insights/wp2/>

Mobility for Humanity

Why do people move?

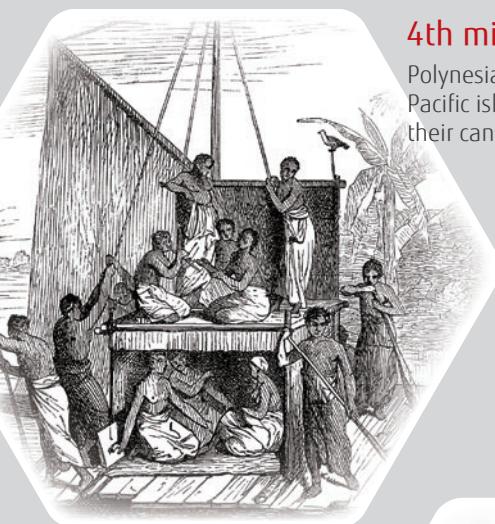
Humanity emerged in Africa around 200,000 years ago. There are various theories as to when humans actually migrated from Africa to elsewhere in the world. But no other animal has spread as far and wide, and because of this mankind is sometimes referred to as "homo mobilitus."

Even after reaching the corners of the earth, human beings have remained on the move. Around the 4th millennium BC, the progressive parching of the northern Sahara began to push inhabitants further south. Meanwhile, Polynesians living in Southeast Asia migrated to various Pacific islands by making use of their canoeing and navigational skills. In addition to such techniques, humans brought

livestock breeding to various regions and crop farming by slash-and-burn practices.

From the end of the 4th century to the beginning of the 6th century there was a great migration of Germanic people. This migration was possibly to escape the encroachment of Asian nomadic horsemen moving west, but another view is that the shortage of arable land was a key underlying factor.

The 15th through to 17th centuries represented the age of exploration. This was sparked by various factors, including advances in marine navigation techniques, the growing demand for spices, and the spread of missionaries. What were the underlying forces driving these waves of migration? Could it be a fundamental characteristic of human nature? Humans have an unceasing curiosity for the unknown and find joy in experiencing new realities. Human movement has led to the creation and development



4th millennium BC

Polynesians migrated to various Pacific islands by making use of their canoeing and navigational skills.



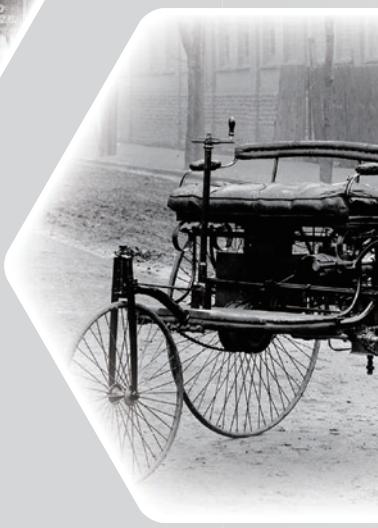
1825

Locomotion No.1, a steam locomotive built by George Stephenson which became the first locomotive to run on a public railway.



15th through to 17th centuries

Christopher Columbus discovered America in 1492.



of new civilizations, cultures, and industries. Experience gained from each movement drives people toward the next movement.

There are many reasons why people move. For example, changes in the natural environment, political issues, acquisition of food, and the pursuit of economic opportunities. Perhaps curiosity has also been a fundamental motivation, as people seek to visit places they don't know, gain new experiences, and meet new people.

Advanced mode of transportation and their side effects

In 1814, a steam locomotive built by George Stephenson made its first successful run, and in 1885 Daimler and Benz developed the first automobile. Then, in 1903, the Wright brothers were

the first to launch a powered aircraft. These innovations have led to revolutions in mobility and laid the groundwork for the transportation systems we enjoy today. Transportation networks have gradually evolved into key components of urban infrastructure. The advances in automobiles, railways, aircraft, and other modes of transport have enabled more people than ever to travel faster, further, and with greater safety. These advances have also spurred economic and social progress, giving us greater access to experiences and knowledge, and enriching our lives.

But there have been costs too. These include the growing environmental impact of carbon dioxide emissions from automobiles and aircraft, as well as injuries and deaths from traffic accidents, and chronic traffic congestion. Mobility has also presented new social challenges, like driving the spread of epidemics.

There are significant gaps in the advancement of mobil-

1903

The Wright brothers were the first to launch a powered aircraft.



1885

Daimler and Benz developed the first automobile.



ity between developed and developing countries, as well as between cities and unpopulated areas. For example, it does not make economic sense to provide public transportation services in unpopulated areas where there are few passengers. This leads to the issue of "mobile refugees". This will become a more serious problem in the future, due to aging populations in many countries.

Human Centric Mobility

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 is experiencing a radical shift to *connected, autonomous, sharing and electricity-powered* modes of vehicles.

What do these changes mean to us? What people really need is not necessarily a *product* in the form of an automobile, but the *experience value of mobility*, allowing movement from Point A to Point B in the most comfortable and efficient manner.

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—automobile, railway, taxi, electric utilities, and the like—will form new autonomous, distributed ecosystems connected via digital technologies, together creating a human-centric mobility society. 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. This is because start-up companies and enterprises from completely unrelated industries will now be able to enter the new mobility services sector.

In the Fujitsu Technology and Service Vision we explain how digital technologies will transform business and society and how we can co-create wide-ranging human-centric value in the future. And in this report, Fujitsu Future Insights The Future of Mobility, we introduce the key emerging megatrends of mobility and make recommendations for realizing a human-centric mobility society.



Megatrends of Mobility



By creating diversified mobility services, we will be able to realize sustainable economic growth, enabling us to solve difficult societal issues. Let's take a look at the six emerging megatrends of mobility.



Urbanization of Mobility

Re-invention of cities by mobility



Urbanization of Mobility

Re-invention of cities by mobility

In cities there are multiple modes of transport available, such as private cars, taxis, buses, and trains. However, increasing demand for transport leads to problems such as traffic congestion. The elimination of traffic congestion has become an important challenge.

There are other urban transport problems too. These include imbalance of demand for human movement and supply of various transport modes at the local level. We have already seen a 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. Though these help enhance mobility experience, it is still difficult for many people to move comfortably within cities.

In the near future, we will see a substantial shift from vehicle ownership to shared usage, together with the spread of connected cars and self-driving vehicles. Automobiles will be integrated into the public transportation service system—along with buses and trains—to form an integral part of urban infrastructure. This will shape a new society. All mobility services can be orchestrated using digital information in an integrated manner. This will allow people to freely select the most suitable combinations of services through networks, anytime and anywhere.



Democratization of Mobility

Mobility that everyone can use and provide



"Robotization" of Logistics

Mobility without human intervention



Mobility as Experience

Making movement more fun and appealing



Moving "Without Moving"

Mobility that replaces physical movement



Mobility in Natural Ecosystems

Mobility coexisting with our planet



Robo-Taxis and ride-sharing using autonomous-driving technology will enable on-demand services that anyone can use whenever they want to get around. In addition, mobility management—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. Some cities have already begun field testing and implementing public transport systems that feature modal mixes² 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. New mobility services will lift the traditional constraints for cities. These services will significantly expand the area that anyone can easily move around. This will allow new designs for both downtown and suburban areas, as well as working and living areas. New mobility

services will connect a variety of urban activities, driving more sustainable cities.



Democratization of Mobility

Mobility that everyone can use and provide

Currently, people who cannot own and maintain a car, and those who cannot drive cars themselves must rely on public transportation. Meanwhile, in unpopulated areas, developing countries, and other economically undeveloped regions it is difficult to establish and maintain transportation infrastructure, making it harder to provide adequate public transport services. This has led to a disparity between people and between regions. Mobility services of the future are expected to address this disparity.

For example, self-driving technology enables even elderly people who are not confident drivers to use cars. As automobile-based public transport and ride-sharing services become more mainstream, people will have access to inexpensive, on-demand modes of transport without owning cars. For those who still want to have their own cars, relatively inexpensive personal mobility will fit.

Robo-Taxis and ride-sharing services supported by integrated operation management systems will allow people to access

² "Modal mix" refers to a mixture of transportation modes created through cooperation between multiple transportation organizations in a way that highlights the features of each mode. It places particular emphasis on strengthening touch-points between automobiles/trucks and railways/shipping. The term modal mix was put forward by Japan's Ministry of Transport (currently Ministry of Land, Infrastructure, Transport and Tourism).

affordable mobility options even in places with low economic viability, such as sparsely populated areas.

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 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 local residents. This may evolve into a new type of sustainable mobility that does not depend on existing public transport infrastructure.

In this way, mobility service has the potential to dramatically reduce costs that individuals and the community must bear, delivering more equitable access to transport.

The "democratization" of mobility benefits not only those who receive the service but also those who provide it. Thanks to digital transformation, mobility as a service is being unbundled from vehicles as a hardware fixed asset. This will enable anyone to offer mobility services. For example, it is becoming easy for individuals to provide ride-sharing services using their own cars, or for large supermarkets to launch regional shuttle bus services.

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 anyone with a good idea and determination to carry it through can innovate.



"Robotization" of Logistics

Mobility without human intervention

The purpose of forming mobility ecosystems will not be limited to movement of people, but relates equally to movement of goods.

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, while managing costs to keep healthy margins is a challenge.

Delivering goods to a destination requires a complex arrangement that connects the trunk-line logistics network



(base to base) with the "last one mile" transport (base to final destination). Innovations such as platooning of autonomous trucks will allow the trunk-line networks to carry large 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.

In Japan, field tests of a semi-automated convoy truck system were conducted in 2018. A convoy of trucks from different manufacturers were connected via an integrated support system to maintain a consistent distance between the vehicles. The tests demonstrated the possibility of automated mass transportation of goods, even before the general availability of fully autonomous driving technologies. It is also expected to reduce road accidents as well as to address the serious issue of driver shortage in Japan.

For elderly people and those living in sparsely populated areas, new services are being introduced. Instead of people moving to destinations, the destinations move to the places where they live. For example, in-home medical care and mobile convenience stores. When self-driving vehicles become more mainstream, we may see an upsurge in mobile retail stores as well as mobile service providers.

What will happen when the entire distribution process will be 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.

It means both the physical process of goods delivery and the digital process of controlling the entire logistics chains are becoming autonomous. Field tests are already under way in various locations aimed at automating home delivery services.

Mobility as Experience

Making movement more fun and appealing

Many people like heading away on a holiday. Some enjoy going for a drive. Others want to have fun during their journey. For some people, the process of travel itself is the main purpose. Mobility services of the future will transform movement into a fun and appealing experience. For example, an AI agent installed in a car will make suggestions according to the owner's preferences, family size, mood, and location. Passengers will be able to





interact with the AI agent and experience the fun and attraction of the journey itself. Of course, people will still be able to enjoy the scenery and conversations without the driver having to hold the steering wheel and watch the road.

In a world where automobiles are connected to networks and autonomous vehicles release people from the need to drive, cars will become digital devices, much like SIM free smartphones. When getting into the car, you will first scan your ID, then the car adjusts its driving mode and set-up according to your preferences and give you recommendations. Just as with a smartphone, you will be able to select apps via a dashboard. By taking advantage of the features related to automobiles in this way, the experience becomes even more enjoyable. For safety reasons, only information services for entertainment or communication, are currently available in automobiles. However, after further developments in advanced safe-driving technologies and online in-vehicle software updates, we can expect the range of services to expand.

Moving "Without Moving" Mobility that replaces physical movement

As mentioned earlier, physical movement may be necessary in some cases, such as for visiting actual sites and meeting people,

but this is not always the case. Teleworking using videoconferencing technologies and playing games via social networks have already become commonplace. The future promises further advances in digital technologies, such as virtual reality (VR), augmented reality (AR), and next-generation computers that understand the five senses and emotions of people. By using such technologies, we will also have the opportunity to move virtually, beyond time and space constraints in addition to moving physically.

For example, everyone will be able to easily participate in an international conference, if it is held in a virtual space. You will also be able to receive treatment from medical specialists even if you reside in a remote area. Moreover, anyone on the planet will have access to advanced education online. People will be able to enjoy the experience of travel and shop together with friends at virtual stores, even if physical movement is difficult due to physical disability or other health conditions. People will even be able to remotely perform tasks under the sea or in outer space-places where it is extremely difficult to actually go. These are no longer mere dreams.

Creating a completely new world requires breakthrough thinking that combines both physical movement and virtual movement.



Mobility in Natural Ecosystems

Mobility coexisting with our planet

In return for developing a modern civilization, humans have created various environmental issues. Carbon dioxide emitted by automobiles and aircraft has a major impact on the worldwide environment. Global warming caused by carbon dioxide and other greenhouse gases represents an unparalleled crisis for human beings and other living creatures. At the current rate, it is predicted that sea levels will rise as much as 82 centimeters during this 21st century.

According to surveys conducted by the International Energy Agency and other authorities, the transportation sector accounted for 23% of total carbon dioxide emissions in 2012. Limiting transport-based emissions is considered one of the most important priorities for the sustainability of the planetary ecosystem.

Under these circumstances, the transport sector is forging ahead with its efforts to reduce carbon dioxide emissions. In addition to energy-efficient cars and eco-drive technologies supported by drive recorders, the future will bring progress in other areas. These include the proliferation of ride-sharing, the use of self-driving vehicles and mobility management to eliminate con-

gestion, the integration of seamless mobility services to promote multi-modal scenarios and other modality shifts. Together, these changes are expected to reduce carbon dioxide emissions from automobiles, which have the greatest environmental impact. One concrete example is the Environmentally Sustainable Transport (EST) initiative, which focuses on initiatives such as eco-commuting. Ultimately, we can achieve dramatic reductions in carbon dioxide emissions if we can replace automobiles with zero emission vehicles (ZEVs) that do not emit air pollutants. Many countries have set target dates to achieve a 100% ZEV rate for new car sales. They include India (by 2030) as well as the United Kingdom and France (by 2040).

The second-highest carbon dioxide emitters in the transport sector are aircraft, and the numbers of planes and flights are expected to continue growing into the future. Avinor, the state-owned Norwegian airport operator, has announced plans to completely switch to electric aircraft for all short-haul domestic flights by 2040. Major aircraft manufacturers are also working to develop hybrid airplanes.

By stepping up efforts to achieve zero emissions and ensure coexistence between mobility and the earth's natural ecosystems, humans will have truly sustainable mobility within their reach.

Fujitsu and the Future of Mobility

Focusing on the Areas of Collecting, Connecting, and Utilizing

As you have seen, we will have a variety of options to move from Point A to Point B. In addition, the future of mobility will be shaped by the organizations in various industries that form new ecosystems, linked by digital technologies, to co-create a human-centric mobility society. Based on its long-standing experience in ICT, Fujitsu is working to realize human-centric mobility in three areas: Collecting (collecting data), Connecting (connecting to networks), and Utilizing (leveraging data).

Collecting: Massive amounts of data will be generated when vehicles connect to a network. This will lead to a major challenge about how we can manage the distribution of this huge volume of data at a low cost, while increasing the speed of data processing. It is expected that the proportion of image data will rise significantly. To address this challenge, Fujitsu has developed a technology to compress and make image data generated by vehicles significantly lighter for transmission than conventional methods. Fujitsu has also realized a technology to allow vehicles

to store the raw data in a distributed manner and to enable a cloud data center to collect the data on-demand when needed. Together, these technologies enable a significant reduction in the costs for communicating and storing the data generated by vehicles. These technologies are also expected to help the development of new services that use data communication between vehicles and data centers. For example, these include new property and casualty insurance services as well as safe-driving assistance services.

Connecting: Leveraging the expertise gained from developing mobile phones for many years, Fujitsu will enable downloads and updates of vehicle software via wireless networks. Even in the event of a recall, users will be able to update their vehicle's software without visiting car dealers. Fujitsu also aims to ensure safer and secure mobility using technology that will enable vehicles in close proximity to communicate with each other via a wireless base station without backhauling to a datacenter.

Utilizing: Fujitsu is developing a digital twin platform for the mobility sector. This will enable the virtual modeling of things and events in the physical world, using data collected from vehicles and other external sensors. This technology will contribute to improving the quality of simulations and enhance

Fujitsu's Technologies Supporting Mobility Society



³ OTA (Over the Air) enables distribution of vehicle software, on-board security, map, and personal interest via wireless networks.

⁴ MEC (Multi-access Edge Computing) enables vehicles in close proximity to communicate with each other via a wireless base station without backhauling to a data center.



various functions of vehicles. These technologies will facilitate a rapid, high-precision evaluation of automobile quality during the development process. They will also lead to the provision of new services to support a mobility society, with the ultimate aim of creating accident-free, safe and sustainable societies.

The vast volumes of data collected from connected cars will be used in developing new services that extend beyond the traditional boundaries of industries. Fujitsu works together with customers and partners from a range of industries using AI and other advanced digital technologies to contribute to the creation of a more prosperous mobility society.

Human-centric principles for autonomous driving

A major consideration about autonomous vehicles is whether people will readily accept them in their everyday lives. How can people embrace and trust such a radical innovation that will lead to major changes in behaviors? Clear and extensive communica-

tions and education will therefore become increasingly important prior to rolling out self-driving vehicles in society.

It will also be important to develop necessary legislation and create rules for enabling this emerging mobility society. Government, industry and academia are currently working together to share ideas across industry sectors. Fujitsu is committed to collaborating with various stakeholders to build a new mobility society.

Co-creation is key

In the so-called Fourth Industrial Revolution, the auto industry and its adjacent industries are changing rapidly. Open innovation is a must-to-do to capture this opportunity. Innovative solutions and new services are co-created by organizations that hold different sets of expertise. Through co-creation with the mobility-related industries as well as diverse other industries, Fujitsu continues contributing to a sustainable mobility society that will enrich our lives.

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