Connected Cars: The Chance of a Lifetime for Industrial and Societal Reform

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1. Introduction

5G is a hot topic in the field of communications, and anticipation is increasing with the approach of the 2020 Olympics. Most people in the industry believe that powerful new 5G capabilities such as 4K/8K video and IoT connectivity will lead to creation of new businesses and will enrich all of our lives. However, there seems to be no real understanding of changes connected cars will bring to society in the near future. Awareness varies, with comments such as, "Why would cars need communication?", "Well, it will probably help reduce accidents," "Of course they will need to communicate if they are going to drive by themselves,", and "I guess cars need to connect for car sharing, but can't I just use the smartphone application?" Most people do not seem to think beyond that connecting will be a good thing.

"Connected, Autonomous, Shared/Service, Electric" (CASE) has been a popular key phrase in the media lately, and competition and collaboration with the ICT industry (largely the GAFAM companies) is shaking up the automobile industry and promises to inject it with new energy and vitality.

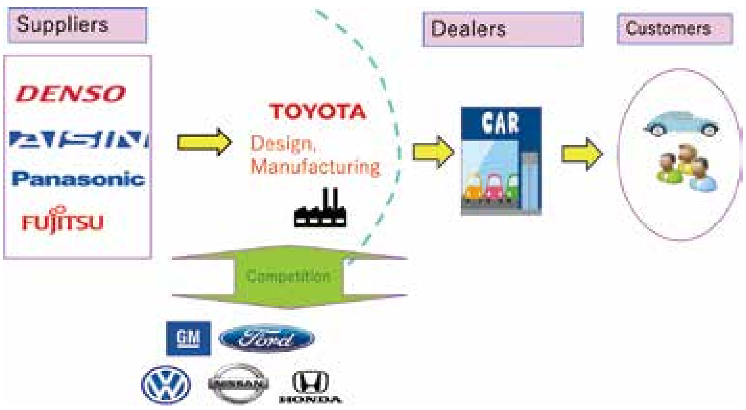
The author is convinced that the so-called digital transformation being discussed around the world ("Society 5.0" in Japan) will be triggered by connected cars even more than by 5G, and they will bring industrial and social reform and innovation over the coming ten years. The next few years will determine whether Japan can play a leading role in this new wave.

2. What is a Connected Car?

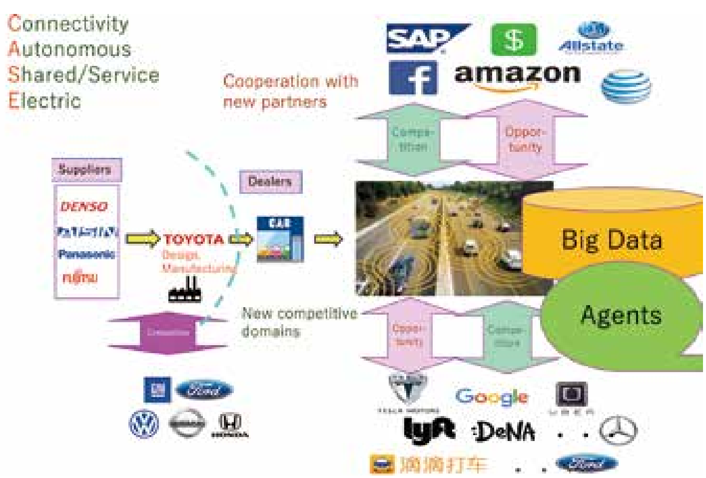
As you would expect, a "connected car" is a car that is connected. But this is not a passive thing, as the name may suggest. Most of the automobile industry has felt that "connecting" is more appropriate than being "connected to". Most images of connected cars so far have the vehicle in the center, making connections with other entities. This is a natural perception, given the 100-year history of the automobile industry, with OEMs holding the top position in the supply chain, as shown in Figure 1 (here, OEM refers to manufacturers that manufacture entire vehicles, such as Toyota. This is in contrast to the electronics sector, where OEMs are often subcontracted manufacturers).

However, connected cars are actually "cars that can accept connections." Already, many smartphones, PCs, IoT devices and other user devices are connected to the Internet, and there are computers and data centers performing tasks and providing services all over the world. These comprise a huge industry and social system. The truth is that connected cars are just a new entity that this existing network will connect to, and there will be no new network just for connected cars. Suppose, for the sake of argument, that an independent network was built for communication between self-driving vehicles. Even that were the case, many ICT businesses would encroach upon it, as shown in Figure 2.

■ **Figure 1: Current manufacturing in the automobile sector**



■ **Figure 2: The CASE era: Cooperation and competition among different sectors**



So, are connected cars to be just another new network user? The author thinks not, because in many aspects, such as price, functionality, industry structure, and role in society, they are very different from conventional network terminals.

3. Connected Cars: A powerful new force in the market

Consider price. Even light vehicles can cost a million yen, luxury vehicles can exceed tens of millions, and there are vehicles on the road worth over 100 million yen. Of course, they have a range of performance characteristics, but there are also elements such as navigation, entertainment and design, which are for comfort or to express human sentiments like individuality or social status. There are also many other important factors that differentiate automobiles, such as safety and environmental considerations. Smartphones and other existing terminals have no ability to move autonomously, but the basic functionality of automobiles is to move people and luggage, and when they are fully autonomous (Level 5), they will be able to move freely over a wide range and at high speed without a driver. The scale of the auto industry GDP is also several times that of the ICT industry.

So what sorts of capabilities will such connected cars have in the future? No one can predict accurately where these advances will lead, but we will focus on five new capabilities that connected cars are predicted to bring in the future, as follows. They are illustrated in Figure 3.

[New capability 1] Information processing power over 2000 times that of a PC

According to a Nikkei XTECH report[1], the processing power required to realize autonomous driving will be equivalent to 2,300 current PCs.

[New capability 2] 1 TB of non-volatile memory and large amounts of DRAM

According to a MONOist promotional report[2], 1 TB of flash memory will be needed to implement autonomous driving, including 256 GB for a dynamic map, and other aspects such as AI. Also including memory for other ordinary functionality, connected cars will require several times the memory of a current PC. Recent developments in memory technology and decreasing prices mean that the cost will no longer be a concern, so we can assume that connected cars will not be restricted by memory capacity.

[New capability 3] Highly reliable communication

The wireless communication requirements of connected cars are not yet settled. The main reasons for this are that the division of functionality between autonomy and cooperation for self-driving cars has not been finalized, and that a uniform division of such functions cannot be set due to great differences in the levels of communication and intelligent transport system (ITS) infrastructure in countries and regions around the world. A major challenge faced in development of autonomous driving technology is ensuring autonomy (the ability of a vehicle to move in standalone situations). From that perspective, strictly speaking, connected cars should not need communication. Mobility as a Service (MaaS) is a typical example of the need for communication. Rather than selling vehicles, a MaaS business such as car sharing sells transport, as described in Section 4. In such cases, all vehicles would be equipped with 5G or the current version of LTE.

Another example of a communication function outside of this trend is to provide communication between vehicles in times of large-scale disaster. This is described in another article in this special feature. Details can be found in the article, but the main point is that systems will be equipped with communication that uses unoccupied wideband signals such as Wi-Fi and digital terrestrial broadcasting and have a message box, in addition to having Dedicated Short Range Communications (DSRC) for ITS. There is also active research on new communication methods to meet the future demand for vehicle-to-vehicle communication, such as overlaying communication on radar functionality, which currently only functions as a sensor.

[New capability 4] Input and output of diverse types of information

The two photos at the top of Figure 3 show bumper models for a self-driving car from Continental Corp., which were exhibited at the Tokyo Motor Show in 2016. Front and rear bumpers are each equipped with about 10 sensors. These sensors play the role of a human driver's eyes, and can include cameras, radio-wave RADAR, and laser RADAR (called LiDAR). The bumpers are also equipped with environmental sensors for factors such as temperature and gases. Outputs include speakers and alarms, and a whole-body display is also being developed, so a diversity of input and output capabilities not seen in other terminals is also a strength.

Combining data from these sensors with vehicle running data, a single vehicle is expected to produce on the order of 100 GB/day [2]. If all 80 million vehicles in Japan were to transmit all of this data, it would amount an astronomical figure of eight exabytes/day (1 exabyte = 1,000 petabytes).

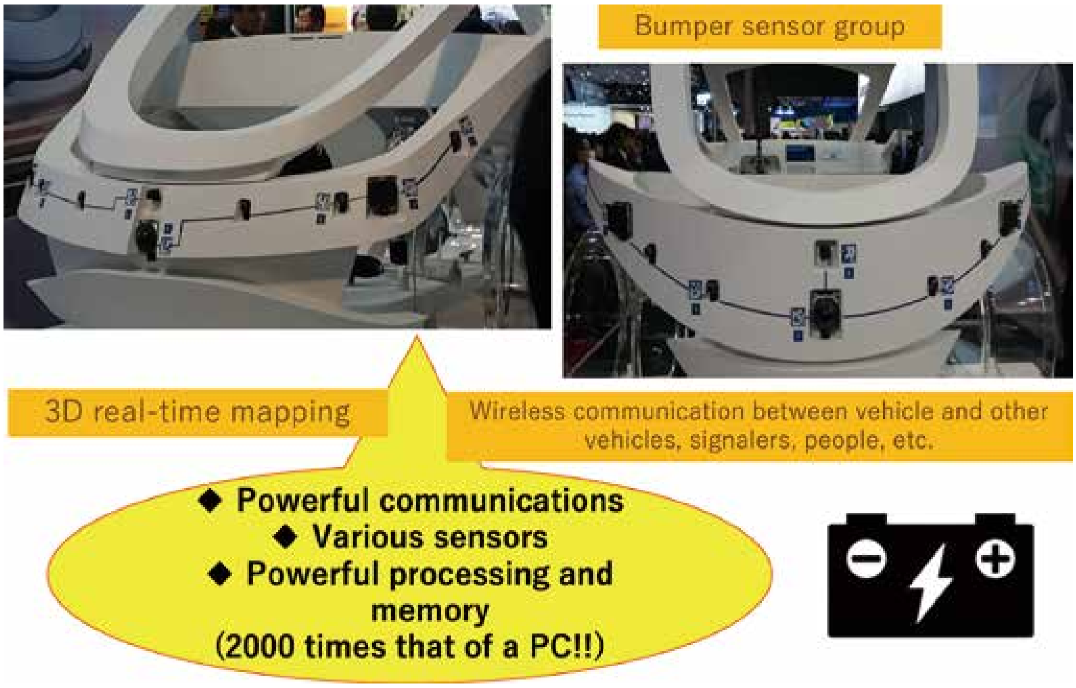
[New capability 5] High capacity battery

Current hybrid cars have battery capacities of around 4 kWh, and electric vehicles, in the range of 40 to 100 kWh, but energy self-sufficiency is expected to continue to increase. In the near future, connected cars will use sustainable energy, and regardless of the state of the ignition key, the vehicle will function full-time and be available as an active data communication hub, 24 hours a day.

4. Using the emerging connected cars

In Japan, specialized services for cars began to appear during the late 1990s and early 2000s, such as collection of traffic congestion data for car navigation systems, and creation of navigable route maps during a disaster. In the USA, most

■ Figure 3: New connected car features



such systems were linked to smartphones. New transportation services such as Uber began to appear in 2009, and with the announcement of Apple's CarPlay and Google's Android Auto in 2013, communication-driven architectures emerged, having the vehicle as a mirror terminal for the smartphone. Currently, there are many implementations of OEM car navigation systems. All of these have been intended mainly to enhance and expand on navigation functions and entertainment services for drivers and passengers, and were not attempting to change how vehicles are used, with the exception of Uber's model.

In contrast, the new type of business model called Mobility as a Service (MaaS) has recently been in the limelight and is becoming more practical. Examples have included features such as discounted insurance based on driving ability or carefulness, and centralized booking and payment of transport to the desired destination, whether by train, car-share or other means[3]. Extensions to the concept of MaaS have also started to appear, with proposals for new connected cars and other vehicles based on CASE. One example is Toyota's e-Palette, which attracted attention at CES in 2018[4]. e-Palette is envisioned as the first model car implementing CASE, and this one vehicle is able to take various forms as needed, whether for ride-sharing, or as a showroom, accommodation, a mobile workshop, a restaurant, or a mobile bazaar. See the promotion video with Reference[4] for an overview of any of these applications.

5. Industrial and societal innovation due to connected cars (author's proposals)

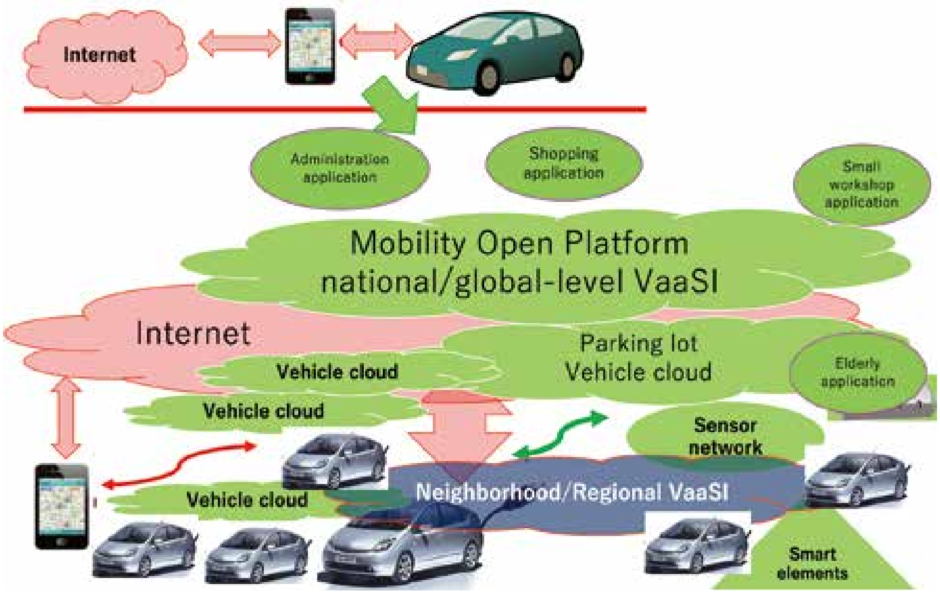
Here, we introduce a new MaaS industry that has begun to operate using the abundant capabilities and potential in the information and communication systems of connected cars. There are many other articles about self-driving and electric vehicles so we refer to them for details, but in this final section of this article, we propose that beyond simply making mobility more efficient and diverse, the capabilities of connected cars in the future will constitute Vehicles as a Social Infrastructure (VaaSI), creating new information and communication infrastructure in society and providing solutions to various social issues.

5.1 Level of connected car adoption

e-Palette and other connected cars (with CASE capabilities) are expected to be introduced and start spreading in society in 2020, as part of an Tokyo Olympic Showcase. Cars are generally replaced every nine years in Japan[5], so ten years from now, in 2030, we can expect that half of the 80 million cars being used in Japan will be equipped with CASE functionality. In other words, within ten years, 40 million vehicles operating in Japan will be equipped with the five new ICT capabilities described in Section 3. Of these, 10 million will be commercial vehicles operating throughout Japan, day and night, whether making deliveries, distributing mail, or collecting trash. On the other hand, 30 million will be for private use, and 95% of the time will be parked, either at home or at work. Thus, 28 million vehicles, each with the processing power of 2000 PCs will be unused (parked) and standing by.

Note that there are reports that the total number of vehicles will drop by 40% due to car sharing[6], but even if the 80 million figure drops to 48 million, it will be an ample amount for a distributed system, and will be effective for VaaSI as proposed in this section.

■ **Figure 4: VaaSI overview**



5.2 VaaSI: Establishing a platform

We propose that a new platform (apart from smartphones) be created that will realize various social functions using the powerful information and communication functions of connected cars (the five new capabilities discussed in section 3). An overview of this platform is shown in Figure 4. Space does not allow discussion of the details, but two main architectural points are as follows.

[Key Point 1] The sensors, display, and speakers of mobile connected cars are used for input and output of information for social services. Of course, they will be linked with smartphones.

With the cameras and other sensors on connected cars, it will be possible to collect real-time image, temperature, gas and other information on environment and other conditions in all corners of the country, day or night. This social data can be used to create detailed administrative services and new commercial services. With a ratio of one connected car per three residents, their information output capabilities would be readily available to residents from any connected car parked nearby, as a means of promoting administrative services, and they could also be linked with smartphones, TV and other mass media.

[Key point 2] Parked connected cars could be used as a local "mobility cloud", with for example, ten cars in a parking lot providing the power of 20,000 PCs.

Tens of millions of connected cars could be connected organically, forming a hyper-distributed virtually layered platform that could be used in a layered fashion, from strictly-local to wide-area. This multi-layer cloud would manage and operate societal data, and also provide APIs to local society, businesses and individuals, to create new types of social service industries. To ensure that such community-contributed social services can be used safely and securely, the administrative system will ensure transparency and assignment of responsibility.

6. Conclusion

Connected cars have finally become devices that "allow connection." There is a wide range of devices such as smartphones and PCs that already connect to the Internet, but connected cars differ from these on the following points.

- They are able to move autonomously,
- They can transport people and goods,
- They have thousands of times the processing power of PCs,
- They can connect with IoT devices (hub functionality),
- They can input and output information in a variety of formats (multimedia)
- Safety is a critical product feature,
- They can store sustainable energy,
- Etc.

Self-driving cars and car sharing are currently attracting attention, but with these strengths, a wide range of uses that we have not even imagined will undoubtedly emerge in the coming ten years. We look forward to Japan taking the lead in realizing these and incorporating them in society, creating social innovation, and triggering revitalization in industry.

References
[1] M. Kimura, "News Trend Commentary: 'Semiconductor processing performance' an issue with Toyota's autonomous driving," Oct. 24, 2017 Update. (in Japanese) http://tech.nikkeibp.co.jp/dm/atcl/feature/15/122200045/102300197/
[2] PR/MONOist, "Why fully autonomous driving vehicles need 1 TB of flash memory," June 20, 2017 Edition (in Japanese) http://monoist.atmarkit.co.jp/mn/articles/1706/20/news001.html
[3] Jidounten LAB, "Introduction to MaaS," Sept. 10, 2018 Update. (in Japanese) https://jidounten-lab.com/y_5750
[4] Toyota, "e-Palette Concept," Jan. 9, 2018 Update. (in Japanese) https://newsroom.toyota.co.jp/jp/album/videos/20508200/
[5] Garbage News, "Graphing annual passenger car replacement (with a new car) rates," Apr. 22, 2018 Update. (in Japanese) http://www.garbagenews.net/archives/2056638.html
[6] T. Miyata, "Shocking prediction of 40% drop in auto sales," May 23, 2016 Update. (in Japanese) http://wedge.ismedia.jp/articles/-/6805