Artificial Intelligence in Japan:
Policy, prospects and obstacles in the automotive industry

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Abstract

As artificial intelligence (AI) has progressed, it seems inevitable for countries and firms across the world to change their old notions and attitudes toward new technologies. Since AI could have a major impact on many aspects of business and society, the future competitiveness of nations, let alone of companies, will hinge upon the effective utilization of AI technologies. However, Japan is currently falling behind the US and even China in the global technology race. Many Japanese companies that were market leaders at some point have lost their position in the international market. Toyota, which leads Japan's automotive industry, is also facing multiple challenges, since AI is significantly changing the competitive landscape.

Whereas the major carmakers have been keeping an eye on AI-directed self-driving cars, initially Toyota had some reservations about the development of self-driving cars. However, the company has recently changed its strategy. Despite sluggish government policies, Toyota has been accelerating its move into the new phase of competition with an unprecedented commitment to self-driving cars. Toyota's recent activities somewhat contrast with the slow response of the Japanese government and most Japanese firms to the global trend. This paper first provides an overview of Japan's AI, followed by the Japanese government's plan for self-driving cars. The third section depicts Toyota's recent activities, focusing on self-driving cars. Reflecting on Toyota's strategic changes as a benchmark, the fourth section discusses what Japan needs to do in order to transform itself and compete in the digital age, followed by a tentative conclusion.

Keywords: Artificial intelligence (AI), government policy, the automotive industry, self-driving cars, Toyota

INTRODUCTION

The 2010s witnessed a sudden boom in the concept of artificial intelligence (AI). The hype around AI has grown rapidly in business and society alike across borders, and Japan is no exception. AI refers to computing systems that are able to engage in human-like processes and cognitive functions in their environment (Perset & Nishigata, 2018; Popenici & Kerr, 2017), although there are numerous variations in the definition of AI. The main goal of AI is to develop machine-learning agents that perceive, adapt, plan and act in a given context to carry out tasks and solve problems (Tecuci, 2012). Because of the highly technology-intensive characteristics of AI, Japan could have a strong presence in this field. However, the progress of AI in Japan is currently significantly lagging behind not only other advanced mature economies but also China, an emerging economy (Nikkei.com, 2018).

ARTIFICIAL INTELLIGENCE IN JAPAN

Japan once enjoyed a reputation for technological excellence, especially in the 1980s; the country was even referred to as one of the world's leading industrial powers alongside the US and Germany (Porter, 1990). In recent decades, however, this attribution to Japan has been fading away. Japanese firms across industries seem to be ill-equipped to cope with rapid changes in local and international contexts (Collison & Wilson, 2006), and the same can be seen in Japan's AI. It is noteworthy, however, that Japan had two earlier booms of AI, first in the late 1950s, just after the term "artificial intelligence" was coined by a computer scientist John McCarthy in 1956, and a second boom occurred in the 1980s (Nishida, 2012). During the 1980s, the Japanese government set up the Institute for New Generation Computer Technology to develop AI; moreover, the Japanese Society for Artificial Intelligence, which consisted of Japan's prominent business and academic institutions, was also launched. However, the former

was dissolved in 1992, while the latter kept a relatively low profile throughout the 1990s until it revitalized its activities after the millennium.

Apparently, the changes related to AI in Japan coincided with the country's economic growth and subsequently the bursting of the economic bubble in the country. In the early time, Japan's scope was overly ambitious (Eriksson, 2017) and adequate data and infrastructure to handle them were not available; eventually, Japan's ambition was tempered as financial resources ran out. However, times have changed. Today, big data and cloud sources, as well as device networks – often called the Internet of things (IoT) – are available around the world for building intelligent agents. Apart from these significant technological changes on a global scale, Japan is facing socioeconomic problems, such as the declining birth rate and the aging population, which have serious impacts on the labor market. For Japan, therefore, the development and implementation of AI is not just a matter of jumping on the global high-tech bandwagon, but an urgent priority wherein the Japanese government must take action to transform the industrial structure in Japan (Prime Minister's Office of Japan, 2015).

Japan's AI strategy and market

In 2015, the Japanese government drafted its first AI strategy, the "Japan re-building strategy," acknowledging that the country was falling behind other countries in adopting IoT, Big Data and AI. In the following year, the Strategic Council for AI Technology was formed. The Council comprised 11 members, mostly from academia and government, but also including two representatives from industry; one was the president of KDDI, one of the biggest telecommunications operators in Japan, and the other was the chairman of Toyota. In 2017, the Japanese government released the AI technology strategy, which envisaged Japan's AI roadmap in three phases: the first phase focuses on the utilization and application of data-driven AI in

various domains; the second phase aims for the public use of AI and data; and the third phase anticipates the establishment of AI-based ecosystems.

[Figure 1]

However, the Japanese government target at each phase is too general and vague. In particular, the government's plan to establish an AI ecosystem in the 2030s seems slow given the rapid growth of AI technologies, as well as the AI market. According to Lundin and Eriksson (2016), Japan's AI market is expected to grow to JPY 87 trillion by 2030; amongst sectors, for instance, the estimated market value of transport (e.g., driverless taxis and trucks) and manufacturing (e.g., self-driving cars) combined will be JPY 42.65 trillion, which equates to nearly half of the total forecasted market value. Ironically, the aging population and labor scarcity in Japan have contributed to making Japan a high-potential AI market. In the international market, moreover, the automotive industry is also becoming a battleground of AI technologies, because automobiles nowadays have various types of digital data and software installed. Although Japanese carmakers have maintained sustained competitiveness in the global market, AI is likely to pose serious challenges to them, since the competitive landscape has been changing alongside the growth of AI.

THE SELF-DRIVING CAR MARKET AS A NEW BATTLEFIELD

Japan's roadmap for self-driving cars

In the global automotive industry, there are four disruptive trends that may transform the industry: autonomous driving, shared mobility, connectivity and electrification (Heineke, Möller, Padhi & Tschiesner, 2017). AI evidently direct influences these trends in a synergistic way, leading the automotive industry to a new era of the Internet of autonomous vehicles (Lee, Gerla, Pau, Lee & Lim, 2016). Autonomous cars, also known as self-driving cars, can broadly

refer to vehicles that have "the capability to perceive the surrounding environment and navigate [themselves] without human intervention" (Jo, Kim, Kim, Jang & Sunwoo, 2014: p. 7131). More specifically, the Society of Automotive Engineers (SAE) (www.sae.org) has categorized driving automation into six levels, from 0 (no automation) to 5 (full automation); only levels 3–5 are considered self-driving cars, whereas levels 0–2 are called driver-supporting cars.

[Table 1]

Currently, firms operating in this field target different segments at different paces. To keep up with international players, the Japanese government organized a discussion group for autonomous-driving business, and the first meeting took place in 2016; members included the major Japanese carmakers (e.g., Toyota, Nissan, Honda, Mazda and Isuzu) as well as suppliers (Denso and JTEKT, both of which are suppliers in the Toyota Group). The discussion group subsequently created a processual plan for the realization of self-driving cars.

[Figure 2]

Compared to the major international players, however, Japan's roadmap is still falling behind in terms of the implementation timeframe. While most foreign firms are aiming to introduce level-4 self-driving cars in the early 2020s, Japan's target during the same period is to launch level-3 self-driving cars on highways only. On the main roads, it is aiming to implement level-2 cars, but with limited features that allow them to go straight ahead only, while turning right/left is prohibited. In the plan, these limited features are expected to continue over a prolonged time on general motorways beyond 2025; the use of level-4 self-driving cars will be restricted to expressways even after 2025. On the other hand, other carmakers, such as BMW, Audi and Ford, intend to introduce level-4 cars on general motorways from 2025. Google, a

new player in the self-driving car market, is even more ambitious; it aims to implement level-5 cars for commercial use from 2025. Considering that several self-driving car accidents have already been reported in the US (Rapier, 2018), is Japan's modest, step-by-step approach a sensible choice, as Davenport and Ronanki (2018) suggested? In a way, it might be a realistic strategy, given that consumers are not yet fully confident with self-driving cars; in an uncertain market, companies do not have to be first movers if they can catch up with a market trend at the right timing. Nonetheless, taking a wait-and-see attitude will not work in technological competition, especially regarding multifaceted technology such as AI.

Japanese firms' position in the global technology race

Although the term AI has increasingly been penetrating the Japanese business world, it remains a buzzword that often refers simply to some new technology or idea, and the progress of actual implementation of AI-based goods and services is very limited in Japan. Lundin and Eriksson (2016) pointed out that most Japanese firms have not been taking advantage of new opportunities that AI offers. The slow approach of Japanese firms is concerning, since the competition in AI is moving rapidly.

Having said that, as long as the patent data are concerned, Japan's position does not seem to be so bleak. According to World Intellectual Property Organization (WIPO) (2019), Japan was ranked the third among major economies by number of patent applications in several categories, such as machine learning, logic programming, fuzzy logic, computer vision and robotics, just to name a few. Although Japan is significantly behind China and the U.S. – the top runners of the AI race – in the overall strength, Japan still performs better than Germany and South Korea in the number of patent filing. In terms of overall AI patenting, 12 of the top 20 companies are Japanese conglomerates, and those 12 mostly operate in the consumer electronics and

telecommunications industry (WIPO, 2019). However, this ranking should be interpreted with caution, because patent ranking per se does not automatically equate to patent holders' innovativeness (Berman, 2015). Since the patent filing process varies from country to country and is often complex, interpreting the patent information of multinational firms is not so simple (Lerner & Seru, 2017). In fact, the recent performance of Japanese electronics and telecommunications companies is not particularly impressive in the global market.

Only one exception, which is not classified as part of the consumer electronics and telecommunications industries, among the Japanese companies in the overall AI patenting ranking, is Toyota. Toyota possesses the largest portfolios in the three subcategories of transportation (autonomous vehicles, transportation/traffic engineering, and driver/vehicle recognition) (WIPO, 2019). However, what is noteworthy about Toyota is not only the amount of intellectual property, but strategic change the company recently made to compete in the AI field, especially for self-driving cars.

TOYOTA'S AMBITION OF PIONEERING SELF-DRIVING CARS

AI-infused business is becoming a key area among major carmakers, and Toyota is certainly one of the most active Japanese companies in this field. However, Toyota was initially not enthusiastic about self-driving cars. At one time, Toyota's president, Akio Toyoda, said that he would consider pursuing the development of self-driving cars only after such a car could win against him – a human driver – in an endurance car race (Sakuma, 2018). However, Toyota's attitude towards self-driving cars has changed because of new competitors entering the market from high-tech industries. Since the 2000s in particular, the automotive industry has had new entrants, such as Waymo, which was originally Google's self-driving car project, and Tesla, which specializes in electric cars, whereas firms in the transportation network industry, such

as Uber and Lyft, have also been strengthening their presence by expanding their business ties with car manufacturers.

Traditionally, Toyota preferred to develop core technologies in-house, or otherwise within the Toyota Group. Likewise, when Toyota started to gear up for developing AI technologies for self-driving cars, it aimed at organic growth by strengthening the prime suppliers in its Group. Nonetheless, Toyota changed the approach upon realizing that in-house (or in-group) capability would not be efficient enough, as AI technologies were being developed by specialist companies with breathtaking speed. To keep up with the pace of global competition, Toyota has been forging strategic alliances to enhance its value chain.

Reconfiguring the global value chain

One of the most notable steps Toyota has taken so far is to establish a new joint venture, MONET Technologies Inc. (hereafter, MONET), with a Japanese telecommunications company, SoftBank Corp. Softbank is a subsidiary of Japan's biggest digital conglomerate, the SoftBank Group. MONET was formed in late 2018 to provide on-demand mobility services, as well as "autonomous vehicle and mobility-as-a-service (Autono-MaaS)" business (Toyota Motor, 2019).

Toyota's relation to Softbank surprised the Japanese public. Retrospectively, in the late 1990s, Softbank suggested to Toyota a joint project to implement cloud-based dealership services, but Toyota declined the new business opportunity. Following this incident, the two companies reportedly kept a distance with each other. Subsequently, SoftBank chose GM as its partner by making a $2 billion investment in GM's self-driving subsidiary, GM Cruise. Yet, more surprisingly, Honda, together with Hino Motors, also joined MONET in 2019. Although Hino

Motors is a Toyota Group company, Honda has been Toyota's competitor not only in the Japanese market but also in the global market; furthermore, Honda is also one of the investors in GM Cruse. As a result of the new form of alliance, Softbank has a 40.202% of ownership in MONET, whereas Toyota owns 39.802%; Hino and Honda own 9.998% respectively (Honda, 2019). Evidently, MONET has added complexity to already complex partnerships in the business of self-driving cars and MaaS.

Toyota's tie-in with Softbank through MONET reflects a sea change in Toyota's strategy as a car manufacturer. Akio Toyoda even announced at the 2018 financial results briefing that he would transform Toyota from a carmaker into a mobility company. Although aiming to become more like a mobility company is a recent trend among major carmakers, it is still a significant change for Toyota because the company has devoted itself to craftsmanship in car manufacturing throughout its history. However, relying solely on its excellency in manufacturing will no longer be tenable in the era of the digital revolution (Lippert, Gruley, Inoue & Coppola, 2018). As Toyota transforms itself, its key suppliers have also played a role.

The "machine" exploring breakthroughs

The unique role of Toyota's suppliers was well known even before the seminal book about Toyota, *The machine that changed the world* (Womack, Jones & Roos, 1990), was published. Toyota suppliers have well-defined responsibilities in the Toyota Group and act as catalysts to enable what Womack et al. (1990) called "lean production." The essence of the complete lean business system – or the "machine" – is the combination of (a) product design, (b) coordination of the supply chain, (c) a high level of efficient customer services, (d) seamless production and (e) managing the business on a global scale, in a mutually supportive way (Jones, Roos & Womack, 2007). Given that "the machine" is not just a production system but a comprehensive

business system, Quibell (2018) argues that it is compatible with IoT and AI, as it allows for designing a better product, developing a collaborative supply chain, aggregating customer data to improve services, creating a digital factory with transparent operations and orchestrating these across borders. Of course, Toyota's "machine" needs to evolve further in order to cope with the digital challenges ahead. Nevertheless, the roles played by two Toyota subsidiaries, namely Denso and Toyota Research Institute-Advanced Development (TRI-AD) amongst others, are noteworthy.

Denso

Denso is a Toyota Group company and probably the most important tier-1 supplier for Toyota. It was originally Toyota's spin-off subsidiary, but today Denso is the world's second biggest auto parts supplier next to Robert Bosch (Automotive News, 2018). With its financial stability and technological competitiveness, Denso has been strengthening its ties with firms outside the Toyota Group. Paralleling Toyota's deepening commitment to self-driving cars, Denso formed a joint venture DensoNext with NEC Platforms in the late 2017. NEC Platforms is a communications equipment company, whose parent company is one of Japan's IT giants, NEC. At DensoNext, Denso and NEC Platforms, will develop information communication devices for "connected vehicles" (Denso, 2017). Connected vehicles refer to cars that use various communication technologies to communicate not only with the driver but also with other cars (vehicle-to-vehicle) and the road infrastructure (vehicles-to-infrastructure) (Gora & Rüb, 2016). NEC Platforms, as well as its parent company, NEC, has expertise in in-vehicle equipment software products and wireless communication, which are critical for the advancement of autonomous and connected cars.

In addition, Denso increased its share in Renesas Electronics, one of Japan's biggest semiconductor manufacturers, from 0.5% to 5% in 2018 (Denso, 2018). While this still represents only a minor shareholding ratio, it makes Denso the third biggest shareholder independently invested in Renesas. Considering the troubling position of Japanese semiconductor manufacturers, this may be a risky investment. However, a business tie with Renesas indirectly provides Denso with connections with multiple entities that have expertise in automotive interface ICs and related software. For instance, the biggest shareholder of Renesas is the Innovation Network Corporation of Japan, which is a public–private partnership between the Japanese government and 19 major Japanese firms; besides, Renesas recently acquired a US semiconductor company, IDT that owns various types of semiconductors (Renesas Electronics, 2018). Apart from these, Denso also played a role in forming a new entity, TRI-AD, a novel element of Toyota's "machine."

TRI-AD

TRI-AD was established by Toyota, Denso, and another Toyota Group company, Aisin Seiki, in 2018. TRI-AD is headquartered in Tokyo, but Toyota appointed former Google engineer and Stanford-graduate roboticist, James Kuffner, as CEO of TRI-AD. TRI-AD's goal is to "build the world's safest automated driving cars" by developing software for autonomous cars and coordinating research results within the Toyota Group (TRI-AD, www.tri-ad.global). The focus of TRI-AD on software for self-driving cars is crucial for Toyota, because Japan on the whole is not competitive enough in the software industry.

Amongst the businesses that TRI-AD has involved, a cross-sectoral alliance with Tokio Marine & Nichido Fire Insurance (TMNF) is notable. Together with Toyota, TRI-AD and TMNF will jointly develop automated driving technology; TMNF is also seeking to develop an advanced

claims system by using data obtained through self-driving cars. To develop safe self-driving cars, both AI technology and real-world data are needed to achieve accurate simulations (Toyota Motor, 2018a). Although connected and autonomous vehicles are expected to reduce the death toll on roads (OECD, 2017), many car manufacturers are still wary of introducing fully self-driving cars because of the unpredictability of technology-caused accidents, and thus the higher risk that car manufacturers might face under product liability laws (Schellekens, 2015). Hence, the collaboration with TMNF is an important step for Toyota and TRI-AD to bring self-driving cars to the market. Another partnership that TRI-AD has formed is a collaboration with a New York based start-up, Carmera, which specializes in high-definition (HD) maps. Road information based on HD map data is expected to enable TRI-AD to advance its open software platform (TRI-AD, 2019).

[Figure 3]

While Denso and TRI-AD are expanding technological networks in their specialized areas, Toyota itself has also been trying to reach out to global intelligences. Some notable outreach efforts have been made through Toyota Research Institute (TRI) and Toyota AI Ventures (TAIV) in the US, as well as Toyota Research on Automated Cars in Europe (TRACE).

TRI was launched in 2016, two years prior to the establishment of TRI-AD. While TRI-AD focuses on self-driving car software, TRI, a mother unit of TRI-AD, is responsible for leveraging AI and machine learning in a comprehensive manner in order to create "safer cars," rather than driver-less cars (TRI, www.tri.global). Whatever the degree of autonomy of vehicles in future may be, information technology and digital media are vital in a technologically connected society. TRI's CEO, Gill Pratt, said, "There's a business need for us [Toyota] to become more like IT companies before the IT companies become more like us" (cited in Lippert et al., 2018). To facilitate investments in promising AI start-ups, Toyota also

founded TRI's venture capital subsidiary, TAIV, in 2017. TAIV focuses on early-stage investments in both AI software and hardware, including non-automotive start-ups (TAIV, www.toyota-ai.ventures). Meanwhile, Toyota has developed a research network, TRACE. TRACE connects universities in Europe, such as KU Leuven in Belgium, the University of Cambridge in the UK, Czech Technical University in the Czech Republic, ETH Zurich in Switzerland and Max Planck Institute for Informatics in Germany, to advance computer vision algorithms for self-driving cars (TRACE, www.trace-lab.com).

So far, Toyota's activities for AI and self-driving cars have been concentrated in Western countries, mostly the US. Nonetheless, another leading nation in the AI race is China. While Toyota already has several factories and three R&D centers in China, these units are largely characterized as Toyota's localization strategy to manufacture cars for the Chinese market. In the global AI race, however, China is not only the world's largest car market but also an AI leader, and the country has a large pool of potential AI talent. Furthermore, it is likely that the Chinese government will impose local content requirements on technologies used in self-driving cars if foreign manufacturers wish to sell such cars on the Chinese market. Given these factors, Toyota has no choice but to deepen its engagement with China for the sake of AI, despite concerns about the weak protection of intellectual property rights in China. In 2019, Toyota announced that it would open new R&D units in Beijing and Shanghai dedicated to the R&D of AI and self-driving cars (Nikkan Kogyo Shimbun, 2019). Surely, dealing with new technologies in emerging markets – and indeed any market – could entail risk. In this regard, Toyota's recent efforts are symbolic of its commitment to survive and thrive in what the company describes as a "once-in-a-century period of profound transformation" (Toyota Motor, 2018b).

CHALLENGES AHEAD

It is still too early to predict whether Toyota's efforts will pay off. In addition, Toyota may not be a perfect prototype for other Japanese firms because Toyota is not a typical Japanese company. However, Toyota's strategic actions for self-driving cars offer several important points that Japan should take seriously to change the country's reactive attitude and revamp its competitiveness. These points include the general tendency of the Japanese government and society alike to resist change, act slowly, and look inwardly; the country needs to overcome these in order to stay competitive internationally.

Resistance to change

In order to clear the first hurdle of resistance to change, Japan needs to overcome not only cognitive barriers to change but also the problem of procrastination. While some Japanese companies, including Toyota, are willing to make changes wherever necessary, most organizations and workforces in Japan lack proactive decision-making skills, preferring instead to maintain the status quo. Given that there could be both benefits and risks associated with AI, careful consideration is indeed important; however, a real risk assessment will not be possible unless the nature of technologies is looked into and tested. Nevertheless, most Japanese workplaces do not have adequate incentives to pursue this; accordingly, the average workforce in Japan tends to maintain a passive attitude towards technological changes.

It should be noted that willingness (or unwillingness) to change is also associated with the degree of commitment. Firms need to decide how and how much they will commit in terms of resources to the AI field. McAfee and Brynjolfsson (2017) suggested that machine-learning systems become better as they increase in size, because faster hardware and more sophisticated software can improve algorithms. Thus, companies need to carefully but steadily plan to scale

up their AI capabilities by integrating existing systems and processes (Davenport & Ronanki, 2018). However, Japanese firms' investments in new systems have been weak for few decades. Most investments that are made are allocated to maintaining old systems, and because of this, it is estimated that 60% of Japanese firms will have obsolete core systems by 2025 (Nikkei Shimbun, 2018). If such a condition persists, it will certainly hinder Japanese firms' AI initiatives.

Speed as an essential component

Slowness of action is another issue that Japan needs to address. While an increasing number of Japanese firms have been changing their attitude by taking quicker actions once a decision is made – as seen in the case of Toyota's tie-up with SoftBank – the Japanese economy as a whole is not readily increasing the pace. The Japanese government is largely responsible for this slowness, because it is very difficult in Japan to put a new idea into practice unless/until the government permits it (Eriksson, 2017). The OECD (2017) suggested that even in other major economies, government policies and practices tend to remain static vis-à-vis the speed of evolution of digital technologies. However, given the acute labor shortages in Japan (Harding, 2017) – let alone the shortage of AI talent – the government must address the problem in related areas as a matter of urgency because the speed of digital transformation relies on the availability of technical talent (Saphir, 2018).

Recognizing its lag in the AI field, the Japanese government has stated that it will speed up its response (METI, 2017). To facilitate innovation in Japan, the government also agreed on a 2019 budget of more than JP¥ 22 billion for a strategic innovation program, making the biggest allocation amongst 11 target areas, of JP¥ 3.12 billion, to R&D for self-driving cars (Cabinet Office of Japan, 2019). While the government's budgetary commitment to transform Japanese

industries is welcome, the real challenge is how innovation is interfaced across target areas and whether regulatory changes could go hand in hand with technological progress. What is necessary is *velocity* – speed with a clear direction – shared by key industries.

The need for a global perspective

Finally, the most serious and well-documented issue in Japan is its inward-looking tendency. This sounds paradoxical given that Japan is one of the major sources of foreign direct investment in the global economy. However, the issue is more about mentality. While Japan's companies are increasingly trying to recruit foreign talent not only to junior-level but also senior-management positions, as exemplified in Toyota's outreach efforts to AI talent, this has been driven by necessity due to the limited supply of specialists in Japan. With some exceptions, most Japanese companies have still a weak awareness of the need for global talent, and Japanese employees and students alike are becoming more reluctant to work or study abroad (Burgess, 2015). This could exacerbate the vicious cycle of Japan's inward-looking tendency. Making things worse, this tendency is often backed by an island mentality that regards the country as somewhat unique; subsequently, the nation and its people often erroneously assume that a certain degree of isolation is justifiable (Shigemura, Nakamoto & Ursano, 2009).

The same tendency can be seen in the Japanese government's attitude. While the government's policies and white papers acknowledge the importance of a global vision, the concept of "All Japan" – the notion of collective action taken by the Japanese government, Japanese industries and Japanese academia – recurs throughout their statements. While such a cross-sectoral and coherent approach is valuable, the government's visions remain just that so far, and actual plan and decision-making are left to individual firms. The Japanese government's approach contrasts that of China, a forerunner in the AI field; the Chinese government is exercising a

hands-on strategy with the government's active coordination of the industrial sector. The Chinese government has even set a clear target in its AI strategy to become the world leader by 2030 (Robles, 2018).

Of course, a simplistic comparison should be avoided since the Japanese economy is at a different level of development from China, and their institutions are very different. Nonetheless, it should be noted that Japan is also remote from the West; Japan is not fully part of the geopolitical and economic unions formed by Western nations. When it comes to AI-related regulations, therefore, Japan cannot be a standard-setter on its own. In the era of AI, various types of technologies are intertwined and must be integrated seamlessly across industries, and possibly across borders. Furthermore, since the Japanese economy relies heavily on the manufacturing industry, and has relatively less competitiveness in services and software development, international collaboration is a must for global connectivity.

CONCLUSION

In view of the competitiveness of the firm as well as of its nation, this paper has outlined AI trends focusing on the automotive industry and Toyota's recent activities for the advancement of self-driving cars. The company's steady endeavor is notable. However, it should be noted that in the age of AI, one manufacturer's action per se cannot change the entire system of a complex web of AI technologies. Furthermore, one industry's competitiveness is not enough to cope with digital challenges. The ecosystem of new technologies needs to evolve across industries and be utilized in society in a productive manner. If Japan truly understands the country's current position and issues, and takes necessary action by facilitating changes in the society while integrating the country more into the international community, then it might rise to the challenges that AI will bring.

References

Automotive News. (2018, June 25). North America, Europe and the world top suppliers. Available https://www.autonews.com/assets/PDF/CA116090622.PDF (accessed 27 April 2019).

Autonomous-Driving Business Discussion Group. (jidō sōkō bijinesu kentōkai). (2018). Jidō sōkō no jitsugen ni muketa torikumi houshin, version 2.0 [Approach and policy for realization of autonomous mobility, version 2.0]. Autonomous-Driving Business Discussion Group, Japan. Available http://www.meti.go.jp/report/whitepaper/data/pdf/20180330002_02.pdf (accessed 9 March 2019).

Berman, B. (2015). The puzzle that is patent quality. *WIPO Magazine*. Available https://www.wipo.int/wipo_magazine/en/2015/04/article_0004.html (accessed 6 April 2019).

Burgess, C. (2015). To globalise or not to globalise? 'Inward-looking youth' as scapegoats for Japan's failure to secure and cultivate 'global human resources'. *Globalisation, Societies and Education*, 13(4), 487-507.

Cabinet Office of Japan. (2019). Heisei 31-nendo senryaku-teki inobēshon souzou puroguramu (SIP) no jisshi houshin [Strategic innovation program, implementation policy 2019]. Cabinet Office of Japan. Available https://www8.cao.go.jp/cstp/gaiyo/sip/96kai/siryo2-2.pdf (accessed 16 April 2019).

Collison, S., & Wilson, D. C. (2006). Inertia in Japanese organizations: Knowledge management routines and failure to innovate. *Organization Studies*, 27(9), 1359-1387.

Davenport, T. H., & Ronanki, R. (2018). Artificial intelligence for the real world: Don't start with moon shots. *Harvard Business Review*, 96(1), 108-116.

Denso Corp. (2017, November 29). Denso and NEC establish a joint venture to develop essential connectivity technologies for cars of the present and future. Available https://www.denso.com/global/en/news/news-releases/2017/20171029-g01 (accessed 11 April 2019).

Denso Corp. (2018, March 9). Denso, Renesas no hoyū hiritsu hikiage [Denso increases its stake in Renesas]. Available https://www.denso.com/jp/ja/news/news-releases/2018/20180309-01 (accessed 11 April 2019).

Eriksson, S. (2017). Internet of things in Japan: Challenges and opportunities. Independently published.

Gora, P., & Rüb, I. (2016). Traffic models for self-driving connected cars. *Transportation Research Procedia*, 14, 2207-2216.

Harding R. (2017, July 28). Japan's labour shortage hits new extreme. *Financial Times*. Available https://www.ft.com/content/59379d9a-733a-11e7-aca6-c6bd07df1a3c (accessed 28 July 2017).

Heineke, K., Möller, T., Padhi, A., & Tschiesner, A. (2017, September). The automotive revolution is speeding up. *McKinsey & Company*. Available https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-automotive-revolution-is-speeding-up (accessed 11 March 2019).

Honda Motor. (2019, March 28). MONET forms capital and business partnership with Hino Motors and Honda. Available https://global.honda/newsroom/news/2019/c190328beng.html (accessed 7 April 2019).

Jo, K., Kim, J., Kim, D., Jang, C., & Sunwoo, M. (2014). Development of autonomous car - Part I: Distributed system architecture and development process. *IEEE Transactions on Industrial Electronics*, 61(12), 7131-7140.

Jones, D., Roos, D., & Womack, J. (2007). Foreword 2007 – Why Toyota won: A tale of two business systems. In Womack, J. P., Jones, D. T., & Roos, D. (2007). The machine that changed the world: How lean production revolutionized the global car wars. New York: Free Press.

Lee, E.-K., Gerla, M., Pau, G., Lee, U., & Lim, J.-H. (2016). Internet of vehicles: From intelligent grid to autonomous cars and vehicular fogs. *International Journal of Distributed Sensor Networks*, 12(9), 1-14.

Lerner, J., & Seru, A. (2017). The use and misuse of patent data: Issues for corporate finance and beyond. NBER working paper 24053. Available http://www.nber.org/papers/w24053 (accessed 2 April 2019).

Lippert, J., Gruley, B., Inoue, K., & Coppola, G. (2018, September 19). Toyota's vision of autonomous cars is not exactly driverless. *Bloomberg*. Available

https://www.bloomberg.com/news/features/2018-09-19/toyota-s-vision-of-autonomous-cars-is-not-exactly-driverless (accessed 4 March 2019).

Lundin, M., & Eriksson, S. (2016). Artificial intelligence in Japan (R&D, market and industry analysis). *EU-Japan Centre for Industrial Cooperation*. Available https://www.eubusinessinjapan.eu/library/publication/report-artificial-intelligence (accessed 14 February 2019).

McAfee, A., & Brynjolfsson, E. (2017). Machine, platform, crowd: Harnessing our digital future. New York: W.W. Norton & Company.

Ministry of Economy, Trade and Industry (METI). (2017). Shin sangyo kouzou vision [New vision of industrial structure]. Ministry of Economy, Trade and Industry, Japan. Available https://www.meti.go.jp/press/2017/05/20170530007/20170530007-2.pdf (accessed 15 October 2018).

Nikkan Kogyo Shimbun. (2019, February 15). Toyota, chūgoku ni AI/jidō unten kyoten nen-nai nimo Pekin, Shanhai de hossoku [Toyota's AI/autonomous driving bases in China to start in Beijing and Shanghai this year]. Available https://www.nikkan.co.jp/articles/view/00506384 (accessed 25 February 2019).

Nikkei Shimbun. (2018, October 14). Nihon no IT tōshi busoku shinkoku 25nen, shisutemu 6-wari ga roukyu-ka [Severe shortage of Japan's IT investment: 60% of the system become obsolete by 2025]. Available https://www.nikkei.com/article/DGXMZO36464910T11C18A0MM8000 (accessed 18 February 2019).

Nikkei.com. (2018, May 2). Nihon kigyo no kenkyū kaihatsu sekai ni okure [Japanese firms are falling behind the world in research and development]. Available https://www.nikkei.com/article/DGXMZO30087700S8A500C1SHA000 (accessed 3 May 2018).

Nishida, T. (2012). Jinkou chinou kenkyu hanseiki no ayumi to kongo no kadai [Artificial intelligence research in the second half century]. *Jōhō Kanri*, 55(7), 461-471.

Organization for Economic Co-operation and Development (OECD). (2017). OECD digital economy outlook 2017. Organization for Economic Co-operation and Development. Paris: OECD Publishing. Available http://dx.doi.org/10.1787/9789264276284-en (accessed 11 March 2019).

Perset, K., & Nishigata, N. (2018, October 10). OECD work on artificial intelligence. OECD global parliamentary network. Available http://www.oecd.org/parliamentarians/meetings/gpn-meeting-october-2018/OECD-Work-on-Artificial-Intelligence.pdf (accessed 4 March 2019).

Popenici, S.A. D., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, 12(22). Available https://doi.org/10.1186/s41039-017-0062-8 (accessed 15 October 2019).

Porter, M. E. (1990). The competitiveness of nations. *Harvard Business Review*, 68(2), 73-93.

Prime Minister's Office of Japan. (2015). Nihon saikou senryaku kaitei 2015 no toushi, seisan-sei kakumei [Japan' revitalization strategy, revised version 2015 – Investment in the future, productivity Revolution]. Available https://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/dai1jp.pdf (accessed 5 March 2019).

Quibell, A. (2018, April 16). Lean management meets artificial intelligence, machine learning, the internet of all things. *Lean Enterprise Institute*. Available https://www.lean.org/LeanPost/Posting.cfm?LeanPostId=856 (accessed 1 April 2019).

Rapier, G. (2018, November 30). GM's Cruise has had the most self-driving crashes in California. *Business Insider Nordic*. Available https://nordic.businessinsider.com/cruise-waymo-apple-which-self-driving-cars-crash-the-most-2018-11 (accessed 9 February 2019).

Renesas Electronics. (2018). Renesas to acquire Integrated Device Technology to enhance global leadership in embedded solutions. Available https://www.renesas.com/sg/en/about/press-center/news/2018/news20180911a.html (accessed 11 April 2019).

Robles, P. (2018, October 1). China plans to be a world leader in Artificial Intelligence by 2030. *South China Morning Post*. Available https://multimedia.scmp.com/news/china/article/2166148/china-2025-artificial-intelligence/index.html (accessed 1 March 2019).

Sakuma, S. (2018, May 19). Jikōkai, Toyoda Akio sin kaichō no syūnin interview [Inauguration interview of new chairperson, Akio Toyoda], *Car Watch*. Available https://car.watch.impress.co.jp/docs/news/1122745.html (accessed 12 December 2018).

Saphir, A. (2018, October 15). As companies embrace AI, it's a job-seeker's market. *Reuters.* Available https://www.reuters.com/article/us-usa-economy-artificialintelligence/as-companies-embrace-ai-its-a-job-seekers-market-idUSKCN1MP10D (accessed 19 February 2019).

Schellekens, M. (2015). Self-driving cars and the chilling effect of liability law. *Computer Law & Security View*, 31(4), 506-517.

Shigemura, J., Nakamoto, K., & Ursano, R. J. (2009). Responses to the outbreak of novel influenza A (H1N1) in Japan: Risk communication and shimaguni konjo. *American Journal of Disaster Medicine*, 4(3), 133-134.

Society of Automotive Engineers International (SAE). (2018, June 15). Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. Available https://www.sae.org/standards/content/j3016_201806/ (accessed 14 February 2019).

Strategic Council for AI Technology. (2017). Artificial intelligence technology strategy (Report of strategic council for AI technology). New Energy and Industrial Technology Development Organization, Japan. Available https://www.nedo.go.jp/content/100865202.pdf (accessed 4 March 2019).

Tecuci, G. (2012). Artificial intelligence. *Wiley Interdisciplinary Reviews: Computational Statistics*, 4 (Marc/April), 168-180.

Toyota Motor. (2018a, October 30). Toyota, TRI-AD, and Tokio Marine & Nichido Fire Insurance to establish business alliance to develop advanced automated driving technology. Available https://global.toyota/en/newsroom/corporate/25142470.html (accessed 2 February 2019).

Toyota Motor. (2018b). Surviving a once-in-a-century period of profound transformation. Available https://global.toyota/en/company/messages-from-executives/details (accessed 2 February 2019).

Toyota Motor. (2019, February 1). Toyota and SoftBank joint venture, MONET, starts operations. Available https://global.toyota/en/newsroom/corporate/26434644.html (accessed 2 February 2019).

TRI-AD. (2019, February 28). TRI-AD and CARMERA team up to build high definition maps for automated vehicles using camera data. Available https://www.tri-ad.global/news/20190228 (accessed 1 March 2019).

WIPO. (2019). WIPO technology trends 2019: Artificial intelligence. Geneva: World Intellectual Property Organization.

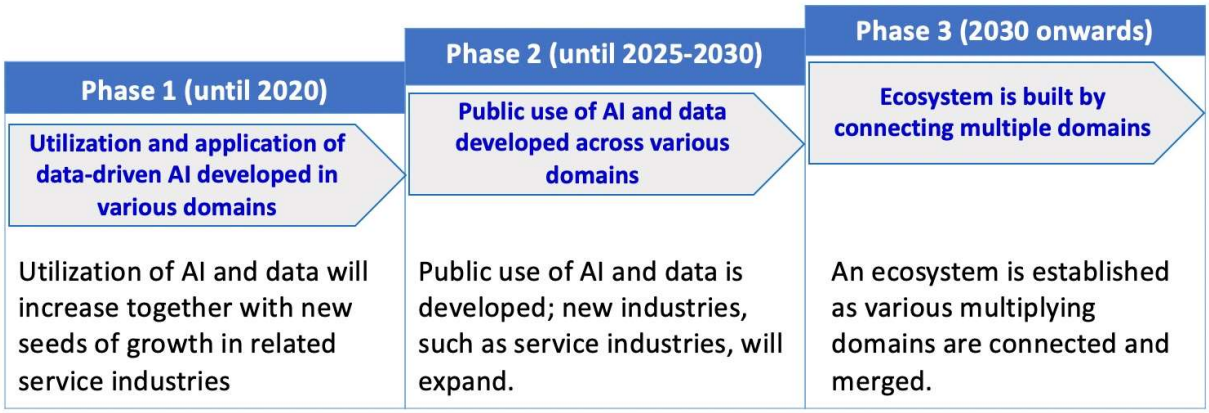
Womack, J. P., Jones, D. T., & Roos, D. (1990). The machine that changed the world: The story of lean production. New York: Rawson Associates.

Table 1: Levels of driving automation

	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
What does the human in the driver's seat have to do?	You <u>are driving</u> whenever driver support features are engaged – even if your feet are off the pedals and you are not steering.			**You <u>are not driving</u> when these automated driving features are engaged – even if you are seated to take over driving.**		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.			**When the feature request,** You must drive	**These automated driving features will not require you to take over driving.**	
	DRIVER SUPPORT FEATURES			AUTOMATED DRIVING FEATURES		
What do these features do?	These features are limited to providing warnings and momentary assistance.	These features provide steering OR brake/acceleration support to the driver.	There features provided steering AND brake/acceleration support to the driver.	**These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met.**		**This feature can drive the vehicle under all conditions.**
Example features	• Automatic emergency braking • Blind spot warning • Lane departure warning	• Lane centering OR • Adaptive cruise control	• Lane centering AND • Adaptive cruise control	• **Traffic jam chauffeur**	• **Local driverless taxi** • **Pedals/steering wheel may or may not be installed.**	• **Same as level 4, but feature can drive everywhere in all conditions.**

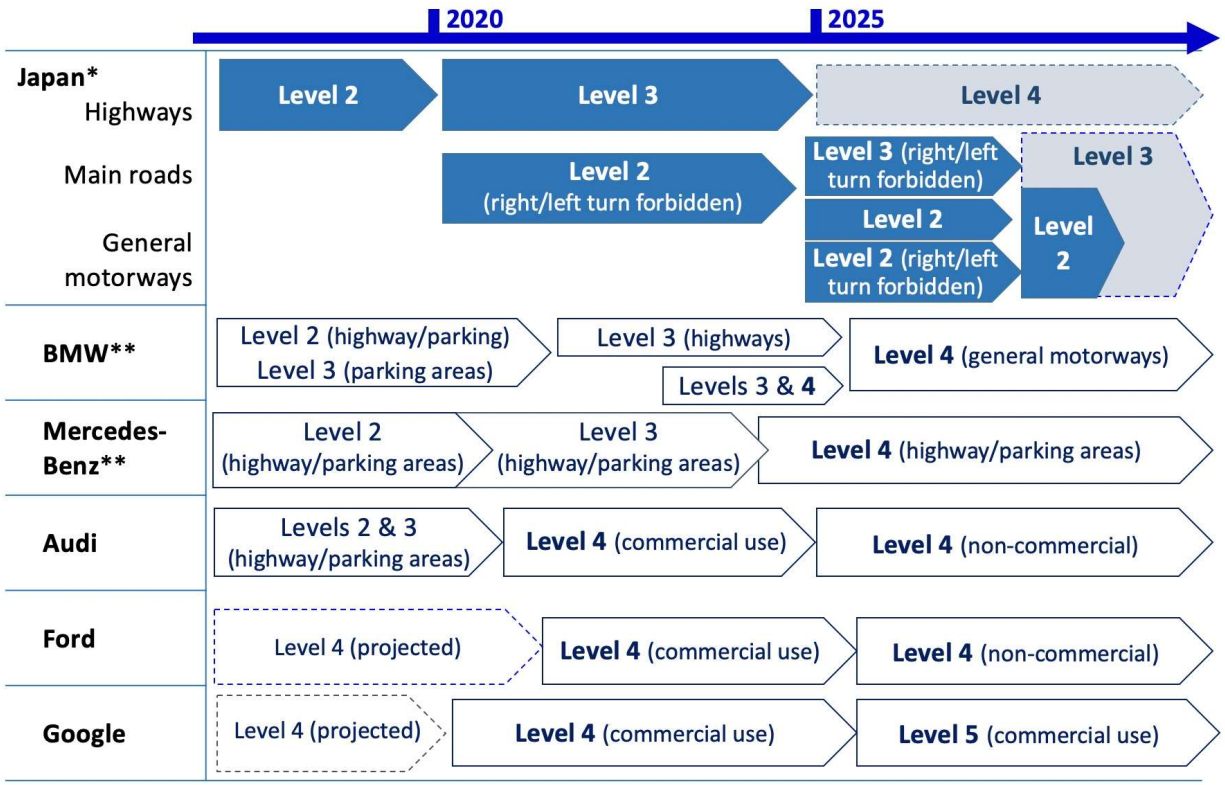
(Source: SAE, 2018)

Figure 1: Development phases of the Japanese government's AI



(Source: Strategic Council for AI Technology, Japan, 2017)

Figure 2. The Japanese government's roadmap for autonomous cars: A comparison with major foreign players' projections



Note: *Japan's plan does not distinguish commercial and non-commercial use; **BMW and Mercedes-Benz develop self-driving cars for both commercial and non-commercial use concurrently.

(Source: Adopted from the Autonomous-Driving Business Discussion Group, 2018)

Figure 3. Some of Toyota's key strategic ties for self-driving cars