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Abstract

The automobile industry has been changing fast over the past few years. Japan's automobile industry has surged, with manufacturers beginning to introduce next generation vehicles (NGVs). Many countries are interested in promoting NGVs especially hybrid electric vehicles (HEVs), electric vehicles (EV) and other alternatives to conventional internal combustion engines because of concerns about energy security, oil dependence, air pollution, and global climate change. Sales rates of NGVs vary in different countries and

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regions. Therefore, many countries have set targets for NGV development in recent years and have adopted a number of policies to decrease air pollution and alleviate energy pressure Despite the fact that the adoption of NGVs has increased in the past few years, more policies, such as financial incentives, technology support or charging infrastructure, should introduced by local and central governments to promote a broader range of uses of NGVs in Japan. This paper will review the relevant policies that different countries may adopt for stimulating the NGV market. Based on the review, the relationship between the policies and the adoption of NGVs by taking Japan as an example, will be analyzed. In conclusion, some effective incentives and strategy policies are summarized to help spur the market. Thereby, different countries may learn from each other by introducing effective strategies based on the actual situation.

Keywords: electric vehicles; incentive; strategies mechanism; relationship

Ⅰ. Introduction

The automobile industry has been innovating fast, which is contributing to social change world-wide through things like urbanization, sustainability and the sharing economy, and changing the way customers interact with vehicles. The automobile industry continues to be one of the most important industries in the Japanese economy, supporting 5.34 million employed in 2016 (JAMA, 2017, 3). It contributed to 17.5 percent of the total value of Japan's manufacturing shipments, and 40 percent of the value of machinery industries in 2014. Automotive shipments (both domestic and export international shipments, including motorcycles, auto parts, and others) in value terms, totaled 53.3 trillion yen in the same year (JAMA, 2017, 3).

Among the various challenges facing the Japanese automobile industry, oil prices (which spiked to over 140 dollars per barrel or 42 US gallons, which

is about 159 litres), environmental protection and safety are important. The automobile industry has been striving to develop and implement innovative environmental and safety technologies which encourage innovation of NGVs as well as electric vehicle development. Currently, Japan leads the way with regard to the endorsement of next generation vehicles (NGVs) like hybrid vehicles (HV) and electric vehicles (EV). For example the Toyota Prius, and Nissan Leaf have initiated the age of mass production and Nissan and General Motors announced their intentions to mass produce the Leaf and Volt, following the minor success of Tesla's Roadster. From 2010 to 2014 total plug-in electric vehicles (PEV) registrations reached 500,000 units worldwide (JAMA, 2017, 3-5); meanwhile, the rate of sales continues to double every year and new models are entering the market. Governments around the world are implementing electric vehicle initiatives and preparing the market with numerous national and regional incentives and supporting charging infrastructure. Despite this increased policy interest in encouraging plug-in electric vehicle (PEV) markets, market penetration rates vary dramatically from region to region.

NGVs are becoming an effective solution to reducing emissions and saving foreign currency for import gasoline in Japan. Despite extensive study on the attributes, and the characteristics of NGVs such as their charging infrastructure and design, the development and network modelling of NGVs is still evolving and limited.

This article provides a comprehensive overview of NGVs research and describes NGVs, especially the hybrid and electric vehicles' concepts, markets share and future markets, prospects and development. Then, the studies goes on to conclude that it is important to take into account electric vehicles' special characteristics in predicting their 'routing behaviors', problems with electric vehicles in the network and charging facilities are discussed in detail.

This study is based on secondary and archival materials and documents. This study will also attempt to verify the innovation strategies and business

opportunities of the automobile industry in Japan. The discussion of this paper is organized as follows: Section 2, Automobile Industry in Japan; Section 3, The Present Trends of the NGVs industry in Japan; Section 4, Government Strategies and Incentives for the NGVs ; and Section 5, Concluding Remarks.

Ⅱ. Automobile Industry in Japan

The automobile industry has been consistently promoting the quality, reliability and productivity of NGV's, in order to make them convenient to people all over the world. Now, a century on since the automobiles were first introduced to the public, with a world population of more than a billion vehicles, the automobile is a core element of personal mobility. Since the end of the twentieth century, auto-makers have contributed to the production of next generation vehicles, especially electric vehicles which have become increasingly popular in the European, American and some Asian markets. The number of next generation vehicles launched (EVs or PHEVs) is increasing while the brand choice is progressively increasing worldwide. Navigant Research (2013) estimates that for example, the number of plug-in electric vehicles on roadways will grow rapidly to more than 3,000,000 globally by 2017.

The auto industry will play an important part in the technology revolution. This pattern holds true in virtually every field, and each pulse opens the door to new innovations that revolutionize industries and, sometimes, society itself. Throughout history, technological innovation in automation has underpinned every industrial revolution. Continuing this trend, progress in scientific disciplines such as mechatronics, computing and communication technologies has given birth to the field of modern robotics and autonomous systems (RAS); giving rise to new capabilities that will enable economies to be more productive and resilient.

The present innovation of the automobile sector is another revolution in

industry. It is part of the larger "fourth industrial revolution"[(1)] that is the theme and focus of the World Economic Forum. In the auto industry, the revolution is being driven by the convergence of[(2)] Is this the correct place for the index connectivity, electrification and changing customer needs.

Japan is the world's second-largest producer of automobile and the third-largest market for auto sales after China and the United States (Table 1). Technological innovation in vehicles will be looked at through recent inventions from a trio of major automobile manufacturers based in Japan: Toyota Motor Corporation, Honda Motor Co., and Nissan Motor Company Ltd. although the Japanese automobile industry includes a number of well-known players like Daihatsu, Mazda, Suzuki, Subaru, Mitsubishi, Kawasaki, Isuzu, Mitsuoka and Yamaha. In terms of innovation, auto manufacturers in Japan, are producing next generation vehicles, higher efficiency internal combustion engines for hybrid vehicles, electric vehicles and self-driving cars (manufactured by Toyota). Japan's technical strength is widely recognized and Japan's auto companies sell globally, especially in emerging countries.

Technology development and innovation have come a long way to date. The world's first self-flying taxi (autonomous air taxis, AAT) service in Dubai astonished people for innovations in high technology. AAT, is an environmentally-friendly vehicle. The two-seater AAT, capable of transporting

Table 1: Production and Sale of the Vehicles in Japan, America and China (Unit: vehicle)

Year	Japan		America		China	
	Production	Sales	Production	Sales	Production	Sales
2000	10,140,796	5,963,042	12,799,857	17,811,673	2,069,069	2,088,626
2005	10,799,659	5,852,067	11,946,653	17,444,329	5,708,421	5,766,679
2010	9,625,940	4,956,136	7,762,544	11,772,220	18,264,761	18,061,936
2015	9,278,321	5,046,510	12,100,095	17,835,789	24,567,250	24,661,602
2016	9,204,590	4,970,258	12,203,587	17,865,376	28,118,794	28,028,175

Sources: Fourin, (2017), 14, 24, *Nikkan jidosha shinbunsha*, (2015), 498,503, 509

people without a pilot, was produced by Volocopter, a Germany-based manufacturer of autonomous air vehicles. The artificial intelligence (AI) technology has also been adopted in the automobile industry[(3)].

The research on NGVs has increased in popularity in recent years, as witnessed by the growing number of publication on green transportation (Demir et al., 2014) and city logistics (Gonzalez-Feliu et al., 2014). Study on green transportation has focused on the pollution routing problems (Bektas and Laporte, 2011) which seek to design optimal vehicle routes in which routing cost and polluting emissions are jointly minimized. However, advances in technology suggest that driving range can be extended, charging time shortened and battery cost lowered. Also, after a few years of massive production, the unit cost for EVs, like most new technologies, is likely to fall (Hidrue, *et al*. 2011, 686-707). Williams explains that there is a wide range of environmental problems associated with the automotive industry, including those linked to high levels of resource use in vehicle production and waste materials when the cars reach the end. (Williams, 2007, 1093-1103).

Next-generation vehicles are expected to be popularized from the viewpoint of environmental improvement and energy consumption reduction (European Commission, 2017; Brady and O'Mahony, 2011; USDOE, 2016, Steinhilber *et al*., 2013). Rezvani *et al.* (2015) organized past studies from the viewpoint of consumer behavior, and attitudinal factors on policies and pro-environmental behaviors, innovation adaptation, symbolic, and emotional behaviors are affecting is discussed. Although Wan et al. (2015) points out that China has a large subsidy for EV aimed at mitigating air pollution, but why isn't the policy wide-spread, but at the same time, a protectionism policy by local governments, EV technology uncertainty and consumer preferences, a lack of investment in charging facilities, and discreet investment by automakers and battery manufacturers. Larson et al. (2014) investigated the level of willingness car buyers to pay for EV vehicles at Monitoba in Canada, revealing that it is almost

the same as that of a conventional car. This means that there is no payment premium on EV on average, even if providing future fuel cost reduction information. On the other hand, about 30 percent of respondents also replied that there is a premium of around $5,000 on cars (Kii and Miyoshi, 2017, 2).

This is an important observation in that, there has been an expansion of demand for NGVs which has encouraged automobile industries to further develop their technology. At the same time, the METI, next generation vehicle promotion center, different ministries, between the central government and local governments, and between the public and private sectors are the basis for the effective implementation of plans and policies of NGVs. In relation to NGVs, the role of the Japanese government has been relatively modest. In the case of conventional automobiles, METI has had no major role in deciding output, investment, product design or global strategy. METI's concerns however have been various, surrounding issues of the industry including air pollution, fuel efficiency, trade negotiations and improving business environments.

1. Types and Technical Difference of NGVs

'Next generation vehicles'[(4)] are sometimes successfully innovation, like hybrid and electric vehicles (EV) vis-à-vis small or light vehicle (LV) and low-cost. There has been considerable successful innovation in hybrid and electric vehicle (EV) vis-à-vis small or light vehicle (LV), as well as improvements (decreases) in production costs.

Over the last 75 years, significant technological development has taken place, changing and re-inventing how motor vehicles are produced. Innovation patterns and industrial dynamics in the automotive industry has been continuous improvement based on process innovation, and adoption of new technologies (Magnusson and Berggren, 2011).

Over the last few years there have been major changes when it comes to the automobile industry and technologies have continued to change with the

rise of more fuel-efficient and eco-friendly vehicles taking over the market place. According to the Ministry of Environment (2016) in Japan, NGVs are environmentally friendly, emit less air pollutants such as nitrogen oxides (NOx) and particulate matter (PM), or do not emit any pollutants at all, and offer excellent fuel economy. Here, it will introduce the type and mechanism of these NGVs (MOE, 2017, 4).

The rise of hybrid electric vehicles in Japan, hands down has the highest penetration of hybrids worldwide. The term "next-generation vehicles" refers to alternative energy-powered vehicles and clean diesel vehicles. Several automakers develop NGVs, they include; Honda, Toyota, Nissan, Mitsubishi to name a few. These automakers all setting up strategic plans for mass production of NGVs in the near future and are broadly divided into hybrid vehicles, electric vehicles. It will attempt to explain the main differences between hybrids and other types of electric vehicles.

(1) Hybrid Vehicles (HV)

Hybrid vehicles are vehicles with a normal internal combustion engine and an electric battery. It is not usually possible to recharge this battery remotely, but it is recharged by the vehicle itself whilst the car is in motion. Various types of HEV now exist, including micro hybrids, mild hybrids, full hybrids, plug-in hybrids, and electric vehicles. The options available stand as a testament to the popularity and importance of the HEVs. According to JAMA, in relation to hybrids, there are two basic concepts with PHEVs: parallel and series. The parallel PHEV is like the Prius and Ford Escape, which can be driven from either a battery, an internal combustion (IC) engine or both. In the series PHEV (is the PHEV series a number of different cars, the original GM Volt, simply used the motor to charge the battery. With larger batteries this becomes an EV with 'range extender' engine (JAMA, website). Hybrid vehicles still use fossil fuel. Doubling the gasoline mileage in hybrid vehicles will reduce fuel

consumption, but is still not the best solution regarding the energy crisis and environment protection (Ahn & Lim, 2006).

(2) Electric Vehicles (EV)

The electric vehicle has technological different from the conventional gasoline vehicles. The electric vehicles are broadly classified into hybrid electric vehicles (HEV) those that generate all their own electric energy; battery electric vehicles (BEV) those that only use electricity from the grid; plug-in electric vehicles (PEV) those that use electricity from the grid and gasoline; and extended-range electric vehicles (EREVs) those that is powered by battery for a certain number of miles. Due to high cost of battery the automobiles manufacturer has been innovating new technology on long existence battery to move vehicles. The price of battery, in the case of i-MiEV of Mitsubishi Motors is 2,400,000 yen. It more than half of price of electric passenger vehicles is 4,599,000 yen, and reduction of this cost is indispensable to the spread of electric vehicles.

(3) Hydrogen Vehicles

Hydrogen vehicles are powered by hydrogen that is subjected to combustion. Fuel cell vehicles are also powered by hydrogen which, without combustion, is converted into electricity by the fuel cells. The hydrogen combustion process generates only water and some nitrogen oxides (NOX); no CO_2, carbon monoxide, hydrocarbons or sulfur compounds are released. The major car manufacturer in Japan laying emphasis on development of hydrogen fueled car most are Toyota and Honda. Toyota in particular sells “MIRAI” which served as the high production cost (per car 7 million yen). According to Ministry of Economy, Trade and Industry, the total sales of FCV in 2017 was 4300 units in Worldwide, and in Japan sold 2200 units, the target of sales in 2020 is 40,000 units annually (MIETI, website). Due to limited hydrogen supply station and

high prices the demand increasing slowly.

(4) Natural Gas Vehicles

Natural gas vehicles, use either compressed natural gas (CNG) or liquefied natural gas (LNG) for propulsion. Most are CNG vehicles, natural gas is composed of methane and other hydrocarbon gases. Natural gas can be used in all classes of vehicles – motorcycles and three wheelers, cars, vans, light and heavy duty trucks, buses, lift trucks, trains, boats, even aircraft locomotives. In 2017, there were more than 24 million Natural Gas Vehicles (NGVs) operating worldwide among these Japan has 46,316. (NGV Global, http://www.iangv.org/)

(5) Clean Diesel Vehicles

The overall emissions performance of diesel engines has improved dramatically in recent years in response to ever more stringent regulatory requirements. Clean diesel engines now provide significantly reduced emissions compared to conventional diesel engines and, in comparison with gasoline engines, considerably (up to 30 percent) greater fuel efficiency.

２．NGVs Manufacturers in Japan

The automobile industry in Japan has been making efforts to innovate and mass produce NGVs, particularly HVs and EVs. (Table 2). Nissan, stands alone with EV being the ‘first car’, while other manufacturers consider EV as a ‘secondary car’ for limited and specified short-distance driving . This is evident in the size of Nissan Leaf, it being a five-person passenger car, while Mitsubishi Motors is introducing the PHV concept car PX-MiEV to be used for long-distance driving while the i-MiEV is to be used for shorter trips and daily commuting.

Toyota, Honda, Nissan, and Mitsubishi are producing NGVs with the release of the Toyota Prius, Honda Fit, Nissan Leaf, and Mitsubishi i-MiEV

Table 2: Production of NGVs by Different Automakers

(Unit: vehicle)

Year	All Vehicles	Toyota		Nissan		Honda		Mitsubishi	
		All Vehicles	PHEV	All Vehicles	Leaf	All Vehicles	Fit	All Vehicles	i-MiEV
2012	9,912,966	3,377,598	480,640	1,148,265	14,000	1,029,313	300,644	517,088	12,585
2013	9,602,591	3,185,473	601,913	964,546	29,230	840,650	250,000	591,893	2,264
2015	9,278,058	3,171,757	267,800	872,796	9,300	730,207	191,000	635,441	5,597
2016	9,204,419	3,187,999	471,000	950,054	22,400	820,240	215,600	555,018	5,248

Source: Fourin, 2014, 275-277.

respectively. Toyota's HV *Prius*, has become popular due to its high gas mileage. The biggest technological challenge in EVs is the performance of the batteries. Japan not only has car manufacturers but also has several EV-battery manufacturers. Car manufacturers and battery manufacturers collaborate closely in the development of EVs. *Prius* delivers up to 26.4 km per liter, while Honda's Accord PHEV can deliver 37.6 km per liter (Table 3).

Table 3: Comparison range, battery and charging time of different NGVs

Vehicles	Range	Battery	Charging time
Mitsubishi i-MiEV	180 km	16 kWh	Quick charging (50kW) 80% 30 min 8 hours 230 volt 10A
Nissan Leaf	228 km	24 kWh	Quick charging (50kW) 80% 30 min 8 hours 230 volt 16A
Toyota Prius PHV	26.4 km in EV mode	4.4 kWh	1.5 hours 230 volt 16A
Honda Accord PHEV	37.6 km		4 hours 20 min Quick charging 80% 30 min

Note: The charging time depends on the size of the battery and the output from the socket. The exceptions are the two pure EVs Mitsubishi i-MiEV and Nissan Leaf which support quick charging through the CHAdeMO protocol
Source: Nikkan Kogyo Shinbunsha, 2014, 29

1） Toyota Automobile Industry

With effort and determination, Toyota Motor Corporation has become one of the most successful companies in the world. The technologies are driving

the rapid changes in the business environment surrounding vehicles, such as electrification, connected systems, and AI. As the creator of the Prius, the Mirai fuel cell, Lexus and Scion brands, Toyota have earned a prestigious position in the top 20 on the IPO[(5)] list in the world automobile industry. Toyota's industry-leading patent numbers illustrate the company's increasing success as one of the world's leading innovators (Toyota 2017,6).

Toyota with its hybrid Prius, is among the leading automotive brands in terms of reliability, initial quality, and long-term durability. Toyota is one of the largest companies to push hybrid electric vehicles in the market and the first to commercially mass-produce and sell such vehicles (Table 4), with the introduction of the Toyota Prius in 1997. The research and development (R&D) of Toyota's ascension is best captured by the Japanese word *jojo:* meaning "slowly, gradually, steadily" which has been the catch phrase for the development of HEVs. In November 2016, Toyota started to develop an EV that will be able to run more than 300km on a single charge by 2020. The future model is expected to use an existing platform, such as Prius or Corolla (Nikkei, 2016). Toyota eventually began providing including smaller cars such as Camry and Lexus divisions, producing some hybrid luxury vehicles. It labeled such technology in Toyota cars as "Hybrid Synergy Drive" and in Lexus versions as "Lexus Hybrid Drive" (Toyota website).

Table 4: NGVs Sales of Some Automobile Industry in Domestic Market (Unit: vehicle)

Year	All New Vehicles	Toyota		Nissan		Honda		Mitsubishi	
		All Vehicles	PHEV	All Vehicles	Leaf	All Vehicles	Fit	All Vehicles	i-MiEV
2012	5,210,290	1,597,608	317,676	662,963	11,115	745,204	209,275	140,493	4,782
2013	5,692,162	1,597,608	253,711	682,659	13,021	763,388	181,414	139,016	2,952
2015	4,937,734	1,435,934	127,403*	594,181	9,057	726,927	154,838	102,009	1296
2016	5,077,904	1,586,822	248,258*	539,719	14,795	707,044	148,176	85,720	408

Note * the data only Prius model
Source: Fourin, 2014, 282-285. Fourin, 2017, 280-283, Nikkan Jidosha Shinbunsha, 2017,334-355

2） Nissan

J*idosha-Seizo Kabushiki-Kaisha* was established in December 1933. The company's new name, adopted in June 1934, was an abbreviation for Nippon Sangyo, a "*zaibatsu*". Nissan produced its first Datsun in 1914. In 1960, Nissan became the first Japanese automaker to win the Deming Prize for engineering excellence. The energy crises of the next decade fueled the rise in exports of affordable, fuel-efficient Japanese-made cars: The third-generation Sunny got the highest score on the U.S. Environmental Protection Agency's tests of for fuel economy in 1973. Nissan-which dropped the Datsun name in the mid-1980s-is the third-largest car manufacturer in Japan, behind first-place Toyota and just behind Honda. By the late 1990s, however, Nissan was struggling, and in 1999 it entered into a partnership with the French carmaker Renault. The partnership was a success, and Nissan's sales buoyed in the early 21st century, driven in part by sales of the company's popular electric automobiles (JAMA, website). In 2009, the EV-11 prototype electric car was based on the Nissan Tiida. In 2010, Nissan introduced the 'Nissan Leaf' as the first mass-market, all-electric vehicle launched globally. As of March 2014, the Nissan Leaf is the world' s best selling highway-capable all-electric car (Table 4). Global sales of Leafs totaled 100,000 in 2014, representing a 45 percent market share of worldwide pure electric vehicles sold since 2010 (JAMA, website).

3） Honda

The Honda Motor Company began producing motor cycles in 1949. Honda was the first Japanese automobile manufacturer to release a dedicated luxury brand, Acura, in 1986. Since then, Honda has also been involved in artificial intelligence/robotics research and released their ASIMO robot in 2000. In late 1999, Honda launched the first commercial hybrid electric car sold on the U.S. market, 'the Honda Insight'. The first-generation Insight was produced in 2006 and had a fuel economy of 3.4 L/100 km, the most fuel-efficient mass-produced

car at the time. Total global sales for the Insight only totaled around 18,000 vehicles.

Honda introduced the second-generation Insight into Japan in 2009, and the ‘Honda Fit’ EV, version starts at 1.59 million yen, the lowest price for a gasoline-hybrid electric vehicle sold in the country (Table 4). The Fit Hybrid features a 1.3-litre engine and electric motor, with an estimated fuel economy of 3.3 liter per 100 kilometers. More recently, the customer base for Honda’s efficient, environmentally friendly cars has grown exponentially. The Fit is selling well, and the company has plans to introduce a five-door hybrid model that will compete with Toyota’s Prius. At the same time, Honda’s R&D have introduced thousands of inventions. In 2012, the International Automotive Patent Board awarded Honda third place for patents, while GM earned top place and Toyota come second (Jeffrey, 2014, 2000).

4） Mitsubishi

Mitsubishi Motors Corporation is a multinational automotive manufacturer headquartered in Minato, Tokyo, Japan. In 2011, Mitsubishi Motors was the sixth biggest Japanese automaker and the sixteenth biggest worldwide by production. It was the first auto maker to mass-produce an EV, the i-MiEV, an all-electric mini-car with a lithium-ion battery pack tucked under its floor. Mitsubishi delivers remarkable eco-efficiency without compromising comfort, performance or convenience.

Ⅲ. The Present Trends of the NGVs Industry in Japan

Japanese automobile manufacturers are mainly focusing on EVs PHEVs, HVs and FCVs when it comes to environmental-friendly vehicles. The major automobile industries in Japan have diverse strategies and are planning to release vehicles featuring different technologies. HEVs, EVs and PHEVs have

been on the market for several years, while FCVs started in 2016. Toyota, Honda, Nissan and Mitsubishi are targeting the fuel cell vehicles market in Japan. Hydrogen fuel suppliers have a goal to construct about 100 hydrogen fueling stations gradually with setting up having started in 2015.

The Next Generation Vehicle Promotion Center in particular set a goal to expand all-electric vehicles and plug-in hybrid vehicles, in addition to the hybrid vehicles in which the Japanese automobile industry has already extended into the international market. To support more financially, it will be necessary for the government to provide incentives such as development and purchasing subsidies, tax advantages, and infrastructure building (Next Generation Vehicle Promotion Center, 2010, website).

The number of hybrid vehicles is considerable larger in Japan than in other markets, mainly due to the success of the Toyota Prius, which is one of the most sold vehicles in Japan. Besides the Toyota Prius, Honda has also sells hybrid vehicles. Among the hybrid vehicles there are a small number of buses, trucks and other special vehicles included. The small numbers of plug-in hybrids are pre-production vehicles, Toyota started to lease pre-production version of its 2012 Toyota Plug-in Hybrid at the end of the 2009 fiscal year to the central government, local governments, and corporations such as electric power companies, and other entities (Toyota 2009). When the 2012 Toyota Plug-in Hybrid was released on the market, the number of PHEVs was expected to increase considerably (Swedish Agency for Growth Policy Analysis, 2012, 12-13).

HEVs have been on the market for several years and are now fairly sophisticated and reliable, and are consequently in high demand. However, conventional hybrids still depend entirely on liquid fuels, while using regenerative braking to increase efficiency. In addition, EVs are also promoted in Japan, and Nissan and Mitsubishi Motors have released EV and Toyota is about to release a plug-in version of its Prius.

1． Production of NGVs

HEVs have the potential to use electricity to power the onboard engine via plugging in appliances. They have the potential to achieve greater fuel economy than conventional gasoline-engine vehicles, as most HEVs will use the power from electricity providers rather than from gasoline stations (Madslien, 2009). Recently, NGVs demand has continued to expand in the Japanese market. Table 5 shows the shifting production system in the automobile industry from the conventional automobile technology to electric and hybrid vehicle technology using the national and multi-regional input-output models in Japan. The development of co-operative infrastructure and low-cost technologies will play a key role in the spread of NGVs. Currently, Japan is one of the leading Asian countries in the world when it comes to EV production.

Table 5: Total Production of NGVs in Japan (Unit: vehicle)

Year	PHV	EV	HV	NGVs	All Vehicles
2005	0	1	260,653	260,654	9,154,147
2006	0	5	333,273	333,278	9,787,234
2007	0	18	516,437	516,455	10,104,399
2008	0	26	407,727	407,753	8,554,399
2009	515	1,744	821,947	824,205	7,708,731
2010	251	16,169	729,682	746,102	7,741,063
2011	8,472	42,036	1,028,162	1,078,670	7,911,073
2012	35,782	29,757	1,244,770	1,310,309	8,190,914

Note: includes NGVs mini-cars
Source; *Jisedai jidosha shinko senta*, 2017.

2． Domestic Market of NGVs

Although the domestic market in Japan has experienced economic stagnation, the global financial recession and the natural disasters of March 11, 2011, the vehicles market has seen a firm upward trend as a result of specific market policies and government incentives.

３． Sales of NGVs

HVs already have a market in Japan, and PHEVs and EVs sales have been growing. Annual sales of electric cars increased over the ten years period from 2005 to 2014. Due to the late introduction of the latest model and associated technology, the sale of NGVs dropped in 2015 to 937,575 HV units and 10,467 EV units. Comparatively, in 2014, HV sold more than one million and EV sold 16,110 units on the Japanese local market. Viewing this as an opportunity Tesla introduced its latest model e-vehicle into the Japanese market, and has had a gradually expanding market with 4,364 vehicles being sold in 2009. sales levels have increased greatly (Table 6). The previous sentence says a ‘gradually expanding market Regarding HV, since Toyota Motor released the “Prius” as the world’s first mass-produced HV in 1997, it is driving global environmental vehicles, and its HV cumulative sales volume in 2016 reached 9.11 million units (Nikkei Sangyo Shimbun, 2016 May 23rd).

In terms of the NGVs market, clean diesel vehicles are still just a tiny fraction of the total, but this means that there is a good possibility for future growth (Table 7). The government has set diffusion targets to pursue for each type of vehicle for accelerating the spread of next generation vehicles. Strategies, incentives, plans and policies has been implemented to expand the share of next generation vehicles in the national vehicle fleet in order to increase not only PHEVs and EVs, but also chargers. There is a remarkable number of car chargers, 40,000 compared to 34,000 gas stations nation-wide (Feb. 16th, 2015), planned for installation between 2020 and 2050 in Japan (Table 7). In relation to this nation-wide project the Next Generation Vehicle Promotion Center (2010) considered next-generation automobile development, future market expansion and market competitiveness.

In 2013, the number of next-generation vehicles in use in Japan was roughly 4.1 million units, or as little as 5.4 percent of the total number of vehicles in use (*Jisedai jidosha shinko senta*, website). In the years ahead, a steady growth is

Table 6: Sales of Next Generation Passenger new car in Japan

(Unit: vehicle)

Year	HV	PHV	EV	Fuel cell	Clean diesel	Total NGVs	Total All Vehicles	Share of NGV(%)
2005	60,871	0	3	0	0	60,874	4,755,369	1.3
2006	88,573	0	15	0	0	88,688	4,557,330	1.9
2007	88,438	0	62	0	0	88,500	4,390,344	2.0
2008	108,518	0	46	0	0	108,518	3,908,881	2.6
2009	347,999	0	1,078	0	4,364	353,441	4,175,456	9.0
2010	481.221	0	2,442	0	8,927	492,590	3,880,266	11.7
2011	451,308	15	12.607	0	8,797	472,727	4,009,988	13.4
2012	887,863	10,968	13,469	0	40,201	952,501	4,439,092	20.8
2013	921,045	14,122	14,756	0	75,430	1,025,353	5,375,513	22.5
2014	1,016,757	16,178	16,110	7	78,822	1,127,874	5,562,888	24.0
2015	937,575	14,188	10,467	411	153,768	1,116,409	5,046,510	26.5
2016	1,275,560	9,390	15,299	1,055	143,468	1,444,772	4,970,260	34.8

Note: “Hybrid vehicles” includes hybrid minicars as of 2016.
Source: JAMA and *Jisedai jidosha shinko senta 2017.*

Table 7: Estimated Market Expansion of NGVs in Japan

(Unit: Ten thousand vehicles)

Vehicle	2020		2030		2050	
	Sales	Owned	Sales	Owned	Sales	Owned
Hybrid	110	800	120	1,180	110	1,350
Plug-in hybrid	35	130	63	500	62	780
EV (Mini car)	34	140	45	380	44	550
EV (car)	17	67	28	210	26	330
Fuel cell	5	17	5	51	8	84
Clean diesel	29	180	27	260	18	270
Total	234	1,348	291	2,627	275	3.551
Share of NGV(%)	43	19	57	38	57	54

Note: “Hybrid vehicles” includes hybrid minicars as of 2016.
Source: JAMA and *Jisedai jidosha shinko senta*

expected was expected and achieved in the number of these vehicles in use by the general public.

Shown in Table 8 is the number of electric and plug-in hybrid cars owned by

Table 8: Number of NGVs owned in Japan (Unit: vehicle)

Year	PHV	EV	Hybrid	Total
2006	0	505	343,626	343600
2007	0	421	429,274	429300
2008	0	389	536,473	536500
2009	165	1,941	983,831	983800
2010	379	9,030	1,418,400	1418400
2011	4,132	22,262	2,029,009	2,029,000
2012	17,281	38,707	2,852,105,	2,852,105
2013	30,171	54,757	3,813,387	3,898,315
2014	44,012	70,706	4,717,344	4,832,212
2015	57,130	80,511	5,764,401	5,902,672

Source: JAMA ,and *Jisedai jidosha shinko senta*, websie

Japanese citizens in 2015. In cumulative numbers in the 2006 to 2015 period, even if the volume remained low compared with hybrid cars (near 6 million), the EVs increased by 80,511 units and the PHEVs by 57,130 units in 2015. This confirms the start of the market, which was pushed by the great number of promotion measures and subsidies by the government for purchasing electric vehicles.

Ⅳ. Government Strategies and Incentives for the NGVs

The roles of the automobile industry, government, and research are important to the development of NGVs. An organized, systematic approach should be taken with respect to moving ahead with the technical development that each party ought to undertake and the efforts that they must make to lay the groundwork for market penetration. The government needs to implement the plans, policies, incentives. These steps, which (will) involve the cooperative efforts of relevant ministries and offices within local and the central governments, are required in order to promote the expeditious development of NGVs and prepare the setting for dissemination of vehicles to the market.

The government of Japan developed a comprehensive plan to coordinate the efforts of government agencies, private entities, and local governments to support NGVs development. The Japanese government first started to support research and development of EVs in an effort to solve the problems with pollution in 1970s and to overcome the oil crisis. With the decline in oil prices, EVs were competitive with conventional vehicles (gasoline-fueled), however with EV's relatively low speed and limited range it took longer time for development and production.

In the 1990s, California adopted a law demanding car manufacturers to participate in a zero emissions vehicle program. Regrettably, due to high costs batteries and the poor performance of charging infrastructure, electric cars were unsuccessful on the American market at that time (Nikkei Weekly 2007, 2008). However, since the being of the 21st century, Toyota, Nissan and Mitsubishi Motors have each successfully produced EVs for a larger market and Toyota has a plug-in version of its Prius.

The government of Japan committed to the Kyoto Protocol (1997)[(6)], to reduce its annual greenhouse gas (GHG) emissions between 2008 and 2012 to 6 percent below 1990 levels. In addition, the Japanese government developed the *Action Program to Arrest Global Warming* to stabilize the level of CO_2 emissions (per capita) to 1990 levels by 2020 (UNCCC, 2006, website). The use of NGVs, and especially EVs, has resulted in large investments towards the development of EV infrastructure and the numerous schemes and promotion programs implemented by the Government, the most important are the "Next Generation Automobile Strategy 2010" and the "Automobile Industry Strategy 2014". The Plan stipulate that 20 to 50 percent of the cars on the on Japanese roads should be NGVs by 2020 and 50 to 70 percent by 2030. They also called for up to 1 percent of that number to be fuel cell vehicles by 2010 and up to 3 percent by 2020 (Table 9). Under these circumstances government emphasis on financial incentives, development of infrastructure and strategies of NGVs are

noted as follows:

1． Financial Incentives of the Japanese Government

Financial incentives have include subsidies, sales tax waivers, and leasing incentive programs. The taxation and incentive regimes, approval processes, insurance policies and repair and maintenance facilities, are all important to demand and expansion of the EVs market. These activities directly support consumer demand of these technologies, and mitigate some of the uncertainty associated with the large-scale adoption of NGVs. In recent years there have been a number of policy initiatives, such as those mentioned above, to encourage the introduction and sales of NGVs. The industry can achieve its planned production targets with the support of policies that encourage investment in manufacturing facilities, that enable technology demonstration and deployment and provide incentives to promote adoption and drive consumer demand.

The Government, especially the MITI, funded the electric vehicle lease program from 1978 through 1996. In 1996, an electric vehicle purchase incentive program was introduced, and in 1998, the Clean Energy Vehicles

Table 9: Diffusion of Government and Private Targets of NGVs

(Unit: %)

Vehicle Types	Government Targets		Private-sector efforts		Actual
	2020	2030	2020	2030	2015
Conventional vehicles	50-80	30-50	80	60-70	73.5
Next-generation vehicles	20-50	50-70	20	30-40	26.5
Hybrid vehicles	20-30	30-40	10-15	20-30	22.2
Electric vehicles, Plug-in hybrid vehicles	15-20	20-30	5-10	10-20	0.27 0.34
Fuel cell vehicles	0-1	0-3	Miniscule	1	0.01
Clean diesel vehicles	0-1	5-10	Miniscule	0-5	3.6

Source: METI (2010) and *Jisedai jidosha shinko senta* (2016)

Introduction Project was adopted for the diffusion of electric, natural gas, methanol, and hybrid vehicles. The government and local authorities provide financial support when purchasing EV and charging equipment. The government support also provides up to 1 million yen through the Next Generation Vehicle Promotion Center for NGVs purchases (Table 10).

As an example, by purchasing a new 2.5 million yen Toyota Prius in 2010, consumers saved 188,700 yen due to tax breaks and received 100,000 yen from the subsidy program. Moreover, the hybrid market share has continued to increase despite the ending of the subsidy program in 2012, although the tax breaks remain in effect for all fuel efficient vehicles. This suggests that Japan has gone well beyond the early market adopters and has likely reached a tipping point where the mass market is increasingly demanding hybrid vehicles (*Jisedai jidosha shinko senta* website).

Table 10: NGVs Subsidy by Government in 2003 (unit: Yen)

	Vehicles	Price of vehicle	Price difference	Amount of subsidy
Electric Vehicles	Mitsuoka CONVOY88	888,000	452,000	210,000
	Araco Everyday Coms	685,000	300,000	140,000
	CQ QUNO	1,290,000	428,000	200,000
	Zero Sports Elexceed RS	1,980,000	975,000	380,000
	Nissan Hypermini	3,500,000	2,556,000	940,000
	Daihatsu Hijet van EV	2,900,000	2,092,000	800,000
Hybrid Vehicles	Toyota Prius	2,150,000	444,000	210,000
	Toyota Estima Hybrid	3,350,000	500,000	240,000
	Honda Insight	2,180,000	487,400	230,000
	Honda Civic Hybrid	2,090,000	482,000	230,000
	Suzuki Twin Hybrid	1,290,000	545,000	240,000
	Toyota Coaster Hybrid EV(EX)	14,550,000	9,360,000	4,510,000

Note: Vehicles to be subsidized EVs and HEVs newly purchased and registered by local governments, corporation, and the other users who use the vehicles for business including commute. Excluding vehicles as follows: taxies, motor cycles, industrial vehicles, and vehicles acquired by their manufacturers or sales affiliates.
Source: JAMA, website

２．Infrastructure Development

The problem all-electric cars have is that their range is limited, to no more than a few of hundred miles even with the most advanced *Tesla* Roadster. Better batteries can only extend the range and reduce charging times, but the batteries used in electric vehicles have a limited life cycle. There has been little research considering different EV users have their own tolerance of ‘range anxiety’ which means that drivers will not always charge their batteries until the batteries are running out. Stochastic range anxiety of EV drivers will affect the charging station location scheme because people will react differently when they arrive at a charging station.

From the above discussion, it may be assumed that EVs cannot be deployed without parallel developments in charging infrastructure. According to JAMA, industrial policy has emphasized batteries as a potential growth industry. The government’s, “The Next Generation Automobile Strategy 2010,” includes a target of installing two million chargers and 5,000 quick chargers in the country by the year 2020. There are more than 40,000 places nationwide where electric car owners can recharge their vehicles, compared with only 35,000 petrol stations. According to Fuji-Keizai, infrastructure was expected to limit the penetration of EVs into the market to 40,000 units in 2015, 140,000 units in 2020, and 1,000,000 units in 2030 (Fuji Keizai 2010).

３．NGVs Strategies

Increased emphasis is appearing in almost every automakers—as it can only be done by playing on production, cost down, technology, quality strategies practice. Innovation is an important method of increasing competitive positions which are improved through higher product quality, greater reliability and the introduction of new products. Technology innovation also impacts on business sustainability.

1） Production strategies

It is an important strategy practices to ‘catch’ emerging markets. Customer expectations of vehicle quality, reliability, safety, and utility are at an all-time high. At the same time, worldwide over-capacity has put pressure on the industry to maintain, and even reduce, vehicle prices. The ability to consistently deliver the right products on time, with high quality, and at an affordable price to the emerging market has distinguished outstanding companies in almost every industry.

The development of electric vehicles meanwhile, comes as the tightening of global emissions regulations prompts more automakers to develop battery powered cars, as the industry struggles with research costs and intense competition from technology companies over technology like self-driving cars. Automakers in Japan have already undertaken innovative solutions, such as ‘cost down’, safety, fuel economy and quality strategies as follows:

2） Cost Down Strategy

There are hundreds of thousands of people riding three to five persons per motor cycle in many countries in Asia, where road accidents are one of the most common occurrences in modern life. ‘No more accidents, no more over – loading, no more social life’ are three of chief motives behind the automobile industries having cost down strategy. This is however a very big challenge for society and auto-makers alike to overcome such problems.

As mentioned above, consumers want to buy cars from companies that offer the latest technologies, reliability, safety, utility and fuel economy. Low cost is also top priority in all world markets. Another important goal for any business, is how to develop, produce, and sell a good or service at a profit. At the most basic level, companies will invest when they expect that they will have customers to buy the goods and services they produce at a price that yields a bigger profit than alternative uses of the investment funds. Japan’s

automobile industry, just like any other industry, continues expanding demand and increasing development strategy and innovation in order to continue making profit margins.

3） Design and Less Parts More Functions Strategy

Competitive world automobile industries however are struggling to maintain profits. Mass production and mass consumption is a very common cost readership strategy. The automobile industry has too much production capacity, too many competitors, too many innovations and too much redundancy overlap. The industry is in the grips of a global price-war. Costs of production, raw materials and human resources has been rising every year. Cost reduction strategies are some of most important strategies that have kept companies alive. In recent times innovation of the automobile industry has becomes more important in making cost reduction programs a major initiative in the industry. Companies have to develop their own cost reduction programs to introduce a ‘less parts more functions’ approach.

Despite the high cost of vehicles, there are hundreds of thousands of Asian people who cannot buy cars. Making a vehicle auto maker using 25,000 to 30,000 parts. It is believed, there are many unnecessary parts used in the production of vehicles, contributing to higher costs. Cost reduction can be achieved through reduction, elimination, the modification of manufacturing activities. Through in-depth analysis the best and lowest cost path can be adopted for each activity. The best method to achieve positive results is for auto-makers to reduce the number of unnecessary parts and goods. It is probably not a that difficult to produce a vehicle with less parts and more functions.

The design of a car includes traditional vehicle components which are designed to convert less parts into more functions. For example, hybrids operate in dual power mode, where the electric battery serves to reduce the amount of petrol that is used. On the other hand, some hybrids will store enough energy

that the battery can be used to power the vehicle alone on short journeys, such as point to point travel within a city.

4） Technology Related Strategy

Past experience suggests that Japan's auto-makers will continue to aggressively reduce emissions, improve fuel efficiency and create breakthrough technology for NGVs, ultimately obviating the need for fossil fuel engines. With the innovation of automobile industries and activities involved in the manufacture of motor vehicles, modern automobiles continue to become complex technical systems employing subsystems with specific functions. Technology related innovation practices for the replacement and improvement of automated labor, is reducing production costs, decreasing production time and increasing efficiency. Technology has increasingly altered the manufacturing process of vehicles. Porter (1985) believes that technology is one of the most significant forces affecting business competition. While cars are produced at faster rates, auto-makers must continue to balance increased productivity and efficiency with quality and technology innovation. (Sehgal, Dehoff, & Panneer, 2010).

The automobile industry is driving innovation and technological advancement. From the early stages of planning, auto-makers design new vehicles with a range of diverse technologies that meet customer needs for comfort, convenience, safety and fuel economy. Technological innovations, company must decide which products will be most beneficial and most profitable from a pool of innovations, and how these products can best be presented into a market. To analyze the business opportunities, introduction of electric vehicles can be described as a collective innovation. Throughout the 20th century, several models of electric vehicles have been produced, but none have really become widely adopted by consumers. The system charges itself while powering all the connected appliances through to regular electricity.

It seems likely that Japan will remain the global green vehicle leader and hold that position as long as it maintains its strong R&D focus on advancing NGV technologies. In terms of technology support, Japan tends to concentrate on core technology. Companies decide their research direction and utilize their own funds or some investment given by government to gather involve research institutions in exploiting technology innovation. This outcome what outcome demonstrates an important lesson, that technology advances in vehicles influence buyer behavior. In the case of HVs and HEVs, the increase in consumer interest is triggered by the introduction of the technologically advanced, more fuel efficient Toyota Prius. HVs and EVs sales both increased substantially. The increase was primarily due to technology advancements. Electric vehicles increased 11-fold, due to the introduction of two new vehicles, the Mitsubishi i-MiEV and Nissan Leaf. Hybrid vehicles also increased 5-fold, due to the introduction of the 3rd generation Prius in 2009.

5） Quality Strategy

Quality is one of the most important strategy practices to products of all manufacturers goods including automobiles. Quality improvement and issues around eliminating problems that involve engineering, manufacturing, and suppliers is a daily struggle for auto-makers and requires much effort. To improve product quality and efficiency in production, automakers invest a large amount of time and money into developing and improving the manufacturing process, and rely heavily on research and technological innovation.

Ⅴ. Conclusions

NGVs more common means of transportation with ten to twenty years and there is highly possibility for more people to use recharging facilities. In the near future, NGVs including EVs, HEVs, PHEVs, and BEVs will dominate

the automobile market. From the above discussion Japan's automakers will continue to improve fuel efficiency, reduce emissions and the environmental burden created, through technology innovation. Consequently, it seems likely that Japan will remain the global NGVs leader and hold that position as long as it maintains its strong R&D focus on advancing technologies.

With the global automobile markets centered in emerging economies, it is anticipated that further intense global competition will further develop in the future, and it is of course important for major Japanese automobile manufacturers including Toyota, Nissan, Honda to challenge the competition. Thus, the Japanese government should continue to make timely and appropriate policies and continue to support these industries. For continued high production to occur there needs to be further cooperation with the middle and small-sized companies that handle automotive parts, which will strengthen management capabilities to help further development and innovation in this sector.

The growing popularity and sales of the NGVs are undoubtedly a result of the production of attractive and affordable models by established vehicles manufacturers. Among the current bestselling of Japanese NGVs are the Nissan Leaf (EV), with its fancy look and hi-tech interior making it a global best seller, while the Toyota HEV Prius is a luxury vehicle which competes directly in global markets with it's futuristic design and excellent performance.

The author strongly believes that NGVs is a nascent market in this perspective, yet has a long way to go and mature. The industry needs to keep an eye on all changing novel trends and must keep up with them. These trends are springing up everywhere with little resistance. The NGVs industry should always be open to innovation and resilient to any contemporary changes. A fruitful result would be a wealthy and vibrant automobile market leading Japan to economic prosperity. The focus of this paper has been strategies of the Next Generation Vehicles (NGV) in Japan. However, because of the breadth of the topic, further study will need to be done in order to keep up with the continual

advances within the industry.

Endnotes

(1) The First Industrial Revolution used water and steam power to mechanize production (took place from the 18th to 19th centuries in Europe and America). The Second used electric power to create mass production (took place between 1870 and 1914, just before World War Ⅰ). The Third Industrial Revolution began in the 1950s with the development of digital systems, communication and rapid advances in computing power, which have enabled new ways of generating, processing and sharing information. The Fourth Industrial Revolution is building on the Third, the digital revolution (Cyber-Physical Systems) that has been occurring since the middle of the last century. The Fourth Industrial Revolution builds on the "physical" (autonomous driving, 3D printing, self-improving robotics, etc.), the "digital" (technological platforms like Uber, which does not own cars but organizes rides), and the "biological" ("genetic sequencing, and, lately . . . activating or editing genes. The Digital Revolution, representing new ways in which technology becomes embedded within societies and even the human body (World Economic Forum. https://www.weforum.org/ Retrieved 2016-12-12, and Klaus Schwab, 2017, 6-8, 21.)

(2) Automobiles that people were driving for a while are also changing with AI (artificial intelligence). AI is the technology which is considered to greatly influence AI's competitiveness is 'Deep Learning'. In addition, global automakers are collaborating with IT companies that have advantages in these technologies.

(3) In full self-driving vehicles, the system performs all driving functions on all road types at all speed ranges and environmental situations. These factors make signal recognition the largest market, by process, in the automotive AI market.

(4) According to the Japan Automobile Manufacturers Association, Inc.(JAMA) next-generation vehicles include Hybrid Vehicles, Plug-In Hybrid Vehicles, Fuel Cell Vehicles, Electric Vehicles, Hydrogen Vehicles, Clean Diesel Vehicles, Natural Gas Vehicles, and Diesel-Alternative LPG Vehicles.

(5) The Intellectual Property Owners Association (IPO) recently unveiled its list of the "Top 300 Organizations Granted U.S. Patents in 2016," and Toyota was among those announced, other key innovators in the top 20 include Apple, Google, IBM and Microsoft.

(6) In 1997, Japan hosted the Third Conference of the Parties for the United Nations Framework Convention on Climate Change in Kyoto, at which the Kyoto Protocol was in acted.

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