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Abstract

The automotive industry has become one of the most significant global industries, not only at the economic level but also in terms of technological innovation and development. In the last two decades, there has been significant progress in several aspects of the production of electric vehicles (EVs) and the use of new technologies, as well as their markets. Similarly, the research efforts have also increased, which has resulted in a significant increase in new EVs and contributed to their cost-effectiveness and affordability.

There are more technical elements that are being added to vehicles to improve both passengers' and pedestrians' safety. In addition, as there is an increasing number of EVs on the roads, more advanced technology and comfort are possible. This study aims to examine how the EV industry was introduced and applied using the Japanese setsuyaku (economize) technology. Furthermore, this study presents a comprehensive survey of the most important aspects of EV technologies and innovation. The study also examines the possibility of reducing production

* Professor, Department of International Liberal Arts and Graduate School of Humanities and Social Sciences, Fukuoka Women's University

materials, cost-effectiveness, and affordability for EVs. The results of the study show that the cost of EVs is decreasing, but there are significant uncertainties regarding the past, current, and future costs of the dominant technologies as well as batteries.

Key Words: electric vehicles, innovation, *Setsuyaku*, cost-efficiencies, and affordable

1．Introduction

This study is based on the NHK morning news on October 13, 2022. According to the news, an ultra-model, high-technology, and luxury electric vehicle (EV) with entertainment technology and equipment was introduced in Japan. Over the coming years, a brand-new technology that is currently being developed for automobiles will be commercialized, fundamentally changing how consumers interact with their vehicles in terms of luxury, convenience, and affordability. Several people buy luxury cars for self-satisfaction, while others do so to meet their basic needs. Both have different purchasing power because the person in need of a car has no high demands and is satisfied with the best car for everyday use, whereas some people demand a car with all advanced features and a distinctive appearance on the road. However, the new technological advancements will drive demand for EVs in the future at an affordable price in Asian markets such as Japan. With this new wave of EVs, the EV industry is looking for *setsuyaku* technological innovations that are more cost-effective and affordable to meet consumer demand.

Despite the COVID-19 pandemic, the challenge has been made even more difficult by Russia's war in Ukraine, which has increased material costs. The depreciation of the Japanese yen will be reflected in higher import prices in yen and lower sales of imported goods. It will be a burden on the importing industries, which are already experiencing difficulties in increasing retail prices to reflect increases in input costs due to weak domestic demand and a widening output gap.

The increasing costs of Japan's massive energy imports and some automobile components, the decline in the competitiveness of the Japanese industry in comparison to American and European companies, and the weaker yen are all factors. However, the depreciation of the Japanese yen and the resulting economic slowdown have had a significant impact on the global and Japanese EV industries.

Therefore, the Japanese *setsuyaku* technology must be used to address some of these issues, which demonstrates significant improvements in cost-effective and affordable scale squeeze materials. Although it is true that today, an increasing number of people are purchasing a new car every few years due to mass consumerism and the investment in "trendiness," Japanese EV technology was created with greatness in mind and gained its impressive reputation as a result of the wide variety of *setsuyaku* technology.

Extensive primary and secondary research is incorporated into the study of the Japanese EV market. Secondary research refines the available data to divide the market into different segments and obtain the total market size, market forecast, and growth rate. This study is based on research on the possibility of using Japanese *setsuyaku* (economize) technology. This study is organized as follows: Section 2 presents a brief discussion on the development and progress of electric vehicles in the twenty-first century; Section 3 examines the Japanese *setsuyaku* (economize) technology. Section 4 evaluates the innovative *setsuyaku* technology, and Section 5 concludes with the possibility that Japanese electric vehicles will dominate the global markets.

2． Development and Progress of Electric Vehicles in the Twenty-First Century

EVs have already existed for more than 100 years as an emerging technology introduced after the industrial revolution in the twentieth century. EVs have become more popular over the past few years because the technology has advanced and prices (especially for batteries) have significantly decreased.

During the twenty-first century, there are several challenges, including the high cost of EVs, the cost of the infrastructure for charging them, and the cost of electricity storage facilities. EVs have promising potential in developing countries of the world if the abovementioned issues are properly addressed. Numerous studies are being conducted to address the issues caused by EVs, which will significantly yield a positive result. The COVID-19 pandemic will encourage more consumers to opt for an EV over an ICE.

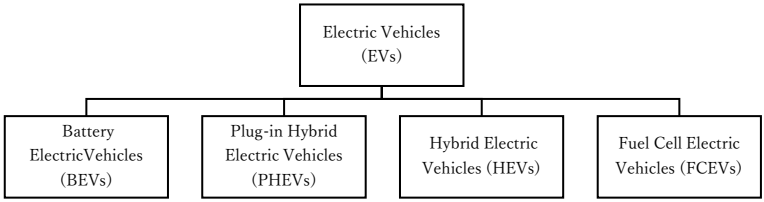
1）Generational Change of Electric Vehicle

The EV generational shift and the fourth industrial revolutions[(1)] through the advancement of digital technology are enabling automobiles to integrate high-tech features, such as autonomous driving and accident prevention. Redefining automobiles includes the use of the internet, connectivity, mobile phones, renewable energy, EV innovations, artificial intelligence (AI), the internet of things, etc. One of the most advanced technological innovations is 3D printing, which will become more prevalent, and the world will continue to reap the benefits of this promising technology. These innovations offer candidates a more tailored employment experience. According to the World Economic Forum on February 13, 2018, "Industry 5.0 will make the factory a place where creative people can come and work, to create a more personalized and human experience for workers and their customers."

(1) The First Industrial Revolution (1IR) started in the mid-1700s, with the arrival of steam engines and their radical influence on manufacturing, enabling machine production and factories. The Second Industrial Revolution (2IR) harnessed the power of electricity in the late 1800s, leading to mass production and rapid transport of people, products, and ideas. In the mid-1900s, the Third Industrial Revolution (3IR) initiated the digital era; mainframe and personal computers and the Internet connected consumers globally and supported the immense storage and dissemination of information. In the Fourth Industrial Revolution (4IR), since machines, devices, and people are all connected everywhere in the twenty-first century, there is virtually no limit to the amount of information that can be transferred quickly and efficiently (Schwab, 2015 and 2016).

There are different types of EVs (Figure 1): battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell electric vehicles (FCEVs). HEVs, which are the most popular in Japan, are not recognized as EVs because they are gasoline-powered vehicles. Meanwhile, BEVs run purely on electricity or batteries, and HEVs run on petrol or diesel. Due to the limited components used in their production, as well as the relatively low maintenance required, EVs are considered to have low running costs. In addition, EVs are also generally quiet, resulting in less noise pollution. With consumers becoming more aware of their carbon footprint and the environment, the demand for EVs is likely to increase in the near future.

Figure 1: Electric vehicles classification according to their engine technologies and settings.



Source: Compiled by author

EVs can result in a new socioeconomic system that opens up countless opportunities for people and a better world. In addition, EVs can increase renewable energy and materials, which can be accelerated by digital innovation. It aims to transform the economy to be regenerative and create new work practices and a new culture rather than simply reducing the ecological and environmental impacts of the industry. Working from home is the new norm, particularly after the COVID-19 pandemic. This is made possible by technological advancements in workplace operations. However, the technological advancements of EVs are not only focused on the technical difficulties of the key components but also consider the possible direction of

future advancements to address these barriers.

2）Present Trend of Electric Vehicles

In addition to being better for the environment than previous models, EVs perform better in general. The trend toward a more sustainable future is accelerating due to the growth of EVs. Currently, the environmentally friendly EV market has been growing globally. EV manufacturers are transforming and creating innovative new models. As a result, the demand for EVs is growing rapidly, and new pricing models are expected to make this growth even larger in the near future. In 2017, the global sales of new EVs surpassed 1 million units for the first time and are expected to reach 10 million by 2025 (Agrawal, and Rajapatel, 2020). During the first half of 2021, 5.6 million EVs were sold from 3.1 million in 2020 and 2.1 million in 2019 and are expected to grow at a compound annual growth rate of 23.1% from 2022 to 2030 (Precedence Research, 2022).

In 2020, China has the newest EV registrations (4.5 million), followed by Europe (3.2 million). In the same year, the United States registered 295,000 new EVs, while Japan only registered 14,604 units. With 2 million units sold in the first quarter, an increase of 75% from the same period in 2021, the global sales of EV passenger cars have continued to significantly rise in 2022 (International Energy Agency, IEA, 2022). Japan continued to have the lowest EV market penetration rates at 0.77% (Table 1).

Japan is working hard to increase its EV production and sales by producing ultra-model and technologically advanced EVs, which are already gaining popularity in global markets. Mitsubishi was the first to mass-produce an EV in 2006 with its i-MiEV in the ultralight *kei* (small) category. Nissan followed in 2010 with the Leaf, and Toyota followed in 2012 with the RAV4 EV, a mid-sized SUV. According to the Japan Automobile Dealers Association (JADA), the demand for HEVs in the Japanese market has been higher than that for EVs or

Table 1: Electric Vehicle (EV) market share of total new car sales between 2013 and 2020 (%)

Country	2013	2014	2015	2016	2017	2018	2019	2020
Norway	6.10	13.84	22.39	27.40	29.00	39.20	49.10	55.90
Iceland	0.94	2.71	3.98	6.28	8.70	19.00	22.60	45.00
Sweden	0.71	1.53	2.52	3.20	3.40	6.30	11.40	32.20
The Netherlands	5.55	3.87	9.74	6.70	2.60	5.40	14.90	24.60
China	0.08	0.23	0.84	1.31	2.10	4.20	4.90	5.40
Canada	0.1	0.28	0.35	0.58	0.92	2.16	3.00	3.30
France	0.83	0.70	1.19	1.45	1.98	2.11	2.80	11.20
Denmark	0.29	0.88	2.29	0.63	0.40	2.00	4.20	16.40
USA	0.62	0.75	0.66	0.90	1.16	1.93	2.00	1.90
United Kingdom	0.16	0.59	1.07	1.25	1.40	1.90	22.60	45.00
Japan	0.91	1.06	0.68	0.59	1.10	1.00	0.90	0.77

Source: The International Energy Agency (IEA, 2022), website

BEVs since the Toyota Prius was first introduced in Japan in 1997. Approximately 97.8% of the new EVs sold in 2020 were HEVs, followed by PHEVs (1.1%), EVs (1.1%), and FECVs (0.1%) (JADA, website). The demand for HEVs is expected to continue increasing. Therefore, it is understandable that Japanese firms, as well as regulators, want to try to recoup the country's enormous investments in hybrid technology (the New York Times, March 9, 2021).

However, more than a decade ago, EVs became one of the world's best-selling models, and the i-MiEV was taken off the market. According to the New York Times (March 9, 2021), just over a decade ago, Nissan became the first manufacturer to offer mass-produced cars that ran on batteries alone. Based on EV standards that hatchback, the Leaf, has been a huge success, selling more than 500,000 units by the end of 2020. However, as the path Nissan blazed becomes increasingly crowded, Japan's mighty auto-industry is in danger of falling (the New York Times, March 9, 2021).

However, developing all-electric vehicles is not easy. The same platforms cannot be used to produce the two types of cars cost-effectively. According to Mr. Inoue, the Leaf EV model designer at Nissan, "if many companies don't change now, the efficient production of EVs will become quite difficult in the future" (the New York Times, March 9, 2021). According to JADA, in 2021, there were approximately 2.4 million new passenger car sales, of which 21,139, or approximately 0.9%, were electric vehicles. In 2020, there were close to 1.4 million new EV sales, accounting for 36.2% of the total new car sales, an increase of 35.2% from 2019 and 32.9% from 2017. EV sales more than doubled in emerging markets, but volume sales remain low (JADA, website).

Table 2: Sales of EVs in Japan (Units)

Year		2016	2017	2018	2019	2020	2021
EV	Passenger Cars	13,056	23,634	23,011	19,774	14,363	24,119
	Mini vehicles	354	94	54	248	396	93
	Others	407	455	346	802	1,480	1,541
PHV	Passenger Cars	13,847	34,102	21,099	17,054	16,695	26,977
FCV	Passenger Cars	1,204	661	603	707	1,545	1,997
Total EV・PHV・FCV		28,868	58,946	45,113	38,585	34,479	54,727
HEV	Passenger Cars	1,102,636	1,080,959	1,120,129	1,029,950	908,774	1,023,470
	Mini vehicles	2,412	2,303	6,507	14,791	14,665	16,853
	Others	232,449	299,174	330,902	391,838	456,867	367,275
Total HEV		1,337,497	1,382,436	1,457,538	1,436,579	1,380,306	1,407,598

Source: Next Generation Vehicle Promotion Center, http://www.cev-pc.or.jp/english

3）Factors EV Behind of Low Trend of Domestic Market in Japan

As the EV market expands rapidly in China, Europe, and the USA, Japan has lagged in terms of EV sales. The production and sales of EVs significantly decreased when the government had to impose strict lockdown restrictions to control the spread of the COVID-19 virus. The EV manufacturers faced a supply

shortage of components imported from other countries, primarily China due to high prices for EVs, limited cruising ranges, inadequate charging infrastructure, and a highly competitive HEV market. Meanwhile, domestic car makers have been offering relatively few efficient and affordable EVs. Japan mandated a switch to EVs, which have fewer components and are simpler to manufacture; this could result in the loss of millions of jobs and the collapse of an entire ecosystem of auto-parts suppliers (the New York Times, March 9, 2021). Thus, the following are the factors that contribute to the low EV market in Japan.

(1) Japanese Consumers Prefer HEV

Japan, the first country in the world to commercialize mass-produced HEVs, was supposed to be a "leading nation in electrification," with HEVs projected to account for more than 40% of the registered vehicles in the country. Toyota Prius used to be the leader and pioneer of HEV and still holds 13% of the market share in this category; however, as more OEMs introduce new HEV brands, the Japanese HEV market is becoming quite saturated. Table 2 shows the state of present HEV trends; however, there is not a strong desire for consumers to switch to EVs immediately because they are generally satisfied with hybrid vehicles. (JAMA, website).

(2) HEVs Contributing to Reducing CO_2

In general, EVs are fuel-oriented cars that reduce or eliminate CO_2 exhaust emissions. In this context, HEVs can lessen the need for fuel and eliminate CO_2 exhaust emissions, which emit a large amount of greenhouse gas. Governments around the world are launching initiatives and policies to reduce CO_2 emissions, which affect air quality. This increased HEV sales because manufacturers believe that selling HEVs has already helped reduce CO_2 emissions. For example, Toyota sold a total of 12 million HEVs in 2018, saving 94 million metric tons of CO_2 (Nippon. Com, 2021).

(3) Limited Fast Charger Facilities

The growth of slow chargers has been increasing, but there are still no charging stations available, and it takes a long time for the battery to fully charge. These factors contribute to Japan's low demand for EVs. EVs accounted for only 0.77% (Table 1) of the total new passenger vehicles sold in Japan in 2020, excluding mini vehicles. The low percentage is believed to be caused by a lack of infrastructure, such as fast-charging stations, as well as the widely held consumer belief that EVs are relatively expensive and have limited driving ranges. However, Japan has a fast-charging infrastructure that is equally accessible to the general public as does Europe. The low numbers are probably caused by the lack of EVs suitable for the Japanese market, the tendency of Japanese homes not to allow the installation of domestic charging points, and the general tendency to be cautious about car purchases.

(4) Falling Car Ownership Tendency Among Young Japanese

The young generation in Japan, particularly those who live in cities, prefers to utilize public transportation instead of owning cars. They no longer view cars as status symbols but as an "economic liability." Owning and operating cars involves numerous expenses, such as mandatory inspections (*shaken*) every two to three years for new cars, yearly automobile taxes, mandatory and optional insurance, high parking fees, toll expressways, and gasoline costs (*Japan Automobile Federation*). This explains why more young Japanese are shifting from owning cars to sharing cars, which is more cost-effective. Therefore, they tend to lose interest in cars due to changes in their attitude toward cars and financial circumstances.

The COVID-19 pandemic, Russia's conflict in Ukraine, and the depreciation of the yen in 2022 all have a significant impact on global supply chains and the automobile industry. Delays in EV deliveries to consumers could slow down the growth of sales in some markets. However, in the long run, government and

corporate efforts to electrify transportation are laying the groundwork for continued growth in EV sales.

３．Japanese *Setsuyaku* (Economize) Technology

Setsuyaku refers to economizing in Japanese. The government of Japan and the automobile industries have emphasized research and development in the three aspects of technology, price, and convenience. In Japan, innovation based on the *setsuyaku* method of production and cost-efficiency are the major strengths of the automobile industry. There are several different ways to look at economizing; by using *setsuyaku* technology, it is possible to create high-quality products and more business by "doing more with less" (squeezing resource materials), which results in cost-effective and affordable products in the market.

１）*Setsuyaku* Phenomenon in Japan

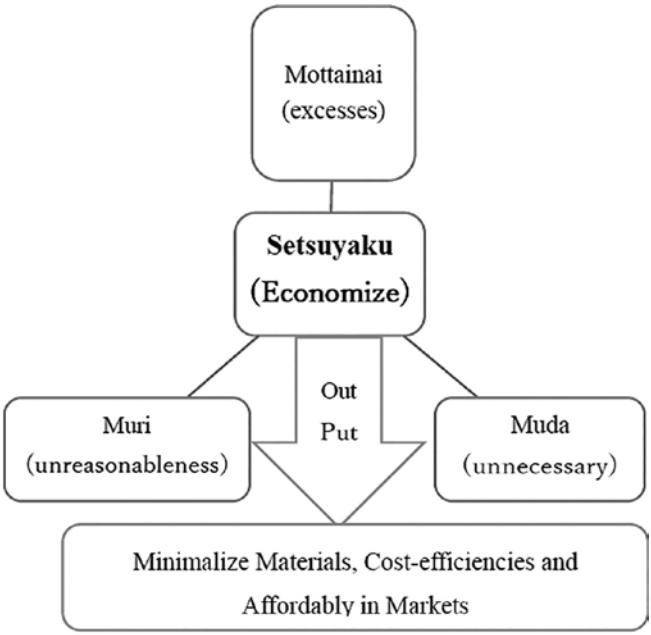
Japanese corporate culture is low risk, gradually improving, and predictable. Meanwhile, the corporate culture before the Second World War until the rapid growth of the automobile industry was complex and comprised of practices and institutions that developed based on both ancient beliefs and contemporary influences, such as setsuyaku. These beliefs were a result of spiritual ideas and internal political and economic structures that developed industrial sectors.

Setsuyaku provides technologies, materials, design methods, financial techniques, and business models. The *setsuyaku* technological strategies and aggressive investments could revitalize, relocate, and lead the global EV markets. The market will be able to afford the product by doing more with less of the *setsuyaku* technology used to create and deliver the product with processes for design and development through the triple factors of *mottainai* (excesses), *muda* (unnecessary), and *muri* (unreasonableness) (Figure 2).

"*Mottainai*," an ancient term, roughly translates to "What a waste!" but the

philosophy goes far beyond the idea of being less wasteful. It resonates with the culture of respect and care that is cherished by the Japanese tradition, but it also satisfies the demands for a more sustainable economy in today's modern society. Professor Wangari Maathai was a Kenyan politician and environmental activist who was awarded the Nobel Prize for Peace in 2004. During the United Nations summit, she introduced *mottainai* as the slogan for an environmental protection campaign, which successfully influenced government policies around the world against the production and use of unrecyclable materials. According to Maathai, to reduce waste, *mottainai* embraced the practice known as the three Rs (recycle, reduce, and reuse) and added a fourth R (respect) for consideration of the environment.

Figure 2: Triple Approaches of *Setsuyaku* Technology



Source: Compiled by author

Setsuyaku refers to a company's conceptualization of new products, processes, and ideas, or its approach to already-existing products, processes, and the three factors *mottainai*, *muda*, and *muri*. These factors contribute to outputs that combine (squeeze) the use of resource materials, cost-effectiveness, and market affordability (Figure 2). *Muda*, *muri*, and a company might pursue different things. However, the three wastes, such as *muri*, which means beyond one's power and too difficult; *Mura*, which means unevenness and irregularity, and *muda*, which means futility, uselessness, and wastefulness, have been removed from the production system by Toyota through the introduction of just-in-time and *Jidoka*. However, more emphasis on "just-in-change" is required, even at some expense in terms of "just-in-time." *Setsuyaku* technology focuses on new EV designs and technologies that can meet cost-reduction objectives and are cost-effective for consumers.

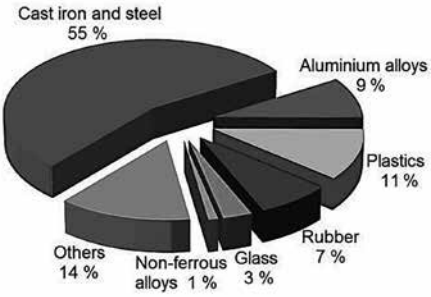
2） Innovation of *Setsuyaku* (Economize) Technology

The scientific literature on innovation systems has so far not resulted in a consistent theory but has produced various approaches to examine innovation. It must be highlighted that innovation system approaches are models and not formal theories (Archibugi *et al*. 1999: 531). However, *setsuyaku* focuses on doing more with less through technologies and by combining resource materials, cost-effectiveness, and affordability in business models. Automobile manufacturers realized that the small, dependable, cost-effective vehicles that Honda, Mitsubishi, Nissan, and Toyota had been successful in producing could be equipped with *setsuyaku* technology. Furthermore, they realized that *setsuyaku* technology could be adapted for use in slightly larger, equally efficient cars.

Steel makes up the majority of a vehicle's weight; an average car uses 1,090 kg of steel, and an average pickup truck or SUV uses nearly 1,360 kg of steel (Hovorun, *et.al*., 2017). The automobile industry uses a tremendous amount of materials to build vehicles, such as cast iron and steel parts (55%), plastics

(11%), aluminum alloys (9%), rubber (7%), glass (3%), and other materials (varnishes, paints, electric wires, facing materials, etc.) (13.5%) (Figure 3). Steel materials are used for cars because of their high strength, deformability, welding ability, color, sufficient service life with proper anti-corrosion treatment, satisfactory cost, and contribution to the heavy weight of a vehicle.

Figure 3: Materials Use Different Parts for the Manufacture of Vehicle



Source: Hovorun *et.al*., (2017)

Japanese EV companies are competing to be the first to produce the new technology. They can adopt the *setsuyaku* technology and focus on producing their own cheaper products, faster to charge, and less susceptible to raw material shortages. Some EV models are already lightweight, have a modest battery pack, and have only the most basic interior elements. As a result, these models will not be particularly heavy. Therefore, using aluminum alternatives to steel to reduce the weight of the vehicle is not necessary. For the doors and bonnets, the same materials are used for the same reasons. *Setsuyaku* technology is the culmination of numerous technological achievements, but the automobile industry still needs to develop and innovate more to reduce the overall number of parts in EVs. In addition, EV manufacturers are pursuing and adapting the following *setsuyaku* technology for their products.

(1) Wireless EV Charging Technology

Wireless charging is another *setsuyaku* technology that could be beneficial for EV freight routes. The development of wireless charging systems for EVs has gained significant momentum over the past decade. It is a very convenient and efficient way of charging the battery that can be installed at home, on the road, or in other places where EVs stop for a while. Most EV manufacturers are working hard to include wireless charging in their new EV models. Wireless charging is a premium charging experience with significant benefits for automakers and consumers because eliminating the cords speeds up the widespread adoption of EVs. Wireless EV charging is the only way to get never-forget, hands-free, automatic charging. Currently, since the majority of people charge their smartphones and earphones without cables, placing them on wireless charging pads at the end of each day, those who drive electric cars have a clear question: Will an EV work the same way? Since EVs use the same lithium–ion battery technology as devices, such as smartphones, EV batteries could also be charged without plugging them into a bulky cable.

(2) Light Weighting Technology

One factor that boosts battery (energy) efficiency is the weight of an EV. There is always room for weight reduction in vehicles. The weight reduction of EVs must strike a balance between cost, affordability, range, and loads. Bolt-on parts, such as steering knuckles, are generally much easier to reduce weight.

In addition, material scientists are working to develop and use ultra-high-strength alloys for the new models. Traditionally, all the necessary components of the vehicle are made of steel or various metal alloys. Steel is strong and reliable, but it adds weight to the vehicle's body. Therefore, instead of using the standard auto-grade iron, aluminum is used. Several parts of the chassis are now made up of aluminum instead of steel, as well as lighter components (Table 3). EV manufacturers prefer aluminum because it has a better strength-to-weight

ratio compared to other metals. The size of the chassis in the upcoming electric options is getting leaner. This reduces the vehicle's weight and makes it more maneuverable and suitable for different types of terrain. In addition to aluminum, players in the automotive industry are researching alternative materials, such as carbon-fiber-reinforced polymers. Based on the latest advances in science, polymer compounds outperform conventional steel in terms of hardness and strength. The use of polymer materials can significantly reduce the cost of manufacturing automotive components (Das, 2000). Japanese manufacturers were limited in their ability to reduce vehicle size by reducing its weight because of their history of producing HEVs, such as the Prius or Honda Insight, the Nissan Leaf, and the Mitsubishi i-MiEV. The production of so-called PHEVs is a recent development.

Table 3: Vehicle Weight of Steel and Aluminum uses in EV and PHEV (Kg, %)

Different Parts of Vehicles	Small EV		Small PHEV	
	Steel (781 kg)	Aluminum (627 kg)	Steel (1205 kg)	Aluminum (1031 kg)
Body in White	183.3 (25%)	91.8 (15%)	231.4 (19%)	123.3 (12%)
Closures	71.5 (9%)	44.2 (7%)	71.5 (6%)	44.2(4%)
Body other	65.5 (8%)	62.1 (10%)	65.5 (5%)	62.1 (6%)
Chassis	174.4 (22%)	151.4 (24%)	174.4 (14%)	151.4 (15%)
Interior	132.7 (17%)	132.7 (21%)	132.7 (11%)	132.7 (13%)
Electrical	23 (3%)	23 (4%)	23 (2%)	23 (2%)
Assembly	34 (4%)	34 (5%)	34 (3%)	34 (3%)
Gas PHEV	0 (0%)	0 (0%)	348.6 (30%)	348.6 (34%)
Battery	58 (7%)	51 (8%)	77 (6%)	69 (7%)
Motor & Controller	38 (5%)	37 (6%)	47 (4%)	43 (4%)

Source: Michael (2011).

Toyota is working with suppliers and considering factory innovations to reduce costs. As a result, Toyota has made it a "top priority" for its suppliers Denso and Aisin to focus on reducing the size and weight of an EV battery pack

to cut costs by thousands of dollars per vehicle (The Japan Times, October 24, 2022). Adopting a front-wheel drive system is one way to reduce the weight of a vehicle, as well as using lighter parts and materials, such as high-tension steel sheeting, aluminum, and plastics. Due to the limited components used in new-technology materials, such as fiber-reinforced metals and plastics, ceramics, their production, and the relatively low maintenance required, EVs are considered to have low running costs. By using aluminum brake calipers, automakers can reduce the weight of a vehicle by an average of 2.72 kg.

(3) CASE Technology

The concept of CASE (connectivity, autonomous driving, shared services, and electric mobility) presents the four major areas of technological development for EVs, each dedicated to a different area of vehicle technology. The CASE mobility model outlines the key technological advancements that have an impact on automotive innovation, consumer demand, and transportation infrastructure. There has been a revolution in development, cost-cutting, new business models, and opportunities in all four areas. The introduction of vehicles powered by technologies, including IoT and AI, has resulted in a revolution in vehicle manufacturing. This has further helped in the development of autonomous cars.

(4) Touch-enabled Displays Technology

Virtual controls with reconfigurable software could replace physical buttons in EVs equipped with *setsuyaku* technology. Controls are made easier and more desirable when using software reconfigurable touch with new touch technologies, such as software-defined sensing. A software download instead of a retrofit or recall would make improvements, upgrades, and enhancements to *setsuyaku* technology possible. The key to moving forward with *setsuyaku* technology will be solutions from innovative companies that approach challenges in a new and better way.

Electronic door locks, power windows and mirrors, CD changers, air

conditioning, cruise control, variable-timed windshield wipers, and heated seat controls became standard, each having its own set of buttons. Due to Bluetooth pairing, mapping software, and large touch displays with full internet connectivity, functionality has advanced beyond our capacity to navigate all the information available to us while maintaining focus on the road ahead. *Setsuyaku* technology is used in vehicle designs that are touch-enabled. Cockpit designs are trending away from physical buttons and switches and replacing them with touch displays. This trend is particularly evident in EVs.

４．Evaluation of Innovative *Setsuyaku* Technology

EVs still require further development and technical improvement to maintain their position as the vehicles of the future. To improve the performance of EVs, material technology that can improve materials for the car frame, motor, and battery is even more necessary than the development of machine techniques. There is a need for smaller, faster-charging batteries. Silicon and lithium metal anodes, solid-state electrolytes, new cathode materials, and cell manufacturing processes play a significant role in reducing the price of EVs (BloombergNEF, 2022).

１）Minimalize (Squeeze) Resource Materials

There are various types of materials used in making these vehicles, such as steel cast iron, sintered metal, copper, zinc, aluminum, rubber, glass, plastic adhesives, and fibers. Steel for the vehicle itself and lithium, nickel, and cobalt for batteries are also used. According to BloombergNEF (2022), the price of lithium will remain high due to ongoing supply chain issues and the slow ramp-up of new production capacity. Increased lithium supply could ease the pressure on prices, while geopolitics and trade tensions continue to pose the biggest uncertainties for the prices of other key battery metals in the short term. These batteries can be charged using solar panels, electric power stations, or other sources.

As shown in Table 3, steel, which is frequently used to make car bodies, is strong and durable but heavy, making it difficult for electric motors to move on their own. The plastic and fiberglass parts in modern cars, such as the front bumpers and rear fenders, reduce their weight, as well as aluminum roofs and deck lids. *Setsuyaku* technology reduces parts because the cost of technology will decrease due to more technological advancements in the cost of production and increased volume, reducing the cost of EVs. Small EVs are not overly heavy because they have a moderate battery pack and basic interior elements, negating the need to use aluminum as an alternative to steel. For the doors and bonnets, the same material is used for the same reasons.

2）Responding to the Need for Cost-Efficiency and Affordability

Automobile purchases are typically the result of careful planning, and for the majority of consumers, the cost of the vehicle is one of the important factors to consider. Middle-income consumers compare the prices of vehicles before making a purchase. This may not always apply in all cases high-income consumers are interested in purchasing luxury vehicles and supercars. In terms of pricing, an EV is equivalent to an entry-level luxury car. While EVs usually have higher upfront purchase prices, owners can save a lot on operating expenses. However, a large number of car brands that sell family cars and SUVs target middle-income consumers; thus, they mainly consider prices.

The need for cost-effectiveness and affordability due to the rise of the middle class is another important factor that affects the demand for and sales of automobiles in various markets. In Asia, sizable middle classes are rapidly growing. In 2020, an estimated 2 billion Asians were part of the middle class, and that number is set to increase to 3.5 billion by 2030. In comparison, in the Americas, 647 million people were considered middle class in 2020, and this number will increase to 689 million by 2030. In terms of purchasing power, the middle class is defined as a household with a daily income and capital of $10 to

$100 (World Economic Forum, 2020). In recent years, middle-class consumers have experienced a rapid increase in their monthly income and are spending more on automobiles, leisure activities, and other things. Currently, a large number of car brands are targeting middle-class consumers and releasing new models of sedans, crossovers, and SUVs designed especially for this consumer segment.

3）Japanese Electric Vehicles Lead the Global Markets

The massive growth of EV technological advancements in the past decade has forced companies to adapt and expand more than ever. The five largest passenger car markets include China, the United States, Germany, India, and Japan. In December 2020, the Japanese government introduced a green growth strategy to make Japan carbon neutral by 2050 by promoting EVs, fuel-cell EVs, PHEVs, and HEVs (Precedence Research, 2022).

In recent years, the booming global EV market has led Japanese automakers to realize that the trend toward EVs is becoming unstoppable; therefore, they have abandoned their original strategies and announced plans for EV models and new plants. Japan is full of innovative ideas, futuristic technology, impressive customs, and other things that will lead the global market in the future. Japanese EV manufacturers invest a substantial amount of time and capital in developing and improving their technological processes, improving the quality and efficiency of EVs.

Asia Pacific dominated the global EV market in 2021, with China accounting for 45% of the total global EV sales. Other countries, such as Japan, Korea, and India, are also promising markets because their governments are significantly investing in EV startups to promote the manufacturing and sale of EVs across the globe. The Japanese EV market is rapidly expanding due to the rising fuel prices in the country. In addition, the presence of leading EV manufacturers in Japan, along with rapid technological advancements, such as the introduction of AI and IoT into EVs, are expected to provide lucrative growth opportunities to the market over the next few

years. The Japanese government's initiatives to support EVs will significantly accelerate the growth of the Japanese EV market. In the near future, due to the more aggressive launch and sales of EV models by Japanese automakers, it is possible to expect significant growth in the Japanese EV market. In addition, the Japanese government provides a very attractive subsidy for BEVs, PHEVs, and FCEVs for manufacturers as well as for battery and EV manufacturers. In addition, they also offer incentives to EV owners. The latest government subsidies for the purchase of new EVs are 650,000 yen (US$5,200) for BEVs, 450,000 yen (US$3,600) for PHEVs, and 2,300,000 yen (US$18,500) for FCEVs (JADA, website). Furthermore, the development of a nationwide infrastructure for charging has received significant funding from the Japanese government.

Japan's new EVs mainly include HEVs, pure EVs, and fuel-cell EVs, which are considered to be the best transitional technologies before the advent of the "zero emission" era. As early as 1997, Toyota launched the world's first mass-produced HEVs, Prius, in Japan. Meanwhile, Honda introduced EVs in 1996. A few years later, Honda switched from EVs to hybrids, and fuel-cell eventually replaced them as the company's primary focus. Honda introduced the FCX Clarity fuel-cell sedan, primarily for the Insight, Civic, and Accord models. Companies such as Nissan and Mitsubishi focused on producing pure EVs. In 2010, Nissan launched LEAF, a pure EV. Its latest model has a range of 280km on a single charge, which can meet short- and medium-distance transportation. By the end of 2017, LEAF had sold more than 240,000 units worldwide, making it one of the best-selling EVs in the world. Mazda spent years developing its award-winning engine technologies to reduce its environmental impact, with no plans of stopping anytime soon. When Mazda unveiled its most environmentally friendly vehicle, its green powertrains−from the energy-efficient Sky active line to the wider adoption of renewable fuels, reached new heights.

The strong competition in the automobile market has forced automakers to develop a new design every four to five years. The Nissan Leaf and the

Mitsubishi i-MiEV are EV models produced in Japan. Nissan and Mitsubishi introduced the Kei car-based BEV models, Nissan Sakura and Mitsubishi eK X EV, respectively. *Kei* cars are predominantly used for daily commutes or short shopping trips within a city, where drivers do not have to worry too much about charging their battery frequently as they won't be driving long distances. Toyota plans to launch an ultracompact, two-seater EV that is smaller than a *kei car* (light car). These are *setsuyaku* technology EVs. In addition, Mazda released its sports utility vehicle (SUV) MX-30 EV in 2020, and Honda introduced its new EV model in Japan in the same year. These new types of EVs are produced by Sony Group and Honda Motor, two Japanese industrial powerhouses, under the banner of Sony Honda Mobility Inc., which aims to change the conventional concept of vehicles as a means of *setsuyaku* transportation.

5. Conclusions

Through innovation, Japanese *setsuyaku* technology reduces their most valuable production materials and increases cost-efficiency, affordability, safety, and dependability. *Setsuyaku* technology provides a competitive edge to manufacturers and suppliers by enabling high technology while remaining comfortable and productive. While any country will benefit from the good practices of the Japanese *setsuyaku* technology, manufacturers should first understand *setsuyaku* before considering adapting some of its techniques.

The performance of the Japanese automobile industry in vehicle production depends not only on their management style but also on their *setsuyaku* technology and innovations management. Perhaps the most important innovations may have challenged fundamental assumptions about mass production. As mentioned above, the global EV market is still a small part of the overall auto-market, and government subsidies are still frequently used to stimulate demand. HEVs are another category that has been growing in Japan. Toyota Prius used to

be the leading pioneer of HEV in the global market. Toyota and other manufacturers have always been known for releasing new technologies; there are a lot of expectations for these Japanese automakers to develop new technologies. In other words, the future of the automobile industry is undoubtedly brighter. In the process of developing EVs, Japanese automakers are also proficient in the technologies necessary for manufacturing pure EVs, and Japanese manufacturers are far from being uncompetitive. In other words, there appears to be ample potential for these manufacturers to succeed in the EV market competition.

References

Agrawal, Manas; Rajapatel M.S. (2020), "Global Perspective on Electric Vehicle 2020", *International Journal of Engineering Research and Technology* [Online]. Volume 9, Issue 01, https://www.ijert.org/research/global-perspective-on-electric-vehicle- 2020-IJERTV9IS010005.pdf, retrieved December 2, 2022.

Archibugi, Daniele *et al*. (1999), "Innovation Systems in a Global Economy", in: *Technology Analysis & Strategic Management*, Vol. 11, No. 4, 527-539.

BloombergNEF (2022), "Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kW", *NEF's* December 6, hhttps://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh, retrieved December 2, 2022.

Chowdhury Mahbubul Alam (2020), "Sustainability and Challenges of Electrical Vehicles in Asia" *Journal of Law and Political Science,* Vol. XLVIII No.1/2, 39-69.

Chowdhury Mahbubul Alam (2021), "Frugal Production and Low Cost Strategy -The Case of Nissan's Electric Vehicles-", *The Studies of International Society*, Vol. 10, 63-80.

Das, S. (2000), "The cost of automotive polymer composites: a review and assessment of doe's lightweight materials composites research" – *ORNL, TM-2000*, 283.

Hovorun T. P., Berladir K. V. , Pererva V. I., Rudenko S. G., Martynov A. I. (2017), "Modern materials for automotive industry", *Journal of Engineering Science*, vol.4, Issue 2, https://jes.sumdu.edu.ua/wp-content/uploads/2018/01/JES_2017_02_F8-F18.pdf, retrieved December 28, 2022.

International Energy Agency (IEA) (2022), "Global EV Outlook 2022 Securing supplies for an electric future", *International Energy Agency* Website: www.iea.org

Japan Automobile Dealers Association (JADA), www.jada.or.jp/

Japan Automobile Manufacturers Association, Inc (JAMA) https://www.jama.or.jp/

Japan Times The (2022), "Toyota scrambles for EV reboot with eye on Tesla, October 24,https://www.japantimes.co.jp/news/2022/10/24/business/corporate-business/ Toyota -ev-strategy-revamp,

retrieved December 28, 2022.

Michael Bull (2011), “Mass Reduction and Performance of EV and PHEV Vehicles” *The Aluminum Association, Aluminum Transportation Group* (*ATG*) U.S.A. Paper Number 11-0346 https://www-esv.nhtsa.dot.gov/Proceedings/22/files/22ESV-000346.pdf, retrieved December 28, 2022.

Ministry of Economy, Trade and Industry, (METI), https://www.meti.go.jp/english/

Next Generation Vehicle Promotion Center, http://www.cev-pc.or.jp/english

New York Times The (2021), “Why Japan Is Holding Back as the World Rushes Toward Electric Cars” March 9, https://www.nytimes.com/2021/03/09/business/electric-cars-japan.html, retrieved December 28, 2022.

Nickel Institute (2021), “How EV markets differ: The curious case of Japan” October 14, https://nickelinstitute.org/en/blog/2021/october/how-ev-markets-differ-the-curious-case-of-japan, retrieved October 28, 2022.

Nikkei Asia, (2022), “Cheaper than Tesla: Honda takes aim at China's middle class” May 15, https://asia.nikkei.com/Spotlight/Electric-cars-in-China/Cheaper-than-Tesla-Honda-takes-aim-at-China-s-middle-class, retrieved October 28, 2022.

Nippon.com (2021), “Can Japan’s Automakers Succeed in the EV Market?” July 21, https://www.nippon.com/en/japan-topics/g01105/, retrieved October 28, 2022.

Precedence Research (2022), “Electric Vehicle Market Size, Trends, Growth, Report 2022-2030”, https://www.precedenceresearch.com/electric-vehicle-market, retrieved December 28, 2022.

Reuters (2021), “New recycling techniques set to make electric vehicles greener”, July 1, London,https://www.reuters.com/technology/new-recycling-techniques-set-make-electric-vehicles-greener-2021-07-01, retrieved December 2, 2022.

Schwab, Klaus (2015), “The Fourth Industrial Revolution: What It Means and How to Respond,” *Foreign Affairs*. December 12 https://www. foreignaffairs.com/ articles/ 2015-12- 12/fourth- industrial- revolution, retrieved October 28, 2022.

Schwab, Klaus (2016), *The Fourth Industrial Revolution*. Crown Publishing Group.

World Economic Forum The (2018), “These 3 elements are crucial to the future of electric cars”, February 13, https://www.weforum.org/agenda/2018/02/mobility-future-electric-cars-fourth-industrial-revolution/, retrieved December 28, 2022.

World Economic Forum The (2020), “This chart shows the rise of the Asian Middle Class”, July 13, https://www.weforum.org/agenda/2020/07/the-rise-of-the-asian-middle-class, retrieved December 8, 2022.