PASSENGER CARS

Overall Trends

1 Introduction

Betraying hopes that the COVID-19 pandemic that has raged throughout the world since January 2020 would abate, the novel coronavirus has repeatedly mutated and spread anew. The omicron variant that developed in 2021, notably, intensified the global spread of the virus, breaking through the border measures put in place in Japan, and showing no signs of abating even as the year came to a close. Over the last two years, countries around the world imposed lockdowns on cities and travel restrictions, as well as severe limitations on the cross-border movement of people. In Japan, the impact of the pandemic on daily life and the economy was felt through the alternating imposition and lifting of a state of emergency or other broad restrictions aimed at preventing the spread of the pandemic. In addition, the Olympic and Paralympic Games were postponed by one year and held without spectators. The way people work also changed, as web conferencing reduced the number of business trips, and working remotely became more common.

In the automotive industry, the pandemic imposed a decrease in production due to plant stoppages, a shortage of semiconductors, and disrupted transportation, and vehicle production in both 2020 and 2021 fell below the numbers for 2019. However, demand has not fallen, and delays in delivering new cars have been repeatedly reported in the news. Similarly, the used vehicle market has thrived.

Despite the slowdown in production, advances in technology retained their momentum. Notable technological trends among automakers include CASE-related advances in safety technologies for automated driving and advanced driving support, as well as technologies that contribute to achieving the SDGs and carbon neutrality. At the same time, the diversity of technical development was also reflected by numerous examples of refinements brought to conventional technologies.

2 State of Vehicle Production, Sales, and Exports

2.1. State of Production in Leading Manufacturing Countries

The number of passenger cars produced worldwide in 2021 was 66.51 million vehicles, an increase of 2.07 million vehicles (103.2%) compared to 2020 (Table 1). Although this was an improvement over the major COVID-induced drop in production in 2020, recovery failed to get back to the 2019 pre-pandemic level. Production was limited not only by restrictions on economic activity aimed at limiting the spread of COVID-19, but also by the shortage of semiconductors resulting from the rapid recovery in de-

Table 1 Passenger Car Production in Leading Manufacturing Countries

	2021	Compared to previous year (%)	2020	2019
Japan	6,619,245	95.1	6,960,411	8,328,756
U.S.	8,841,996	103.4	8,550,513	10,522,753
Canada	1,102,498	81.0	1,361,904	1,898,546
Europe	10,912,259	95.1	11,474,186	15,351,566
Germany	3,162,365	90.1	3,509,500	4,728,116
UK	859,571	93.4	920,649	1,303,135
France	862,449	99.5	866,398	1,473,339
Italy	492,151	103.5	475,623	587,366
Spain	1,863,705	101.4	1,838,474	2,467,527
Russia	1,352,740	107.3	1,260,517	1,523,594
South Korea	3,129,012	98.6	3,174,728	3,612,587
China	21,010,477	107.2	19,598,869	20,958,175
India	3,628,267	127.3	2,849,841	3,623,167
Brazil	1,708,546	106.2	1,609,294	2,449,347
World total	66,512,651	103.2	64,442,519	77,932,993

Note 1: The production unit numbers from Japan were obtained from Japan Automobile Manufacturers Association data.
Note 2: Numbers for other countries were obtained from the applicable collated MarkLines data.
Note 3: The values for Europe are the total for the EU automobile producing nations (15 countries) and the U.K.
EU automobile producing nations (15 countries) and the U.K.: Germany, the U.K., France, Spain, Italy, Portugal, Belgium, the Netherlands, Austria, Sweden, Finland, the Czech Republic, Slovakia, Hungary, Romania, and Slovenia.
Note 4: The totals include the SUVs, MPVs and other light-duty trucks treated as passenger vehicles in the U.S. and Canada.
Note 5: Including the SUVs and MPVs treated as passenger vehicles in South Korea, China, and India.
Note 6: The global total consists of the sum of available collated data for all countries, including the major countries above.

Table 2 Passenger Car Production in Japan

	2021	Compared to previous year (%)	2020	2019
Ordinary passenger vehicles	4,165,631	99.4	4,192,767	5,317,165
Light-duty passenger vehicles	1,169,284	82.9	1,409,994	1,538,380
4 -wheeled mini-vehicles	1,284,330	94.6	1,357,650	1,473,211
Total	6,619,245	95.1	6,960,411	8,328,756

Source: Japan Automobile Manufacturers Association (JAMA)

mand for goods worldwide and the disruption of the parts supply chain.

In European countries, disruptions in the supply chain and the need to conform to CAFE regulations resulted in production falling below the global average, to 95.1% of the 2020 level.

Following a severe drop in 2020 due to the spread of the pandemic, production in India rose to 127.3% of the 2020 level, but was still affected by the shortage of semiconductors. Similarly, production in Brazil recovered compared to the major slowdown in 2020 cause by a large number of infections, but remained between the 2019 level due to the lack of semiconductors.

The shortage of semiconductors and parts was somewhat mitigated in China compared to other countries. In conjunction with robust production and sales of new energy vehicles, production rose to 107.2% of the 2020 figures, recovering to a level in line with that of 2019.

The United States also saw production recover to 103.4% of 2020 figures, but failed to climb back to the 2019 level due the cold wave in Texas at the start of the year and to the shortage of parts resulting from the spread of COVID-19 in Southeast Asia. These statistics take regional particularities into account and count SUVs and other light-duty trucks as passenger vehicles.

2. 2. State of Japanese Vehicle Production, Exports, and Sales

(1) Production

Passenger car production in Japan was 6.62 million vehicles, or 95.1% of the 2020 production (Table 2). Although production continued amid recurring surges and lulls in the spread of COVID-19, the shortage of semiconductors due to a fire at a semiconductor manufacturer and the inordinate global demand, in conjunction to a lack of parts due to the spread of the virus in Southeast Asia, kept the number of units produced, domestic sales, and the number of exports down.

(2) Exports

The number of exported passenger vehicles in 2021 was 3.37 million vehicles, representing 98.8% of the 2020 figure (Table 3). The drop in production due to the semiconductor and parts shortage, as well as the global spread of COVID-19, reduced the number of vehicle exports significantly, to an even lower level than in 2020.

The sluggish market recover in Europe stagnated at 83.6% of the 2020 figures as a result of both limited supply and restrictions imposed on movement due to the resurgence of COVID-19. In comparison with 2020 figures, production rose to 96.3% in the U.S., and to 104.0% and 156.9% in the Middle-East and South America, respec-

Table 3 Number of Passenger Cars Exported from Japan According to Destination

	2021	Compared to previous year (%)	2020	2019
North America	1,461,382	96.3	1,517,169	1,881,825
Europe	554,636	83.6	663,785	965,115
Oceania	378,403	118.0	320,707	339,948
Asia	499,167	106.3	469,419	514,962
Middle-East	274,232	104.0	263,710	390,155
Central America	103,943	101.9	102,048	138,552
South America	59,936	156.9	38,194	87,535
Africa	33,487	109.5	30,582	52,140
Others	2,404	100.8	2,385	2,413
Total	3,367,590	98.8	3,407,999	4,372,645

Source: Japan Automobile Manufacturers Association (JAMA)

Table 4 Passenger Car Sales in Japan

	2021	Compared to previous year (%)	2020	2019
Ordinary passenger vehicles	1,446,655	105.5	1,370,755	1,586,342
Light-duty passenger vehicles	953,207	86.0	1,108,077	1,235,544
4-wheeled mini-vehicles	1,275,836	95.8	1,331,149	1,479,205
Total	3,675,698	96.5	3,809,981	4,301,091

Source: Japan Automobile Manufacturers Association (JAMA)
Note: The classification criteria of the sales statistics are based on the license plate number (excluding mini-vehicles).

Table 5 Used Vehicle Sales in Japan

	Ordinary passenger vehicles	Light-duty passenger vehicles	4 -wheeled mini-vehicles	Total	Compared to previous year (%)
2010	1,592,110	1,816,696	1,873,466	5,282,272	98.9%
2011	1,542,614	1,733,519	1,906,523	5,182,656	98.1%
2012	1,688,606	1,826,335	2,133,725	5,648,666	109.0%
2013	1,666,732	1,740,725	2,255,560	5,663,017	100.3%
2014	1,630,421	1,653,214	2,367,235	5,650,870	99.8%
2015	1,668,429	1,602,719	2,354,077	5,625,225	99.5%
2016	1,729,194	1,564,982	2,322,533	5,616,709	99.8%
2017	1,802,956	1,588,747	2,414,874	5,806,577	103.4%
2018	1,834,306	1,523,537	2,449,940	5,807,783	100.0%
2019	1,885,765	1,485,339	2,504,576	5,875,680	101.2%
2020	1,898,616	1,443,889	2,394,963	5,737,468	98.8%
2021	1,872,619	1,373,160	2,386,963	5,632,742	95.9%

Sources: Japan Automobile Dealers Association (JADA) for ordinary and light-duty vehicles, and the Japan Light Motor Vehicle and Motorcycle Association for mini-vehicles.

tively, but has yet to return to 2019 levels. In contrast, despite the spread of COVID-19, Oceania, buoyed by policies to stimulate investment, recovered to 118.0% of 2020 figures, while in Asia credit-based measures and tax systems supported a robust market that led to a growth of 106.3% over the previous year.

Table 6 Imported Vehicle Sales in Japan

2021 ranking	2020 ranking	Brand	2021 (Units)	2020 (Units)	Compared to previous year [%]
1	1	Mercedes-Benz	51,722	57,041	90.7
2	4	Nissan (vehicles produced outside Japan)	43,872	24,147	181.7
3	3	BMW	35,905	35,712	100.5
4	2	VW	35,215	36,576	96.3
5	6	Toyota (vehicles produced outside Japan)	27,340	21,257	128.6
6	5	Audi	22,535	22,304	101.0
7	7	BMW Mini	18,211	20,196	90.2
8	8	Volvo	16,638	15,547	107.0
9	9	Jeep	14,294	13,588	105.2
10	10	Peugeot	12,072	10,752	112.3
11	13	Renault	7,666	5,964	128.5
12	12	Porsche	7,009	7,284	96.2
13	14	Fiat	6,995	5,891	118.7
14	11	Honda (vehicles produced outside Japan)	6,188	10,026	61.7
15	15	Citroën	5,894	5,031	117.2
16	16	Land Rover	4,784	3,959	120.8
17	—	Mazda (vehicles produced outside Japan)	2,860	886	322.8
18	19	Mitsubishi (vehicles produced outside Japan)	2,619	2,216	118.2
19	18	Abarth	2,489	2,571	96.8
20	20	Alfa Romeo	2,341	1,674	139.8
21	17	Suzuki (vehicles produced outside Japan)	1,594	3,235	49.3
		Total for non-Japanese manufacturers	259,752	256,096	101.4
		Total of vehicles produced outside Japan	84,800	61,837	137.1
		Total	344,552	317,933	108.4

Source: Statistics of the Japan Automobile Importers Association (JAIA)
The total includes ranks 21 and below.

(3) Sales

Sales of passenger vehicles in Japan were 3.68 million units, or 96.5% compared to 2020 (Table 4).

Sales slowed down as production decreased due to the shortage of semiconductors and the disruption of the parts supply chain resulting from the spread of COVID-19 in Southeast Asia, delaying the delivery of new vehicles. They fell below those of 2020, which had already dropped considerably because of the pandemic.

(4) Used Vehicle Sales

Sales of used vehicles in Japan were 5.63 million units, representing 95.9% of the 2019 figure (Table 5). As delays in the delivery of new cars caused by the constraints on supply due to the shortage of semiconductors and parts continued, demand for immediately available used vehicles rose. However, the bottleneck in new vehicle delivery also reduced the number of trade-in vehicles, consequently limiting the supply of used vehicles and bringing their sales down below the 2020 figures.

(5) Imported Vehicle Sales

The number of vehicles imported in Japan was 345,000, or 108.4% of 2020 levels (Table 6). The restrictions on movement imposed to prevent the spread of COVID-19 in 2020 caused a major drop in the sales of non-Japanese manufacturers. Those sales increase slightly in 2021, to 101.4% of the 2020 figures. In contrast, the volume of models produced outside Japan by Japanese manufacturers rose significantly, reaching 137.1% of the 2020 figures, a second consecutive year of increase. By manufacturer,

Table 7 Passenger Car Sales in Leading Manufacturing Countries and share of Japanese Vehicles

	2021			2020			Compared to previous year	
	No. of units sold	Japanese vehicles	Share of Japanese vehicles	No. of units sold	Japanese vehicles	Share of Japanese vehicles	No. of units sold	Japanese vehicles
Japan	3,675,698	3,415,946	92.9%	3,809,981	3,553,885	93.3%	96.5%	96.1%
US	15,082,812	5,795,134	38.4%	14,582,301	5,337,351	36.6%	103.4%	108.6%
Canada	1,663,850	613,999	36.9%	1,541,476	546,113	35.4%	107.9%	112.4%
Brazil	1,535,853	267,449	17.4%	1,595,650	249,484	15.6%	96.3%	107.2%
China	21,323,014	4,735,974	22.2%	20,071,308	4,985,755	24.8%	106.2%	95.0%
India	3,082,421	1,625,571	52.7%	2,433,064	1,370,517	56.3%	126.7%	118.6%
Russia	1,666,780	244,513	14.7%	1,598,825	241,643	15.1%	104.3%	101.2%
Total for Europe	11,711,367	1,490,835	12.7%	11,884,604	1,488,113	12.5%	98.5%	100.2%
UK	1,647,181	264,258	16.0%	1,631,064	257,356	15.8%	101.0%	102.7%
Germany	2,622,132	216,148	8.2%	2,917,678	244,290	8.4%	89.9%	88.5%
France	1,659,146	166,988	10.1%	1,650,118	168,073	10.2%	100.5%	99.4%
Italy	1,463,592	184,586	12.6%	1,381,496	161,158	11.7%	105.9%	114.5%

Note 1: The Japanese sales figures are collated from figures obtained from the Japan Automobile Dealers Association (JADA) for ordinary and light-duty vehicles, from the Japan Light Motor Vehicle and Motorcycle Association for four-wheeled mini-vehicles, and from the Japan Automobile Importers Association for imported vehicles. Imported Japanese brand vehicles are counted as Japanese vehicles.
Note 2: Numbers for other countries were obtained from the applicable collated MarkLines data. The proportion of Japanese vehicles was collated by picking out Japanese brand vehicles in each country.
Note 3: The totals include the SUVs, MPVs and other light-duty trucks treated as passenger vehicles in the U.S. and Canada.
Note 4: Europe includes the 27 EU nations, the three EFTA nations (Iceland, Norway, and Switzerland), and the U.K. Of those, figures for Cyprus, Latvia, Lithuania, Malta, and Iceland have not been included as no data is available.

Mercedes-Benz and Volkswagen, the top two ranking manufacturers of the previous year both saw lower sales than in the previous year, while Nissan (vehicles produced outside Japan) rose to second place from the previous year's fourth place as its sales grew by 181.7% compared to the previous year.

2. 3. Vehicle Sales in Markets outside Japan

Table 7 shows passenger car sales in leading manufacturing countries along with the share of Japanese vehicles. Despite repeated mutations causing resurgences in the propagation of COVID-19, the growing rate of vaccination and other measures led countries to resume their economic activities. However, the intense surge in demand created a worldwide shortage of semiconductors, constraining production and dragging sales down on a global scale.

In the U.S., the quick spread of the vaccines led to a resumption of economic activity. While government subsidies and high stock prices increased consumer willingness to spend, supply disruptions caused by the lack of semiconductors kept sales to 103.4% of the previous year. Despite supply chain constraints, the reduced impact of the pandemic and measures to stimulate spending lifted sales in China to 106.2% of the previous year. Successive restrictions on movement imposed in Europe due to the resurgence of the pandemic caused sales to stall at 98.5% of the previous year, while the semiconductor shortage limited sales Brazil to 96.3% of the 2020 figures.

Overall sales of Japanese vehicles also stagnated, with variations in the level of impact. Market share rose in the U.S., Canada, Brazil and Europe, and either remained unchanged or dropped in other countries and regions. The differences are attributed to the ability of manufacturers to procure semiconductors and parts.

3 Product Technology Trends

3. 1. Safety Technologies

Automakers have focused their efforts on developing safety technologies to eliminate traffic accidents entirely, leading to the announcement of the first level 3 automated vehicle in Japan and other advances in automated driving and advanced driving support technologies. They are also striving to install those safety technologies in all their vehicles and make them more widespread. The scope of technology is also broadening as manufacturers also pursue security and comfort in conjunction with safety through the use of AI and the introduction of new forms of control.

3. 2. Environmental Technologies

Various countries are proposing the development of fuel cells, electrification, greater fuel efficiency, and alternative fuels as means of achieving carbon neutrality. Similarly, Japanese manufacturers are adopting a multifaceted strategy encompassing fuel cell electric vehicles

Table 8 List of the Main Vehicles Featuring Notable Technologies Announced in Japan in 2021

Category	Company	Name of technology	Description of technology	Featuring vehicle
Safety technologies	Toyota Motor Corporation	Advanced Drive	This technology incorporates deep learning-based AI techniques to anticipate various potential situations that can arise while driving and provide appropriate support. Advanced Drive is a system that assists with driving on the main lanes of expressways and other roads restricted to four-wheeled vehicles. After the GPS is used to set a destination, the on-board system, under driver supervision, offers appropriate recognition, decision-making and operation assistance for tasks such as lane keeping, maintaining following distance, branching and overtaking to support driving—including branching—until the destination is reached. This frees the driver from having to operate the accelerator, brake, and steering wheel, reducing fatigue during prolonged driving and allowing greater attention to be paid to the surroundings to drive more safely. The system also realizes polished, natural driving adapted to various driving scenarios such as curves, congestion, and overtaking to offer a smooth driving experience in line with the driver's intent.	Mirai LS500
	Honda Motor Co., Ltd.	Honda Sensing Elite	The Honda Sensing Elite name was chosen to symbolize the elite, superior nature of the technology relative to the Honda Sensing system already deployed in current Honda vehicles. The Traffic Jam Pilot (congestion assist function), in particular, has received the Ministry of Land, Infrastructure Transport and Tourism type approval for automated driving systems and constitutes an advanced technology corresponding to level 3 automated driving (conditional automated driving (in restricted areas)). This enables the system to take over driving operations for the driver under certain conditions such as congestion on the expressway.	Legend
	Subaru Corporation	Eyesight X	Newly developed Eyesight X advanced driving support system that makes use of high-accuracy maps (installed in the GT-H and STI Sport R EX). Eyesight X combines an advanced driving support system with the next-generation Eyesight. It broadens and expands the field of driving support on roads limited to four-wheeled vehicles more than ever, offering an even more stress-free, secure, and comfortable driving experience.	WRX S4

Table 8 List of the Main Vehicles Featuring Notable Technologies Announced in Japan in 2021 (cont.)

Category	Company	Name of technology	Description of technology	Featuring vehicle
Environmental technologies	Mazda Motor Corporation	e-SKYACTIV	Turn day-to-day driving time into a time to reset and go back to your normal self. Let go of your tensions and enjoy driving. The more you get in the car, the more you will look forward to driving every day. The MX-30 comes in EV and mild hybrid variants, and the Mazda jinba ittai (rider and horse as one) driving performance has been polished for equally for each of those different powertrains to provide the pure and pleasant driving experience described above. The e-SKYACTIV electrification technology, which uses the SKYACTIV engine and SKYACTIV vehicle architecture as a base to perform cooperative control of the engine, motors, brakes, generators and other components and achieve smooth and refined dynamic performance at a high level of efficiency. The first electric vehicle among the Mazda mass-production vehicles (the MX-30 EV) is equipped with originally developed technology that is part of e-SKYACTIV. In addition to high precision torque control based on human characteristics and the incorporation of natural feedback using sounds that correctly transmit the vehicle condition, the system enhances the consistency of vehicle response to operations in all directions and performs seamless G linking via the electric G Vectoring Control Plus (e-GVC Plus) system. This car offers an even deeper level of the Mazda joy of driving philosophy.	Mazda MX-30 EV
	Nissan Motor Co., Ltd.	e-Power	The e-Power system consists of high voltage batteries and a compact powertrain that integrates a gasoline engine, generator, inverters, and high-power motor. The e-Power system distinguishes itself from common existing parallel hybrid systems that combine a drive engine with compact motors, by using the engine only to generate electricity without directly connecting it to the wheels, and providing 100 % of the drive using only motors. It also differs from fully electric vehicles like the Nissan Leaf in its use of power generated from the gasoline engine in addition to the electricity stored in the battery. The Nissan Leaf uses only its batteries as a source of energy and has to be recharged using an external charger.	Note Serena Kicks
	Suzuki Motor Corporation	ISG	This vehicle is equipped with a proprietary mild hybrid system that combines the R06D engine, which realizes nimble driving and superb fuel efficiency in all practical speed ranges, from low to medium and high speeds, an integrated starter generator (ISG), and a dedicated lithium-ion battery. It has a mini-vehicle-best fuel efficiency of 27.7 km/L in WLTC mode (Hybrid S, Hybrid X), and is the first mini-vehicle to achieve 95 % of the fuel economy standards for fiscal 2030, qualifying it for a tax exemption under the program for fuel-efficient car tax reduction (motor vehicle weight tax). (This applies to the Hybrid S and Hybrid X 2 WD models.)	Alto
Other technologies	Mitsubishi Motors Corporation	Super All Wheel Control (S-AWC)	Adding an AYC system that performs brake control to a twin motor 4 WD base, the Outlander S-AWC controls front and rear, as well as right and left drive force distribution. Exclusive tuning of ABS and ASC control has also been applied as a complement to control of drive and regenerative torque. The constant optimized control of the four wheels provided by this system balances and maximizes the performance of the tires for all four wheels under a variety of driving conditions. This system achieves superior vectoring that faithfully traces the visualized line on any road surface, as well as a high level f driving stability that remains unaffected by changes in road surface conditions.	Outlander
	Daihatsu Motor Co., Ltd.	CVT for front-engine, rear-wheel drive vehicles	This fully redesigned commercial vehicle is the first deployment of the Daihatsu New Global Architecture (DNGA) in response to the changing circumstances around commercial mini-vehicles expected to address the diversification of the workforce, the labor shortage resulting from the decline of the population, and new vehicle uses. In addition to the revamping the Hijet Cargo and Atrai platform, Daihatsu installed the CVT for front-engine, rear-wheel drive vehicles has been adopted in the Hijet Truck and other commercial mini-vehicles for the first time, improving basic performance elements such as fuel efficiency, quietness, and standing start performance. The adoption of the latest Smart Assist active safety functions also addresses the growing need for safety and security.	Hijet

(FCEVs), battery electric vehicles (BEVs), reduced fuel consumption by gasoline-engine vehicles, and refining hybrid vehicles. Electrification technologies are accruing importance not only for their contribution to the environment, but also for the quietness and responsiveness that can be achieved by taking advantage of motor characteristics.

3. 3. Other Technologies

The evolution of automotive technologies is not limited to the field of CASE. It also encompasses numerous major advancements in conventional technologies. Examples of such major advancements include maximizing tire performance through new forms of torque control to significantly enhance driving stability, as well as greater quietness and improved standing start performance obtained by developing a CVT for front-engine, rear-wheel drive vehicles. That CVT also decreases fuel consumption, enhancing product value by achieving several outcomes from a single technology.

Table 8 lists the main vehicles featuring the notable technologies announced in Japan in 2021. Each of those vehicles also features many technologies other than those listed. Refer to the information published by the various manufacturers for details.

1 Trends in Japanese Vehicles

Looking at the passenger vehicles launched in Japan in 2021 demonstrates the prevalence of crossover SUVs, including the Nissan Ariya battery electric vehicle, the Subaru Solterra/Toyota bZ4X.

This article describes the individual trends in exterior design for the crossover SUV, compact class, medium class, sports car, and mini-vehicles categories, as well as the overall trends in interior design.

2 Exterior Design

2. 1. Crossover SUVs

As even luxury brands have entered the fray, the product lineup of all manufacturers has featured crossover SUVs for several years. The crossover SUV category itself has become a trend, as demonstrated by complete product lineup presented by Toyota with the introduction of the Corolla Cross. Meanwhile, package designs that place the large and heavy battery in the underbody are appropriate to the planning of battery electric vehicles. It is likely that crossover SUVs will represent a large proportion of BEVs introduced to the market for the foreseeable future. The Nissan Ariya (Fig. 1) and Subaru Solterra/Toyota bZ4X (Fig. 2) follow a common trend, presenting a coupé-like silhouette within a body with a sleek surface, dispensing with the front grille, and featuring narrow, piercing headlamps. The Honda Vezel (Fig. 3) presents a redesign that integrates those trends while also presenting a simpler, more elegant and sophisticated design than its predecessor.

Fig. 1 Nissan Ariya

Fig. 2 Toyota bZ4X

Fig. 3 Honda Vezel

Fig. 4 Lexus NX

The second generation Lexus NX (Fig. 4) capitalizes on the shift from the coupé-like personal feel of the first generation to the sportier stance provided by the wheels, produces a new feel with its simpler surface, and expresses the Lexus identity through its radiator grille as well as front and rear lamps.

At the same time, the Toyota Land Cruiser (Fig. 5), Mitsubishi Outlander (Fig. 6), and Subaru Legacy Outback serve as flagship vehicles demonstrate an emphasis on the SUV role demonstrating that the trend toward coupé styles does not sacrifice utility. They feature a refined design that highlights full-fledged off-road power and utility over the image of a crossover. The use of disc wheels with large diameters is also becoming more prevalent, with the Lexus NX and LX featuring 20-inch and 22-inch aluminum wheels, respectively.

2. 2. Compact Class

Toyota announced a redesign of the Toyota Aqua (Fig. 7), while Nissan added the Note Aura (Fig. 8) to the Note lineup. Even as it retains its design concept, the second generation Aqua expresses its novel elements through a solid and impressive rear fender that fits within the

Fig. 5 Toyota Land Cruiser

Fig. 6 Mitsubishi Outlander

Fig. 7 Toyota Aqua

Fig. 8 Nissan Note Aura

width dimensions required of Japanese 5-series plates, as well as through teardrop-shaped side windows. Based on the theme of refinement, the Note Aura joints the Note Aura Nismo and Note Autech Crossover in complementing the base Note model, establishing a series offering differentiation that addresses a broad variety of needs.

2. 3. Medium Class

This class feature the announcement of the Honda Civic (Fig. 9) and the Subaru WRX S4 (Fig. 10). Both models adopt a design that emphasizes a sporty style, with the Civic leveraging its five-door hatchback structure into a fastback silhouette and using sharp lines and graphics that highlight its edges to bring out that style, while the WRX S4 does so by slanting the quarter pillar within the limits of three-box structure and bringing the fender and air intake ports to the fore. The different ex-

Fig. 9 Honda Civic

Fig. 10 Subaru WRX S4

Fig. 11 Toyota GR86

pressions of sportiness presented by both models reflect the global trend in sporty sedan coupés that also encompasses the large class of vehicles.

2. 4. Sports Cars

The Subaru BRZ/Toyota GR86 (Fig. 86) each evolved into a second generation BRZ/GR86, and Nissan announced the seventh generation of the Fairlady Z (Fig. 12). Compared to the previous generation, the exterior design of the Subaru BRZ/GR86 features a rounder, vigorous body surface and cooling intake ports that integrate beautility even as it clearly carries on the identity of the model. In contrast, the Fairlady Z follow the recent American sports car trends exhibited by the Chevrolet Camaro, Ford Mustang, and Dodge Challenger, and distinguishes itself by reproducing the motif of the flagship initial model that debuted over 50 years ago in a modern style.

2. 5. Mini-Vehicles

The mini-vehicle category saw the release of the Alto/Wagon R (Fig.13) by Suzuki. The sharp design approach of the previous generation Alto and Wagon R/Wagon R Stingray was replaced with a friendlier, more approachable "rounded square" style evocative of the Hustler. The use of two-tone colors with a separate roof color

Fig. 12 Nissan Fairlady Z

Fig. 13 Suzuki Alto/Wagon R Smile

coating in both model is indicative of the strong adoption of the trend of using a different color for the roof.

3 Interior Design

3. 1. Impact of Larger Monitors

Monitors seem to have become an essential component of modern passenger cars, and the growing adoption of large screens has made touch interface standard, and their placement at the center of the instrument panel and rectangular shape have an impact on the overall form of the panel. Although there differences in the solidity and graphic wrapping applied to the instrument panel, the majority of designs adopt an overall horizontal pattern. The Honda Vezel and Civic (Fig. 14), as well as the Nissan Ariya and Mitsubishi Outlander (Fig. 15) all share a layout that sets the monitor on the upper part of the solid horizontal part of the panel. In contrast, vehicles from Subaru and Toyota emphasize vertical solidity continuing from the monitor set against the horizontal pattern. The actual use of the monitor itself is also changing. Examples such as the fully graphic display continuing from the meter in the Lexus NX (Fig. 16) and Nissan Ariya and Note Aura (Fig. 17), the use of two monitors in the Lexus LX (Fig. 18), or the vertical monitor in the Subaru Legacy Outback and WRX S4 (Fig. 19) suggest that user interfaces designed around large monitors will become key to expressing functionality and innovation.

Fig. 14 Interior of the Honda Civic

Fig. 15 Interior of the Mitsubishi Outlander

Fig. 16 Monitor in the Lexus NX

Fig. 17 Monitor in the Nissan Ariya

3. 2. Impact of by-Wire Technologies

By-wire technologies replace mechanical control with control based on electric signals. While the transition from opening and closing throttle butterfly valves to by-wire control using electric signals did not change the design of the accelerator pedal, more recent by-wire technologies are starting to have an impact on interior design. The electric parking brake can be described as having led to an evolution from a center console lever to a switch. In shift-by-wire, using a small area for selector operation results in greater flexibility for the placement of other switches or storage areas, and has also let to at-

Fig. 18 Monitor in the Lexus LX

Fig. 19 Monitor in the Subaru WRX S4

tempts as moving away from the conventional lever knob design of the selector itself. Steer-by-wire technology is essential to upcoming automated driving technology, and its ability to provide non-linear control between

Fig. 20 Center console of the Nissan Note Aura, Steer-by-Wire in the Toyota bZ4X

the turning angle of the steered wheels and the steering wheel means that it is not necessary to make the latter round, as demonstrated by the Toyota bZ4X (Fig. 20).

3. 3. Other Trends

The shift from chrome to satin plating for metallic decorative portions, the adoption of soft materials and stitching for the instrument panel, and the installation of a head-up display and ambient lighting are becoming more entrenched as trends across all vehicle sizes and categories.

Body Structures

1 Trends in Body Technologies

Growing social awareness of carbon neutrality, the circular economy, and other environmental issues is making its presence felt in modern-day automobiles and the development of vehicle body technologies. Global greenhouse gas emissions continue to rise, with some forecasts predicting a 4 to 5° C rise in the surface temperature of the Earth in 2100 compared pre-industrial levels, and warning that climate change could potentially lead to disastrous consequences. Various countries are making efforts to curb that rise in temperature (Fig. 1). Automakers are also joining in those efforts with a shift toward battery, plug-in hybrid, and other electric vehicles that reduce the emission of CO_2 emitted when vehicles are running. At the same time, achieving carbon neutrality requires reducing CO_2 emissions in each of the building, transport, use, and disposal processes. This makes it necessary for all industries involved, as well as the government and research institutes, to collaborate on achieving low-CO_2 power generation and reducing the amount of CO_2 generated from manufacturing or the production of materials.

Many batteries have to be installed on BEVs and PHEVs to accommodate cruising range needs, which results in increased vehicle weight (Fig. 2). In turn, this makes weight reduction and passive technology to protect the batteries even more critical to achieving more efficient electric power consumption and securing driving performance.

This section presents the vehicle body technologies observed in models sold in 2021 in the context of the above trends and concerns.

2 Body Structures

2. 1. Electrification and Vehicle Bodies

The growing shift toward BEVs and electrification in automobiles is bringing major changes to vehicle platforms. Reducing cost, development expenses, and development time through chassis designs, production processes, and commonization adaptable to powertrain variations that encompass BEVs is the key point in chassis that share common specifications between models or units.

The BEV model of the Mazda MX-30 announced in January 2021 shares the primary body structural layout,

	Greenhouse gas reduction goals		Automobile-related goals
EU	55% reduction by 55%	Compared to 1990	Ban internal combustion engine vehicles in 2035
U.S.	50 to 52% reduction by 2030	Compared to 2005	50% ZEVs* and PHEVs in 2030 *Zero-emission vehicle: BEVs and FCEVs
China	60 to 65% reduction by 2030 (CO_2 emissions relative to GDP)	Compared to 2005	50% NEVs* in 2035 50% HEVs *New energy vehicle: BEVs, FCEVs, and PHEVs
Japan	46% reduction by 2030	Compared to 2013	100% electric vehicles in 2035

Fig. 1 GHG Reduction Goals and Automobile Related Goals in Various Countries

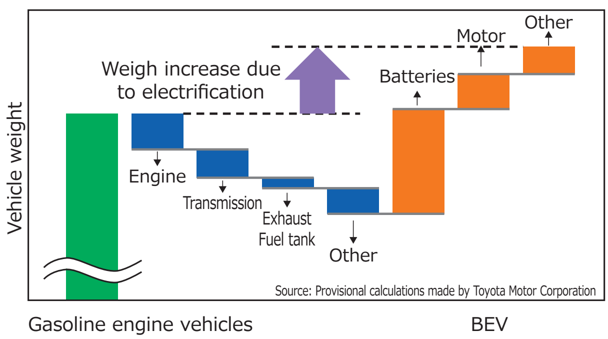

Fig. 2 Visualization of vehicle weight increase with the shift to BEVs

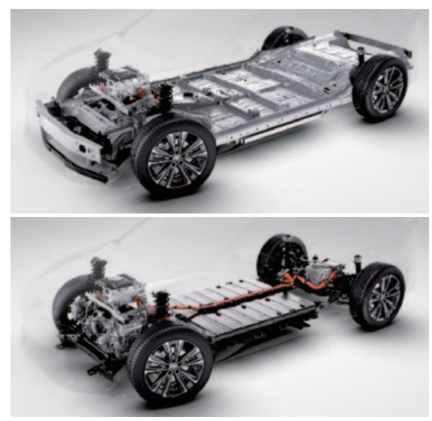

Fig. 3 Structure and unit layout of the Toyota bZ4X

cross-section shape, and manufacturing criteria of the mild hybrid model, and follows the same manufacturing process, thereby offering a powertrain unit option that addresses market needs. In addition, vehicle performance is secured by differentiating the specifications for body materials and thickness, as well as making the battery case part of the structure.

The Toyota bZ4X launched in October 2021 uses a dedicated BEV platform. The wheelbase was expanded to secure battery space in the cabin underbody, and the front of the cabin was reinforced and structured to disperse input loans along multiple paths to provide protection for occupants and the batteries in the event of a frontal or side collision. In addition, a cross frame linking the right and left front side members was set to ensure efficient energy absorption in the event of a vehicle collision (Fig. 3).

Nissan announced the new Ariya BEV model as well as the Nissan Intelligent Factory production process. That process accommodates diverse unit specifications via batch mounting of the powertrain while contributing to carbon neutrality through automation, lower vehicle plant energy consumption, and electrification. In the coating process, the integrated painting and baking of the steel sheet body and bumper using water-based paints that harden at low temperatures reduces energy use by 25%.

We will be keeping a close eye on the strategies, including BEVs, PHEVs, and drive based on e-fuel (fuel synthesized from hydrogen, CO_2, or other elements) automakers choose to adapt their vehicle platform to increasingly diverse unit types, as well as to achieving carbon neutrality in manufacturing processes and vehicles.

3 Vehicle Body Technologies

Reducing vehicle body weight and optimizing design requires a wide range of approaches encompassing vehicle planning, structural design, and material selection. The vehicle package and performance targets set during vehicle planning are expected to serve as the basis for selecting appropriate material from a design perspective and lead to structural design based on a sound concept.

In that respect, this section summarizes trends in the fields of materials, aerodynamics, and impact performance.

3. 1. Body Materials

(1) Steel Sheets

Steel is the main material comprising the vehicle body structure, and advances to further strengthen the hot- and cold-stamped cabin frame steel sheets that suppress body deformation in an impact continue to be made. The hot stamping technique makes it easy to achieve high strength as well as precision in complex shapes and dimension requirements, and is used to produce the cabin frame material in many vehicle models. The Honda Vezel and Civic, as well as the Mitsubishi Outlander use 1,500 MPa class hot-stamped material for the A pillar, side sill, and other major parts of the cabin frame, achieving greater vehicle body strength while simultaneously reducing weight (Fig. 4).

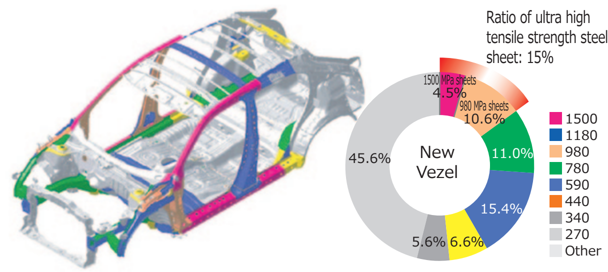

Fig. 4 Body Materials in the Honda Vezel

Advances are also being made in developing high strength cold-stamped steel materials and production technologies that do not require hot stamping. Such materials offering strength equivalent to that of hot-stamped materials while preserving formability are gradually being adopted in cabin frames. The Lexus NX uses 1,470 MPa cold-stamped steel sheets in its roof center reinforcement, and 1,180 MPa steel in the rocker outer reinforcement. In general, the cold stamping of high strength steel is prone to cracking, wrinkling and springback (recovery deformation after forming) and requires expensive press molding technology. However, advances in production technologies are increasing cold stamping adoption.

At the same time, these high strength steel sheets have low elongation at break, and using them in locations subject to deformation control in a vehicle impact or similar situation causes cracking or rupture, and fails to produce the intended energy absorption or deformation behavior. Consequently, the Honda Vezel and other models use high lambda (high stretch flanging) 980 MPa steel in the floor center cross member and the center pillar. These examples illustrate the importance of selecting material appropriate to the location in vehicle body design.

(2) Aluminum and Fiber-Reinforced Plastic

Aluminum or fiber-reinforced plastic (FRP) is used to further reduce weight below that of steel bodies. The accompanying increase in cost limits the adoption of those materials to a subset of parts such as the hood or doors, as well as to relative high-priced models. Although they have a high specific strength, they have a lower Young's modulus and elongation limit that calls for caution concerning where they are used and the design of those locations.

The Toyota Land Cruiser and Nissan Qashqai use aluminum in the hood, fenders, roof and doors, and GFRP in the undercover (Land Cruiser) or back door (Qashqai) to reduce weight. In addition, the parts manufacturing process for those models recovers the resulting scrap and reuses them to manufacture aluminum coils to build a closed loop recycling process that significantly reduces the amount of CO_2 produced in aluminum manufacturing.

The BMW iX and Mercedes-Benz S-Class feature a multi-material body that combines aluminum-extracted material or aluminum castings in the front side member and front pillar with steel or FRP, greater weight reduction that capitalizes on high energy absorption characteristics, while also achieving integrated parts and higher rigidity through die casting (Fig. 5). The adoption of such multi-material bodies involves not only manufacturing and material costs, but also calls for technology to bind dissimilar materials, structures that prevent galvanic corrosion, and advanced design and manufacturing technology that relies on differences in the coefficients of thermal expansion to control heat strain.

(3) Plastics

Plastics are frequently used in vehicle interiors and exteriors due to their light weight and high degree of formability. In conjunction with growing resource availability needs, the development of materials such as recycled plastic (material or chemical recycling), biomass plastics, and bioleather, and their use in vehicle parts, has been drawing attention. At the International Motor Show Germany held in Munich in 2021, BMW, Mercedes-

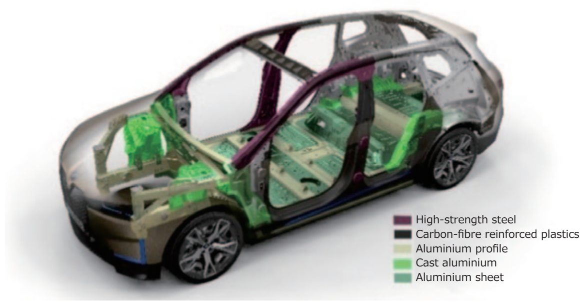

Fig. 5 BMW iX Multi-Material Body

Fig. 6 THUMS (Version 4) Occupant Models

Benz, Volkswagen, and other automakers presented concept cars using materials with a low environmental impact.

3. 2. Aerodynamic Technologies

Aerodynamic technologies represent are important to performance as they reduce running resistance and contribute significantly to reducing fuel and electricity consumption while also making a positive impact on vehicle behavior and handling stability. Progress has been made in lowering the drag coefficient (Cd), with the updated Tesla Model S and the new Nio ET7 achieving a Cd of 0.208, the best value in mass-produced vehicles, in 2021. Further advances in research simulating the effects of drag around the tires while driving, and in vehicle computational fluid dynamics (CFD) hold the promised of even greater progress in the field of vehicle aerodynamics.

3. 3. Passive Safety Technologies

Recent advances in active safety technologies have been matched by advances in passive safety technologies as well. A new, stricter mobile progressive deformable barrier (MPDB) was introduced in Europe (in 2020), and the addition of oblique impacts and other new impact patterns is under consideration. In addition, the use of virtual tests in safety evaluations of passive safety performance of impact patterns and occupant posture and physique is being evaluated as a complement to existing regulations and assessments to improve occupant safety in the diverse collisions found in the real world. There are plans to introduce virtual tests in Euro NCAP. In a similar vein, the application of the Total Human Model for Safety (THUMS) virtual human body enabling the analysis of human injury in automobile collisions (Fig. 6), which was released royalty-free in January 2021 by Toyota Motor Corporation, in automaker safety performance development and individual vehicle assessments by universities and research institutes is under consideration.

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