PASSENGER CARS

Overall Trends

1 Introduction

The 2018 global automotive market, marked by factors such as a slowdown in growth, was a year of changes leading to major turning point. The trade friction between the U.S. and China and the withdrawal of the U.K. from the EU, and other murky political and economic conditions, further pushed the consumer mindset toward caution, leading to lower sales in all three major markets of China, Europe and the U.S. In contrast, some markets, such as those of India and Brazil, exhibited growth. At the same time, needs in new domains centered on the connected, autonomous, shared & services, electric (CASE) concepts are emerging, and current automakers are increasing their investments in new fields. This is pushing those automakers to review their strengths and apply a select-and-focus strategy involving, for example, shifting from projects expanded globally to concentrating on primary regions.

In the Chinese market, the number of vehicles sold fell for the first time in 28 years. The main factors behind these results are the end of tax reduction measures for light-duty vehicles with a displacement of 1.6 L or less and the economic slowdown, as well as the drop in demand resulting from the declining consumer sentiment due to the uncertainty caused by the trade friction with the U.S. since March 2018. Despite this, sales of new energy vehicles (NEVs) have continued to rise significantly.

The European market contented with a number of negative factors. The unstable political and economic conditions, exemplified by the withdrawal of the U.K. from the EU and the confusion surrounding the Italian budget, depressed consumption. Also, sales in Germany dropped after last minute demand due to the introduction the Worldwide Harmonized Light Vehicles Test Procedure (WLTP) fuel economy and emissions standards in September 2018 leveled off. Moreover, demand for the long-popular diesel vehicles also fell. Conversely, France, Poland, the Netherlands, Spain and other countries provided support for a robust market, but results for Europe as a whole were slightly lower than in the previous year.

Since demand peaked in 2014, sales the passenger vehicle category in the U.S. market have continued to decline. In the truck category, however, sales of SUVs (CUVs), have kept growing, overtaking those of other vehicles for the first time in 2018. The shift from sedan and light-duty vehicles to SUVs (CUVs) is attributed to the robust economy and the rising age of drivers.

The Japanese market grew for a second consecutive year. The increase in sales of mini-vehicles continuing for a second year compensated for the decrease in registered vehicle sales, confirming the strong popularity of mini-vehicles.

2 Production, Sales, and Exports

2. 1. State of Production in Leading Manufacturing Countries

Table 1 shows passenger car production in leading manufacturing countries. Overall production dropped to 70.47 million vehicles, or 97% of the previous year. In the main regions, production in China decreased 23.71 million vehicles, or 96% of the previous year due to the effects of policies and the economy, adjustments made in response to stagnant sales of sedans and other models in the U.S. cut production to 2.80 million vehicles, or 92% of the previous year, and in Germany the scaling down in production accompanying the enforcement of the WLTP in the EU resulted in a production of 5.12 million vehicles, or 91% of the previous year. In contrast, the emerging countries of India and Brazil produced 4.06 million and 2.39 million vehicles, respectively, an increase of 103% over the previous year in both cases.

Table 1 Passenger car production in leading manufacturing countries.

	2018	2017	Compared to previous year (%)
Japan	8,359,286	8,347,836	100.1
U.S.	2,795,971	3,033,216	92.2
Canada	655,896	※ 751,048	87.3
EU	16,060,576	※ 16,598,459	96.8
Germany	5,120,409	※ 5,645,584	90.7
UK	1,519,440	1,671,166	90.9
France	1,763,000	※ 1,754,000	100.5
Italy	670,932	742,642	90.3
Spain	2,267,396	※ 2,291,474	98.9
South Korea	3,661,730	3,735,399	98.0
China	23,709,782	※ 24,718,321	95.9
India	4,064,774	※ 3,961,327	102.6
Brazil	2,386,758	※ 2,307,443	103.4
World total	70,466,344	※ 72,663,013	97.0

Note 1 : The values announced by the International Organization of Motor Vehicle Manufacturers (OICA) are preliminary figures. However, the values for Japan are from the Japan Automobile Manufacturers Association monthly report on motor vehicle statistics.
Note 2 : * denote revised values
Note 3 : The 27 EU countries.
Note 4 : The number of vehicles for the U.S. and Canada excludes SUVs and other models that are considered as trucks in those countries.

Table 2 Passenger car production in Japan.

	2018	2017	Compared to previous year (%)
Ordinary trucks	5,256,226	5,147,256	102.1
Light-duty trucks	1,605,162	1,715,970	93.5
4-wheeled mini-vehicles	1,497,898	1,484,610	100.9
Total	8,359,286	8,347,836	100.1

Source: Japan Automobile Manufacturers Association (JAMA)

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

2. 2. 1. Production

Table 2 shows passenger car production in Japan. Production of ordinary cars and mini-vehicles rose slightly, reaching 5.26 million vehicles, or 102% of the previous year for the former, and 1.5 million vehicles, or 101% of the previous year for the latter. However, production of light-duty vehicles decreased to 1.61 million vehicles, or 94% of the previous year, bringing overall production of passenger vehicles to 8.36 million vehicles, the same level as in the previous year.

2. 2. 2. Exports

Table 3 shows the number of passenger cars exported from Japan according to destination. Export volume grew steadily not only in North America, Europe, and Asia, but also in regions such as the Middle-East and Oceania, reaching 4.82 million vehicles overall, which represents a considerable rise of 114% over the previous year.

Table 3 Number of passenger cars exported from Japan according to destination.

	2018	2017	Compared to previous year (%)
North America	1,929,781	1,892,647	102.0
Europe	885,705	842,045	105.2
Oceania	438,362	382,243	114.7
Asia	635,045	444,254	142.9
Middle-East	476,157	350,838	135.7
Central America	182,879	148,500	123.2
South America	140,712	106,338	132.3
Africa	119,549	49,561	241.2
Others	9,280	2,003	463.3
Total	4,817,470	4,218,429	114.2

Source: Japan Automobile Manufacturers Association (JAMA)

Table 4 Passenger car sales in Japan.

	2018	2017	Compared to previous year (%)
Ordinary trucks	1,582,828	1,548,214	102.2
Light-duty trucks	1,312,626	1,394,796	94.1
4 -wheeled mini-vehicles	1,495,706	1,443,368	103.6
Total	4,391,160	4,386,378	100.1

Source: Japan Automobile Manufacturers Association (JAMA)
Note 1 : The classification criteria of the sales statistics are based on the license plate number.

2. 2. 3. Sales

Table 4 shows passenger car sales in Japan. Sales of ordinary cars and mini-vehicles rose slightly, reaching 1.58 million vehicles, or 102% of the previous year for the former, and 1.5 million vehicles, or 104% of the previous year for the latter. However, sales of light-duty vehicles decreased to 1.31 million vehicles, or 94% of the previous year, bringing overall sales of passenger vehicles to 4.39 million vehicles, the same level as in the previous year.

2. 2. 4. Used Vehicle Sales

Table 5 shows used vehicle sales in Japan. Sales in 2018 remained level at 5.81 million vehicles, representing 100% of the previous year, matching the trends observed for production and new vehicle sales. By category, ordinary cars accounted for 1.83 million vehicles, or 102% of the previous year, mini-vehicles exhibited a continuation of their 2017 increase, accounting for 2.45 million vehicles, or 102% of the previous year, while light-duty vehicles dropped to 1.52 million vehicles, or 96% of the previous year.

2. 2. 5. Imported Vehicle Sales

Table 6 shows imported vehicle sales in Japan. The

Table 5 Used vehicle sales in Japan.

	Ordinary trucks	Light-duty trucks	4 -wheeled mini-vehicles	Total	Compared to previous year (%)
2009	1,619,370	1,855,071	1,864,874	5,339,315	94.2
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

Source: Japan Automobile Manufacturers Association (JAMA) and the Japan Light Motor Vehicle and Motorcycle Association

Table 6 Imported vehicle sales in Japan.

Ranking (Previous year)	Manufacturers	2018 (Units)	2017 (Units)	Compared to previous year [%]
1 (1)	Mercedes-Benz	67,531	68,215	99.0
2 (3)	VW	51,958	49,036	106.0
3 (2)	BMW	50,982	52,527	97.1
4 (4)	Audi	26,473	28,336	93.4
5 (5)	BMW Mini	25,984	25,427	102.2
6 (6)	Volvo	17,392	15,764	110.3
7 (18)	Honda (vehicles produced outside Japan)	14,130	2,987	473.0
8 (7)	Nissan (vehicles produced outside Japan)	12,169	14,899	81.7
9 (8)	Jeep	11,438	10,101	113.2
10 (9)	Peugeot	9,881	8,242	119.9
11 (10)	Renault	7,252	7,119	101.9
12 (11)	Porsche	7,166	6,923	103.5
13 (12)	Fiat	6,013	6,522	92.2
14 (13)	Suzuki (vehicles produced outside Japan)	4,442	5,768	77.0
15 (16)	Land Rover	3,964	3,597	110.2
16 (17)	Citroën	3,560	3,152	112.9
17 (19)	Jaguar	3,260	2,614	124.7
18 (15)	Mitsubishi (vehicles produced outside Japan)	3,117	3,909	79.7
19 —	Alfa Romeo	2,510	1,838	136.6
20 (14)	smart	2,465	4,638	53.1
	Total (including ranks 20 and below)	342,770	333,451	102.8

Sources: Japan Automobile Dealers Association (JADA)

expansion observed in 2017 continued, with overall sales reaching 340 thousand vehicles, representing 103% of the previous year. By manufacturer, the high-ranking Volkswagen came out strong, overtaking BMW for the first time since 2016 and taking second place. Amid declining sales of imported vehicles for the majority of Japanese manufacturers, Honda has ranked first among them as its sales have risen since 2016.

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. With the major markets of the U.S. and Europe stagnating in 2018, sales of Japanese vehicles also dropped. Although market share was maintained in the U.S., it dropped in Europe. China is noteworthy in that despite a drop in overall passenger vehicle sales, Japanese vehicle sales rose and their market share expanded. Elsewhere, the increase in sales observed in 2017 in Brazil and India continued, also boosting sales of Japanese vehicles. In Brazil, however, the rise in sales of Japanese vehicles remained below the overall increase, and market share declined.

3 Product Technology Trends

This section covers the main technologies incorporated in new, completely redesigned, and partially redesigned domestically produced ordinary cars, light-duty vehicles, and mini-vehicles introduced in the Japanese market in 2018. Table 8 shows the new product technologies for Japanese-produced ordinary and light-duty vehicles, while Table 9 presents those for mini-vehicles. OEM models are excluded.

Table 7 Passenger car sales in leading manufacturing countries and share of Japanese vehicles.

	Total passenger car sales 2018	Japanese vehicles within the total (share of Japanese vehicles)	Total passenger car sales 2017	Japanese vehicles within the total (share of Japanese vehicles)	Total passenger car sales Compared to previous year
Japan	4,391,160	4,082,771 (93.0%)	4,386,378	4,081,335 (93.0%)	100.1%
U.S.	5,304,347	2,511,314 (47.3%)	6,080,949	※2,863,790 (47.1%)	87.2%
Canada	581,977	271,202 (46.6%)	635,454	※285,280 (44.9%)	91.6%
Brazil	2,099,611	401,231 (19.1%)	1,856,096	※379,754 (20.5%)	113.1%
China	23,709,782	4,584,856 (19.3%)	24,718,321	4,401,173 (17.8%)	95.9%
India	3,394,756	2,102,162 (61.9%)	3,230,603	※1,976,977 (61.2%)	105.1%
EU + EFTA total	15,624,486	1,389,515 (8.9%)	15,630,555	1,439,224 (9.2%)	100.0%
UK	2,367,147	372,702 (15.7%)	2,540,617	421,433 (16.6%)	93.2%
Germany	3,435,778	319,747 (9.3%)	3,441,262	329,956 (9.6%)	99.8%
France	2,173,481	216,216 (9.9%)	2,110,748	215,940 (10.2%)	103.0%
Italy	1,910,025	209,072 (10.9%)	1,971,345	※212,163 (10.8%)	96.9%

Source: Automobile manufacturers association in each country

Note 1 : Japanese vehicles refer to all Japanese brand vehicles and include those produced outside Japan.

Note 2 : The number of vehicles for the U.S. and Canada excludes SUVs and other models considered trucks in those countries (Source: Ward's).

Note 3 : Calculated from the 26 countries in the EU and 3 countries in the European Free Trade Association (EFTA: Iceland, Norway, and Switzerland) (source: European Automobile Manufacturers' Association (ACEA)).

Note 4 : Japanese vehicles in the EU represent the total number of vehicles for Toyota, Nissan and Honda (ACEA).

Table 8 Main Product Technology Trends in Ordinary and Light-Duty Automobiles Produced in Japan In 2018

Release date	Vehicle model	Brand	Main technologies
March 1	Eclipse Cross (New model)	Mitsubishi	Retaining the excellent view provided by the high hip point and spacious interior SUV functionalities, this model has a coupé style with a distinctive presence in the urban landscape. The 4 WD version is equipped with an electronic 4 WD control system that constantly distributes appropriate transfer torque to the rear wheels based on factors such as the accelerator angle and vehicle running conditions. This is complemented by a Super All Wheel Control (S-AWC) integrated vehicle dynamics control system enhanced with the Active Yaw Control (AYC) brake control function. It offers the three driving modes of AUTO, SNOW and GRAVEL, which are available from the drive mode selector set in the center console. It uses a newly developed 1.5 L downsized direct injection gasoline turbocharged engine. Fine control of in-cylinder injection and intake port injection based on driving conditions provide excellent fuel efficiency and clean emissions. Thanks to the turbocharger, its low- to medium speed range torque surpasses that of the conventional 2.4 L naturally aspirated engine despite its displacement of 1.5 L. The compact turbocharger equipped with an exhaust manifold with integrated cylinder heads, the MIVEC intake and exhaust system, and electronic waste gate actuators provides superior response. It qualifies for the Safety Support Car S wide category.
March 1	Serena (e-Power model added)	Nissan	The Serena e-Power is driven by the electric motor that use the electricity generated by the mounted gasoline engine. Retaining the spacious interior characteristic of the Serena, it offers highly responsive acceleration fully powered by motor drive, and is also very quiet. The efficient generation of electricity by the engine and superior aerodynamic performance result in a fuel economy of 26.2 km/L (JC08 test cycle). It adopts the ProPilot system, which automatically controls all accelerator, brake, and steering functions when driving in a single lane on the highway. It qualifies for the Safety Support Car S wide category.
May 31	CX-3 (Redesigned)	Mazda	Building on the theme of "refined beauty and sharpness", enhancements made in a broad range of areas including stability and controllability, the engine, design, and safety performance provide a driving experience matching the sensations of occupants and superior environmental and safety performance in everyday use by customers. This is the first Mazda vehicle to adopt the SKYACTIV-D 1.8 diesel engine. Fuel efficiency and environmental performance have been improved, and the high torque in the high engine speed range provides powerful and unconstrained acceleration. The SKYACTIV-G 2.0 gasoline engine uses new technologies such as edge-cut pistons and new dispersion injectors with nozzles, also featured in the CX-5, to improve torque in all engine speed ranges and improve actual fuel economy.
June 21	Atenza (Redesigned)	Mazda	All three existing engine models (the SKYACTIV-G 2.0, SKYACTIV-G 2.5, and SKYACTIV-D 2.2) have been upgraded. The SKYACTIV-G 2.5 adopts technologies such as cylinder deactivation to enhance the joy of driving and improve actual fuel economy. Adopting the SKYACTIV-G 2.0 gasoline engine and the SKYACTIV-G 2.5 enhanced with cylinder deactivation technology provides easier handling in everyday situations and improves actual fuel economy. The SKYACTIV-D 2.2 diesel engine used rapid multiple combustion technology to raise output from the previous 129 kW (175 PS) to 140 kW (190 PS) and the torque from 420 Nm (42.8 kgfm) to 450 Nm (45.9 kgfm).
June 22	Century (Complete redesign)	Toyota	Developed under the theme of "Tradition and Evolution" High environmental performance is achieved with the shift to hybrid specifications, and the renewed and appealing interior and exterior design provide sophistication and comfort worthy of a chauffeur vehicle, all while retaining the traditions of the craftsmanship and high quality monozukuri. Ride comfort, quietness and driving stability have all been raised a notch. The newly installed V8 5.0 L hybrid system achieves both the smooth and effortless driving performance expected of a chauffeur vehicle and high environmental performance. Fuel economy in the JC08 test cycle is 13.6 km/L. Active Noise Control is used to cope with noise and vibration when starting the engine, providing amazing quietness. In addition to adopting an electronically-controlled air suspension with AVS, fine-tuning extend to details such as using structural adhesive to improve body rigidity, developing new tires designed specifically to offer ride comfort, and adopting rubber parts in the suspension arms, bushings, and mounts, resulting in a ride with minimal up and down motion that feels soft and maintains a level line of sight. The newly installed Toyota Safety Sense package is supplemented with Blind Spot Monitor to detect vehicles in the blind spot in the neighboring lane, as well as Parking Support Alert to monitor the surroundings and provide assistance while parking. The HELPNET® service (linked to the airbags), in which a dedicated operator notifies the police or fire department in the event of an accident or medical emergency, has been added as a new feature, with the additional benefit of connecting to the operator automatically upon airbag activation. The D-Call Net®, which uses vehicle data to estimate the severity of the injury and determine whether early rescue via a medical helicopter is necessary, is also supported.
June 26	Corolla Sport (New model)	Toyota	This vehicle inherits the DNA of the Corolla, which has always changed with the times, and integrates the connectivity representing the mobility lifestyle of the future with the original pleasure of cars the series has built up. A DCM on-board communication device is standard equipment on all versions. It is equipped with connected functions such as e-Care Service and LINE My Car Account, which provide remote advice and vehicle diagnostics. Further advancing TNGA, it achieves a "fun to ride" high-quality driving performance and ride comfort. All versions have the latest Toyota Safety Sense with the ability to detect pedestrians at nighttime and cyclists.
June 26	Crown (Complete redesign)	Toyota	Redesigned as the first-generation car proposing a new mobility lifestyle. A DCM on-board communication device is standard equipment on all versions. It is equipped with connected functions such as e-Care Service and LINE My Car Account, which provide remote advice and vehicle diagnostics. Driving performance in line with driver intent achieved, notably, through a revamped TNGA-based platform. All versions have the latest Toyota Safety Sense with the ability to detect pedestrians at nighttime and cyclists, and other advanced active safety technology.

Table 8 Main Product Technology Trends in Ordinary and Light-Duty Automobiles Produced in Japan in 2018 (cont.)

Release date	Vehicle model	Brand	Main technologies
July 5	Note (4 WD model added)	Nissan	A 4 WD version (motor assist) offering even higher driving performance has been added to the e-Power grade. The newly developed combined e-Power and motor assist 4 WD system provides assistance on snowy or frozen roads. The precise control provided by driving all four wheels improves stability on frozen roads, steep hills, during right or left turns, or on roads with deep snow with strong tire resistance, offering confidence without sacrificing the driving performance of the e-Power. It qualifies for the Safety Support Car S wide category.
July 5	Jimny Sierra (Complete redesign)	Suzuki	Carrying on the distinctiveness of half-a-century of incarnations, this model further enhances the performance expected of the Jimny as a full four-wheel drive vehicle. It inherits the traditional Jimny configuration of front-engine, rear-wheel drive, part-time 4 WD with auxiliary transmission, and three-link rigid axle suspension, which is applied to a newly developed ladder frame. All versions have brake LSD traction control as standard equipment, offering high rough road performance. This model is equipped with the newly developed K15 B 1.5 L engine, resulting in higher reliability and drive performance. The installation of the Suzuki Safety Support active safety technology provides a full set of safety systems. It qualifies for the Safety Support Car S wide category.
July 19	Forester (Complete redesign)	Subaru	This model offers a packaging that balances excellent handling with a spacious interior, as well as user-friendly amenities, to allow all occupants to share a pleasant, comfortable space. Based on the shared Subaru philosophy of "dynamic and solid", its modern cubic design exudes the robustness expected of an SUV, functionality, and user friendliness. The adoption of the Subaru Global Platform provides top ranking passive safety and collision avoidance performance in its class, handling fully in line with driver intent, and pleasant ride comfort. Featuring the first driver monitoring system occupant recognition in a Subaru vehicle, as well as the e-Boxer system that combines a horizontally-opposed with electric drive technology that add new value, it has refined its functionality and performance to become a familiar presence giving customers the emotional appeal of abundance, comfort, pleasure, and a sense of adventure. It offers the latest pedestrian airbag and EyeSight Touring Assist advanced safety systems as standard equipment on all versions.
July 20	Clarity (Setting of plug-in hybrid model specifications)	Honda	This plug-in hybrid vehicle has all the charms of a luxury sedan, including high environmental performance, powerful EV driving performance, passenger space ample enough for five adults to relax, and plenty of luggage space. Based on the two-motor Sport Hybrid i-MMD system, it includes a higher capacity battery, stronger converter output, and other electric component performance improvements that result in an EV cruising range (range when cruising on a charged battery) of 114.6 km. The considerable increase in EV drive power significantly extents the start to high speed range of EV cruising. Three drive modes are available for high efficiency driving. The vehicle automatically selects the EV, hybrid, or engine drive mode based on the battery charge and driving conditions, shifting between modes seamlessly. It is the first vehicle to use a system that combines an inline 4-cylinder 1.5 L Atkinson cycle engine and a two-motor hybrid system. The inline 4-cylinder 1.5 L Atkinson cycle engine has been refined to raise thermal efficiency and lower emissions, exhibit a world-class maximum thermal efficiency of 40.5 %. The charging system includes not just a normal charging port, but also rapid charging an external supply ports as standard equipment. Electricity can be supplied to compatible external devices by plugging them in. The Honda Charging Service, a charging card service allowing the use of the 20,800 charging devices of the NCS network, was made available with the launch of the Clarity PHEV. The Honda Sensing advanced driving safety support systems is installed as standard equipment (qualifying for Safety Car S Basic+).
July 31	Leaf (Added Nismo specifications)	Nissan	This version exudes the stylish image and performance associated with the Nismo. It adopts the signature layered double wing of the Nismo road car series to improve downforce without worsening the drag coefficient. The models has a low center of gravity and an aggressive and stylish pure Nismo exterior design that evokes is driving performance. Its uses Nismo-exclusive 18-inch aluminum wheels with a sporty design that have a large diameter and lower weight, and also reduce aerodynamic drag behind the rear surface of the wheel. The exclusive 18-inch high-grip tires and exclusive suspension providing both ride comfort and stability and controllability achieve driving in line with driver intent.
August 23	Outlander PHEV (Redesigned)	Mitsubishi	The plug-in hybrid EV (PHEV) system received a major upgrade, with approximately 90 % of its main components receiving improvements, including the installation of a newly designed drive battery and engine, as well as higher motor and generator output. The drive battery capacity was raised from 12.0 kWh to 13.8 kWh, and maximum output was improved by 10 %. Increasing the output of the rear motor by approximately 12 % and that of the generator by approximately 10 % extended the EV cruising range from 60.8 km (S Edition, 60.2 km for the G Premium Package) to 65.0 km while simultaneously achieving powerful driving. The high expansion ratio (Atkinson) cycle resulting from increasing displacement from the conventional 2.0 L to 2.4 L, modifying the cam profile, and valve timing control, enables efficient power generation in the low engine speed range. Noise produced by the engine was reduced significantly by decreasing engine speed when the engine generates power, optimizing the amount of power generated, and even making improvements to the air cleaner and main muffler. The signature smooth and powerful acceleration and high degree of quietness of motor drive were further improved, highlighting the EV aspect that uniquely characterizes the Outlander PHEV. Two new drive modes (the SNOW and SPORT modes) were added to the Super All Wheel Control (S-AWC) integrated vehicle dynamics control system based on twin motor 4 WD, enabling more confident and enjoyable driving. The inclusion of the collision mitigation braking system (FCM) and false start control function (forward and rear) as standard equipment qualifies all versions as Safety Support Car S wide vehicles.

Table 8 Main Product Technology Trends in Ordinary and Light-Duty Automobiles Produced in Japan in 2018 (cont.)

Release date	Vehicle model	Brand	Main technologies
August 31	CR-V (Complete redesign)	Honda	This redesign strove to supplement the original strengths of a spacious interior and user friendliness with dynamic performance offering confident and pleasant driving in any and all conditions. In addition to adopting the Sport Hybrid i-MMD 4WD system for the first time, the gasoline model offers three rows of seat that accommodate seven occupants. This first hybrid model in the CR-V series uses the Sport Hybrid i-MMD system. The vehicle switches seamlessly between the EV, hybrid, or engine drive mode based on driving conditions, achieving both powerful driving and a top-of-its-class lower fuel consumption of 25.8 km/L. This is the first vehicle to add 4 WD specifications to the Sport Hybrid i-MMD system. The swift, real time AWD that relies on electronic control to distribute drive force to the front and rear wheels with precision provides superior rough road performance during starts on snowy roads, cornering, or when climbing hills. The gasoline model uses a direct injection 1.5 L VTEC turbocharged engine with dual VTC intake and exhaust. The exclusively developed turbocharger produces a torque comparable to that of a 2.4 L naturally aspirated engine and ensures an unconstrained and powerful feel up to high engine speeds. All grades offer the Honda Sensing advanced driving safety support system as standard equipment. The detection of conditions ahead of the vehicle using a millimeter wave radar and monocular camera and the brake and steering control operate cooperatively to provide confident and pleasant driving as well as support for avoiding accidents. This is the first Honda vehicle in Japan to adopt the hands-free access power tailgate. Users can open the tailgate can be opened simply by placing their toes below the sensor under the bumper, and can also use a button to stop the tailgate partway. A function to record and set the desired opening height is also available. A full range of amenities, including the eight-way power seat with a memory function, four-way electric lumbar support for the driver's seat, and electric panoramic sunroof with a wide opening.
October 24	Lexus ES (New model)	Lexus	The ES is part of the original Lexus lineup including the flagship LS sedan originally released in 1989. Acclaimed for its high quality ride comfort and quietness, as well as its spacious interior, it has written Lexus history as a key model in numerous countries and regions. Lexus has started selling the new ES, which is the seventh generation of the model, in its home country of Japan for the first time. A new platform and powertrain further enhance the high quality ride comfort inherited from its predecessors while also reconciling conflicting elements to offer a comfortable driving experience via superior stability and controllability. It is the first mass-production vehicle in the world with digital outer mirrors which, in conjunction with the Lexus Safety System+ active safety package, were designed to offer driving that is safer and more enjoyable thanks to cutting edge technology. Non-seating valves have been set in the oil flow paths of the shock absorbers in the GA-K platform, making it the first vehicle in the world to use swing-valve shock absorbers, which generate damping force via flow path resistance against even the smallest of movements. Producing damping force event at extremely low absorber stroke speeds results in excellent responsiveness and high-quality ride comfort. The 2.5 L inline 4-cylinder engine of the 2.5 L hybrid system achieves world-class thermal efficiency through high-speed combustion resulting from an improved intake ratio and a stronger airflow in the combustion chamber. It balances the superb fuel economy of 23.4 km/L in the JC08 test cycle with strong dynamic performance and quick response.
November 27	Lexus UX (New model)	Lexus	Built on the concept of creative urban explorer and intended to become a CUE to a new lifestyle, this new addition to the Lexus lineup is a concept crossover targeted at urban users. The sturdy body emphasizing toughness and power and the flared fenders suggesting agile driving result in a bold and elegant exterior. The interior consists of a cockpit delivering a sense of driving exhilaration while also offering a liberating field of view. In addition to adopting the GA-C platform, it achieves excellent steering response and stability thanks to a highly rigid body and a lower center of gravity obtained via weight reduction. It is equipped with the latest powertrain, which includes a newly developed inline 4-cylinder 2.0 L direct injection engine and a 2.0 L hybrid system. It adopts the Lexus Safety System+, which has been enhanced with functions such as lane-keeping assistance.
December 14	Insight (Complete redesign)	Honda	In this age when environmentally friendly vehicles are diversifying and multiplying, this model was developed as a vehicle with intrinsic appeal that transcends the ages, not just in terms of driving and design, but also in all its aspects. The powertrain combines the unique Honda Sport Hybrid i-MMD system, which offers the powerful acceleration and smooth driving characteristic of two-motor systems, with a 1.5 L DOHC i-VTEC engine. The vehicles achieves a high level of balance between fuel economy and not compromising high-quality driving for the sake of building an environmentally friendly vehicle. All versions offer the Honda Sensing advanced driving safety support system as standard equipment.
December 17	Prius (Redesigned)	Toyota	This model inherits the signature advanced image of the Prius, while making the interior design friendlier as well as more intelligent and refined. All variants are equipped with a dedicated DCM on-board communication device as standard equipment, making them connected cars. Using communications to connect the car to people and the community allows the use of various services that offer a more bountiful car lifestyle 24 hours a day, 365 days a year. Safety is covered by the inclusion of the Toyota Safety Sense collision-avoidance support package as standard equipment on all variants, as well as the addition of Rear Cross Traffic Alert, which detects vehicles approaching from the rear left or right sides when backing out of a parking spot and warns the driver.

Table 9 Main Product Technology Trends in Mini-Vehicles Produced in Japan in 2018

Release date	Vehicle model	Brand	Main technologies
June 25	Mira Tocot (New model)	Daihatsu	Build on the concept of a car requiring no effort anyone can use easily, this model strives for a reasonable price point and compact feel appropriate to a mini-vehicle. In addition to a package that facilitates getting a feel for the vehicle and has few blind spots, it offers a full set of safety and security systems. Complementing the adoption of the Smart Assist III collision avoidance assist system, SRS side airbags and SRS curtain shield airbags have been made standard equipment on all variants of a mini-vehicle for the first time. Planning and development focused on the sensibilities of today's young women. A project team consisting of female staff close to the target customer in age participated in the planning, and concepts based on the viewpoint of customers and opinions on items to include were reflected in the Mira Tocot.
July 5	Jimny (Complete redesign)	Suzuki	Carrying on the distinctiveness of half-a-century of incarnations, this model further enhances the performance expected of the Jimny as a full four-wheel drive vehicle. It inherits the traditional Jimny configuration of front-engine, rear-wheel drive, part-time 4 WD with auxiliary transmission, and three-link rigid axle suspension, which is applied to a newly developed ladder frame. All versions have brake LSD traction control as standard equipment, offering high rough road performance. This model is equipped with the exclusively fine-tuned R06 A turbocharged engine, resulting in higher reliability and drive performance. The installation of the Suzuki Safety Support active safety technology provides a full set of safety systems. It qualifies for the Safety Support Car S wide category.
July 13	N-Van (New model)	Honda	This model was developed to become the de facto standard for mini-vehicle vans based on observing the day-to-day life of working people and the pursuit of ease of use for various types of work, as well as excellent driving and safety performance. This is the first Honda mini-vehicle van to offer the Honda Sensing advanced driving safety support system as standard equipment on all its variants. The vehicle not only contributes to passive safety performance by placing lightweight, high-strength material throughout the vehicle, but also adopts a door-in-pillar structure for the passenger door and left sliding door, providing a large opening when the door is open while retaining a structure equivalent to a pillar when it is closed to ensure passive safety performance.

3. 1. Environmental Performance

The continued strengthening of fuel economy and CO_2 regulations in countries around the world, along with a growing social awareness of environmental issues, led automakers to introduce technologies that enhance environmental performance. With respect to the prominent technologies related to electrification, new and face lift models equipped with plug-in hybrid or hybrid systems were announced by all manufacturers, who expanded their product lineups. Improvements to internal combustion engines continued to be made, and several engines achieving a maximum thermal efficiency of 40% or more were introduced.

Ongoing improvements were not limited to powertrains, but covered the vehicle as a whole in areas such as weight reduction and aerodynamic performance. The WLTC was introduced for the fuel economy mode listed in catalogs, making it possible to look up mode fuel economy closer to the driving condition of users. More real world fuel efficiency improvement technologies have been adopted. In addition, technologies that enhance environmental performance, including switching to LED lamps to reduce power consumption, applying thermal management to raise efficiency and reduce heat loss, and performing efficient control of the charging and discharging of the hybrid battery based on driver behavior and information from the navigation system map have been introduced.

3. 2. Safety Performance

The government campaign to spread "Safety Support Car" conducted as part of efforts to prevent traffic accidents by elderly drivers has been bearing fruit, and the installation of the applicable advanced safety features as standard equipment has expanded to Kei-car. With the Japan New Car Assessment Program (JNCAP) introducing the evaluation of collision mitigation braking systems (that detect pedestrians during nighttime), "High-performance headlights" and "Unintended starting out prevention" in the active safety performance assessment, more vehicles supporting these functions have been introduced.

Other equipment contributing to safety has also become more common. "Digital outer mirrors" which ensure visibility that is minimally impacted by weather conditions by replacing the traditional mirror with compact digital cameras, were installed on a mass-produced

vehicle for the first time in the world. Driver monitoring systems, which monitor the driver, estimate drowsiness or distraction and provide alerts and warnings, have also become more widespread. In addition, traffic sign recognition functions, which display speed limit and other signs in the meter and notify the driver, as well as "Lane keeping assist system" which assist with steering to keep the vehicle near the center of the lane while driving on expressways, have also been adopted in mini-vehicles.

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Design Trends

1 Introduction

Getting into a car lets people go where they want whenever they want. With many people welcoming this convenient and comfortable means of transportation, many diverse cars were created, providing us with numerous benefits. However, a greater number of cars also leads to problems such as air pollution and traffic accidents, and automakers have been regularly establishing emissions, safety, and other measures. Japan faces various issues as the decline of the birth rate and aging of the population accelerates. This section takes a look at passenger car design in 2018 in the context of the diversifying social expectations and technical requirements imposed on cars.

2 The Japanese Market

The market in Japan is unique in that the proportion of sedans is declining, while that of mini-vehicles, minivans, and SUVs is rising. In response, automakers are striving to create designs that offer greater originality and emotional value.

2. 1. Mini-Vehicles

After gaining recognition thanks to the guidelines for building a national car (People Car's Plan) proposed by the Ministry of International Trade and Industry (current Ministry of Economy, Trade and Industry) in 1955, mini-vehicles went through three major expansions of the limitations on their dimensions. They initially went through a long period of being branded with the "three mini evils" label of "cramped, loud, and dangerous". However, with the sale of super high mini-vehicle vans, notably spearheaded by the Daihatsu Tanto and followed by the Suzuki Palette/Spacia and Honda N-Box, they were transformed into stress-free spacious, comfortable, and convenient vehicles on par with registered vehicles. In the past, economic factors the vehicle purchase price along with taxes and other ownership costs were selling points, but the focus of people of all ages has shifted now that it is possible to enjoy appealing designs and colors suited to the buyer's desires and intended use. One out of three new vehicles sold is a mini-vehicle.

In 2018, Suzuki revamped the Jimny, the original mini-vehicle SUV (Fig. 1). In the 48 years since the first generation, and 20 years since the previous generation of the model, the concept of a tough and wild feel has remained a constant selling point, and it has been remade into an even more sturdy form. The lineup has been enhanced by complementing the fun-filled Hustler (Fig. 2) with the release of the Spacia Gear (Fig. 3). Mitsubishi has also added the eK Cross (Fig. 4) to the SUV little brother family (March 2019 launch) to fill out its SUV series.

Fig. 1 Suzuki Jimny

Fig. 2 Suzuki Hustler

Fig. 3 Suzuki Spacia Gear

Fig. 4 Mitsubishi eK Cross

Fig. 5 Honda N-Van

For its part, Honda brought the N-Van (Fig. 5) to its popular N series. The ability to make the cargo space floor flat and the large rear door opening offer user-friendly loading or unloading of items. Its mild boxy style and multiple color various suggest a fun approach to carrying cargo not found in existing commercial vans. These increasingly unique mini-vehicles merit undivided attention.

2. 2. Minivans

Comfort and user-friendliness achieved via thoughtful attention to occupant seating and cargo loading are the selling points for this category. Minivans come in a one-box configuration that allows all occupants to share a high vantage point and sense of openness, and in a compact configuration characterized by a driving position close to that of passenger cars and highly mobile handling. They are proving popular as vehicles the entire family can enjoy.

Fig. 6 Nissan Serena

Fig. 7 Toyota Alphard

In 2018, Nissan released a new e-Power specifications version of the Serena (Fig. 6). In conjunction with the ProPilot advanced driver assistance system from the initial launch of the model, this version foreshadows the popularization of electrification and intelligent systems. One of the many one-box minivans with the strong and imposing front face spearheaded by the Toyota Alphard (Fig. 7), the Serena gives a clean and fresh impression through an exterior appearance graced by character lines and a silhouette that flow from front to rear.

2. 3. Sedans

As more and more users switch to mini-vehicles, minivans, or SUVs, or to imported premium sedans from Mercedes-Benz, BMW, Audi, or other manufacturers, Japanese sedans are being left behind. The Toyota Crown (Fig. 8) has been renewed in the face of these circumstances. In the 64 years since its initial launch in 1955, this flagship Japanese luxury sedan has constantly protected its name while evolving to reflect the times. This new version has rejected the three-box and thick C-pillar symbols of the sedan it had preserved since its inception and morphed into a sporty, fastback-like design with quarter windows. It has brought out a fresh personality in a quest to find new users.

Fig. 8 Toyota Crown

Fig. 9 Honda CR-V

Fig. 10 Audi Q3

Fig. 11 BMW X4

Fig. 12 Mitsubishi Eclipse Cross

Fig. 13 Lexus UX

Fig. 14 Volvo XC40

Fig. 15 BMW X2

3 Continuously Increasing SUVs and Crossovers

This category has become increasingly popular as its mainstream models have shifted from off-road vehicles characterized by their back door tire to on-road crossovers, and manufacturers have been preparing lineups finely attuned to users. This trend can be observed on a global scale, and as noted in the 2017 and 2018 editions of this journal, has even reached European traditional brands such as Bentley, Maserati, and Aston Martin, which have been putting out a succession of new models. Major completely redesigned models introduced in the Japanese market in 2018 include the aforementioned Jimny, the Honda CR-V (Fig. 9), the Audi Q3 (Fig. 10), and the BMW X4 (Fig. 11). New models featured a variety of appealing SUVs such as the Mitsubishi Eclipse Cross (Fig. 12), the Lexus UX (Fig. 13), the Volvo XC40 (Fig. 14) and the BMW X2 (Fig. 15). Each manufacturer is strengthening its lineup through the evolution of the family face and form language. In China, which grew rapidly to become the world's largest market, increased SUV sales are driving the overall market as sales of sedans and compact cars have stagnated. Their toughness

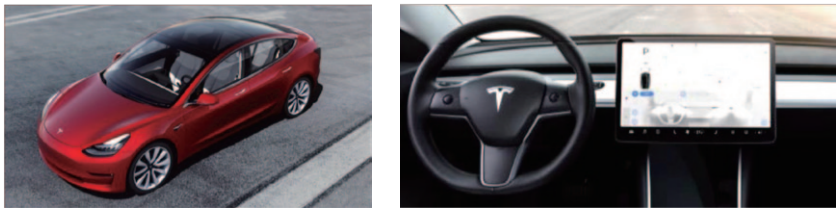

Fig. 16 Tesla Model 3

Fig. 18 NIO ES8

Fig. 17 Digital Outer Mirror

Fig. 19 Audi e-tron

and the sense of safety they impart, combined with improved design and quality, makes SUVs extremely popular, especially with young people. In 2018, SUVs accounted for 1,000 of the approximate total of 2,400 passenger vehicles sold in China.

4 The Search to Express New Designs

The Tesla Model 3 EV (presented in Japan for the first time in 2018) is the first vehicle to introduce in terms of expressing a new design. It has a very simple front face with no radiator grille, as well as a highly distinctive instrument panel (IP). The meter and ventilation louvers normally found on the IP are absent, and other than the main body, the interior contains only the steering wheel and a large 15-inch display. Ventilation is provided by controlling the direction and temperature of air coming out of slits at the top of the IP (Fig. 16). The next notable design is the use of the first mass-production digital outer mirrors on the Lexus ES (Fig. 17). Cameras embedded in the tube-shaped garnish attached to the front doors capture the rearview scenery, and the images are presented and the small display units placed at both ends of the IP. This eliminates the poor visibility caused by drops on the glass when it rains, greatly enhancing safety. The consideration given to the shape of the exterior garnish also promises major improvements in aerodynamic performance.

At the 2018 Beijing Motor Show, the new NIO brand supported by investments from Chinese IT corporations exhibited the ES8 EV SUV (Fig. 18). It drew attention for the NOMI robot equipped with an AI system that sits on the IP. It has a round shape with an LED panel, and can turns toward the user while changing its expression during a conversation. It is a superb device with communication functions capable of making various searches. Large displays in front of the driver and on the center console offer a UI design that makes the display very easy to read. It seems likely to make the ride very enjoyable for people who get into the NIO ES8.

In Europe, EVs such as the Audi e-tron (Fig. 19), Jaguar I-PACE (Fig. 20), and Mercedes-Benz EQC (Fig. 21) have fully entered the market. The front face and form language of the exteriors distinguishes the brands at a glance, while details such as emphasizing edges or adding roundness bring out their individual originality. The most noteworthy is found in the Mercedes-Benz EQC

Fig. 20 Jaguar I-PACE

Fig. 21 Mercedes-Benz EQC

which, like the aforementioned NIO ES8, introduces an AI infotainment system called MBUX. The information display area merges two high-resolution wide displays into a single glass cover that appears to float in the cockpit and is very easy to read. In 2018, as illustrated above, IT technology continued to serve as a backdrop in the quest to express various new designs.

5 Issues in Design

Vehicle emissions (CO_2) is said to account for approximately 20 percent (Note 1) of the causes of the air pollution that adversely affects our health. Although anti-emission measures have been repeatedly implemented over the years, even stricter regulations have been initiated in Europe, with the 2021/2030 CO_2 regulations, which are deemed impossible to achieve (Note 2), and in China with the new energy vehicle (NEV) regulations for 2019 and later (Note 3). Manufacturers face a situation where they will be unable to meet the requirements if they do no switch the power source from internal combustion engine (ICE) to electricity-based vehicles such as BEVs/PHVs, HEVs, or FCVs (Note 4). Another often heard key word poised to significantly transform the automotive industry is CASE (Note 5). The C stands for connected, the A for autonomous, the S for shared/services and the E for electric, and those four fields are expected to change product configurations, variations, and business models. Amid these turbulent times, manufacturers spent 2018 tackling the challenge of creating designs that offer greater originality and emotional value. As the relationship between people and cars evolves further, other fields and industries are predicted to continue to make a major impact. This will make incorporating those new ideas and knowledge, as well as continuously anticipating ever-changing user needs more critical than ever to achieve ideal designs.

Note 1: According to International Energy Agency (IEA) data, the transportation sector was responsible 24% of CO_2 emissions from global energy sources in 2015, with automobiles accounting for 75% of that figure.

Note 2: Regulations that limit passenger vehicle CO_2 emissions to 95 g per kilometer. In addition, plans to reduce 2030 emissions by 30% compared to 2021 levels (15% compared to 2025) are under consideration.

Note 3: System that imposes production and sales quota of battery electric vehicles (BEVs), plug-in hybrid vehicle (PHVs), or fuel cell vehicles (FCVs) on automakers that produce or import and sell 30,000 or more internal combustion engine vehicles per year. In 2019, the first year, the NEV quota is 10% of internal combustion engines sold, and it will rise to 12% in 2020.

Note 4: Battery electric vehicles (BEVs), plug-in hybrid vehicle (PHVs), hybrid electric vehicles (HEVs) or fuel cell vehicles (FCVs).

Note 5: Advocated at the 2016 Paris Motor Show by the CEO of Daimler as part of his mid- to long-term strategy. It is perceived as specific implementation of the automakers eventually turning into mobility service providers strategy described at the International Motor Show Germany the previous year (in 2015).

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Body Structures

1 Circumstances Affecting the Automobile

Global sales of automobile continue to rise, particularly in emerging countries, a situation that, combine with growing urban development, is anticipated to further bring air pollution and energy security issues to the fore. This will place even greater demand on countries around the world to improve environmental performance through measures such as the tightening automobile fuel economy regulations.

Enhanced environmental performance through electrification is the key to contributing to measures to combat climate change caused by automobiles. Japan is one of the countries with the most advanced electrification is in the world. (Approximately 30% of new vehicles sold are electrified (xEVs: battery electric vehicles (BEVs), plug-in hybrid electric vehicle (PHEVs), hybrid electric vehicles (HEVs) or fuel cell electric vehicles (FCEVs)). This is the result of getting an early start in developing and selling vehicles that balance environmental performance and customer needs as well as in establishing an institutional environment and infrastructure for electric vehicles.

Electrified vehicles (xEVs) share common core technologies (batteries, motors, inverters). Since electrification increases vehicle weight due to the mounting of a battery, innovation in related technical fields, exemplified by the growing importance of technologies to reduce the vehicle body weight, are required[1].

This section highlights on notable new vehicles and technologies introduced in 2018 to review trends in body structure technologies from the point of view of balancing weight reduction and body performance (stability and controllability, NVH, and safety).

2 Technological Trends Concerning Body Performance

2.1. Stability and Controllability

In addition to letting the driver to feel the joy of controlling the vehicle as desired, stability and controllability performance is crucial to offering safe and worry-free driving.

To enhance its dynamic performance as a sedan for drivers, the Toyota Crown uses a new TNGA platform, applies exhaustive adjustments to inertial parameters (distribution of gravity determined by the placement of heavy components and moment of inertia), adopts a low center of gravity package that lowers the position of the powertrain, one of the heavy components, as well as of the occupants and optimizes the longitudinal weight distribution and moment of inertia to achieve smooth and natural vehicle behavior during cornering, deceleration and acceleration[2].

The Mitsubishi Eclipse Cross uses a three-point strut tower bar and reinforces the suspension assembly to ensure rigidity. It also reduces weight by adopting high strength steel sheets and rationalizing components, and offers excellent handling[3].

Applying knowledge gained from the CX-5 and CX-9, the Mazda CX-8 has a continuous liftgate opening cross-section and inserts a high-rigidity foam filling agent at the bottom of the opening joining portion. This suppress deformation of the liftgate opening box and increases rear body rigidity. These measures result in a 7.0% improvement in torsional rigidity compared to the CX-5[4].

2.2. Noise, Vibration and Harshness (NVH) Performance

The engine compartment of electric vehicles contains a high-frequency noise generating device, and PHEVs also have an engine. Advances in electrification call for more complex measures to improve quietness.

In the Honda Clarity PHEV, measures against road noise, which stands out while driving in EV mode, concentrate on the floor, as well as front and rear wheelhouses, which are the locations from which noise penetrates the vehicle. Measures applied to the floor include setting a sound absorbing undercover made of unwoven material on the outside (under the floor), a now common approach in environmentally friendly vehicles, and a sound insulating carpet on the inside (in the cabin). Integrated forming that encompasses the surface pile layer makes the carpet thinner than in conventional adhesive forming while raising sound insulation performance. Sound absorbing inner fenders are set on the outside of the rear wheelhouses, and insulators on the inside (cabin side). Resin-impregnated unwoven material is used to install sound absorbing inner fenders in the front wheelhouses[5].

In the Lexus LS, panels of different thicknesses joined using the tailored blank technique are used at each location enclosed by the reinforcing agent that crisscrosses the floor panels to adjust their vibration frequency[6].

2. 3. Safety

Regulations and publicly released test information in various countries have led to stricter evaluation methods, increasing the importance of improving the safety performance of vehicle bodies. Passive safety performance improvements is based on the three basic approaches of using straighter basic structures, multi-load path structures, and cyclic structures to efficiently absorb and disperse the energy from front, side or rear collisions and suppressing the deformation of the body.

The Subaru Forester uses the Subaru global platform and markedly improves collision energy absorption through measures such as a significant reinforcement of the body and the optimization of the framework. Passive safety performance has been enhanced for each of the front, side, and rear collision directions. Joining strong pillars and frame parts to enclose the cabin aims to prevent its deformation in a collision to give the vehicle a body offering high vehicle occupant protection performance. In the event of a frontal collision, the low overall height of the horizontally-opposed engine gives it a structure that makes it likely to slide under the floor, which not only offers energy-absorbing benefits, but also reduces the chances that the engine will penetrate the cabin, mitigating injuries to the occupants[7].

The Nissan Serena e-Power further enhances the Zone Body Construction that consists of a high strength cabin and energy-absorbing body. That construction makes it a compatibility-compliant that both improves protection for the vehicle itself and mitigates damage to the other vehicle. In a crash, the energy-absorbing body efficiently absorbs energy. The high-strength members used in the frame structure realize a high-strength cabin. At the same time, the adoption of a pedestrian injury reduction body enhances the energy-absorbing capacity of the hood and other areas, and mitigates injuries to the heads or legs in the event of a collision with a pedestrian.

3 Technological Trends Concerning Weight Reduction

3. 1. Steel Sheets

Press hardened steel is increasingly used, mainly in the frame of the cabin, which protects the occupants, to reduce weight by using thinner steel sheets.

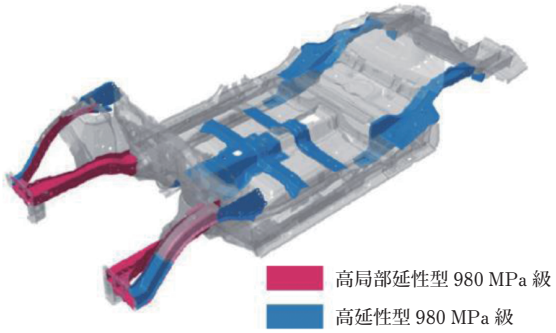

Fig. 1 Honda Clarity PHEV[5]

The Honda Clarity PHEV uses 1,500 MPa-class press hardened steel sheets in the body frame. In addition, two types of new 980 MPa-class galvannealed steel sheets, created from 980 MPa-class advanced high strength steel sheets previously only used for members with simple shapes due to forming restrictions, were put into practical use. The first is a high ductility 980 MPa-class advanced high strength steel sheet with excellent formability that was applied to the floor cross member and rear frame. The second is a high local ductility 980 MPa-class advanced high strength steel sheet with excellent local deformation adopted for the front side frame and upper members[5] (Fig. 1).

The Honda Insight uses hot-stamped materials with different strengths created using soft zone technology in the center pillar stiffener and the rear frame. This forms a single part that contains both a 1,500 MPa-class portion highly resistant to bending and a 550 to 650 MPa-class portion with superior energy absorption properties. These are some examples of selectively using high tensile strength material based on the required strength to realize lightweight body structures with superb passive safety performance[9].

The increased adoption of hot-stamped materials for the cabin also helps ensure sufficient structural strength to stop the tire or wheel in a small overlap collision. The disadvantages of hot-stamped materials, namely cracking under excessive deformation and cracking in the soft spot welding heat-affected zones (HAZ) are addressed by selectively softening the materials. At the same time, tailor rolled blanks and tailor welded blanks are becoming more common and are also being adopted in lower priced models.

3. 2. Aluminum

The Audi A6 is a medium-duty model that falls be-

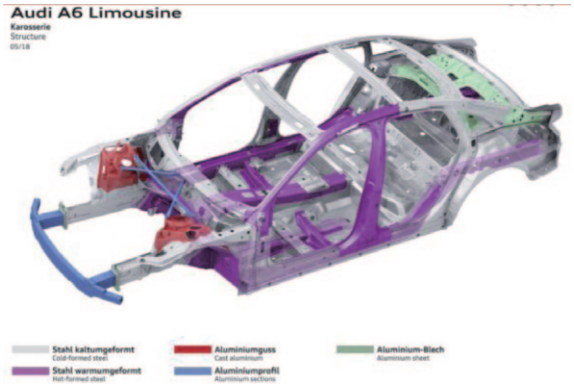

Fig. 2 Audi A6[11]

tween the A4 and the A8. The upper insulator panel of the A6 luggage compartment consists of an aluminum alloy. In the A4, that part is a steel sheet, while in the A8, it is made from carbon fiber reinforced plastic (CFRP). Comparing the materials used in each of those body structures makes it clear that they were designed with due consideration for both cost and performance[10] (Fig. 2).

In the Toyota Crown, aluminum is used in members located far the center of gravity of the vehicle, which affects the moment of inertia (the engine hood, front fender, and front suspension tower)[2]. Aluminum is also seeing greater use in lower priced models, with the Subaru Forester using an aluminum alloy for the engine hood and front fender.

3. 3. Composite Materials

A rear bumper beam using glass fiber reinforced plastic (GFRP) was newly developed for the Honda Clarity PHEV. The use of hybrid molding that layers non-continuous and continuous glass fiber enhances moldability and achieves an extremely lightweight, yet high-strength structure[5].

Use of carbon fiber reinforced thermoplastic (CFRTP) in the inner panels of the GMC Sierra pickup truck box reduced weight significantly. Although CFRTP is more expensive than aluminum, if offers excellent impact resistance and a scratch-resistant surface[12] (Fig. 3).

3. 4. Joining

Manufactures have been making efforts to optimize body structures, leading to the use of composite materials, aluminum, and other dissimilar materials to compensate for the loss of rigidity resulting from weight reduction, and turning the spotlight on technologies to join such materials.

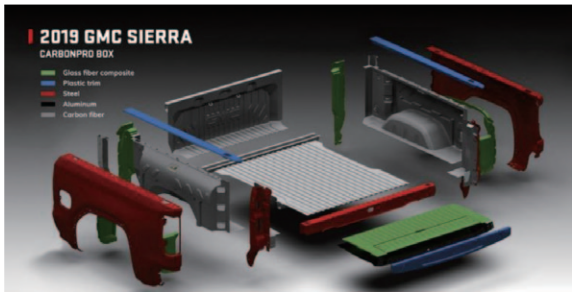

Fig. 3 GMC Sierra[13]

The Mitsubishi Eclipse Cross uses structural adhesive at the cabin opening, which is subject to considerable deformation from road inputs during maneuvers such as cornering. In the Outlander PHEV S-Edition, the further addition of coating at the side door openings enhances direct response while steering while also achieving high ride comfort quality[14].

In lower priced models, cost restrictions are limiting the adoption of parts that use aluminum or CFRPs, but the proportion of ultra-high tensile strength steel sheet use is rising. The high carbon content of ultra-high tensile strength steel sheets is known to cause a reduction in the strength of spot welded areas relative to the base material, and means of ensuring the necessary nugget diameter are being devised.

4 Technological Trends Concerning Structural Optimization Methods

Recently, topology optimization is being used to develop high-performance, lightweight body structures. The development of a multi-material topology optimization method using several dissimilar materials to improve basic body structure performance while achieving radical weight reduction is being pursued as part of an Innovative Structural Materials Association (ISMA) project.

The assembly structure of the strut tower bar in the Mitsubishi Eclipse Cross makes use of topology optimization, leveraging it to design parts that are both lightweight and highly rigid.

Examples of topology optimization applications in the Ford Focus and PSA DS3 Crossback were also presented at EuroCarBody 2018.

Technologies involving material substitution, structure optimization, or joint strengthening will be used in many vehicles, and the applications of calculations based on topology optimization are predicted to expand.

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