PASSENGER CARS

Overall Trends

1 Introduction

In the 2019 global automobile market, the turn from expansion to contraction that began the previous year continued, and the slowdown in the leading countries that had supported growth was one of several factors that accentuated the decline of the global market over the year.

Notably, the impact of additional tariffs between China and the U.S., along with uncertainty about the economy, cause the two largest automobile markets to stagnate. The European market saw the introduction of vehicles compliant with the Worldwide Harmonized Light Vehicles Test Procedure (WLTP) established in 2018. Despite signs of a recover in sales in Germany, the departure of the U.K. from the EU and the ongoing slump of the Italian contributed to a continued slowdown for Europe as a whole.

In India, which had become a leading market exhibiting remarkable growth, a stricter automobile loan approval process triggered by the bankruptcy of the largest domestic non-banking institution, higher insurance rates, and a reluctance to buy before the introduction of new emissions regulations conspired to bring the Indian domestic automobile market to a halt.

The Japanese market was robust in the first half of 2019, but natural disasters caused by typhoons and the revision of the consumption tax rate held growth back, resulting in a slight decrease in both production and sales over the second half of the year.

Even in that year of sluggish market growth, automakers have led the way in technical development related to the connected, autonomous, shared & services, and electric (CASE) concept touted as the pillar of next-generation technology. In addition to driving assistance technologies stemming from autonomous driving and electrification, the newly introduced vehicles have made the environmentally-friendly and fuel-efficient technologies called for by the increase in emissions regulations worldwide, which include the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), pending adjustments to the bonus-malus scheme, and revisions to the Chinese regulations aimed at accelerating the production of NEVs.

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 2019 was 67.15 million vehicles, representing 98.7% of the 2018 production and dropping below 70 million vehicles (Table 1). In the U.S., due to the shift in demand toward SUVs (CUVs), which are categorized as light-duty trucks, and the economic uncertainty caused by the U.S.-China trade friction, the production adjustments made in response to the drop in passenger vehicle sales, as well as strikes at completed vehicle manufacturing plants, decreased production to 2.51 million vehicles, which is 90.2% of the figure for 2018.

In leading European countries, the temporary suspension of plant production in the U.K. due to the Brexit issue, the stalled Italian economy, and other factors caused production to drop in all five major countries, and production for the 27 EU nations was 15.84 million vehicles, which amounts to 94.6% of the 2018 production.

In China, concerns stemming from the trade friction led to a GDP growth rate of 6.1% in 2019, a decrease of 0.5% compared to 2018. In addition, compliance with the NEV regulations introduced in some provinces in July 2019 held the automobile market back, and sales fell below those of the previous year for a second consecutive year. In India, production plummeted to 89.9%, or 3.62 million vehicles. In contrast, a recovery in domestic demand in Brazil led to a production of 2.45 million vehicles, or 102.5% over the previous year, making it the sole lead-

Table 1 Passenger Car Production in Leading Manufacturing Countries

		2019	2018	Compared to previous year (%)
Japan		8,328,756	8,359,286	99.6
U.S.		2,512,780	※ 2,785,164	90.2
Canada		461,370	655,896	70.3
EU		15,837,082	※ 16,746,049	94.6
	Germany	4,661,328	5,120,409	91.0
	UK	1,303,135	1,519,440	85.8
	France	1,675,198	※ 1,772,641	94.5
	Italy	542,007	※ 673,196	80.5
	Spain	2,248,019	2,267,396	99.1
South Korea		3,612,587	3,661,730	98.7
China		21,360,193	※ 23,529,423	90.8
India		3,623,335	※ 4,032,481	89.9
Brazil		2,448,490	※ 2,387,967	102.5
World total		67,149,196	※ 71,750,946	98.7

Note 1: Preliminary figures announced by the International Organization of Motor Vehicle Manufacturers (OICA) However, the values for Japan are from the Japan Automobile Manufacturers Association monthly report on motor vehicle statistics.
Note 2: *denotes 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 considered trucks in those countries.

Table 2 Passenger Car Production in Japan

	2019	2018	Compared to previous year (%)
Ordinary trucks	5,317,165	5,256,226	101.2
Light-duty trucks	1,538,380	1,605,162	95.8
4-wheeled mini-vehicles	1,473,211	1,497,898	98.4
Total	8,328,756	8,359,286	99.6

Source: Japan Automobile Manufacturers Association (JAMA)

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

	2019	2018	Compared to previous year (%)
North America	1,881,825	1,892,221	99.5
Europe	965,115	866,377	111.4
Oceania	339,948	389,949	87.2
Asia	514,962	486,088	105.9
Middle-East	390,155	409,358	95.3
Central America	138,552	141,272	98.1
South America	87,535	118,203	74.1
Africa	52,140	51,809	100.6
Others	2,413	2,505	96.3
Total	4,372,645	4,357,782	100.3

Source: Japan Automobile Manufacturers Association (JAMA)

ing country to see an increase.

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

(1) Production: Passenger car production in Japan was 8.33 million vehicles, or 99.6% of the 2018 production (Table 2).

In the first half of the year, production of ordinary passenger cars, light-duty vehicles, and mini-vehicles increased slightly compared to 2018. However, the halt of vehicle and parts production plants in eastern Japan due to the arrival of Typhoon No. 19 in October and the drop in sales of new vehicles following the revision of the consumption tax rate resulted in essentially the same level of production as the previous year for 2019 as a whole.

Table 4 Passenger Car Sales in Japan.

	2019	2018	Compared to previous year (%)
Ordinary trucks	1,586,342	1,582,828	100.2
Light-duty trucks	1,235,544	1,312,626	94.1
4-wheeled mini-vehicles	1,479,205	1,495,706	98.9
Total	4,301,091	4,391,160	97.9

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

Table 5 Used vehicle sales in Japan.

	Ordinary trucks	Light-duty trucks	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

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

(2) Exports: The total number of exported passenger vehicles remained virtually the same at 4.37 million vehicles, representing 100.3% of the 2018 figure (Table 3). As in 2018, exports to Europe and Asia rose, although that pace of growth for the latter destination fell due to the trade friction between China and the U.S., as well as to economic slowdown.

(3) Sales: Sales of passenger vehicle in Japan fell to 4.3 million vehicles, or 97.9% percent of 2018 sales, partly due to the halt in orders in and after October in the wake of the typhoon (Table 4). Although the 1.59 million ordinary passenger cars sold is comparable to the 2018 level, sales of light-duty vehicles continued to decrease, only reaching 1.24 million units, which represents 94.1% of the 2018 figure. Since the October revision of the consumption tax rate was not accompanied by tax incentives, sales of mini-vehicles dropped to 98.9% of their 2018 level, to 1.48 million units.

(4) Used Vehicle Sales: The number of used vehicles sold in Japan in 2019 reached 5.88 million vehicles, increasing for a third consecutive year (Table 5).

Ordinary passenger cars accounted for 1.89 million vehicles and mini-vehicles for 2.5 million, an increase that has continued since 2017.

However, as with new passenger vehicles, sales of light-duty vehicles declined, falling below 1.5 million units in 2019.

(5) Imported Vehicle Sales: Impacted by the slump in sales in the latter half of the year resulting, notably, from fewer customers visiting dealerships after the typhoon sales of imported vehicles in Japan stopped at 3.26 million units, or 95% of the 2018 level (Table 6). By manufacturer, the top five brands, as well as Nissan and Honda among the Japanese manufacturers, had lower sales than in the previous year, but some of the lower ranked brands enjoyed robust sales.

Table 6 Imported Vehicle Sales in Japan.

Ranking (Previous year)	Manufacturer	2019 (Units)	2018 (Units)	Compared to previous year [%]
1 (1)	Mercedes-Benz	66,523	67,531	98.5
2 (3)	BMW	46,814	50,982	91.8
3 (2)	VW	46,791	51,958	90.1
4 (4)	Audi	24,222	26,473	91.5
5 (5)	BMW Mini	23,813	25,984	91.6
6 (6)	Volvo	18,583	17,392	106.8
7 (9)	Jeep	13,354	11,438	116.8
8 (10)	Peugeot	10,626	9,881	107.5
9 (8)	Nissan (vehicles produced outside Japan)	9,374	12,169	77.0
10 (7)	Honda (vehicles produced outside Japan)	9,181	14,130	65.0
11 (12)	Porsche	7,192	7,166	100.4
12 (11)	Renault	6,803	7,252	93.8
13 (13)	Fiat	5,987	6,013	99.6
14 (14)	Suzuki (vehicles produced outside Japan)	4,744	4,442	106.8
15 (15)	Land Rover	4,549	3,964	114.8
16 (16)	Citroën	4,113	3,560	115.5
17 (17)	Jaguar	3,259	3,260	100.0
18 (18)	Mitsubishi (vehicles produced outside Japan)	3,182	3,117	102.1
19 —	Abarth	2,628	2,352	111.7
20 (19)	Alfa Romeo	2,370	2,510	94.4
	Total (including ranks 20 and below)	326,261	342,770	95.2

Sources: Japan Automobile Dealers Association (JADA)

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.

As in 2018, sales of passenger vehicles fell in all leading countries, including the U.S. and China, with India also experiencing a decline. Japanese vehicles managed to retain their market share, but could not avoid the reduction in the number of vehicles sold.

Moreover, total vehicles sales rose slightly in some leading European countries such as France and Germany, but the decrease in the number of Japanese vehicles sold indicates a loss of market share. A similar loss was also observed in Brazil where the increased sales ratio for Japanese vehicles are less than the overall increase in sales.

3 Product Technology Trends

Table 8 presents the main product technologies in the ordinary and light-duty vehicles introduced in the market by Japanese manufacturers in 2019.

Along with new or redesigned models using clean energy, technology for environmental performance continued to focus on better fuel efficiency. The spread of safe driving support vehicles with built-in measures to prevent accidents caused by elderly and other drivers and to mitigate damage has broadened the range of devices featuring driving support and advanced safety technologies, and expanded the number of models in which they are installed.

3. 1. Environmental Performance

Even further energy efficiency is called for against a

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

	Total passenger car sales 2019	Japanese vehicles within the total (share of Japanese vehicles)		Total passenger car sales 2018	Japanese vehicles within the total (share of Japanese vehicles)		Total passenger car sales Compared to previous year
Japan	4,301,091	4,002,713	(93.1%)	4,391,160	4,082,771	(93.0%)	97.9%
U.S.	4,727,342	2,333,221	(49.4%)	5,303,580	※ 2,511,314	(47.4%)	89.1%
Canada	492,254	232,441	(47.2%)	581,977	271,202	(46.6%)	84.6%
Brazil	2,262,069	409,509	(18.1%)	2,099,605	※ 401,230	(19.1%)	107.7%
China	21,444,180	4,711,126	(22.0%)	23,709,782	4,584,856	(19.3%)	90.4%
India	2,962,118	1,772,503	(59.8%)	3,394,790	※ 2,102,162	(61.9%)	87.3%
EU + EFTA total	15,782,990	2,009,577	(12.7%)	15,607,302	※ 2,054,721	(13.2%)	101.1%
UK	2,311,140	351,891	(15.2%)	2,367,147	372,702	(15.7%)	97.6%
Germany	3,607,258	313,959	(8.7%)	3,435,778	319,747	(9.3%)	105.0%
France	2,214,279	210,685	(9.5%)	2,173,481	216,216	(9.9%)	101.9%
Italy	1,916,320	210,009	(11.0%)	1,910,701	※ 208,624	(10.9%)	100.3%

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)).

Table 8 Main Product Technology Trends in Ordinary and Light-Duty Automobiles Produced in Japan In 2019

Release date	Vehicle model	Brand	Main technologies
January 23	Leaf (added models).	Nissan	The lineup was extended with the addition of the Nissan Leaf e+ equipped with the newly developed e-Powertrain. It extends the 322 km cruising range (WLTC mode) of the original Leaf by about 40 % to 458 km (WLTC mode).
January 31	Vezel (Added model)	Honda	Honda Sensing has been added to the Vezel Touring. It is the first Vezel variant equipped with a direct injection 1.5-liter VTEC turbo engine featuring dual VTC intake and exhaust, allowing it to achieve 17 .6 km/L in the JC08 test cycle.
March 11	Mark X GRMN (Added model)	Toyota	Laser radar detects the preceding vehicle, which is followed while maintaining a proper distance. The vehicle stops, and stays stopped, if the preceding vehicle stops. The following function resumes when the vehicle starts moving again.
March 15	Delica D:5 (Redesigned)	Mitsubishi	Advances in off-road and cruising performance resulting from a refined clean diesel engine, a newly developed 8 -speed sports mode A/T, and improved 4 WD performance, along with the installation of active safety technology, make this an all-around minivan. Yaw rate feedback control has been added to the electronically-controlled 4 WD system. This is the first Mitsubishi vehicle to come with a urea SCR system that purifies the diesel turbo engine emissions. A new dual pinion electric power steering system is used to provide stability in the initial stages of steering. The newly adopted e-Assist active safety technology enhances safety through the installation of a collision mitigation braking system, a lane departure warning system and a radar cruise control system, qualifying all models as "Safety Support Cars".
April 10	Rav4 (Complete redesign)	Toyota	The new Dynamic Torque vectoring (AWD) 4 WD system adopted in this model relies on a torque vectoring mechanism providing independent control of the rear right and left wheels in addition to distributing torque between the front and rear in response to driving conditions to achieve high cornering performance. The greater fuel efficiency obtained from the disconnect mechanism that detaches the driveshaft transmitting drive force to the rear wheels when 4 WD is deemed unnecessary give it a fuel economy of 20 .6 km/L when using hybrid four-wheel drive, and 15 .2 km/L when using gasoline four-wheel drive. The Toyota Safety Sense active safety package is standard on all variants.
April 10	SX4 S-Cross (Redesigned)	Suzuki	The next-generation ALLGRIP four-wheel control system provides excellent off-road performance and driving stability. The passenger seat is equipped with a seat belt reminder. In addition to the Radar Brake Support II collision mitigation braking system, the front seat SRS side and SRS curtain airbags, adaptive cruise control, and other features have been made standard.
May 6	Lexus NX (Redesigned)	Lexus	The Active Cornering Assist (ACA) system that mitigates understeering has been made standard on all variants, offering excellent cornering performance and a high degree of vehicle stability. This model is equipped with safety functions such as a pre-collision system, Road Sign Assist (RSA), a preceding vehicle start notification system (TMN), as well as with the Lane Tracing Assist (LTA) system that provides steering support to cruise in the center of a single lane when using radar cruise control on a vehicle-only road.
May 9	Prius PHV (Redesigned)	Toyota	Riding capacity has been increase to five people from the previous four while offering a spacious interior. All models have a dedicated data communication module (DCM) as standard equipment. Connected services such as e-Care Service, which offers remote driving advice and vehicle diagnostics, and LINE My Car Account are available. This version adds the Rear Cross Traffic Alert system that provides support for mitigating damage from rear-end impacts, and the Panoramic View Monitor system that displays a bird' s-eye view of the vehicle on the navigation system screen. More variants have been equipped with the Intelligent Clearance Sonar (Parking Support Brakes [Stationary Objects]) system. With its V2 H system that can supply the electricity stored in the car to the house, the vehicle can serve as a storage battery. It is also possible to store extra electricity produced by home solar power generation in the vehicle drive battery.
May 10	Shuttle (Redesigned)	Honda	The interior and exterior design, as well as soundproofing materials, have been revised. Auto high beam has been added to Honda Sensing.
May 13	Lexus RC F (Redesigned)	Lexus	The reduced weight and improved aerodynamic performance obtained from components such as the ceramic brakes and titanium muffler are supplemented by refinements to the powertrain, tires, and suspension.
May 17	Supra (Complete redesign)	Toyota	The wheelbase to track ratio was set to 1 .55 , achieving a top class small value and improving cornering performance. This version has an even lower center of gravity than the Toyota 86 . It features an inline 6 -cylinder (3 .0 -liter twin-scroll turbocharged engine. The maximum torque of 500 r/min is generated at the low engine speed of 1 ,600 rpm, and operating the accelerator produces the acceleration matching the driver' s intent. The active differential provides continuously optimized control of the left and right rear wheel lock ration in a range of 0 to 100 via an electronically-controlled multiplate clutch and, in coordination with the vehicle stability control (VSC) system, achieves high cornering speed and stability, as well as neutral steering characteristics. All models feature the latest active safety technologies, including the pre-collision safety (millimeter wave radar and monocular camera) system, blind spot monitor, radar cruise control (with all-speed tracking) and lane departure alert, as standard equipment.
May 24	Mazda3 (Formerly Axela, complete redesign)	Mazda	The SKYACTIV Vehicle Architecture next-generation vehicle structure technology, which defines the ideal driving position as equivalent to the unconscious balancing of the body while walking, was newly developed. The powertrain uses the world' s first commercialized spark controlled compression ignition (SPCCI). In combination with the M-Hybrid mild hybrid system, it offers improved fuel efficiency through efficient motor assist. The next-generation SKYACTIV vehicle dynamics control technology enhanced with new brake-based vehicle stability control (direct yaw moment control) improves stability and provides better vehicle traceability and behavior convergence. New AWD control that improves vehicle dynamics in coordination with the G-Vectoring Control (GVC) technology. In response to steering operation, it provides optimal control of the torque to the front and rear wheels while cornering. This model features the Mazda Harmonic Acoustics audio system (8 speakers) newly developed around the characteristics of human sound perception. The human-machine interface (HMI) inherits and further advances the current Mazda head-up cockpit concept that minimizes the distraction between gaze, awareness and operation, providing an environment that makes it easy to focus on driving through a simple display of only the necessary information and alert notifications. Performance and the accuracy of cooperative control are improved by linking the information from the sensors, radar, and cameras used in the advanced safety i-Activesense system. This model features the addition of the Cruising & Traffic Support (CTS) system that provides following and steering assist functions to help reduce driving fatigue in congestion on expressways or other vehicle-only roads, and of the Front Cross Traffic Alert (FCTA) system that uses a newly installed front side radar to detects approaching vehicles at T-shaped intersections with poor visibility and alerts the driver.

Table 8 Main Product Technology Trends in Ordinary and Light-Duty Automobiles Produced in Japan In 2019 (cont.)

Release date	Vehicle model	Brand	Main technologies
June 13	Eclipse Cross (Added model)	Mitsubishi	The use of an 8 -speed sports mode A/T in a model equipped with a clean diesel engine gives powerful and smooth acceleration from low speeds. A urea SCR system that purifies emissions from the diesel engine has been added.
June 24	Hilux (Redesigned)	Toyota	Installation of the rear differential lock designed to improve rough road performance has been expanded to become standard equipment on all variants. The detection function of the pre-collision system that mitigates impacts has been improved to recognize pedestrians at night and cyclists during the day. The lane departure alert system that helps prevent lane deviations features not only a warning, but also a yaw assist function that provides lane departure control. Other features include radar cruise control (with brake control), Road Sign Assist, and a preceding vehicle start notification system.
June 27	Levorg (Special specifications)	Subaru	The scope of High Beam Assist activation has been expanded from a vehicle speed of 40 km/h to 30 km/h, improving the safety of nighttime driving. This model features Subaru Rear Vehicle Detection (a system providing alerts for vehicles in the rear), High Beam Assist (with automatic anti-glare rearview mirror), and Front and Side View Monitors.
July 25	Leaf (Special specifications)	Nissan	While (and yellow) lines are detected by a monocular camera. A warning is displayed if there is a risk of deviating from the lane. Control to steer back into the lane is also provided.
August 1	Serena (Redesigned)	Nissan	Interior and exterior ornamentation and new colors have been added. The All-Around Driving Support System providing a 360° view has been made standard equipment on all variants. This is the first Nissan model equipped with the Adaptive LED Headlight system, an evolution of the high beam assist functionality. It uses a front camera to detect conditions ahead and varies the illumination from each of the twelve LEDs based on whether there are oncoming or preceding vehicles to provide a high degree of visibility at all times. At the rear, Intelligent BSI, a system that helps prevent rear collisions, Blind Spot Warning (BSW) and the Rear Cross Traffic Alert (RCTA) system that detects vehicles when reversing have been added. Emergency Assist for Pedal Misapplication has been made standard equipment, qualifying all models for the Safety Support Car S wide category.
August 1	Mazda6 (Formerly Atenza, redesigned)	Mazda	This model introduces the SKYACTIV-G 2 .5 T 2 .5 -liter turbocharged gasoline engine. All grades come with GVC Plus as standard equipment and provide safe steering maneuverability as well as improved driving performance.
August 29	Lexus RX (Redesigned)	Lexus	The rigidity of the body and chassis have been improved. This model is equipped with shock absorbers containing friction control dampers, as well as the NAVI AI-AVS that makes seamless continuous variable control possible, to offer a high level of handling stability. The vehicle comes with the new BladeScan AHS, which shines LED-sourced light on blade mirrors rotating at high speed and reflects it into a lens to illuminate the road ahead while moving at high speed, and the next-generation Lexus Safety System+.
September 12	Mazda2 (Formerly Demio, redesigned)	Mazda	The concept of the SKYACTIV Vehicle Architecture vehicle structure technology has been introduced. In addition to the Mazda Radar Cruise Control (MRCC) system with all-speed tracking, this model comes with Adaptive LED Headlights (ALH), which use a headlight LED unit containing 20 individual arrays to improve nighttime visibility. This model features GVC Plus. All grades have advanced safety systems as standard equipment and qualify for the Safety Support Car S wide category.
September 17	Corolla (Complete redesign)	Toyota	The Corolla (sedan) and Corolla Touring (station wagon) were both renamed and redesigned, and the Corolla Sport (hatchback) received a facelift. These models capitalize on the TNGA platform, and balance driving pleasure and good cornering through a design exclusive to Japan. The latest Toyota Safety Sense is standard equipment on all variants. They are the first Toyota models in Japan to come with Display Audio as standard equipment to offer a full range of connected services.
September 17	Skyline (Redesigned)	Nissan	A 3 .0 -liter V6 twin turbocharged has been newly installed in the gasoline model. Intelligent Dynamic Suspension, which precisely controls the damping force for the suspension according to driving conditions and stabilizes vehicle body behavior, is a new addition to the series. The Direct Adaptive Steering system improves steering response at the start of a turn. This model offer the new NissanConnect Services package offering a variety of connected services such as include over-the-air (OTA) map updates, Door-to-Door Navigation, and Docomo in Car Connect®. The world-first ProPilot 2 .0 advanced driving support technology, which coordinates multiple expressway lanes with the navigation system and allows hands-free driving in a single lane as long as the driver is clearly ready to take back control of the steering wheel, is standard equipment on the hybrid model. The system determines the appropriate timing to make a lane change for junctions along the route or to pass a vehicle, and suggest it to the driver. This function initiates assistance for the lane change when the driver touches the wheel and activates a switch to accept the suggestion. The system is also equipped with with an SOS call service that automatically establishes an audio connection to a dedicated call center operator when an emergency vehicle stop is initiated by the system.
October 1	Camry (Partially refined)	Toyota	Display Audio and a DCM have been made standard equipment. Coordination with smartphones and connected services are available. Blind Spot Monitor, which provides assistance when checking behind the vehicle during a lane change, Parking Support Brake (vehicles approaching at the rear), and Rear Cross Traffic Auto Brake have been made standard equipment.
October 1	Lexus GS F (Partially refined)	Lexus	New interior and exterior colors have been added. The chassis boasts refinements to the suspension. Steering bush rigidity has been raised to provide a more linear transmission of driver intent. Changing to aluminum die-cast rear toe control arm brackets reduces weight while achieving high rigidity.
October 3	Lexus LS (Partially refined)	Lexus	The shock absorbers in the rear wheel drive model uses the same pressure expansion independent orifices as the AWD model. Ride comfort has been improved by expanding the range of the variable damping force and reducing friction. A further enhancement of ride comfort was achieved by optimizing the reinforcing layer of the run-flat tires and tuning the AVS and rear suspension mounts.
October 18	Freed (Redesigned)	Honda	New ornamentation and colors have been added to the interior and exterior. Honda Sensing has been made standard on all variants. A new rear false start prevention function has been added.

Table 8 Main Product Technology Trends in Ordinary and Light-Duty Automobiles Produced in Japan In 2019 (cont.)

Release date	Vehicle model	Brand	Main technologies
October 18	CH-R (Redesigned)	Toyota	Ornamentation for the interior and exterior. The GR Sport has been added to the lineup. The 1 .2 -liter turbo model (FWD) now offers a grade with the 6 -speed Intelligent Manual Transmission (iMT). The Display Audio (DA) system allowing interaction with smartphones and an on-board DCM have been made standard equipment on all variants.
October 24	CX-30 (New model)	Mazda	This series features the latest engines, notably the SKYACTIV-X 2 .0 model representing the next-generation in vehicle structural technology, as well as Off-Road Traction Assist in AWD models. Models equipped with the SKYACTIV-G 2 .0 or SKYACTIV-X 2 .0 come with the choice of the 6 -speed SKYACTIV-Drive automatic transmission or the 6 -speed SKYACTIV-MT manual transmission, and models equipped with the SKYACTIV-D 1 .8 feature SKYACTIV-Drive. The new technology and structure adopted in the Mazda3 has been complemented with a lower arm angle and roll center height optimized to match the higher vehicle ground height. The i-ACTIV AWD system interprets tire motion, G sensor, and other information to detect the driving conditions of the vehicle in real time and automatically distributes torque to efficiently bring out the force of the four wheels based on road surface conditions and tire load, thereby providing smooth and stable driving. Cooperative control with the GVC system has been added. The AWD model comes with the newly developed Off Road Traction Assist system, which relies on coordination between the AWD and Traction Control System (TCS) to maximize the transmission of drive force to the wheels in contact with the ground and smoothly escape rough roads. The vehicle is equipped with the latest i-Activsense safety technologies, including the Driver Monitoring System, which uses a camera to capture changes in all aspects of the driver' s facial features, estimate driver fatigue or drowsiness, and encourage rest through indications on the multi-information display and audible warnings, the Cruising & Traffic Support (CTS) following function, and a steering assist function.
October 31	Lexus RC (Partially refined)	Lexus	The multimedia system is compatible with SmartDeviceLink™, Apple CarPlay, and Android Auto™, and can connect an iPhone or Android™ smartphone to the 10 .3 -inch display to enable screen or audio operations.
November 5	Raize (New model)	Toyota	This vehicle offers the best level of large luggage capacity in the compact SUV class (369 liters), as well as a highly convenient cabin space. The newly developed lightweight rigid body and suspension provide handling stability and pleasant ride comfort. The 1 .0 -liter turbocharged engine is combined with the first Toyota D-CVT, which adds split gears to provide drive with both the belt and gears in the high-speed range to achieve torque equivalent to the 1 .5 -liter class while keeping fuel consumption low. The 2 WD model achieves a WLTC mode fuel economy of 18 .6 km/L, while the 4 WD model achieves 17 .4 km/L. High rigidity is ensured by the optimization of the frame shape and the use of lightweight and strong high tensile strength steel sheets, providing stable behavior that makes the vehicle ground height unnoticeable. This model features cruise control with all-speed tracking and various other safety and driving support systems.
November 5	Rocky (New model)	Daihatsu	Making full use of the DNGA packaging technology, this model offers a spacious interior and extensive luggage capacity. In addition, it features 17 -inch tires. It is the first model equipped with the Daihatsu Connect service that utilizes smartphones. The new DNGA platform offers high levels of basic performance in areas such as ride comfort, handling stability, and acceleration feel. A blind spot monitor, which detects vehicles in difficult to sea areas and alerts the driver, and rear cross traffic alert, which detects vehicles crossing behind and alert the driver, have been added to the next-generation Smart Assist system, offering greater safety when checking the rear.
November 15	XV (Redesigned)	Subaru	The 2 .0 e-L EyeSight and 2 .0 e-S EyeSight variants have been added. The X-Mode feature offers a snow/dirt setting for snowy, gravel or other slippery roads, and a deep snow/mud setting for roads with deep snow or mud in which the tires can sink. An access-key-linked driver seat position memory function is provided for greater convenience.
December 5	Mazda3 (Added model)	Mazda	This model features the next-generation SKYACTIV-X gasoline engine (43 % thermal efficiency) which uses the proprietary SPCCI combustion control technology to achieve the first commercial application of compression ignition in a gasoline engine.
December 16	Gran Ace (New model)	Toyota	This full-size van takes full advantage of its overall length of 5 .30 m and wide width of 1 .97 m. The slide door is designed with a wide 1 ,000 mm opening for easy entry and exit in the rear. This model is equipped with a 1 GD series 2 .8 -liter clean diesel engine and 6 -speed automatic transmission. It achieves a cruising fuel economy of 10 .0 km/L in WLTC mode. The adoption of DPR and urea SCR systems has greatly reduced nitrogen oxide emissions. The vehicle is compliant with the Post New Long Term Regulations emissions standards. A front-engine, rear-wheel drive layout is used. Installed safety and driving support technologies include radar cruise control (with brake control) and the Smart Panorama Parking Assist system.
December 19	Clarity Fuel Cell (Partially refined)	Honda	The change in color and blocking of ultra-violet rays has been complemented with the adoption of glass that blocks infrared light. Performance at low temperatures has been improved.

backdrop of not only global increases in CO_2 emissions regulations, but also vagaries in crude oil demand and the gasoline market caused by the international situation.

In 2019, concerns over the trade friction between China and the U.S., the drop in crude oil prices caused by the latter's increased production of shale oil, and a further curtailing of production by crude oil countries resulted in an average gasoline retail price that fluctuated in the upper 140 yen/liter range after peaking at 150.4 yen/liter in May (source: average national price of regular gasoline from the survey of refueling station retail prices in the survey of petroleum product prices conducted by the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry.)

Under those circumstances, environmentally-friendly and fuel efficient technologies in the Japanese market were represented not only by the introduction of new and redesigned models featuring a hybrid or plug-in hybrid system, but also the addition of electric vehicle lineups featuring an expanded cruising range thanks to greater battery capacity and more powerful motors, as well as enhanced fuel cell vehicle performance at low temperatures. The engine and powertrain field featured the use of new combustion systems and greater adoption

Table 9 Technology and Characteristics in Adaptive High Beam Systems

Manufacturer & Name of technology	Light shielding method	Characteristics	Activation conditions
Toyota BladeScan® Adaptive High-beam System (AHS)	Mirror blades rotating at high speed reflect the light from LEDs. The illuminated area is controlled by turning those LED lights on or off.	Synchronization with the rotation of the blade mirrors and turning the LED lights on or off enables control of an illumination range equivalent to the range obtained by adjusting 300 LED lights.	Activates at all vehicle speeds when the high beams are on.
Mazda Adaptive LED Headlights (ALH)	Individually-controlled left and right blocks containing 20 LEDs are turned on and off to control the illumination range.	Three illumination range patterns are used in accordance with driving conditions. (a) Glare-free High Beams Control of the illumination range by turning off the corresponding block of LEDs when the headlamps of an oncoming vehicle or tail lamps of a preceding vehicle. (b) Wide-range Low Beams Wide-range low beams fitted to the side of the headlights provide illumination to the left and right. (c) Highway Mode The axis of illumination is automatically raised when driving on the highway to enhance visibility at a distance.	Glare-free High Beams 40 km/h or more. Wide-range Low Beams 40 km/h or less. Highway Mode 95 km/h or more.
Subaru Adaptive Driving Beam	Shades inside the headlamps are used to block the portion of the light that would reach the vehicle ahead.	Laser radar detects the preceding vehicle, which is followed while maintaining a proper distance. The vehicle stops, and stays stopped, if the preceding vehicle stops. The following function resumes when the vehicle starts moving again.	30 km/h or more.
Nissan Adaptive LED Headlight System	Control of the illumination range by individually turning LEDs arranged in multiple blocks on or off.	Illumination range controlled to have high beams on the left if there is an oncoming vehicle, high beams on the right if there is a preceding vehicle in the left lane, and split high beams if the preceding vehicle is in the same lane.	30 km/h or more.
Daihatsu Adaptive Driving Beam (ADB)	Control of the illumination range by individually turning LEDs arranged in multiple blocks on or off.	The illumination range is controlled when passing an oncoming vehicle.	30 km/h or more.

Note: Table based on information from the public relations website of the manufacturers.

of exhaust control technology, as well as the introduction of technology that balances high torque and low fuel consumption through a new drive system with refined transmission control technology.

3. 2. Safety Performance

One measure to prevent traffic accidents is a joint public-private sector initiative to raise awareness of, and encourage the spread of safe driving support vehicles. The December 2019 supplementary budget contains a subsidy system for such "Safety Support Cars", and the subsidies will offered starting in 2020.

All completed vehicle manufacturers are actively launching "Safety Support Car" and "Safety Support Car S" lineups, and the growth in the installation rate of driving support and safety technologies, as well as the introduction of new technologies, continued in 2019.

In the area of driving support technologies, Nissan launched models equipped with its ProPilot 2.0 autonomous driving technology, becoming the first manufacturer in Japan to offer vehicles allowing hands-off driving under certain conditions. Like its previous incarnation, the system is a level 2 autonomous driving system (using the Society of Automotive Engineers classification). When driving on the expressway along a route linked to the navigation system, this version allows drivers to take their hands off the wheel as long as the driver monitoring camera inside the vehicle confirms that they are still paying attention to the road ahead and are ready to hold the wheel again at any time.

Automakers have introduced driving support technologies in a wider range of models for ordinary and light-duty vehicles launched in 2019. Systems such as following, lane keeping, and lane departure functions have become standard equipment on more models. Drawing on the impetus provided by the *Public-Private ITS Initiatives/Roadmap*, completed vehicle automakers are expected to lead the way in developing more autonomous driving and advanced driving support systems, as well as in bringing them to the market.

With respect to safety technologies, the installation of systems that detect vehicles approaching from the rear-a frequent blind spot—and alert the driver, as well as of systems to suppress acceleration due to pedal misapplication, stood out. In addition, new technologies, such as more precise control of the illumination range of LED lights to offer better nighttime visibility than before, were introduced.

Table 9 summarizes the automatic high beam function offered by the various automakers.

Table 10 presents the main product technologies in the mini-vehicles introduced in the market by Japanese manufacturers in 2019.

Mini-vehicles have also benefitted from new technologies resulting from refinements to powertrain mechanisms. The use of low-friction belts, high efficiency oil pumps, and split gears has made it possible to install newly developed CVTs. In terms of driving support and safety performance, object detection functions, collision mitigating brakes that recognize crossing cyclists, rear false start suppression functions, and other systems be-

Table 10 Releases and Technology Trends for Mini-Vehicles Produced in Japan in 2019

Release date	Vehicle model	Brand	Main technologies
March 28	Dayz (Complete redesign)	Nissan	The newly developed CVT with a low friction belt and technology to improve quietness is complemented by the new smart simply hybrid powertrain design featuring a new lithium-ion battery to improve dynamic performance and fuel efficiency. This is the first mini-vehicle to use D-step control that gives a sense of extended acceleration. The adoption of a newly developed platform provides both a spacious cabin and a large luggage compartment. It is the first Nissan mini-vehicle equipped with the Zero Gravity seats designed to reduce fatigue from sitting. The Advanced Drive-Assist Display (4 .2 -inch TFT LCD) has been added to the meter. Safety features including an advanced automatic accident reporting system (Helpnet), Intelligent Emergency Brakes, Lane Departure Warning (LDW), Intelligent Lane Intervention (LI), Emergency Assist for Pedal Misapplication, Intelligent Around View Monitor and High Beam Assist, have been complemented with Moving Object Detection and installed on a Nissan mini-vehicle for the first time. Use of the ProPilot autonomous driving technology is another mini-vehicle first.
March 28	eK Wagon (Complete redesign)	Mitsubishi	The adoption of a new engine with reduced friction and a high compression ratio, along with a new CVT with a high efficiency oil pump and low friction belt have improved fuel efficiency. It is the first Mitsubishi vehicle to feature the MI-PILOT single-lane driver assistance technology for highways. Driving assistance is provided by adaptive cruise control (ACC) and a lane-keeping assistance (LKA) function that detects the white lines and helps keep the vehicle in the center of the lane. Grip Control, which provides assistance when starting or accelerating on slippery road surfaces, has been made standard on all variants. This vehicle is also equipped with Multi Around Monitor, Moving Object Detection, and Lane Departure Prevention (LDP). The Digital Rearview Mirror (with Multi Around Monitor display) that shows images from a camera at the rear of the vehicle has been installed in a mini-vehicle for the first time. All models qualify for the Safety Support Car S wide category.
March 28	eK Cross (New model)	Mitsubishi	Laser radar detects the preceding vehicle, which is followed while maintaining a proper distance. The vehicle stops, and stays stopped, if the preceding vehicle stops. The following function resumes when the vehicle starts moving again.
July 9	Tanto (Complete redesign)	Daihatsu	In addition to a spacious cabin, this redesign enhances ease-of-use with the Miracle Walk-through Package that takes advantage of the Miracle Open Door. Functionality and performance have been enhanced through features such as the adoption of the next-generation Smart Assist system. A rebuilt platform that rethinks the layout of suspension and frame parts from zero was developed. In addition to a new CVT that uses new split gear technology, refinements to multi-spark ignition and the fuel injection method, along with improved fuel efficiency, have made the NA model the first mini-vehicle to achieve five-star emissions (75 % reduction relative to the 2018 emissions standards) rating. This vehicle is equipped with the world' s first long sliding driver' s, a front-passenger easy closing door and the first Touch & Go locking and Welcome Open functions on a mini vehicle. The next-generation Smart Assist active safety system is installed. That system is complemented with the Smart Assist Plus driving support system to provide a total of 15 functions.
July 25	Chiffon (Complete redesign)	Subaru	The new Smart Assist, which includes function such as Adaptive Driving Beam and Lane Departure Warning, has been adopted in a Subaru for the first time and made standard equipment on all variants. In addition, various Smart Assist Plus package functions, including Adaptive Cruise Control with all-speed tracking, Lane Keep Control, Smart Panorama Parking Assist, and Side View Lamps that help provide nighttime visibility for left and right turns, have been adopted. The weight reduction and high rigidity achieved by the revamped platform significantly improve driving performance in the areas of handling stability, ride comfort, and passive safety. At the same time, refinements to the engine and CVT successfully balance the performance of acceleration and fuel economy.
August 9	N-WGN/N-WGN Custom (Complete redesign)	Honda	The N-WGN is built with a firm, smooth surface that extends from the front, past the door and up to the rear gate. The use of a center tank layout has made it possible to provide a spacious interior and easy to use cargo space. The N-WGN Custom follows the basic design concept of the N-WGN, and its boldly emphasized front and rear bumpers give an impression of strength while expressing a level of quality that appeals to adult sensibilities. Honda Sensing has been made standard on all variants. This is the first mini-vehicle to feature functions such as collision mitigation braking system (CMBS) that recognizes crossing cyclists, adaptive cruise control (ACC) with congestion tracking, pedestrian collision mitigation steering, preceding vehicle start notification, road sign recognition, and a lane keeping assistance system. A rear erroneous start prevention function and automatic high beams complement those functions. This is also the first Honda mini-vehicle to offer the Parking Sensor System as standard equipment.
October 15	Copen GR Sport (Added model)	Toyota/ Daihatsu	The addition of strengthening members to the underbody and changes in the shape provide a sense of stability. The chassis has been optimized and parts that improve aerodynamics have been used. The exclusively tuned electric power steering improves maneuverability. Vehicle stability is ensured by functions that control side slipping using VSC and wheel skid using TRC, offering enhanced accelerator operability.

Table 11 Main Advanced Driving Support Technologies Installed and Adopted in 2019

Category		Manufacturer & Name of technology	Characteristics	Speed allowing tracking (activation)
Safety & driving support	Advanced driving support system (semi-autonomous driving)	Nissan ProPilot 2 .0	Links to navigation system and starts driving along a predefined route when merging onto a main expressway lane. The system determines the timing of lane changes for branching or overtaking along the route based on the navigation system and the 360 -degree surroundings sensing information obtained from the trinocular camera and the millimeter wave radars. Touching the steering wheel and activating the switch initiates lane change support, enabling lane changes, overtaking, and returning to the cruising lane. Using 3 D high-precision data covering the approximately 29 ,000 km of expressway and vehicle-only roads throughout Japan, the system anticipates curves, gradients, and other road features beyond the recognition range of the camera, and controls vehicle speed.	0 to 110 km/h

Table 11 Main Advanced Driving Support Technologies Installed and Adopted in 2019 (cont.)

Category		Manufacturer & Name of technology	Characteristics	Speed allowing tracking (activation)
Safety & driving support			Control of steering and other actions based on highly accurate recognition of the vehicle position enable driving that, for example, takes branching and exit ramps into consideration to drive in the appropriate lane. When cruising on an expressway main lane, hands-off driving in a single lane is possible as long as the driver is clearly ready to immediately take back control of the steering wheel.	
	Preceding vehicle following system	Toyota Adaptive Cruise Control with all-speed tracking function	A monocular camera and millimeter wave radar measure the distance to the preceding vehicle, The system maintains the preset distance and provides support for stopping, staying stopped, and starting off again.	0 to 135 km/h (180 km/h for some models)
		Nissan Intelligent Cruise Control	Laser radar detects the preceding vehicle, which is followed while maintaining a proper distance. The vehicle stops, and stays stopped, if the preceding vehicle stops. The following function resumes when the vehicle starts moving again.	0 to 100 km/h. Following begins after the vehicle has accelerated to 30 km/h after starting off.
		Honda Adaptive Cruise Control with congestion tracking	A monocular camera and millimeter wave radar measure the distance to the preceding vehicle. The system maintains the preset distance and provides support for stopping, staying stopped, and starting off again. Three levels (four in some models) of distance from the preceding vehicle can be set.	30 to between 100 km/h and 115 km/h. Following begins after the vehicle has accelerated to 30 km/h after starting off.
		Mazda CTS and MRCC with all-speed tracking	A millimeter wave radar measures the distance to the preceding vehicle. The system maintains the preset distance and provides support for tracking, stopping, and starting off again. The CTS also has a function to remain stopped.	0 to 180 km/h
		Subaru EyeSight Touring Assist	A stereo camera measures the distance to the preceding vehicle, which is followed while maintaining a proper distance. The vehicle stops, and stays stopped, if the preceding vehicle stops. The following function resumes when the vehicle starts moving again.	0 to 120 km/h
		Daihatsu Adaptive Cruise Control (ACC) with all-speed tracking function	A stereo camera detect the distance to the preceding vehicle and its speed, and the system maintains the proper speed and distance. Control extends to following the preceding vehicle and stopping. Stopping is maintained for two seconds after the vehicle stops.	0 to 115 km/h
		Suzuki Adaptive Cruise Control (ACC) with all-speed tracking function	The system uses a millimeter wave radar to measure the distance to the preceding vehicle and maintain a proper distance by automatically accelerating and decelerating. The vehicle stops if the preceding vehicle stops. Stopping is maintained for two seconds after the vehicle stops. Three levels (short, medium or long) of distance from the preceding vehicle can be set.	0 to 120 km/h
		Mitsubishi Adaptive Cruise Control (ACC)	A millimeter wave radar measures the distance to the preceding vehicle. The system maintains the preset distance and provides support for tracking, stopping, and starting off again. Stopping is maintained for two seconds after the vehicle stops.	0 to 100 km/h
	Lane departure warning and control systems	Toyota Lane Departure Alert, Lane Keep Control (LKC)	A monocular camera detects white (yellow) lines, curbs, and other markers. A warning is displayed if there is a risk of deviating from the lane. Control to steer back into the lane is also provided.	Activates at approximately 50 km/h or higher.
		Nissan Intelligent Lane Intervention (LI) and Lane Departure Warning (LDW)	The front camera detects white (yellow) lines. An alert is displayed and a warning is sounded if there is a risk of deviating from the lane. The system also controls the brakes and briefly applies force in the direction of the lane to assist in moving back into it.	Activates at approximately 60 km/h or higher.
		Honda Road Departure Mitigation System and Lane Keeping Assist System (LKAS)	The system uses a monocular camera to detect the white (yellow) line and alerts the driver by vibrating the steering wheel when there is a risk of deviating from the lane. It also provides control for steering back into the lane.	Activates at approximately 65 km/h or higher.
		Mazda Lane-Keep Assist System (LAS)	The system uses a camera to detect the lane and applies control to steer back into the lane when there is a risk of deviating away from it.	Activates at approximately 60 km/h or higher.
		Subaru EyeSight Touring Assist	The system uses a stereo camera to detect the lane, and displays an alert and sounds a warning if there is a risk of deviating from the lane. Control to steer back into the lane is also provided.	Steering control activates at approximately 60 km/h or higher, and warnings at approximately 40 km/h or higher.
		Daihatsu Lane Keep Control (LKC) an Lane Departure Prevention	An alert is displayed and a warning is sounded if there is a risk of deviating from the lane. Control to steer back into the lane is also applied.	Activates at approximately 60 km/h or higher.
		Suzuki Lane Departure Warning and Lane Keeping Assist System	While (and yellow) lines are detected by a monocular camera. A warning is displayed if there is a risk of deviating from the lane. Control to steer back into the lane is also provided.	Steering control activates at approximately 65 km/h or higher, and warnings at approximately 60 km/h or higher.
		Mitsubishi Lane Keeping Assist (LKA) and Lane Departure Prevention (LDP)	An alert is displayed and a warning is sounded if there is a risk of deviating from the lane. The system also controls the brakes and briefly applies force in the direction of the lane while controlling steering to move back into the lane.	Activates at approximately 60 km/h or higher.

Note: Table based on information from the public relations website of the manufacturers.

came more common in mini-vehicles for the first time. The year 2019 also saw the first installation of a full-speed range following cruise control function in mini-vehicles.

Table 11 summarizes the semi-autonomous driving and cruise control function subset of driving support technologies installed in ordinary, light-duty and mini vehicles.

Design Trends

1 Introduction

The Tokyo Olympic and Paralympic Games that had been scheduled for the summer unfortunately had to be postponed. These are the second Games held in Tokyo, which hosted them for the first time in 1964. That was over half-a-century ago, in the middle of Japan's period of high economic growth that witnessed the birth of expressways and represented a thriving period for motorization. Even then, the automotive industry was striving for higher performance and a unique appeal as it learned from the technologies and designs of the West. Exports to other countries grew, and Japanese manufacturers joined rallies, F1 competitions, and other international races. Japanese designers also started making their mark working for automakers outside Japan at that time, initiating the era of Japanese automaking opening up to the world. In the fifty years since, the Japanese automotive industry navigated through tough situations such as the oil shock, the collapse of the economic bubble, and the global financial crisis and grew on a global scale.

It has been 100 years since automobiles have become widespread, with the Japanese automotive industry sharing most of that history with the world and growing into an automaking leader. Looking ahead, new players such as venture businesses drawing on electrification or digital technology expertise, and emerging countries, are poised to take part in the next chapter of that history.

The major transformation epitomized by CASE (connected, autonomous, shared, electric), which has become a household term, will bring never before seen changes to the design and manufacturing of automobiles. This section looks back on 2019 car designs in and outside Japan as the latest slice of that 50-year period.

2 Battery Electric Vehicle Design Trends

Battery electric vehicles (BEVs), which are poised to take over from internal combustion engines as the mainstream technology, have seen the release of many new models over the last few years even as they tackled issues such as cruising range and cost. Hinting at new technologies tying in to the aforementioned CASE, most of the designs center around concept cars with futuristic expressions. The 2019 International Motor Show Germany in Frankfurt exhibited different design approaches for mass production BEVs, which are described below.

The Taycan (Fig. 1), the first BEV released by Porsche, inherits the design motifs of the over 50 years of tradition of the 911 series. The original incarnation resulted from a rear engine layout, and despite its completely different mechanical layout, the BEV fully adopts the same design technique. This is also true of the front engine layout Cayenne and Panemara models, and the design is recognized as Porsche at a glance. The BEV is also built to offer the sporty feel of Porsche in terms of space, field of view, and performance.

The Honda-e (Fig. 2) announced by Honda has a design based on a universal hatchback form that fuses simplicity and refinement. With a display that takes up the full with of the cabin, the interior design offers a space reminiscent of a living room. This interior and exterior design has also been featured in design media other than those dedicated to automobiles.

The Volkswagen ID.3 (Fig. 3) also presents a simple, unassuming design that adopts a monobox silhouette dis-

(Source: Porsche press site)

Fig. 1 Porsche Taycan

Fig. 2 Honda Honda-e

(Source: Volkswagen press site)

Fig. 3 Volkswagen ID.3

tinct from that maker's iconic Golf and Polo models. The cockpit uses a large head-up display that takes full advantage of a graphic user interface, and the design achieves realistic next-generation safety performance for a compact car.

The placement of the battery under the vehicle body common to all three above models has become the norm, but at this point the mechanical layout of BEVs, including motors and accessories, is still open to various possibilities. Consequently, it will be important to go beyond the efficiency and methodologies built up in the era of the internal combustion engine and also adopt the perspective of what added value to offer in the proportions and design expressions.

3 SUV Design Trends

In the past, the popularity of SUVs was reported as a trend, but as things currently stand, the genre can be viewed as a mainstay of the market. Many of the SUVs sold around the world are four-wheel drive rather than 4 × 4s, and equipping them with hybrid engines has become more common. They are mainly used in cities and suburbs, and have shed their 1980s image of vehicles driven on rough roads. They are expected to provide a passenger vehicle-like refined ride, and sleek designs have understandably largely taken over the tough impression of the past. Current SUVs give an impression of safety, offer excellent spatial functionality, and are also stylish. It is easy to see what gives them a universal value as an automobile. This turnaround was initiated in the 1990s by Japanese brands built on a passenger vehicle platform, such as the Toyota Rav4 or the Honda CR-V, and spread mainly in Japan and North America. In emerging countries, they are popular with the young and the wealthy, whose pursuit of upward mobility attracts them first and foremost to the prestigious and distinctive designs of the SUV genre. In addition, the high vehicle ground height of SUV frame is well suited to the placement of the battery under the vehicle characteristic of BEVs.

(Source: Toyota Motor Corporation website)

Fig. 4 Toyota Rav4

(Source: Mercedes-Benz press site)

Fig. 5 Mercedes-Benz Maybach GLS 600

(Source: Aston Martin press site)

Fig. 6 Aston Martin DBX

(Source: Land Rover press site)

Fig. 7 Land Rover Defender

The Japanese SUV market is relatively strong, and the Toyota Rav4 (Fig. 4), first sold in the U.S., has also been made available in Japan. The impression of toughness projected by the exterior design of the Rav4 has proven popular, and this divergence from mainstream sleek designs suggests a new recognition of the SUV style.

Most automakers now introduce SUVs in all classes, and the models introduced by premium brands outside Japan illustrate how borderless a genre this has become.

Mercedes-Benz announced the GLS 600 (Fig. 5), a Maybach version of its full-size GLS. That class competes with SUVs from Rolls-Royce and Bentley, and much of its large, square GLS-based frame features the Maybach design ornamentation. In the rear, it offers two independent seats as well as a refrigerator.

The Aston Martin DBX (Fig. 6) is the company's first mass-produced SUV. As with Porsche, the sports car manufacturer identity is fully retained, with a stylish exterior that immediately marks the vehicle as an Aston Martin. Despite the use of 4WD on all variations, neither

the interior nor the exterior present a cross-country design.

The Land Rover Defender (Fig. 7) was redesigned for the first time in 71 years. The previous model had a functional and practical design aimed at professional users, and was also appreciated by individual users who favor that classic feel. The new model carries on the functional approach with a straight-line theme, while also presenting a modern form in all areas.

At first glance, these premium brand SUVs have entirely different designs, but they share the common feature of clearly emphasizing their brand design. This distinguishes them from diverse concepts and designs put out by mass-market brands.

4 Mass-Market Vehicle Design Trends and the Japanese Market

Volkswagen announced the 8th generation of the Golf (Fig. 8). A benchmark for compact cars since its launch in 1974 that has sold 35 million units worldwide, this model is a rare example of a mass-market vehicle that has always retained the same brand identity. This new version inherits the distinctive two-box hatchback style and thick C-pillar, while making a bold step forward with a sportier form and stance. Similarly, the design of the interior features the latest technologies, including a touch panel display and shift-by-wire selector while remaining faithful to its hallmark functionality.

Mazda unveiled its Mazda3 in Japan at the Tokyo Auto Salon in January 2019. Formerly known as the Axela in Japan, it was given the same name as the versions outside Japan to present a unified global brand. Since 2010, Mazda has adhered to a clear design identity referred to as "soul in motion design", and this model is its first mass-market vehicle that adopts the "beauty of subtraction" concept representing the next step in that design approach.

Two global small cars made their world debut in Japan.

The Toyota Vitz was redesigned and given the Yaris global name (Fig. 10). Bucking the trend of making compact cars bigger, it retains the compact dimensions of the previous model while featuring a sporty exterior design that eschews "class boundaries".

Honda released the 4th generation of the Fit (Fig. 11). The simple design follows the theme of comfort for both the interior and the exterior while preserving the mono-

(Source: Volkswagen press site)

Fig. 8 Volkswagen Golf

(Source Mazda Motor Corporation website)

Fig. 9 Mazda Mazda3

(Source: Toyota Motor Corporation website)

Fig. 10 Toyota Yaris

Fig. 11 Honda Fit

box silhouette and expanded space that make the Fit immediately recognizable. The contrast in design expression between these two small cars released in Japan at the same time is thought-provoking.

Daihatsu unveiled the 3rd generation of its Tanto (Fig. 12), the model that created the now mainstream super high mini-vehicle vans market. Despite the many restrictions on design imposed by the square frame that provides ample spaciousness, this model exhibits charm through a soft and modern form not found in commercial vehicles. Design in this field involves precise design and can also be described as advanced technology unique to Japan.

Since the decline of sedan passenger vehicles in the 1990s, box-like vehicles such as minivans or the above mini-vehicles have taken over as the primary vehicles on the road in the Japanese market. This is a significant difference from the global market preference for the sporty designs typified by European vehicles. From that point of view, Japan represents a unique market despite being

(Source: Daihatsu Motor Co., Ltd. website)

Fig. 12 Daihatsu Tanto

Fig. 13 Byton M-Byte
(Source: Byton website)

(Source: Volkswagen press site)

Fig. 14 Volkswagen ID.3

a country with eight automakers that produce and sell cars globally.

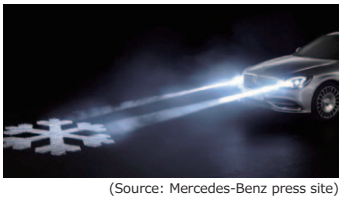
5 Cockpit Design Trends

In interiors, new sensing and connectivity technologies have been accompanied by a remarkable evolution in cockpit design. The M-Byte (Fig. 13), a BEV from the Chinese Byton brand was unveiled at the Consumer Electronics Show (CES) in the U.S. It features a large 48-inch curved display, and voice control offered in conjunction with Amazon Alexa, which as a proven track record in personal use. (The consumer electronics-focused CES has already become a venue for automakers to strategically present advanced functions.)

The growing use of larger displays spurred by AI and connectivity, especially in BEVs, including the Honda-e mentioned earlier, has led to horizontally-themed dashboard designs that take affinity with square displays into consideration. Similarly, the large head-up display in the Volkswagen ID.3 (Fig. 14) or the BMW display that links to the outside world exemplify the many advances seen in the design of graphical user interfaces. The trends are likely to be accentuated by the transition toward autonomous driving.

6 Headlight Design Trends

Whereas remarkable technological advances lead to a revamping of interior design, technological advances with a strong impact on exterior design were largely perfected in the 1990s (as exemplified by glass, outer panel molding technologies, or aerodynamic factors such as flush surfaces). After that, striking progress was made in the design of headlights. The premium German brands



(Source: Mercedes-Benz press site)

Fig. 15 Mercedes-Benz Digital Light

(Source: Audi press site)

Fig. 16 Audi Digital Matrix LED

continue to pave the way in this field.

Signature expressions for the front and rear headlights featuring daytime running lights (DRL) and tail lamps has become the norm, and adaptive driving beam (ADB) systems have made their way to mass-market vehicles. Headlight branding is also pursued through new functions such as the Mercedes-Benz Digital Light (Fig. 15) and Audi Digital Matrix LED (Fig. 16) high-performance ADB systems, as well as projectors headlights. In addition, the increasing use of full LED and digital headlights has popularized the use of animation such as that seen in sequential turn signals. Premium brands are also starting to make use of visual effects such as the reactive welcome sequence (triggered by activating or deactivating the key) using wide rear combination lamps.

As described above, headlights consist of a collection of a wide variety of functions that reach beyond the demand for improvements in safety technology to play a crucial role in expressing individual, leading-edge design while reinforcing brand identity. Moreover, as illustrated by the welcome sequence, the movement of light itself has opened up a new area of design. This aspect will eventually become part of promising human-machine interface (HMI) functions used by autonomous vehicles to communicate with their surroundings. How these many elements will tie in to part of the appeal of exterior design will be important.

7 Color and Materials

Monotone exterior colors are maintaining their over 70% share of the global market, with gray gaining in popularity in Europe while silver is losing favor. Among the chromatic colors, red has been followed by a prominent increase in blue variations. Although they traditionally expressed sporty performance, blue hues have become representative environmental colors and are increasingly used on SUVs and small cars (Fig. 17). Concept cars are leading the way in offering a fresh expression using matte metallic colors (Fig. 18) and solid grays. Technological advances in materials and processes have

(Source: Audi press site)

Fig. 17 Audi Q4 e-tron

(Source: Smart website)

Fig. 18 Smart Forease+

also resulted in many white hues emphasizing a sense of solidity. For seats, natural materials such as wool and vegetable tanned leather have become available. In addition, the recycling of materials that began with PET bottles has diversified to, for example, processes that recycle food waste such as coffee beans or apples. Following in the wake of the fashion industry, BEVs and other vehicles are starting to stand out in terms of promoting sustainability.

8 Upcoming Car Design

Moving into 2020 for a second, the January CES featured cross-industry presentations such as the plan for a smart city, called Woven City, that integrates CASE and MaaS, announced by Toyota, as well as the Vision-S BEV unveiled by Sony. Recent observation of the market in China shows that new brands that use Chinese capital to leverage foreign labor and technology are emerging. The BEVs sold by those brands exhibit radical and refined designs, and their sales technique based on connectivity, entertainment, and the Internet represents a new approach surpassing that of existing manufacturer. In contrast, an unprecedented decline in sedans swept through the North American market, where the share of Japanese vehicles is close to 40%. Finally, the replacement of power plants stemming from electrification and advances in sensing technology accompanying the transition to autonomous driving will undoubtedly bring major changes to the dynamic element of car design.

Designers will be called upon to present unorthodox creations that move away from mere extensions of past experience. It will become more important than ever to offer value that spans mobility as a whole rather than stop at a standalone product, engage in design communication from the perspective of the brand, and clearly define the intended audience. Reflecting on what makes individual brands, and the design of Japanese vehicles, appealing must take these factors into account.

Lastly, this section wraps up with a word on two Japanese vehicles that received prestigious international design awards. The Mazda3 by Mazda received the World Car Design of the Year 2020 award, while the Honda-e by Honda won the Red Dot: Best of the Best 2020 in the German Red Dot Design Award competition. Both represent designs made into commercial products in 2019.

Body Structures

1 Technological Trends

Current trends in global sales are seeing the market recede by half in developed countries, while China and other emerging markets are exhibiting rapid growth. In the long terms, emerging nations other than China will also benefit from growth, and the markets in emerging nations is anticipated to constitute 60% of the global market in 2030[(1)]. As fuel economy and environmental regulations expand worldwide, HEV, PHEV, and BEV powertrains adapted to diverse environmental needs are in greater demand not just in the markets of developed countries, but also in those of emerging countries.

These circumstances have spurred progress in the diversification of powertrains and the adoption of technologies that reduce running resistance as effective means of decreasing CO_2 emissions. In the vehicle body field, technologies to reduce running resistance have not been limited to relying on weight reduction and low rolling resistance tires. Devices that improve aerodynamics, such as underbody covers with high coverage.

Primary safety technologies, typified by collision mitigating brake systems have seen greater adoption and even become standard in the mini-vehicles class. Conversely, regulations on secondary passive safety are scheduled to be strengthened further, necessitating the continued application of vehicle frame reinforcement technologies.

Since the emergence of connected, autonomous, shared & services, and electric (CASE) and other new fields of technology required for vehicles, there has been a relative drop in the amount of money expended on the traditional vehicle body performance field. The total cost factoring in unit effectiveness, rather than only the cost-effectiveness determined when deciding to apply any given technology, is coming into the spotlight.

In short, vehicle body engineers are being asked to minimize the weight increasing factors stemming from compliance with new passive safety protocols while also contributing to reducing the running resistance and cost of the vehicle as a whole. Trends in body technologies for passenger vehicles announced in fiscal 2019, focusing on weight reduction, will be surveyed in that optic.

2 Vehicle Body Technologies

Making vehicle bodies lighter helps overall dynamic performance and boosts the appeal of vehicles. Furthermore, downsized powertrains, compact chassis components and lower strength requirements for frames create a virtuous cycle for both weight and cost reduction that also provides the resources to install additional devices without increasing the weight of the vehicle. Reducing vehicle body weight also benefits all vehicles regardless of their powertrain, making it a universal approach effective across a broad range of units.

At the same time, weight reduction technologies have been favored over options as a basic technology for reducing running resistance. Consequently, the remaining weight reduction technologies are starting to exhibit poor cost-effectiveness and lose their relative advantage compared to other technology options. Nevertheless, fuel economy requirements remain stringent and almost impossible to achieve without approaching basic running resistance reduction technologies from all possible angles. The application of vehicle body weight reduction technologies must now be determined after making a comparison with other basic technologies that achieve equivalent performance.

2. 1. Chassis Technologies

Shared chassis not only benefit completed vehicle makers by keeping development cost down and shortening development time, but also result in providing users in all markets a wider selection of products and the opportunity to make purchases at a reasonable price. Moreover, the sharing of chassis between companies in the same group, which enhances the effect that integration, continues to gain momentum. For example, the light-duty GA-C version of the Toyota New Global Architecture (TNGA) shared chassis technology introduced with the 2015 Prius by Toyota has been applied to the new Corolla, while the medium-duty GA-K version has been applied to the Rav4. Similarly, Daihatsu has announced the Daihatsu New Global Architecture (DNGA)[2] shared chassis technology for models ranging from mini-vehicles to B-segment light-duty vehicles and first applied it to the new Tanto model. That chassis was also subsequently used for the new Daihatsu Rocky and the Toyota Raize.

2. 2. Steel Sheets

Steel sheets currently still account for the majority of body material composition, and are an essential material in the main frame, which bears collision inputs. This is due to the high level of balance between specific strength, specific rigidity, formability, stretch flanging and cost offered by this material, as well as continued technological advances made with respect to material characteristics.

Hot stamped material is a global technology that is seeing increasing use as one way of achieving the high-strength frames made crucial by the growing number of passive safety standards. Hot stamping is a technology that achieves high strength by heating steel sheets to approximately 900° C and stamping them in a die with a cooling function. Consequently, although the forming process is very precise, the heating and cooling processes take time and the die requires a complex cooling pipe layout, which presents drawbacks compared to cold stamping in terms pf productivity and die costs.

At the same time, cold-formed high tensile strength steel sheets with deformation characteristics in the 980 MPa class, and higher formability than in the past in the 1,180 and 1,310 MPa classes, have been developed. Technologies for springback prediction and forming are essential to the cold forming of high tensile strength steel sheets, and refining them to production-level quality takes time. In addition, the increase in machining load rises in step with the strength of the material and the fact that, unlike in hot stamping, the number of machining processes cannot be consolidated, imposes restrictions on the shape and size of parts, and can even require updating the stamping equipment. And of course, few designers want to further subdivide parts or change their shape.

Since each material technology has its drawbacks, it has become increasingly common to use either hot stamped material or cold-formed high tensile strength steel sheets according to purpose or location. The Mazda3[3] uses 1,310 MPa material in locations such as the hinge pillar reinforcement and front pillar inner portion of the front, which has a high level of forming difficulty. Beads or similar shapes are distributed on these parts to

control springback. In contrast, hot stamped material is used for the center pillar reinforcement, which has an even higher level of forming difficulty and more stringent strength requirements. In the Rav4(4), hot stamped material is used in the center pillar and roof side rail reinforcements and in the reinforcement members of the lower dashboard, while 1,180 MPa material is used for the side sill and front lower frame. Achieving higher strength while retaining formability equivalent to that of existing material will remain expected of steel sheets in their role as a vehicle body weight reduction technology. Doing so will entail the development of material technology over a broad scope that encompasses research on forming and machining processes, improving resistance against delayed fracture characteristics, and welding technologies that allow the welding of complex sheet combinations.

2.3. Variable Strength and Thickness Technologies

This section presents variable strength and thickness technologies in the context of weight reduction. These technologies apply the concept of tailored properties to subdivide parts according to how their performance requirements are distributed and assign the necessary material strength and thickness to each subdivision to produce a uniform, lightweight structure. Achieving this through integrated press forming would simultaneously reduce die investment costs and raise productivity. Basic technologies include tailor welded blanks, tailor rolled blanks, and patchwork blanks. They are typically often used in frame parts and are found in many mass-market vehicles such as the Golf, which adopts the Modular Transverse Matrix (MQB) platform. A few distinctive examples are presented below.

The first-generation N-Box uses tailor welded blanks in the outer panel. They consisted of 270 MPa 0.65 t and 590 MPa 1.6 t blanks that were welded, and then molded integrally in a molding die. This overcomes the technical issues of achieving partial changes in thickness and high strength in outer panels, which are the largest parts of the vehicle body and must present a high quality external appearance. Shifting the strength burden to the outer panel made it possible to eliminate the conventional stiffener. This not only reduced waste, but also increased space efficiency by allowing the seat belt mechanism to be stored inside the pillar cross-section. The second-generation N-Box goes even further. The blanks were changed to a combination of 270 MPa 0.6 t and 780 MPa 1.0 t, reducing weight through the use of high-strength, thinner panels. This technological advance was inherited by the second-generation N-WGN released in 2019, which features a structure that combines 270 MPa 0.6 t and 780 MPa 0.9 t blanks.

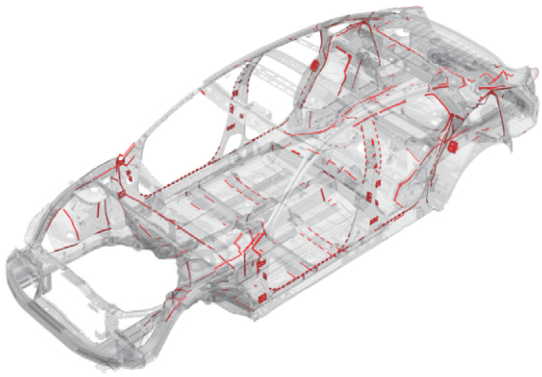


Fig. 1 Structural adhesive locations in the Accord

2.4. Continuous Joining Technologies

Part joining technologies are vital to enable current vehicle body compositions consisting of multiple parts to function as a structure. In mass-produced vehicles, numerous single-point joints typically produced by resistance spot welding are distributed to produce the vehicle body structure. Applying that premise to efforts to reduce weight while aiming for equivalent strength by increasing the strength and decreasing the thickness of parts material results in reduced vehicle body rigidity. Techniques that make up for that loss in rigidity are therefore necessary.

Continuous joining is one such technique. European—and especially German—manufacturers took the lead in applying structural adhesives in continuous joining, and Japanese completed vehicle manufacturers have also started to use them more frequently. The Rav4[4] uses structural adhesive mainly in the floor and door opening, improving quietness and handling stability. In the Mazda3[5], the existing structural adhesive has been complemented with the development of a high-damping adhesive that was used at strategic joints in the vehicle frame and on one side of the partitioning component placed in the frame cross-section, thereby reducing sound pressure in the vehicle cabin. The use of structural adhesive in the Accord[6] (Fig. 1) reduced weight by 9 kg.

In addition to issues such as application quality, precision control, anti-shower resistance in the formation section and material aging, problems in combining the use

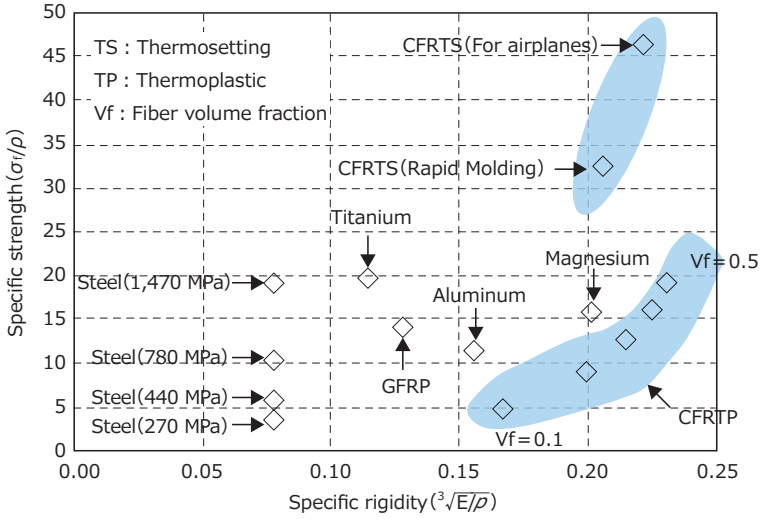


Fig. 2 Comparison of the Specific Strength and Specific Gravity of Various Structural Materials (Source: March 2006 issue of JAMA Magazine)

of adhesives with high strength steel sheets are also coming to the fore. Attempting to apply adhesive to locations that combine with difficult to weld high strength steel sheets worsens the welding conditions and, in the worst of cases, prevents welding altogether. Expectations are being placed on advances in welding technologies for the areas around the adhesive, in addition to adhesive materials, coating tools, and inspection tools, to find solutions to those issues.

2. 5. Low Specific Gravity Materials

Aluminum alloys are the material of choice among substitute low specific gravity materials expected to reduce weight, with other alternatives such as magnesium alloys and CFRP seeing little use. Aluminum alloys have twice the bending rigidity of steel (Fig. 2), and are anticipated to provide a 50% reduction in weight when applied to members with bending rigidity. Moreover, aluminum alloys contribute to vehicle dynamics through weight distribution, a low center of gravity, and low inertia while also keeping material replacement costs down and reducing the complex joining of dissimilar materials. Therefore, they are increasingly used for vehicle outer panels and closure parts.

In contrast, there are significant technical and economic obstacles to their application in vehicle frames involving the joining of dissimilar materials, which impose requirements such as strength, collision deformation performance, and high-level production control. This makes them easy to apply in the closure parts that complete the structure or in beam structures, and their use often stops there. The frame of the Rav4, for example, consists of steel sheets, while aluminum alloys are used for the hood, front fender, back door, and bumper beams. In mass production brands, restraint is exercised with respect to the use of aluminum alloys in the vehicle frame. The Ford Explorer heavy-duty SUV is one of the few exceptions seen in 2019. The Explorer[7] uses aluminum alloys in the front side frame and front damper housing, and magnesium alloys in the front tower bar. The weight ratio of these low specific gravity materials only represents approximately 7% of the total vehicle weight, including closure parts. There are, of course, luxury brand heavy-duty vehicles featuring multi-material bodies with a high ratio of aluminum alloys, but they are not discussed in this article.

2. 6. Passive Safety Technologies

Technologies that limits the added weight of frame reinforcements required for passive safety are becoming an increasingly crucial element in the control of vehicle weight as a whole. However, various markets will be updating, or making plans to update their passive safety protocols in 2020 and later. In Europe, the MPDB frontal impact test was introduced in January 2020, while in the U.S., there are plans to introduce oblique impact testing and update side impact tests.

All of these new protocols bring changes not only to the amount of impact energy imparted to the vehicle body, but also to elements such as the direction of input and the contact area. Given the weight increase concerns presented by a localized approach to additional reinforce-

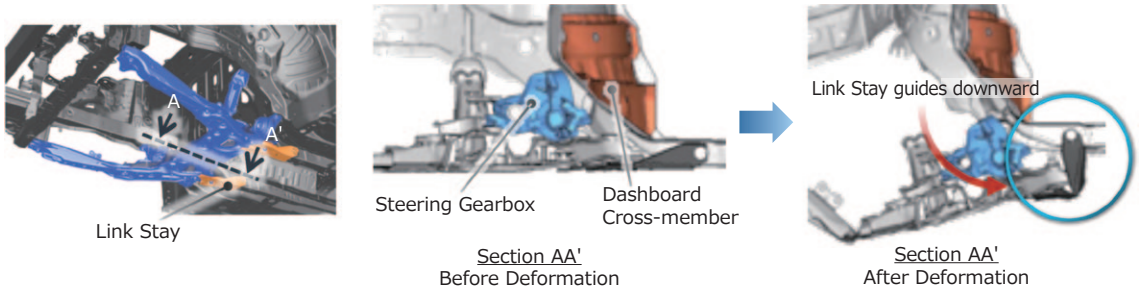


Fig. 3 Link Stay Falling Off Control in the Accord

ment, the expectations placed on greater passive safety are prompting demand for more efficient frame structures.

To raise energy absorption efficiency in oblique and frontal impacts, the Accord sold in the North American market since September 2017[8] features a link stay that can control the trajectory even after falling off on the rear end of the front subframe (Fig 3), and adopts an approach that avoids the load increase resulting from interference in the latter half of an impact.

In 2020, automakers will be releasing frames compliant with the new protocol for MPDB frontal impact testing in the European market. Vehicle body design engineers and safety researches will be comparing the test results and frame structures for the vehicles of the various automakers and keeping an expectant eye on what basic technologies and ideas were used to build them.