1 Introduction

Recently, the social demand to reduce the environmental impact of vehicles while also enhancing safety has been increasing. In addition, as the transition to autonomous driving is becoming a real possibility, automakers are locked into continuous competition to develop these technologies and to put them into practical use.

England and France addressed environmental friendliness in the summer of 2017 by announcing that they will prohibit the sales of new gasoline and diesel vehicles by 2040. Since then, government-led efforts to shift from internal combustion engine to Electric Vehicle (EV) have been accelerating, prompting one automaker after the other to announce plans to introduce EVs.

Active safety technology and other aspects of safety performance are being reflected in the revision of the Advanced Emergency Braking Systems (AEBS) international standard (UN R131) is currently taking place to expand its scope from only heavy-duty vehicles such as trucks and buses to include passenger vehicles, as well as to add regulations on tests for pedestrian protection. In parallel, the Japanese government established a national certification system for AEBS performance.

One measure to prevent traffic accidents involving elderly drivers promotes vehicles equipped with features such as automatic braking systems and functions that suppress acceleration when the accelerator is depressed by mistake, as safe driving support vehicles under the nicknames Safety Support Car and Safety Support Car S to raise awareness and encourage the spread of such vehicles.

Requirements concerning autonomous driving at speeds of 10 km/h or less (automatic parking) and lane-keeping assistance while holding the steering wheel have been added to the international standard on steering equipment (UN R79), and also included in the safety regulations in Japan. Phase 6 of the Advanced Safety Vehicle (ASV) Promotion Project (FY 2016 to FY 2020) similarly advocates the study of concrete technologies focused on autonomous driving and the popularization of such technologies. Vehicles equipped with level 2 autonomous driving functions have been released, and public road demonstration tests for higher levels of autonomous driving will also be conducted.

This article describes the chassis and vehicle control device trends focusing on the new models and technology released in 2017 in the context of these social trends. The main new models launched in and outside Japan in 2017 are shown separately in Table 1\(^1\). However, technologies such as Electronic Stability Control (ESC) that are mandatory in various countries, and warning functions that are part of active safety technologies, have been omitted.

2 Suspension

2.1 Base Suspensions

As shown in Table 1, the suspension types of new models in 2017 follow recent trends and present nothing new. The main types of front suspension continue to be the strut type for medium-sized or smaller vehicles, and the double wishbone type for larger vehicles.

The recent trend of standardizing suspension types due to automakers adopting large-scale platforms is continuing. Examples from 2017 include the Toyota Prius PHV and Camry, which use the Toyota New Global Architecture (TNGA), the Subaru XV built on the Subaru Global Platform (SGP), the Volvo XC60 which adopts the Scalable Product Architecture (SPA), and the Volkswagen Polo which uses Modulare Quer Baukasten (MQB). The Subaru SGP achieves both straight line driving in accordance with driver intent through increased vehicle body and component part rigidity, and pleasant ride comfort and stability through decreased unpleasant vibration and noise\(^2\).
<table>
<thead>
<tr>
<th>Market</th>
<th>Manufacturer/brand</th>
<th>Name of vehicle model</th>
<th>Drivetrain type</th>
<th>Drive system</th>
<th>Suspension type Front/ Rear ( ) suspension for AWD layout</th>
<th>Vehicle control systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Swift Sport</td>
<td>ICE</td>
<td>FF</td>
<td>Strut/TBA</td>
<td>Hill Hold Control/Dual Sensor Brake Support /Erroneous Start Prevention/ Lane Departure Prevention Function</td>
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<td>Wagon R</td>
<td>ICE/ MHEV</td>
<td>FF/AWD</td>
<td>Strut/TBA (3 link)</td>
<td>Hill Hold Control/Dual Sensor Brake Support /Erroneous Start Prevention</td>
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<td>Swift</td>
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<td>FF/AWD</td>
<td>Strut/TBA (TBA)</td>
<td>Hill Hold Control/Dual Sensor Brake Support /Erroneous Start Prevention</td>
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<td>Subaru</td>
<td>XV</td>
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<td>Strut/DW</td>
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<td>Daihatsu</td>
<td>Mira eS</td>
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<td>FF/AWD</td>
<td>Strut/TBA (3 link)</td>
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<td></td>
<td>Toyota</td>
<td>Camry</td>
<td>HEV</td>
<td>FF</td>
<td>Strut/DW</td>
<td>Toyota Safety Sense P (Pre-collision Safety System (Collision Avoidance Assist Type with Pedestrian Detection)/ Lane Departure Alert (with Steering Control)/ Radar Cruise Control (with Full-speed Following Function)/ Intel- ligent Clearance Sonar (with Rear Cross-Traffic Braking)/ S-VSC (Steering-assisted Vehicle Stability Control)/ Drive-start Control/ Hill Start Assist Control/Vehicle Speed Sensitive Type EPS</td>
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<td>Prius PHV</td>
<td>PHEV</td>
<td>FF</td>
<td>Strut/DW</td>
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<td>FF</td>
<td>Strut/TBA</td>
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<tr>
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<td>Honda</td>
<td>N-Box</td>
<td>ICE</td>
<td>FF/AWD</td>
<td>Strut/TBA (TBA)</td>
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<tr>
<td></td>
<td>Civic</td>
<td>ICE</td>
<td>FF</td>
<td>Strut/Multi-Link</td>
<td>Honda SENSING (Collision Mitigation Braking System/ Adaptive Cruise Control with Low-Speed Following/ Lane Keeping Assist System/ Road Departure Mitigation System/ Hill Start Assist Function/ Agile Handling Assist</td>
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<tr>
<td>Outside Japan</td>
<td>Mazda</td>
<td>CX-8</td>
<td>ICE</td>
<td>FF/AWD</td>
<td>Strut/Multi-Link</td>
<td>Hill Launch Assist/ Advanced Smart City Brake Support (Forward/Reverse) &amp; Pre-collision Throttle Management (Start/Reverse)/ Smart Brake Support/ Mazda Radar Cruise Control (with Full-speed Following Function)</td>
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<td>Outside Japan</td>
<td>CX-9</td>
<td>ICE</td>
<td>FF/AWD</td>
<td>Strut/Multi-Link</td>
<td>Hill Launch Assist/ Advanced Smart City Brake Support (Forward/Reverse) &amp; Pre-collision Throttle Management (Start/Reverse)/Smart Brake Support/ Mazda Radar Cruise Control (with Full-speed Following Function)</td>
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<td>Lexus</td>
<td>LS</td>
<td>ICE/ HEV</td>
<td>FR/AWD</td>
<td>Multi-Link/Multi-Link</td>
<td>Lexus Safety System + A (Pre-Collision Safety System (with Active Steering Assist)/ Lexus CoDrive (All-Speed Dynamic Radar Cruise Control) &amp; Lane Tracing Assist &amp; Lane Change Assist/ Driver Emergency Stop Assist (coordinated with Lane Tracing Assist)/ VDIM (with Integrated Active Steering Control) &amp; Lexus Dynamic Handling System/ Parking Support Brakes/ Hill-start Assist Control/ Brake Hold</td>
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<td>ICE/ HEV</td>
<td>FR</td>
<td>Multi-Link/Multi-Link</td>
<td>Lexus Safety System + (Pre-Collision Safety System/ Collision Avoidance Assist Type with Pedestrian Detection)/ All-Speed Dynamic Radar Cruise Control/ Lane Keeping Assist/ VDIM (with Integrated Active Steering Control)/ Lexus Dynamic Handling System/ Drive-Start Control/ Hill-start Assist Control/ Brake Hold</td>
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<td>Outside Japan</td>
<td>Audi</td>
<td>Q5</td>
<td>ICE</td>
<td>AWD</td>
<td>DW/DW</td>
<td>Audi Pre Sense City (Automatic Braking)/ Adaptive Cruise Control/ Traffic Jam Assist (Vehicle Distance Maintenance)/ Active Lane Assist/ Side Assist/ Turn Assist/ Park Assist/ Exit Warning</td>
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<td>A8</td>
<td>ICE</td>
<td>AWD</td>
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<td>Outside Japan</td>
<td>BMW</td>
<td>M5</td>
<td>ICE/ HEV</td>
<td>AWD</td>
<td>DW/Multi-Link</td>
<td>Active Cruise Control/ Steering and Lane Control Assistant/ Active Side Collision Protection</td>
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<tr>
<td>Outside Japan</td>
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<td>X3</td>
<td>ICE</td>
<td>AWD</td>
<td>Strut/Multi-Link</td>
<td>Hill Descent Control/ Active Cruise Control/ Steering and Lane Control Assistant/ Active Side Collision Protection</td>
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<tr>
<td>Outside Japan</td>
<td>MINI Countryman</td>
<td>ICE/ PHEV</td>
<td>FF/AWD</td>
<td>Strut/Multi-Link</td>
<td>Parking Assistant</td>
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<tr>
<td>Outside Japan</td>
<td>MINI Series</td>
<td>Touring</td>
<td>ICE</td>
<td>FR/AWD</td>
<td>DW/ Air suspension</td>
<td>Active Cruise Control/ Steering and Lane Control Assistant/ Active Side Collision Protection</td>
</tr>
</tbody>
</table>

Table 1: Chassis and vehicle control systems of new vehicles launched in 2017.
Table 1  Chassis and vehicle control systems of new vehicles launched in 2017 (cont.)

<table>
<thead>
<tr>
<th>Market</th>
<th>Manufacturer/brand</th>
<th>Name of vehicle model</th>
<th>Drive/Train type</th>
<th>Drive system</th>
<th>Suspension type</th>
<th>Front/Rear (if) suspension for AWD layout</th>
<th>Vehicle control systems</th>
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</thead>
<tbody>
<tr>
<td>Outside Japan</td>
<td>Mercedes-Benz</td>
<td>CLS</td>
<td>ICE</td>
<td>FR/AWD</td>
<td>Strut/MultiLink</td>
<td>DISTRONIC PLUS (with Steering Assist)/Brake Assist PLUS (with Cross-Traffic Assist)/PRE-SAFE Brake (with Pedestrian Detection)/Rear-end Collision Warning System with Damage Mitigation Brake/Active Blind Spot Assist/Active Lane Keeping Assist</td>
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<td></td>
<td>Citroën</td>
<td>C3</td>
<td>ICE</td>
<td>FF</td>
<td>Strut/TBA</td>
<td>Active Safety Brake/Hill Start Assist</td>
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<td>Ford</td>
<td>Lincoln Navigator</td>
<td>ICE</td>
<td>FR/AWD</td>
<td>Multi-Link/Multi-Link</td>
<td>Active Park Assist/Adaptive Cruise Control/Pre-Collision Assist with Pedestrian Detection (Automatic Braking)/Hill Descent Control</td>
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<td>Honda</td>
<td>Accord</td>
<td>ICE/HEV</td>
<td>FF</td>
<td>Strut/MultiLink</td>
<td>Honda SENSING (Adaptive Cruise Control with Low-Speed Follow/Lane Keeping Assist System/Collision Mitigation Braking System)</td>
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<td>Peugeot</td>
<td>5008</td>
<td>ICE</td>
<td>FF</td>
<td>Strut/TBA</td>
<td>Active City Brake/Active Cruise Control/Active Lane Keeping Assistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Porsche</td>
<td>Cayenne</td>
<td>ICE</td>
<td>AWD</td>
<td>Multi-Link/Multi-Link</td>
<td>Electronic Air Suspension</td>
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<td>Renault</td>
<td>Megane GT</td>
<td>ICE</td>
<td>FF</td>
<td>Strut/TBA</td>
<td>Emergency Brake Assist (Active Brake)/Easy Park Assist/Multi-Sense/Hill Start Assist</td>
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<tr>
<td></td>
<td>Tesla Motors</td>
<td>Model 3</td>
<td>EV</td>
<td>RR/AWD</td>
<td>Multi-Link/Multi-Link</td>
<td>Autopilot/Automatic Braking</td>
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<td>Volkswagen</td>
<td>Polo</td>
<td>ICE</td>
<td>FF</td>
<td>Strut/TBA</td>
<td>Front Assist (Semi-autonomous Driving)/City Emergency Braking (Pedestrian-aware Collision Mitigation Braking System)/Park Assist/Adaptive Cruise Control</td>
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<td>Arteon</td>
<td>ICE</td>
<td>AWD</td>
<td>Strut/MultiLink</td>
<td>Adaptive Cruise Control/Park Distance Control (with Collision Mitigation Braking Function: Forward/Backward)/Rear Traffic Alert (Warning Backward, Collision Mitigation Braking Function)</td>
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<td>XC40</td>
<td>ICE</td>
<td>AWD</td>
<td>Strut/MultiLink</td>
<td>Semi-autonomous Drive Function (Pilot Assist)/City Safety/Run-off Road Mitigation/Run-off Road Protection</td>
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<td></td>
<td>XC60</td>
<td>ICE/PHEV</td>
<td>AWD</td>
<td>DW/MultiLink</td>
<td>Adaptive Cruise Control/City Safety (Automatic Braking)/Oncoming Lane Mitigation (Oncoming Lane Departure Prevention Assist)/Pilot Assist (Lane-keeping Assistance Function)/Blind Spot Information System with Steer Assist and Cross Traffic Alert/Lane Change Merge Aid/Lane Keeping Aid</td>
<td></td>
</tr>
</tbody>
</table>

2.2. Suspension Controls

There were no major changes in suspension control devices. In line with recent trends, electronically controlled damping force adjustment mechanisms and air suspensions have been adopted in high-class sedans and sports vehicles, and settings suited to the individual drive modes are available. Suspensions that use magnetic fluid continue to be adopted on a subset of luxury vehicles outside Japan.

Along with the vehicle height adjustment function that can be switched between normal and high settings, the electronically controlled air suspension been adopted in the Lexus LS features an access mode function that adjusts the vehicle height automatically to make it easier to get in and out of the vehicle[9].

Citroën vehicles are being equipped with a mechanism called Progressive Hydraulic Cushions, which is a function that smooths bumps and rebounds using two hydraulic stops set respectively on the compression and rebound sides, to form a structure in which the springs and hydraulic stops dissipate the energy from large road inputs. This improves comfort by avoiding the impact at the end of travel that occurs with conventional stops[8].

In the area of occupant comfort, Bose, which is widely known for its electromagnetic suspension system, refined its suspension seating system. Bose announced further advances to the single axis (vertical direction) motion control system used in vehicles such as heavy-duty trucks with a switch to an active multi-axis motion design that adds roll control. This system relies on moving the seat in opposite phase to the vibrations to cancel them[5].

3. Steering

The mainstream Electric Power Steering (EPS) systems, which have widely replaced hydraulic power steering due to their superior fuel efficiency, remain unchanged, with column-assist EPS used in compact and smaller vehicles, and rack-assist EPS in medium-sized and larger vehicles. The rack thrust in rack assist EPS becomes progressively more powerful in single pinion, dual pinion, and belt drive EPS, and belt drive systems with even higher output are also being developed. In contrast, development to improve fuel efficiency by downsizing and reducing the energy consumption of column assist EPS is also underway. Ongoing development targeting even greater fuel efficiency is anticipated for light- and medium-duty vehicles, which are subject to

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strict expectations in that respect, while more powerful
rack thrust is predicted to remain the main demand in
the development of heavy-duty vehicles.

In addition, technologies featuring both steering stabil-
ity at high speeds, and good handling and a smaller turn-
ing radius at low speeds are also becoming more preva-
 lent. One example is the adoption of the variable gear
ratio mechanism used in vehicles such as the Audi A4. This
mechanism changes the gear ratio at high and low
speeds to achieve both steering stability at high speed
and good handling at low speeds.

Another example is the four-wheel steering systems
introduced in a few models toward the end of the 1980s,
which have recently become more common in mainly
luxury vehicles, such as the Audi A7, but can also be
found in the Renault Mégane GT C-segment model, for
example. The system in the Mégane GT uses control to
set the in-phase at speeds of 60 km/h or higher, and the
counter-phase at speeds below 60 km/h, achieving both
stable cornering and good handling in situations such as
parking.

EPS represents an essential system in the context of
the rapid progress automobile and parts manufacturers
have been making in driving safety support and autono-
mous driving technologies. The increased motor capacity
resulting from adapting to the needs of driving support
and autonomous driving are enabling greater active
steering control which is expected to eventually be ap-
plied to steering functions used for lane keeping, lane
changes, or automatic parking.

4 Brakes

The spread of ESC actuators and other brake pressur-
ization devices has expanded the role of the brakes be-
yond just decelerating the vehicle to active use as a
means of controlling various vehicle dynamics and be-
havior.

Brake-based traction control and stability control have
long been used to ensure vehicle driving stability, and a
technology called torque vectoring, which uses braking
force as a way to transfer load to the wheels to improve
cornering performance, has also become commercially
available on some models.

In addition, collision mitigation braking systems are
being used in a variety of cases, as exemplified by sys-
tems such as Honda SENSING, Suzuki Dual Sensor
Brake Support, Daihatsu Smart Assist III, which respond
to pedestrians as well as vehicles, have been extended to
mini-vehicles, and are gaining more advanced functions.

One example is post-collision braking systems, widely
adopted in vehicles ranging from mass-market vehicles
such as the Volkswagen Polo to luxury vehicles, which
automatically apply deceleration to prevent secondary
injuries caused the vehicle entering the oncoming lane or
multiple collisions, in the event of a rear-end or other col-
lision. Another example are the rear-end collision warn-
ing with collision mitigation braking systems installed in
Mercedes-Benz and Volvo luxury models, which aim to
reduce injuries to occupants and avoid pile-ups by apply-
ing brake pressure just before the rear-end collision
while simultaneously warning (on-screen and hazard lamps) both drivers when there is a risk of the vehicle
getting rear-ended. In Japan, the application of collision
mitigation braking systems is being extended to a broad
variety of situations other than just before or after an ac-
cident, or of whether the vehicle is stopped or in motion,
as illustrated by the function in Lexus vehicles that de-
tects abnormal driver states and stops the vehicle.

Electric Parking Brakes (EPB) are no longer limited to
luxury or hybrid vehicles, but have also been made stan-
dard equipment on some mini-vehicle models. The sys-
tems do not simply replace human operation with elec-
tric switch, but include an automatic parking function
that activates itself in accordance with engine stops or
other situations, the already widespread hill-start assist
function that facilitates starts on a slope, and even a
downhill assist function in some vehicles such as SUVs.
Technology applied in the field of brakes is exhibiting
dynamic changes, including replacing functions in which
actuator heat generation limited activation time if only
hydraulic devices are used.

5 Vehicle Controls

Although vehicle controls are quite varied, they can
be broadly categorized into those that prevent accidents
beforehand, and those that enhance comfort.

Representative vehicle controls for preventing acci-
dents beforehand are the collision mitigation braking
system which detects an object ahead and applies the
brakes, or the erroneous start prevention function that
prevents accidents caused by pressing the wrong pedal.
Moreover, the number of vehicles controls that operate
the steering wheel to prevent collisions due to the vehi-
cle swerving, lane deviations, or lane changes have also
increased.

The Honda Lane Keeping Assist System (LKAS) detects the lane using a monocular camera and provides steering assist to keep the vehicle in the center of the lane. Volvo Blind Spot Information System with Steer Assist and Rear Collision Warning detects the other vehicles approaching from behind using millimeter wave radars in the left and right sides of the rear bumper during a lane change or unintended lane deviation. If the system determines that there is a high risk of collision, it automatically directs the steering to move the vehicle back into its original lane. BMW Active Side Collision Protection uses four sensors mounted on the front, rear, right, and left sides of the body to monitor traffic conditions at the sides of the vehicle. When the risk of side collision increases, such as when the vehicle in an adjacent lane moves into the lane of the vehicle, the system intervenes to steer the vehicle away from the approaching vehicle without leaving the current lane to help avoid a collision.

The improvements in the recognition, decision-making, and operation brought to these functions are expected to transfer to fully autonomous driving. Current systems corresponding to autonomous driving level 2 include the Nissan ProPILOT, and Volvo Pilot Assist which, on roads such as highways, provide lane keeping steering assistance while maintaining an appropriate following distance from the preceding vehicle or driving at a set speed if the vehicle is in the lead.

The Lexus LS offers the Driver Emergency Stop Assist system, which decelerates and eventually stops the vehicle within its lane while alerting other road users in the vicinity through the hazard lamps and the horn, unlocks the doors and also a rescue request upon detecting an abnormal driver state, thus applying emergency measures if the condition of the driver changes suddenly.

There are vehicle controls for enhancing comfort that do not rely on stabilizing the vehicle when cornering to improve ride comfort.

The Nissan Leaf has adopted Intelligent Ride Control, which suppresses unpleasant vibrations when passing over bumps on the road by controlling the engine and brakes, and provides pleasant ride comfort. The Mercedes-Benz Magic Body Control detects small road surface irregularities via a stereo camera and independently controls the hydraulic units of each wheel to suppress rolling and pitching and maintain a level posture like that on a smooth road under various conditions. It also achieves exhilarating cornering while allowing occupants to remain stably seated by tilting the vehicle towards the inside of the corner when cornering.

Vehicle controls for preventing accidents beforehand are anticipated to evolve even further to continue to respond to the needs for safety performance and autonomous driving, and to be installed in various vehicle models rather than only in luxury vehicles. Similarly, vehicle controls for enhancing comfort are also likely to develop even further from the standpoint of enhancing product appeal.

References

(1) Websites of Automotive Manufacturers
(3) Website of Lexus, https://.lexus.jp/ (in Japanese)
(4) Website of CITROËN UNITED KINGDOM, http://www.citroen.co.uk/
(10) Global site of Nissan Motor Co., Ltd., https://www.nissan-global.com/