



TIP

Consider the entire landscape of vehicle technology rollout, deployment, and use when investigating incidents involving advanced vehicle technology.

environmental conditions, or (3) be 100 percent effective 100 percent of the time.

In 2006, Acura's Collision Mitigation Braking System (CMBS) and Mercedes-Benz's Brake Assist BAS Plus on its flagship S-Class model were the first radar-based systems capable of providing automatic braking. In the 2006–2008 time frame, other vehicle manufacturers followed suit with similar systems on their higher-end vehicles.

S curve. While more and more vehicles are being equipped with ADAS, such technology has not

been deployed yet on every vehicle being produced and sold. This is not surprising as new technology deployment typically follows an S curve of market penetration, as seen in Figure 2 below. Historically, the first 10 to 15 years after a technology's introduction are characterized by a low-volume deployment rate (the flat part of the curve), followed by an increase in the deployment rate as the technology matures, and often taking another five to 10 years to reach the high-volume deployment rate on the top, or right, end of the S.

NHTSA and deployment rates. When the National Highway Traffic Safety Administration (NHTSA) promulgates rulemakings (e.g., Corporate Average Fuel Economy (CAFE) standards), it expends considerable effort understanding and accounting for the deployment rate of a technology in its analyses.

For the CAFE rulemakings, emerging technologies are assumed to penetrate the market only in the single-digit percentage growth rate range per year; and even mature technologies, which are in the maximum growth rate regime of

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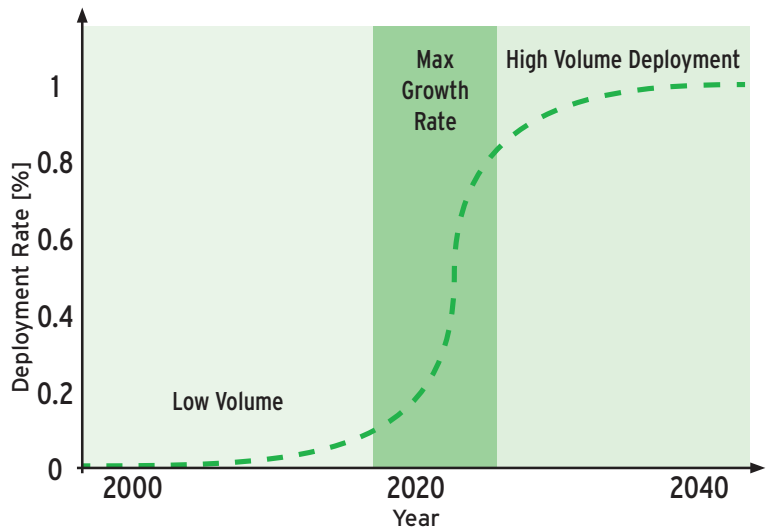


Figure 2. Deployment characterized by the S curve.

The shape of the S curve is defined by, among other things, the following:

- Capital investment and engineering resources,
- Technological breakthroughs and intellectual property (IP) considerations,
- Maturity of manufacturing processes,
- Design, production, and durability validation testing,
- Vehicle refresh and redesign cycles,
- Supplier capacity,
- Consumer acceptance and affordability, and
- Voluntary or mandatory standards.

the S curve, are assumed to penetrate the market at growth rates of only 10 percent to 20 percent per year. The time horizon for the entire process of a technology becoming standard equipment on all vehicles produced can be 15 to 30 years. Furthermore, when considering the entire fleet, historical data suggests that it can, and does, take many decades for a technology to be present on nearly every vehicle on the road.

The 2017 announcement between the NHTSA, the Insurance Institute for Highway Safety (IIHS), and 20 vehicle manufacturers regarding those manufacturers' voluntary



SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features			These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	<ul style="list-style-type: none"> • automatic emergency braking • blind spot warning • lane departure warning 	<ul style="list-style-type: none"> • lane centering OR • adaptive cruise control 	<ul style="list-style-type: none"> • lane centering AND • adaptive cruise control at the same time 	<ul style="list-style-type: none"> • traffic jam chauffeur 	<ul style="list-style-type: none"> • local driverless taxi • pedals/steering wheel may or may not be installed 	<ul style="list-style-type: none"> • same as level 4, but feature can drive everywhere in all conditions

For a more complete description, please download a free copy of SAE J3016: https://www.sae.org/standards/content/j3016_201806/

Figure 1. SAE J3016 graphic depicting the six levels of driving automation (as discussed on page 17).

commitment to introduce AEB as standard equipment on most vehicles by model year 2022 seems to acknowledge the NHTSA's understanding of the current state of AEB (i.e., still an evolving, not yet fully mature technology) and the time required to achieve widespread deployment of the emerging AEB technology.¹ Even with this voluntary commitment to equip new vehicles with AEB, and with the impending transition into the max growth rate phase of the S curve, it still will take decades past 2022 before a substantial portion of the entire U.S. fleet of vehicles on the road will be AEB-equipped. Higher levels of automated vehicles, on the other hand, are still in the lower left corner of the S curve (in the low-volume deployment region) and will require more time to enter the max growth rate phase.

USER TRUST AND ACCEPTANCE

As vehicle manufacturers, suppliers, and technology developers bring

ADAS and automated technologies to market, in addition to working within the frameworks provided by federal, state, and local authorities, care must be taken to consider how consumers will accept and use these systems. Regardless of how the technology functions, for any of these systems to have the desired effects that they often advertise, the ADAS-equipped vehicles must get into the hands of drivers, and the systems must be used by the drivers. For this to occur, consumers must be able to afford, perceive the benefits of, and ultimately use ADAS technologies.

Affordability. Affordability is one of the forces that drives newer technologies' debut in higher-end luxury makes and models because these vehicles and their prospective owners are more likely to bear the cost of new and expensive technology. Referring to the S curve mentioned above, an increase in market penetration of ADAS technology typically occurs as the technology enters a mature stage

with associated lower production costs.

Trust. As these vehicles get into the hands of more users and the technology continues to mature and proliferate, the success of these systems' emergence also will be influenced by how the users trust the technology. Research on trust in automation has shown that an unreliable system can cause the user to lose trust and will be underutilized—and, thus, not effective due to nonuse.² At worst, the user will disable the system entirely.³ Conversely, when a system performs reliably and is accepted by the user, trust (and use) can be facilitated. One study comparing drivers' reactions to adaptive cruise control systems with varying levels of reliability showed that trust grew over time for drivers exposed to a 100 percent reliable system.⁴ With the knowledge that trust of the technology is integral, and that even infrequent violations of that trust can have a lasting effect on users' feelings toward automated

systems,⁵ consideration of these issues will go a long way to ensuring that ADAS will be integrated successfully into the automotive marketplace and become common equipment on larger portions of the automotive fleet.

If higher reliability fosters more trust among users, then a key challenge for ADAS development is the accuracy—and perceived accuracy—of hazard alerts that are provided by the system. False alarms or alerts are those provided by the ADAS device that are triggered in the absence of an actual hazard. A false alarm occurs, for example, when the system provides a forward collision alert in the absence of cars or other obstacles in front of the driver’s vehicle or when the alert references an out-of-path vehicle or roadside object such as a guard-rail or a sign that is not a hazard to the vehicle or the vehicle’s intended path. Even a small number of false alarms can turn into a nuisance for the operator. Nuisance alerts include a subjective component; they can be triggered by an actual hazard but viewed as inappropriate or unnecessary due to the manner in which they are delivered, e.g., frequency, timing, intensity, or modality.⁶ Whether or not the nuisance stems from false alarms or alerts that are deemed inappropriate by the user, the achievement of nuisance status will lead to higher rates of disuse and mistrust.

The “truth table” (Table 1) on this page summarizes performance outcomes from alerts provided by ADAS devices.

Usage. Though the literature shows mixed driver responses to false alarms and nuisance alerts, either of these can affect driver behavior, performance, and acceptance of ADAS. For example, one study showed that false alerts resulted in longer brake reaction times immediately following a previous false or missing alert, and that drivers tended to brake for false

	Situation Warrants Alerting the Driver	Situation Does NOT Warrant Alerting the Driver
Alert Provided to the Driver	True Positive (hit)	False Positive (either a false alert or nuisance alert)
No Alert Provided to the Driver	False Negative (miss)	True Negative

Table 1. Performance outcomes from ADAS alerts.

Source: Adapted from Raymond J. Kiefer, David LeBlanc, Melvin D. Palmer, Jeremy Salinger, Richard K. Deering & Michael A. Shulman, Nat’l Highway Traffic Safety Admin., DOT HT 808 964, Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning/Avoidance Systems (1999).

alarms when they were timed to provide a relatively longer time-to-collision.⁷ False alerts or alarms therefore can induce carryover effects from previous experiences such that experience with an alert can change behaviors and responses to subsequent alerts.

A field operational test of vehicles equipped with multiple collision-warning technologies (e.g., forward collision, curve speed warning, lane departure warning, and blind spot warning) found a nuisance alarm rate of 0.83 per 100 miles of driving across all warning types.⁸ Despite this rate of nuisance alarms, 72 percent of all drivers were still interested in having the integrated system in their cars, versus 25 percent who were not interested. However, although many drivers found the nuisance rate to be tolerable, several drivers reported that the false alarms caused them to distrust the system and begin to ignore alerts.⁹ While ignoring false alarms is appropriate, the danger is that drivers may ignore true positive alerts and not initiate an appropriate response in a hazardous situation that requires a response.

Driver acceptance data obtained from an independent evaluation of this same field operational test was similarly nuanced. One study reported that while false/nuisance alerts were the system characteristic liked least by 50 percent of the drivers, 81 percent still found the warnings helpful, and 82 percent

were satisfied with the system overall.¹⁰ These findings suggest, in general, that drivers find many of these systems useful but that the specific user experience and design of any individual advanced driver-assistance system will necessarily affect its utility and adoption.

Drivers also may respond differently to false alarms as compared to nuisance alerts. One study found that nuisance alerts were associated with greater compliance to the alert in critical situations, while false alarms were associated with less compliance.¹¹ Overall, false alarms and nuisance alerts can influence drivers’ perception of the reliability of the ADAS device and change their degree of trust in the system;¹² impact their responses to alerts; reduce system effectiveness if “true” alerts are ignored; and, finally, as mentioned above, affect the overall efficacy of ADAS technology.

CONSUMER EDUCATION

Another aspect of the driver-ADAS interaction that will be critical to evaluate in order to understand the potential effectiveness of a given technology is the information available with respect to the systems’ capabilities and limitations and how that information is communicated to the driver. Specifically, consumers’ understanding of what the technology can do, and what it cannot do, will directly affect proper use and potential misuse. For example, certain forward collision mitigation