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RESEARCH REPORT

Navigant Research Leaderboard Report: Automated Driving

Assessment of Strategy and Execution for 18 Companies Developing Automated Driving Systems

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Section 1
EXECUTIVE SUMMARY

1.1 Market Introduction

Automated driving is increasingly being considered the key technology to address societal problems caused by the proliferation of automobiles around the world. These include traffic congestion, injuries, and fatalities caused by crashes and air quality. The development of automated driving has been ongoing since at least the 1950s. However, it has accelerated in the last decade, enabled by advancements in computational architectures and sensing technology, along with dramatic cost reductions. These advancements, combined with vehicle electrification and ubiquitous connectivity, are enabling automated driving to rapidly become viable.

Since the *Navigant Research Leaderboard Report: Autonomous Vehicle OEMs* was published in 3Q 2015, the landscape for automated driving has advanced significantly. Multiple new players are becoming more prominent, and some established participants are being overtaken. For this edition of the report, the scope has been expanded beyond the automotive OEMs to include several of the prominent Tier One suppliers as well as non-traditional entrants in the field.

This *Leaderboard Report* assesses which participants are best equipped to be the leaders in developing complete automated driving stacks, including perception systems, processing, control software, and services platforms. It quantifies the current relative position of each of these companies as the latest features are being developed and commercialized to help drivers and improve safety. Complete details of the automated vehicle market and forecasts for 2015-2035 are provided in the recent Navigant Research report, *Autonomous Vehicles*.

1.2 The Evolution of the Automated Driving Market

During the second half of 2016 and into early 2017, there were a flood of announcements about new partnerships, investments, acquisitions, developments, and even production plans for vehicles with at least SAE Level 4 automation capability. This is the baseline level for a vehicle that relies more on automated capabilities for basic driving functions than on the human driver.

Over the course of 2016, it also became increasingly clear that not every OEM is likely to have the expertise or the resources to develop fully automated vehicles in-house. These manufacturers are expected to rely on either the established supply base or new entrants to assist with integration and development of this technology into their vehicle lineup. This *Navigant Research Leaderboard Report* therefore includes not only automotive OEMs but also other companies that are expected to provide full-stack solutions for automated

driving, including integration of a sensor suite, a processing platform, and the software for perception and vehicle management. Tier One suppliers and other non-traditional entrants to the automotive market are included in this *Leaderboard Report* if they meet that criteria. Other suppliers that are expected to focus on offering components for integration by others into full system stacks have not been included to ensure that the report makes an apples-to-apples comparison. Moreover, due to the number of non-OEMs that have demonstrated clear capability in the past year, several OEMs that had previously been included as market followers were excluded in this update.

Some of the non-OEM companies are expected to license their systems to OEMs while others are likely to partner with OEMs to provide them with a vehicle platform to install the system onto. This latter group, which includes companies like Uber and Waymo, is expected to use these vehicles to provide automated mobility services to consumers.

Navigant Research expects that most people will get access to automated vehicles via on-demand mobility services rather than individual ownership. Questions around liability, maintenance, and the updating of automated vehicles will likely push the business toward vertical integration, whereby companies provide the vehicles and services platforms. For this update of the *Leaderboard*, the services component has been factored into how these companies are scored.

1.3 The Navigant Research Leaderboard Grid

The criteria by which manufacturers are compared in this *Navigant Research Leaderboard Report* include:

- Vision
- Go-to-Market Strategy
- Partners
- Production Strategy
- Technology
- Sales, Marketing, and Distribution
- Product Capability
- Product Quality and Reliability
- Product Portfolio
- Staying Power

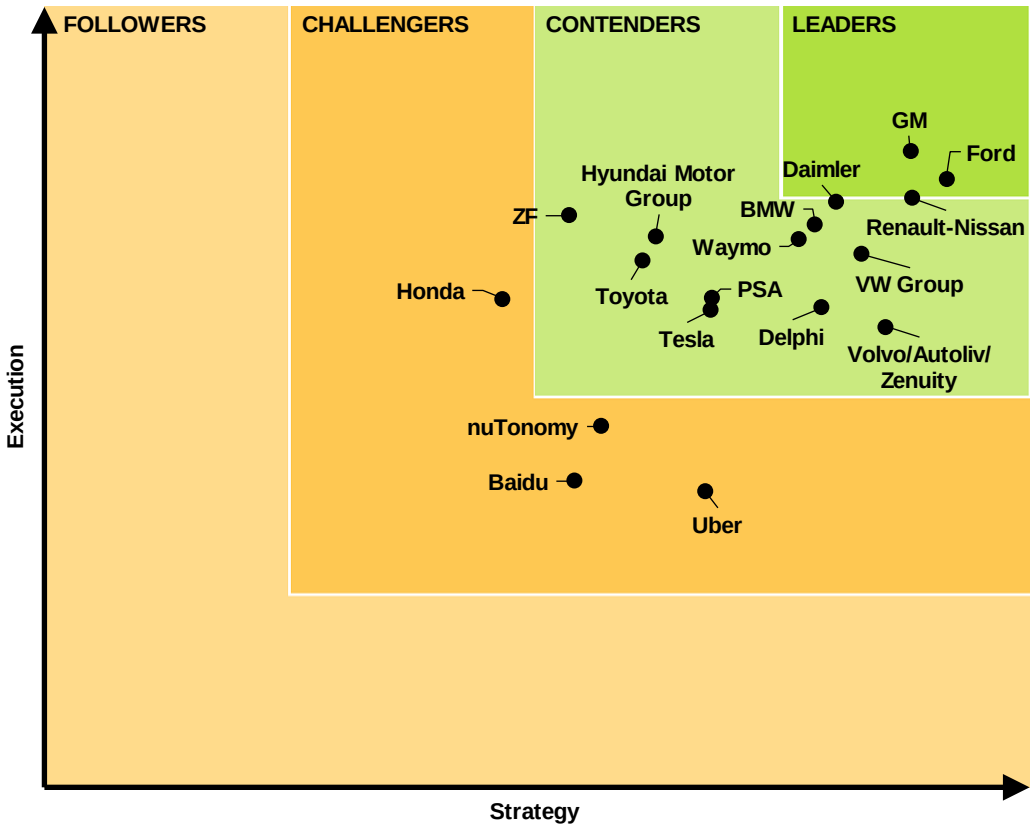
Detailed descriptions of each criterion are provided in Section 8.2.3 of this report. Scoring is based on an assessment of each company in terms of how established and comprehensive its current deployment of advanced driver assistance systems (ADAS, the

building blocks of automated driving) is; what public announcements it has made regarding the next generation of self-driving features; and how committed it is to the longer-term goals of automated vehicles.

The scores of each company are shown graphically in Chart 1.1. Four companies meet the Leaders definition, with both Strategy and Execution scores of greater than 75. Ford has moved up to the top position in this round of evaluation and is followed closely by General Motors (GM). The Renault-Nissan Alliance and Daimler round out the Leaders.

Most of the remaining companies were evaluated as Contenders, with a handful assessed as Challengers. As the number of participants actively involved in development of advanced automated driving has grown, it has become increasingly challenging to distinguish where they stand relative to each other. Also note that as the technology comes closer to series production in the coming years, the rankings in this group will likely continue to shift—especially among the established players that have demonstrated capability with ADAS.

Chart 1.1 The Navigant Research Leaderboard Grid



(Source: Navigant Research)

Section 2
MARKET OVERVIEW

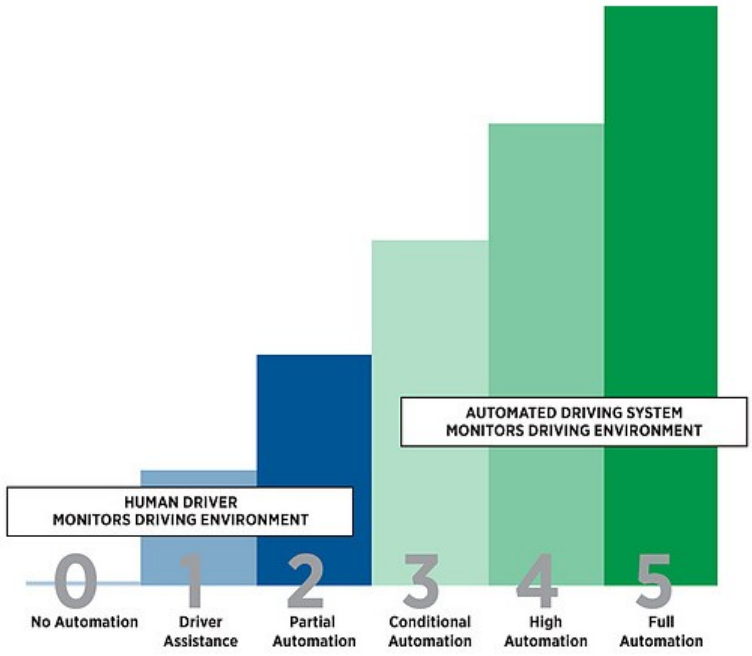
2.1 Market Definition

One of the challenges in discussing the automated driving market is being clear about the type of automated system and level of automation. In the past year, the industry and the US National Highway Traffic Safety Administration (NHTSA) have coalesced around SAE International's definitions of automated driving, which settled on six levels of automation—in contrast to the five levels previously described by NHTSA and used in Navigant Research's previous vehicle automation analysis. For consistency, Navigant Research has chosen to follow the six levels in SAE standard J3016:

- **No Automation (Level 0):** The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.
- **Driver Assistance (Level 1):** The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.
- **Partial Automation (Level 2):** The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.
- **Conditional Automation (Level 3):** The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.
- **High Automation (Level 4):** The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.
- **Full Automation (Level 5):** The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

As seen in Figure 2.1, Levels 3 through 5 are considered as stages of adoption where automated driving predominates in the driving environment, rather than the automated systems supporting the human driver's actions.

Figure 2.1 SAE J3016 Standard Core Reference for Automated Vehicles



(Source: SAE International)

This *Navigant Research Leaderboard Report* aims to assess the status of the leading automotive manufacturers, suppliers, and technology companies regarding their readiness to develop and launch Level 3, 4, and 5 systems in the next decade. Scores are boosted for those that have made a strong commitment to launching Level 1 advanced driver assistance systems (ADAS) across their full range of models and those that have already announced plans for a Level 2 system in 2017 or 2018. Scores are also boosted for companies that have publicly demonstrated Level 4 capability and provided insight into deployment plans.

Entrants such as Google/Waymo, Uber, and nuTonomy are developing the underlying technology, and in some cases, have announced partnerships with OEMs to provide base vehicle platforms targeted at production. Apple had been widely reported to be developing automated electric vehicles, but has never publicly acknowledged these efforts. In the past 6 months, Apple reportedly scaled back its automotive aspirations significantly and is not currently expect to build a complete vehicle anytime soon. Thus, the company has not been included in this evaluation.

Concerns about cost and liability for the performance of these systems are also expected to play a major role in how automated vehicles are deployed. In order to ensure that vehicles perform correctly and are properly maintained and updated with the latest hardware and software, Navigant Research expects a significant degree of vertical integration. Rather than sell these high-cost vehicles to consumers, most are expected to be made available through automated mobility services (AMS). As AMS becomes more common, this is also expected to have a negative effect on total vehicle sales. Thus, manufacturers will want to develop new business models where they provide the AMS.

Going forward, companies that are currently considered Tier One suppliers will likely still have a viable business providing components and subsystems—even if they do not pursue the services business. However, the lack of vertical integration may hurt revenue growth prospects in the long run. For this reason, scores for companies that are more actively involved in developing the services to support deployment of automated driving have been boosted.

2.2 Market Drivers

The primary market drivers continue to be a desire to reduce the number of injuries and deaths resulting from traffic accidents, along with other societal costs such as the time wasted when people are stuck in traffic jams and excessive fumes from idling engines. Automated driving also offers significant potential to reduce overall energy use by eliminating driver behavior as a variable in vehicle control, enabling optimization for efficient operation. Improving traffic flow by reducing accidents and unpredictable human driver behavior can also reduce energy consumption. In addition, enabling automated parking in available spots can reduce the need to drive around in search of an empty space.

Increasing comfort and reducing boredom for commuters would be a real consumer benefit of automated driving. Automated vehicles also present the possibility of enhanced mobility for people that may not be able to drive traditional vehicles as a result of age, disability, or lack of access to mass transit. Shared fleets of on-demand automated vehicles with high utilization rates have the potential to reduce urban congestion and improve air quality in cities. For existing ride-hailing companies such as Uber and Lyft, AMS also provides the ability to dramatically shift their cost structure by eliminating the need to pay human drivers. However, in the near to mid term, it is not clear whether there would be any actual cost savings or margin improvement for these companies due to the need for substantial capital investment for the purchase or manufacture of automated vehicles.

For incumbent OEMs, the addition of AMS to their business structure opens the potential for new revenue streams as overall vehicle sales plateau in developed markets. In a market environment where affordability of new vehicles is an increasing concern, AMS also provides a mechanism for OEMs to deploy these higher cost vehicles to price-sensitive customers.

2.3 Market Barriers

Increasingly stringent regulatory pressures on fuel efficiency, emissions, and occupant safety over the next decade will continue to drive up the cost of new vehicles. Depending on how the regulatory environment evolves under the new US administration that took office in January 2017, this may be less of an issue in this market, but that remains highly uncertain. This rising cost of new vehicles will make it more difficult to offer new technologies that would further drive up cost and potentially make vehicles less affordable for consumers—such as automated driving.

Reliability and security concerns also pose major barriers to the adoption of automated driving. Connectivity will be a key enabler of robust automated driving systems, and cybersecurity for these connected vehicles has become a top priority for the automotive industry. As security researchers delve deeper into the networks of vehicles, they are likely to find more vulnerabilities that have the potential to allow vehicle systems to be controlled remotely by bad actors. OEMs and suppliers will have to continue taking a holistic approach to security to gain the trust of consumers.

Issues around the liability for crashes or other failures of automated vehicles is another potential barrier. With traditional, human driven vehicles, manufacturers and suppliers are responsible for design and construction defects, but drivers are generally responsible for the actions they take while in control. In automated vehicles, a software algorithm running on a computer is effectively the driver, so the developers of those algorithms should be responsible for any failings of the system. Until a complete legal framework for this liability is defined and codified into law, it is not clear if consumers will accept the technology—especially if they are still expected to take control of the vehicle from time to time. This is likely to be a contributing factor to manufacturers retaining control of these highly automated vehicles rather than selling them to consumers.

2.4 Market Trends

ADAS are rapidly proliferating across vehicle lineups, even on entry-level models at more affordable prices. Entry-level vehicle models are increasingly available with camera-based lane departure warnings and blind spot monitoring; these features are no longer limited to premium or luxury models and backup cameras are now mandatory in the US market. Such ADAS features will be available in the newest model of the bestselling car in the US market—the Toyota Camry. Introduced in January 2017 at the North American International Auto Show, the 2018 Camry will feature a comprehensive ADAS suite with radar-based adaptive cruise control, lane keeping system with steering assist, and pre-collision warning with pedestrian detection as standard equipment. In October 2015, Tesla launched its Level 2 Autopilot system on the Model S and similar systems have been introduced by Volvo, Mercedes-Benz, and soon General Motors (GM).

Most major OEMs and Tier One suppliers are actively developing Levels 2, 3, 4, and 5 automation technology—even though many of them express doubt that Level 5 systems will gain widespread adoption for anything but limited use urban mobility vehicles before the late 2020s. It is widely believed that Level 2 systems will provide significant safety and efficiency benefits. Most initial deployments of Level 4 systems in the early 2020s are being targeted at AMS, although some premium brands, including Tesla, Volvo, and BMW, have indicated that they plan to make this capability available to individual consumers. Level 3 systems may actually see limited deployment due to concerns with the time required for control hand-off to the driver when the automated system is unable to handle a situation. Many manufacturers have indicated that they opted not to develop Level 3 systems.

Section 3
THE NAVIGANT RESEARCH LEADERBOARD

3.1 The Navigant Research Leaderboard Categories

Navigant Research scored the vendors in this *Navigant Research Leaderboard Report* according to four categories: Leaders, Contenders, Challengers, and Followers. These categories are defined below.

3.1.1 Leaders

Leaders are companies that scored 75 or above in both Strategy and Execution. These companies have differentiated themselves from the competition through exceptional technology development, strong supplier relationships, and a viable business model. Leaders are currently in the strongest position for long-term success in the automated driving market.

3.1.2 Contenders

Contenders are manufacturers that scored above 50 in both Strategy and Execution but are not yet leaders in this market. While these companies have a solid foundation for growth and long-term success, they have not yet attained a superior position in the market. They are well-positioned to become Leaders, but have not yet fully executed their technology launches and or articulated a strong-enough supporting business model for automated driving.

3.1.3 Challengers

Challengers are companies that scored higher than 25 in both Strategy and Execution but are not yet Contenders for market leadership. While these companies are fundamentally sound, they face significant challenges in the automated vehicle market stemming from a lack of strategic vision or investments or risks to successful potential execution. Challengers may also be early in their arc of ADAS or self-driving feature launches, therefore resulting in Execution scores that are based on few or no relevant production launches.

3.1.4 Followers

Followers are vendors that have failed to distinguish themselves and scored below 25 in either Strategy or Execution. These companies are not currently expected to challenge the Leaders unless they can substantially alter their strategic vision and expand their resources. None of the companies assessed in this *Leaderboard* fell into this category.

3.2 The Navigant Research Leaderboard Grid

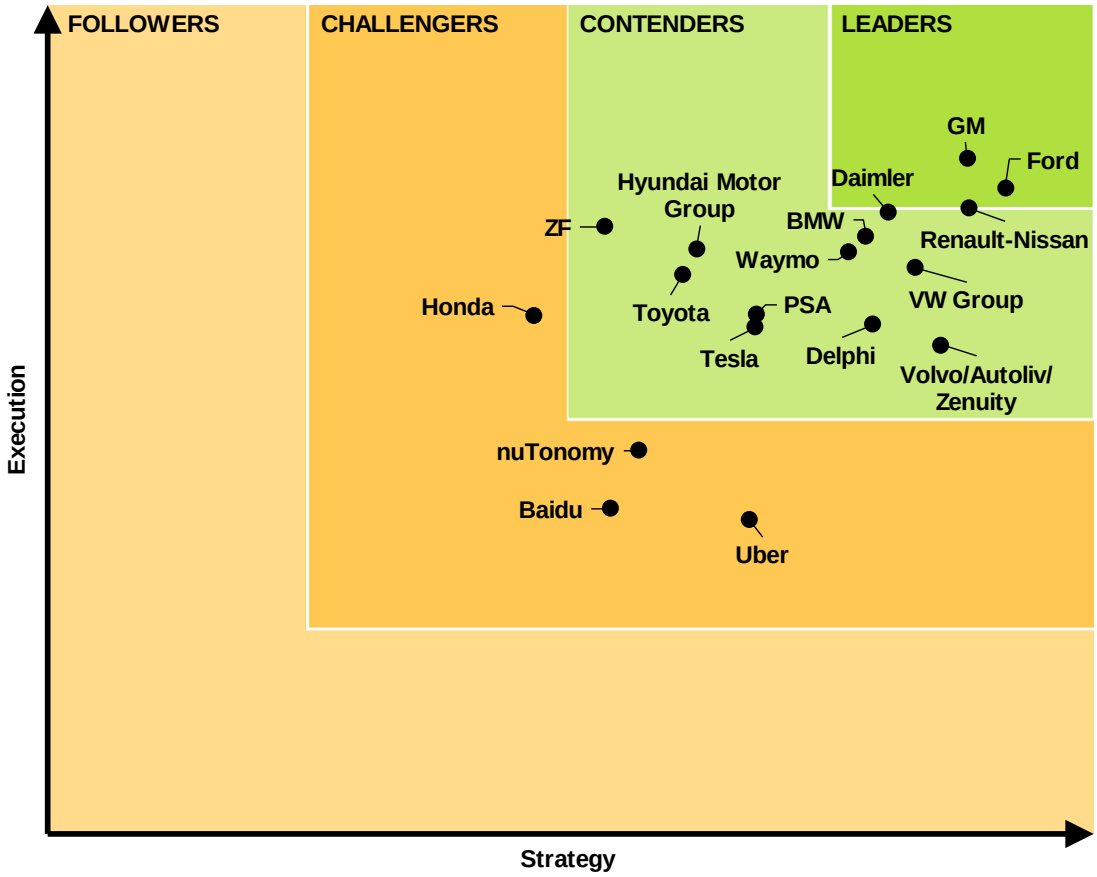
Many traditional OEMs were initially skeptical about the commercial prospects for automated driving. Most notable was Ford under its previous CEO Alan Mulally, who frequently spoke publicly about how people actually enjoy driving. However, through a combination of strategic investments and development of supporting business models, Ford and other OEMs have begun to move to the forefront. Several OEMs and suppliers have even announced production plans, most prominently Ford, GM, Delphi, and BMW.

In this 2017 analysis, Navigant Research has identified the top four Leaders in this technology today to be Ford, GM, the Renault-Nissan Alliance, and Daimler. They are closely followed by Volkswagen (VW) Group, BMW, Waymo, and Volvo/Autoliv/Zenuity, which are highly ranked in the Contenders category. These eight companies are projected to lead the race in putting the first Level 4 automated driving systems into production.

Six more companies—Delphi, Hyundai Motor Group, PSA, Tesla, Toyota, and ZF—make up the next group of Contenders. These are companies that could step up to join the group above if some of their weaker areas in Strategy and Execution are addressed. While they have the basic infrastructure and capability in place, most have decided to be cautious in their rollout plans. The exception to this is Tesla, which has an aggressive automated policy but is limited by unrelated business issues, including profitability and limited distribution. The remaining Challenger companies all have potential to break through to the next grouping, but face either business model or technology challenges.

There are several other Tier One suppliers with traditional strength in active safety systems that are capable of providing all of the elements of automated driving systems, including Continental, Bosch, and Denso. These companies either have not articulated a vision to produce full-stack automated driving solutions or have specifically said that they will work with their OEM customers either to provide components or work on integration. These suppliers have also shown less commitment to services. As a result, they have been excluded from this ranking.

Chart 3.1 The Navigant Research Leaderboard Grid



(Source: Navigant Research)

Table 3.1 The Navigant Research Leaderboard Overall Scores

Rank	Company	Score
1	Ford	85.0
2	GM	84.8
3	Renault-Nissan Alliance	82.0
4	Daimler	77.7
5	VW Group	75.9
6	BMW	75.2
7	Waymo	73.4
7	Volvo/Autoliv/Zenuity	73.4
9	Delphi	70.7
10	Hyundai Motor Group	66.4
11	PSA	65.3
12	Tesla	64.5
13	Toyota	64.2
14	ZF	64.0
15	Honda	55.1
16	Uber	54.5
17	nuTonomy	51.6
18	Baidu	47.1

(Source: Navigant Research)

Section 4
COMPANY RANKINGS

4.1 Leaders

With scores above 75 in both Strategy and Execution, companies ranked as Leaders are already considered advanced in terms of the development of the foundation ADAS technology and have accumulated some years of experience in production. Solid plans for bringing Level 2 and above systems to production in the next few years have been announced.

The Leaders have supplemented their technological capabilities with prominent plans to deploy automation for AMS including in-house development of such services. Much of the sensor technology for ADAS is coming down in price and the advancements are primarily on the electronics and software side, as previously discrete functions are being integrated.

4.1.1 Ford

Overall Score: 85.0

Strategy: 91.5

Execution: 77.9

Dearborn, Michigan-based Ford Motor Company was an early participant in the Defense Advanced Research Projects Agency (DARPA) Grand Challenge program, developing its automated F-250 pickup truck largely in-house as opposed to other automakers that partnered with universities. During much of the tenure of Alan Mulally as CEO, the company deemphasized full automated driving in favor of offering ADAS capabilities on mainstream models. As recently February 2012 at the Mobile World Congress in Barcelona, Executive Chairman Bill Ford laid out a blueprint for mobility that envisioned fully automated vehicles arriving in the late-2020s. In mid-2013, Ford began testing an in-house developed automated driving system on a fleet of Fusion hybrid sedans and expanded its test program to include a wide variety of environments, including winter driving on snow covered roads and lights-out night driving in the desert using only its sensors.

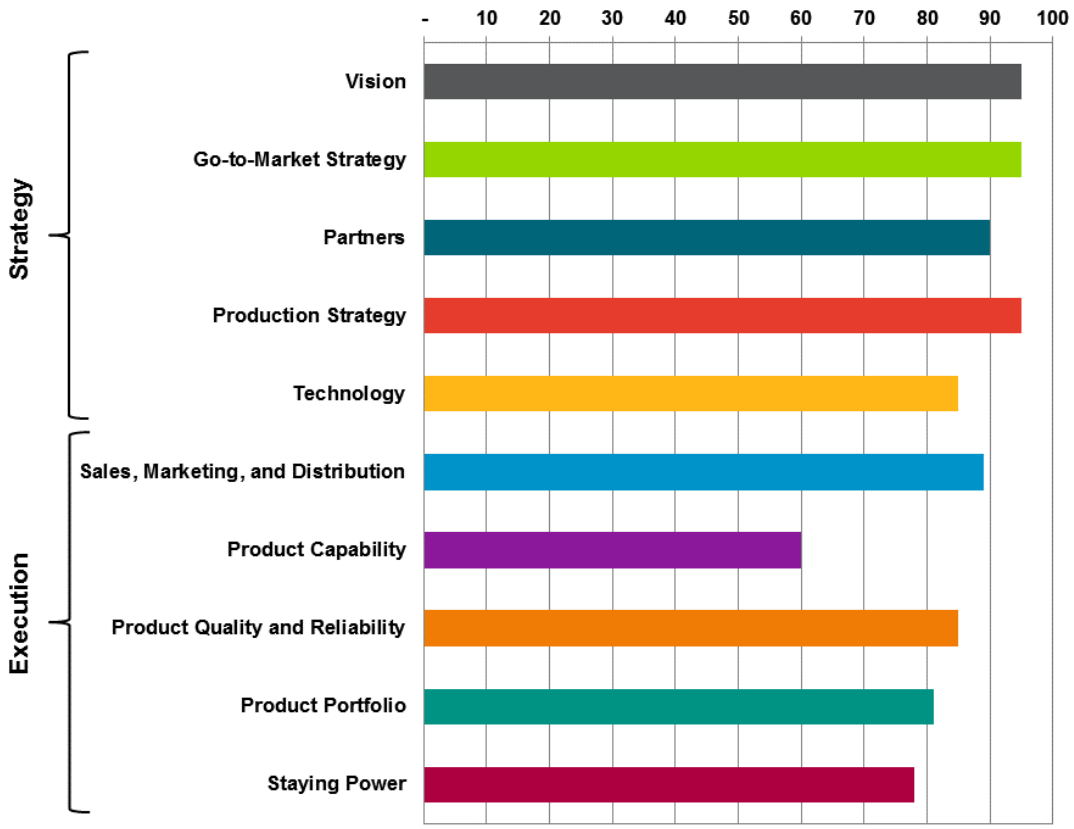
Ford has also augmented its technology development with a range of strategic investments in companies producing supporting technologies and services, with 2016 being a particularly busy year. In August 2016, Ford announced plans to mass-produce a dedicated Level 4 capable automated vehicle for ride-hailing services in 2021. The promised vehicle will not have a steering wheel or pedals. In early January 2017, Ford revealed its second-generation automated Fusion hybrid development vehicle with new generation sensors that are more tightly integrated into the vehicle. On January 3, 2017,

CEO Mark Fields announced a $700 million investment in the Flat Rock Assembly Plant in Michigan that includes support for production of the Level 4 vehicle.

Over the course of the year, Ford invested in or acquired Civil Maps, Saips, Velodyne, Chariot, and several other companies that will help it achieve full vertical integration for automated mobility—from the sensing systems to the consumer services. Much of the services development is being conducted under the umbrella of the newly formed Ford Smart Mobility LLC subsidiary. In February 2017, Ford also augmented its ability to recruit software engineers from the technology industry with the announcement of a $1 billion investment in a startup called Argo AI. Ford will be a majority shareholder in the company, but a significant portion of the equity will be set aside to provide stock option grants to employees, as Silicon Valley companies typically do. Argo AI plans to have 200 software engineers on its development team by the end of 2017. Many of them will be transitioning over from the existing Ford virtual driver system engineering team, along with an undetermined number of new recruits. The Argo team will be spread across locations in southeast Michigan, Pittsburgh, Pennsylvania, and the San Francisco Bay Area.

www.ford.com

Chart 4.1 Ford Strategy and Execution Scores



(Source: Navigant Research)

4.1.2 GM

Overall Score: 84.8

Strategy: 87.9

Execution: 81.6

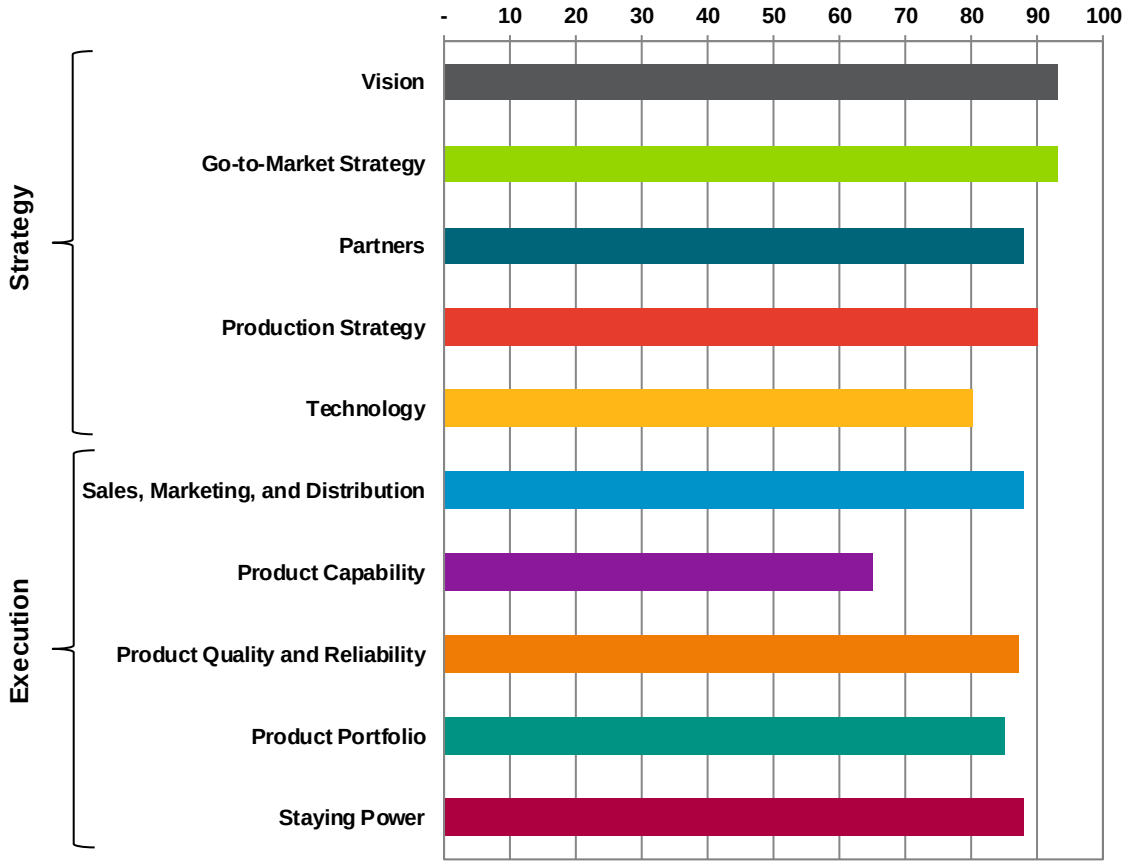
Detroit, Michigan-based GM had a busy year in 2016, beginning with the announcement of a $500 million investment in ride-hailing provider Lyft. A key component of that investment was a partnership to develop automated ride-hailing services. GM also acquired San Francisco startup Cruise Automation to integrate its image recognition capabilities into the automated driving stack it was developing. The Chevrolet Bolt EV was specifically optimized for use in ride-hailing services with a small footprint combined with a tall stance that makes for a comfortable environment for passengers and easy ingress/egress.

Following the Cruise Automation acquisition and Lyft investment, GM made the Bolt its primary development platform for automated driving. Late in 2016, after production of the Bolt began for customer deliveries, CEO Mary Barra announced that GM would begin building automated driving prototypes on the assembly line in Orion, Michigan by spring 2017. In that same announcement, Barra declared that GM would begin testing the automated Bolt on Michigan roads during the coming winter.

In the wake of the 2015 ignition switch recall GM also upgraded its safety engineering, leading to a delay in the launch of the Level 2 Super Cruise system on the Cadillac CT6. GM added additional safety features and redundancy to ensure that the system would only be used in appropriate scenarios and protect occupants in the event of a system failure.

www.gm.com

Chart 4.2 GM Strategy and Execution Scores



(Source: Navigant Research)

4.1.3 Renault-Nissan Alliance

Overall Score: 82.0

Strategy: 88.1

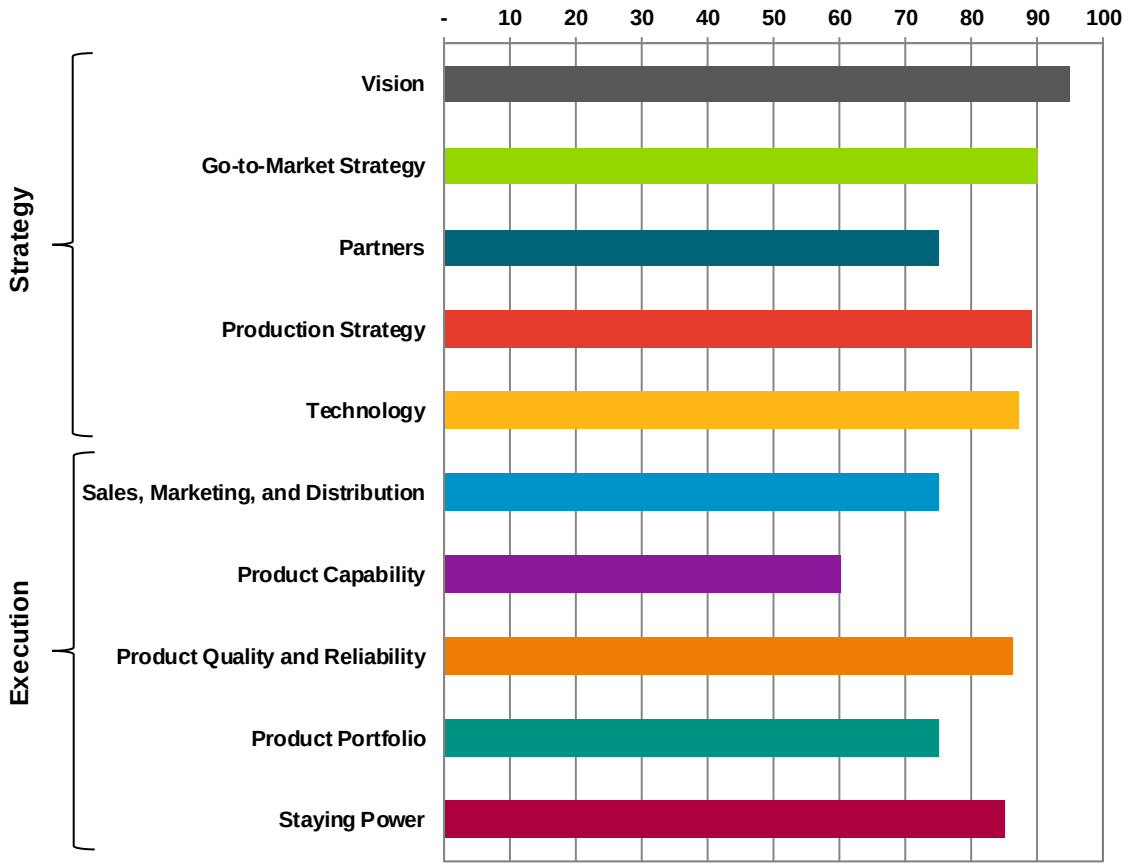
Execution: 75.5

Nissan and Renault have had a mixed record of applying ADAS to mainstream models, with the premium Infiniti brand being the first to deploy lane departure prevention back in 2009. Today, most high-volume models offer adaptive cruise control and lane keeping systems available. Over the last several years, Nissan has been testing automated technology on the LEAF EV, mostly in Japan and more recently in California. Carlos Ghosn, CEO of Nissan and Renault, has stated on numerous occasions that Nissan will have automated vehicles in production by 2020.

In 2016, Nissan deployed its first Level 2 automation system in the Japanese market, the Serena van, branded as ProPilot. At the 2017 CES, Ghosn announced that the second-generation LEAF would be revealed in the near future, and that it would include the same single lane, highway driving ProPilot used on the Serena. Over the next several years, the company plans to launch more capable iterations that include the capability to automatically change lanes and eventually drive in urban areas. Ghosn also announced a partnership with NASA to connect automated vehicles with human operators when they encounter situations that vehicles do not know how to deal with (such as construction zones). The human operators will be able to view real-time sensor information from the vehicle and manually provide a path around the obstacle. It is not clear how scalable this approach would be, but connectivity will enable other vehicles on the same route to automatically follow the same path.

www.alliance-renault-nissan.com

Chart 4.3 Renault-Nissan Alliance Strategy and Execution Scores



(Source: Navigant Research)

4.1.4 Daimler

Overall Score: 77.7

Strategy: 80.4

Execution: 75.0

Daimler brand Mercedes-Benz has long been a leader in introducing new automotive technology in both consumer and commercial vehicles. One of the first with anti-lock brakes and adaptive cruise control, Mercedes is now offering an option for semi-automated freeway and traffic jam driving modes on the 2016 S-Class, and a more capable version launched on the new E-Class in 2016, as well. While Daimler has been a leader in launching these systems, independent reviews have indicated that they are less capable and functional than some other brands, notably Tesla.

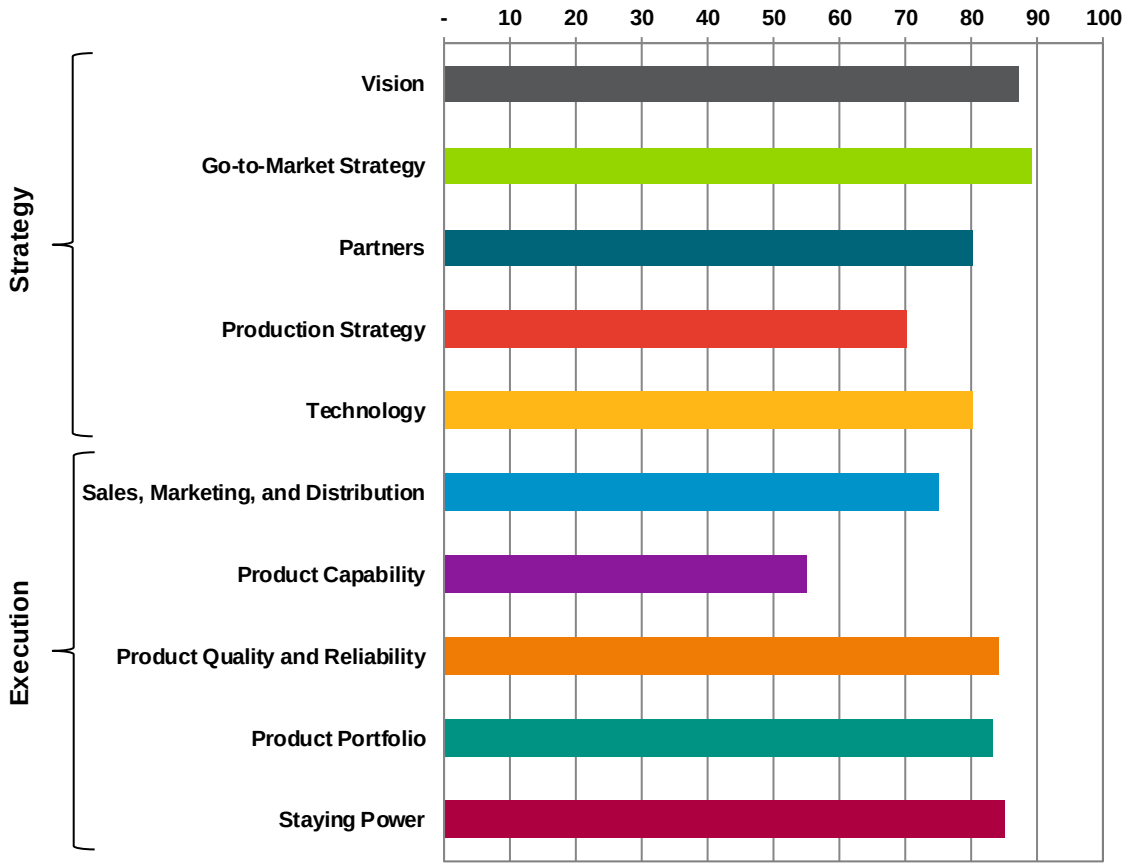
In May 2015, Daimler's Freightliner division became the first company to get a road testing license for an automated heavy duty truck in Nevada. The Freightliner Inspiration truck adopts many of the sensing and actuation technologies from the Mercedes-Benz Future Truck 2025 concept that was demonstrated in Germany in 2014. The Inspiration is now undergoing testing on public roads in Nevada in preparation for bringing the Highway Pilot semi-automated system to market in the coming years.

Daimler's commitment to ADAS consistently has been strong, and the company has been active in promoting new features and highlighting future technology in concept vehicles. Historically, it has taken a few years from flagship launch for the latest options to become available on higher-volume models, but this delay seems to have become shorter in recent years. In January 2017, Daimler announced a partnership with Uber to deploy its automated vehicles on the ride-hailing platform in the coming years in addition to in-house services such as the Car2Go sharing service.

Daimler is likely to continue as a leader in technology development; however, its position as a premium brand makes it inherently less accessible to mainstream audiences. Daimler is also more reliant on its supplier base for some of the core technologies with fewer direct investments, which may put it at a disadvantage. While Daimler is active in mobility services and may be able to leverage the Smart brand for affordable services, it may not be able to grab as much market share as the companies ahead of it in the rankings.

www.daimler.com

Chart 4.4 Daimler Strategy and Execution Scores



(Source: Navigant Research)

4.2 Contenders

The Contenders ranking is defined by companies that score more than 50 but under 75 in both Strategy and Execution. Companies at the top of this category are close to the Leader rankings, and incremental improvements will see them move into that category. Developing stronger partnerships with suppliers that may or may not include equity investments as well as more active development of new business models around AMS could help the leading Contenders move up to the top group. Another factor that could see companies move up or down in future rankings is consumer trust. Companies that ensure their technology is robust prior to public deployment may gain an advantage over those that sell it prematurely. The technology also needs to be secure and resilient to electronic attacks. A company that is the victim of a cyber attack could see its products rejected by the market.

4.2.1 VW Group

Overall Score: 75.9

Strategy: 82.9

Execution: 68.3

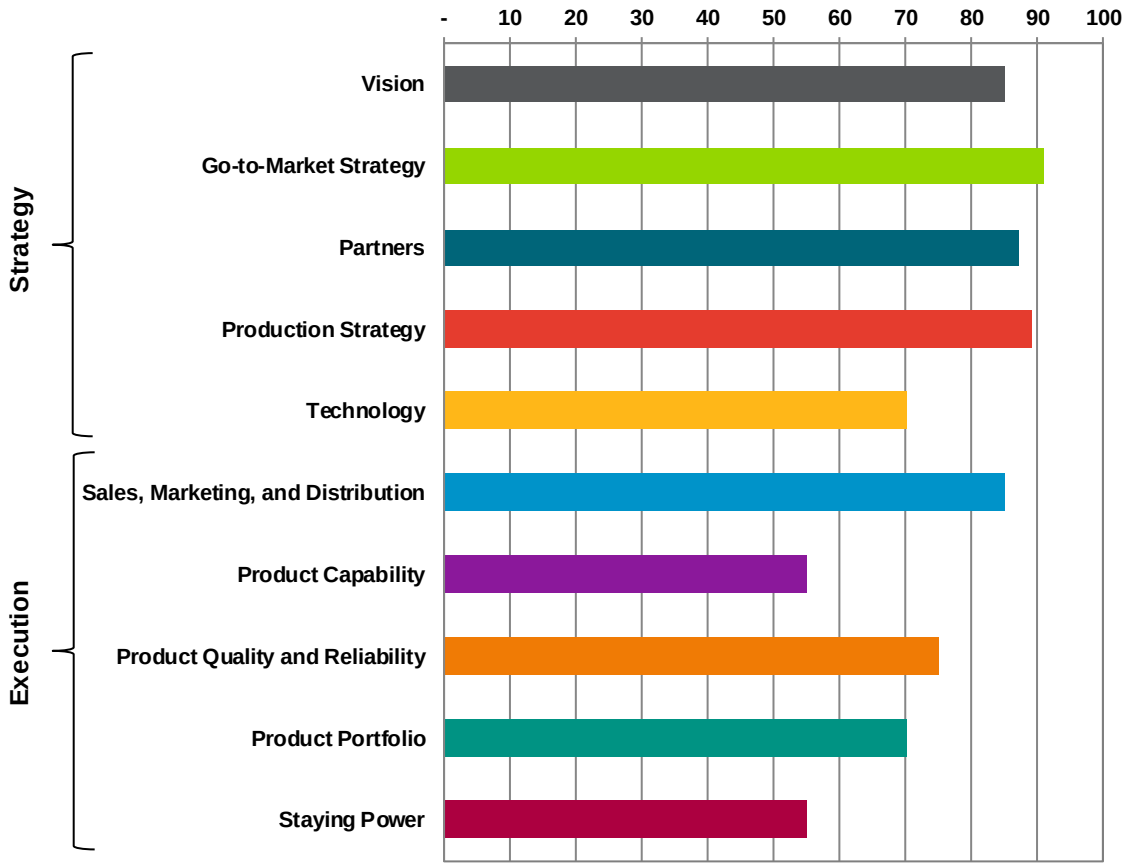
The Wolfsburg, Germany-based VW Group has been active in the development of automated driving since winning the initial DARPA Grand Challenge in 2006 in collaboration with Stanford University. Since then, the company's Audi brand has taken the lead on commercializing automated driving, and is expected to launch a system with at least Level 2 capability when the new generation A6/A7/A8 arrives in late 2017.

While the Audi brand has been the public face of the VW Group's automation since 2010, large scale deployment of automation for mobility services is likely to be done through the more mainstream VW brand, especially through its new electrified platforms. VW Group has substantially accelerated its electrification efforts across all of its volume brands in the wake of the diesel emissions scandal in 2015. The I.D. concept shown at the 2016 Frankfurt Motor Show will be the first of many models to debut on the company's new dedicated electric platform in 2020. By 2025, VW intends to offer high-level automation on all of these models, supplementing the capability on premium brand models from at least Audi and Porsche (and possibly Bentley) that will debut in the 2021 timeframe.

VW has been an investor in ride-hailing company Gett, and it announced a new spinoff mobility company called Moia in December 2016. Through Moia, VW hopes to generate a major portion of revenue from services by 2025. At the 2017 Geneva Motor Show, VW showed a concept for an automated mobility shuttle called the Sedric, and the company expects its mobility services to rely heavily on automation in the 2020s.

www.vw.com

Chart 4.5 Volkswagen Group Strategy and Execution Scores



(Source: Navigant Research)

4.2.2 BMW

Overall Score: 75.2

Strategy: 78.2

Execution: 72.1

Like many of its German competitors, BMW has traditionally developed much of its automotive technology in partnership with Tier One suppliers Bosch and Continental. However, for high-level automation, it is bringing more of the technology in-house. In 2016, BMW launched a partnership with Mobileye and Intel to develop automated driving technology using processors from those companies.

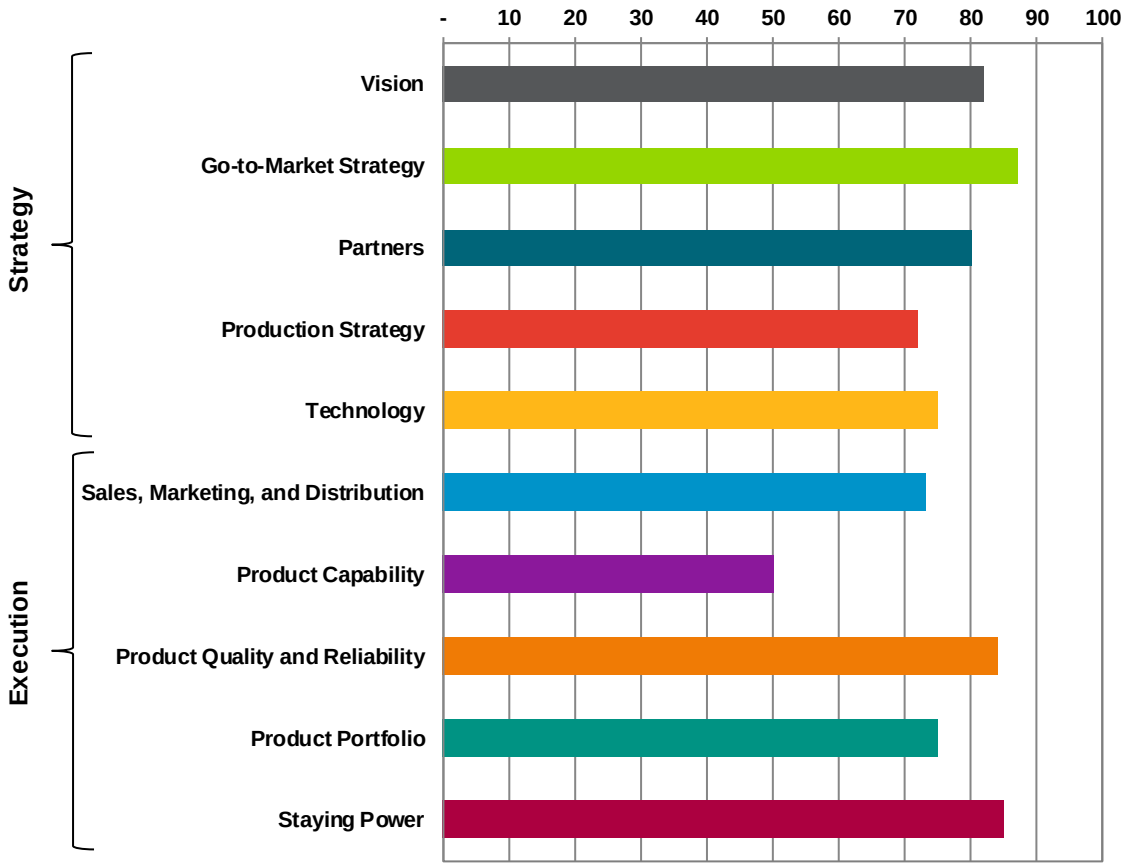
Similar to other manufacturers, BMW tends to introduce leading-edge technologies in top-of-the line vehicles—in this case the sixth-generation 7 Series sedan launched in late 2015 and the new 5 Series debuting in early 2017—before eventually migrating features through the rest of the lineup as costs come down. As well as the Driving Assistant Plus package, the new 7 Series offers several semi-automated capabilities. One of these is remote parking assist, which enables the driver to park the car into a perpendicular space while commanding it from an advanced key fob. The Plus package features both traffic jam assist and lane keeping with active side collision protection. Over the coming years, BMW will be expanding availability of its Level 2 systems and plans to launch Level 3 and 4 systems by 2021. While automation is expanding to other BMW-brand vehicles, there has been little discussion about the more affordable MINI-brand, which itself remains more upmarket from brands like VW.

BMW is also actively involved in developing its own mobility services, most prominently its ReachNow carsharing system. ReachNow already offers one-way carsharing in the Seattle area that enables drivers to collect a car at one location and drop it off somewhere else. Ongoing development of ReachNow is expected to eventually include automated mobility that will give riders the ability to summon a vehicle to their location.

With a focus on driver experience, Munich, Germany-based BMW has always been conservative about introducing options that take control away from the driver. As a result, it has put a lot of effort into the human-machine interface. In 2017, BMW demonstrated its HoloActive Touch HMI that projects virtual buttons that the user can press, and that provides haptic feedback using ultrasonic transducers.

www.bmw.com

Chart 4.6 BMW Strategy and Execution Scores



(Source: Navigant Research)

4.2.3 Waymo

Overall Score: 73.4

Strategy: 76.6

Execution: 70.2

Late in 2016, the Google self-driving car project that was launched as an experiment within the X lab in 2009 was spun out as a separate company called Waymo under the umbrella of Alphabet, Inc., the holding company that now owns Google. At the 2017 NAIAS, Waymo CEO John Krafcik officially revealed the company's next generation development platform, an automated Chrysler Pacifica Hybrid. In May 2016, Google announced a limited partnership with Fiat Chrysler Automobiles (FCA) to purchase 100 of the minivans and work with FCA engineers to integrate the automated driving stack. However, Waymo is not collaborating with FCA on development on an ongoing basis and sees FCA only as a vehicle platform provider. Waymo is widely considered by much of the media to be the leader in the development of automated driving. This is a result of its transparent with its program and its hiring of many of the top engineers and researchers who were involved in the DARPA Grand Challenge efforts, including former program leader Chris Urmson.

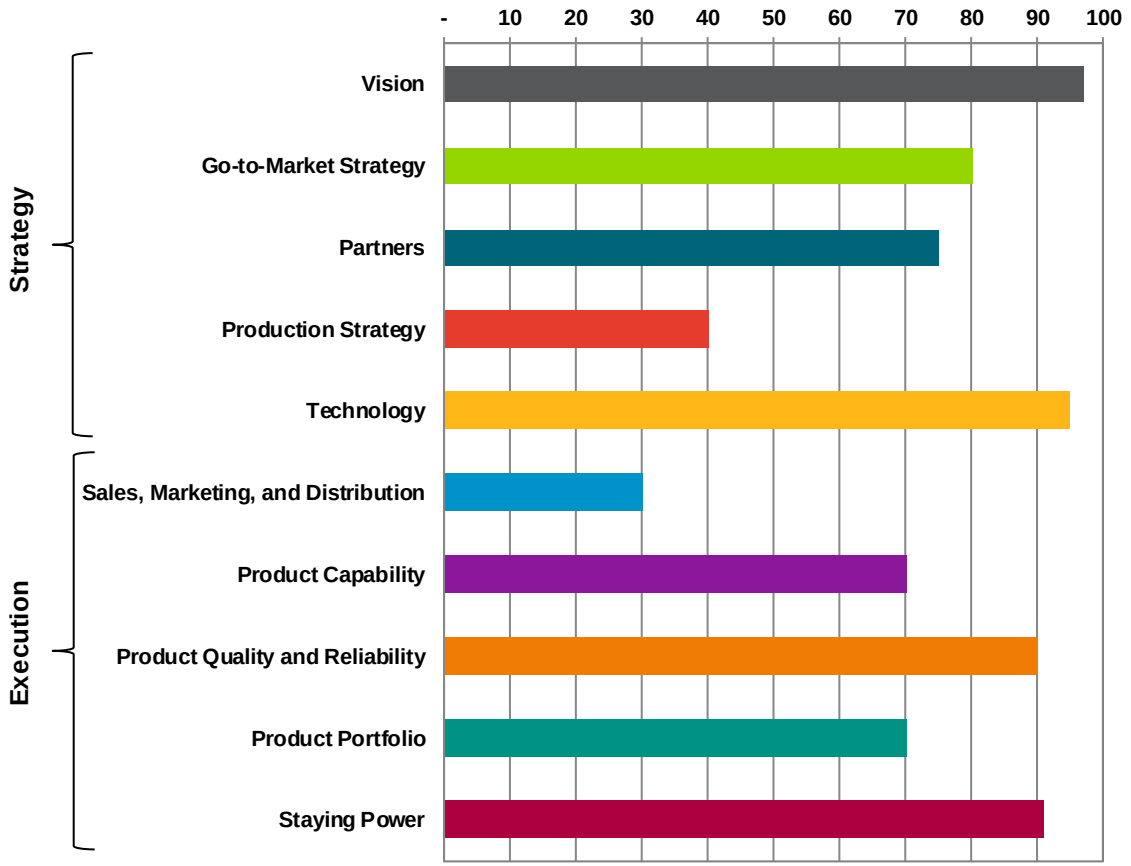
A major component of Krafcik's NAIAS announcement was that Waymo has shifted from using off-the-shelf sensor hardware to design and manufacturing all of the sensors and processing platforms in-house. Since launching the project in 2009, Waymo has reduced the cost of sensors by 90%. Since launching the self-driving car program, Waymo's test fleet has accumulated more than 2.5 million miles of real world testing, including nearly 636,000 miles in 2016. According to data submitted to the California Department of Motor Vehicles, Waymo vehicles have by far the lowest rate of disengagement of any company that is publicly testing. The company reported 0.20 disengagements of the automation per 1,000 miles in 2016.

At this time, Waymo has stated that it has no plans to become a vehicle manufacturer or supplier to the auto industry. Instead, Waymo intends to partner with other companies to provide vehicle platforms while retaining control of the automated driving stack and providing mobility services to consumers.

GV, the venture capital arm of Waymo's parent company Alphabet Inc., is an investor in Uber. Waze, the crowd-sourced navigation company owned by Google is now expanding the car-pooling service that it recently piloted in the San Francisco Bay area. Between these and other as yet unannounced developments, Waymo is likely to have a variety of mobility services in the future that it can use to commercialize its technology.

www.waymo.com

Chart 4.7 Waymo Strategy and Execution Scores



(Source: Navigant Research)

4.2.4 Volvo/Autoliv/Zenuity

Overall Score: 73.4

Strategy: 85.4

Execution: 59.0

Protecting the safety of both vehicle occupants and pedestrians has been a priority for Volvo for decades. To that end, CEO Håkan Samuelsson has articulated the company's Vision 2020, "Our vision is that by 2020 no one should be killed or seriously injured in a new Volvo car." Advanced driver assists and automation are a key component for reaching that goal. Volvo has been a leader in developing technologies such as blindspot monitoring, pedestrian detection, and automatic emergency braking. The latest generation 90 series models include a Pilot Assist system that attempts to give Level 2 capability at speeds up to 80 mph. While the adaptive cruise control component works reliably, the lane

tracking capability appears to be less dependable than what is available on some other vehicles, notably Tesla's Autopilot.

In 2016, Volvo made a number of important moves in its effort to reach higher levels of automation. In August 2016, two important partnerships were launched. Volvo agreed to collaborate with ride-hailing company Uber to develop automated vehicles for the service based on the company's scalable product architecture that underpins the XC90, S90, and V90. The first phase of this involved Volvo selling a fleet of current XC90s to Uber and assisting with integration of Uber's automated driving stack. The Volvo/Uber partnership only extends to the base vehicle development and does not include the development of automated systems.

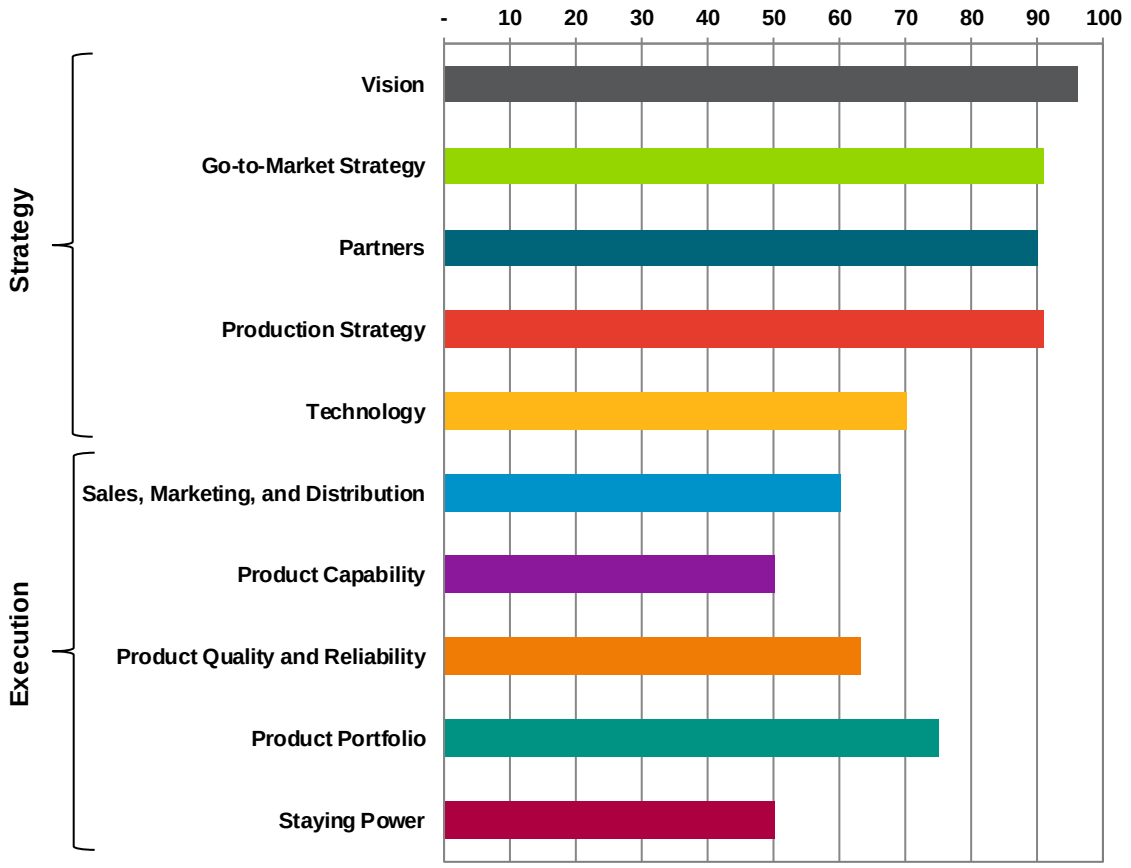
With the supplier Autoliv, Volvo has also established a new joint venture called Zenuity to develop automated driving systems that will be used by future Volvo vehicles and licensed to other OEMs. Swedish supplier Autoliv has a long-standing relationship with Volvo and supplies a wide range of passive and active safety systems to many OEMs. Both Volvo and Autoliv are contributing staff and intellectual property to Zenuity to develop the control systems for automated driving. Volvo plans to use the Zenuity controls in its future automated vehicles, and Autoliv will market Zenuity products under the Autoliv brand to the rest of the industry.

Late in 2016, Volvo also unveiled the first in a fleet of its in-house developed automated XC90s that will be utilized for the DriveMe test program. Three fleets of 100 vehicles each will be deployed to regular consumers in Gothenburg, Sweden, London, England, and an unannounced location in China for evaluation under different conditions and with different users. The Level 3 capable vehicles will provide automated driving in geofenced areas.

Volvo hopes to start selling vehicles to consumers with Level 3 or 4 capability by 2020 or 2021 and to also deploy vehicles in AMS. Up to this point, aside from supplying a vehicle platform to Uber for its development efforts, Volvo has had relatively little involvement in developing AMS and has not made any major announcements in this regard.

www.volvocars.com

Chart 4.8 Volvo/Autoliv/Zenuity Strategy and Execution Scores



(Source: Navigant Research)

4.2.5 Delphi

Overall Score: 70.7

Strategy: 78.9

Execution: 61.5

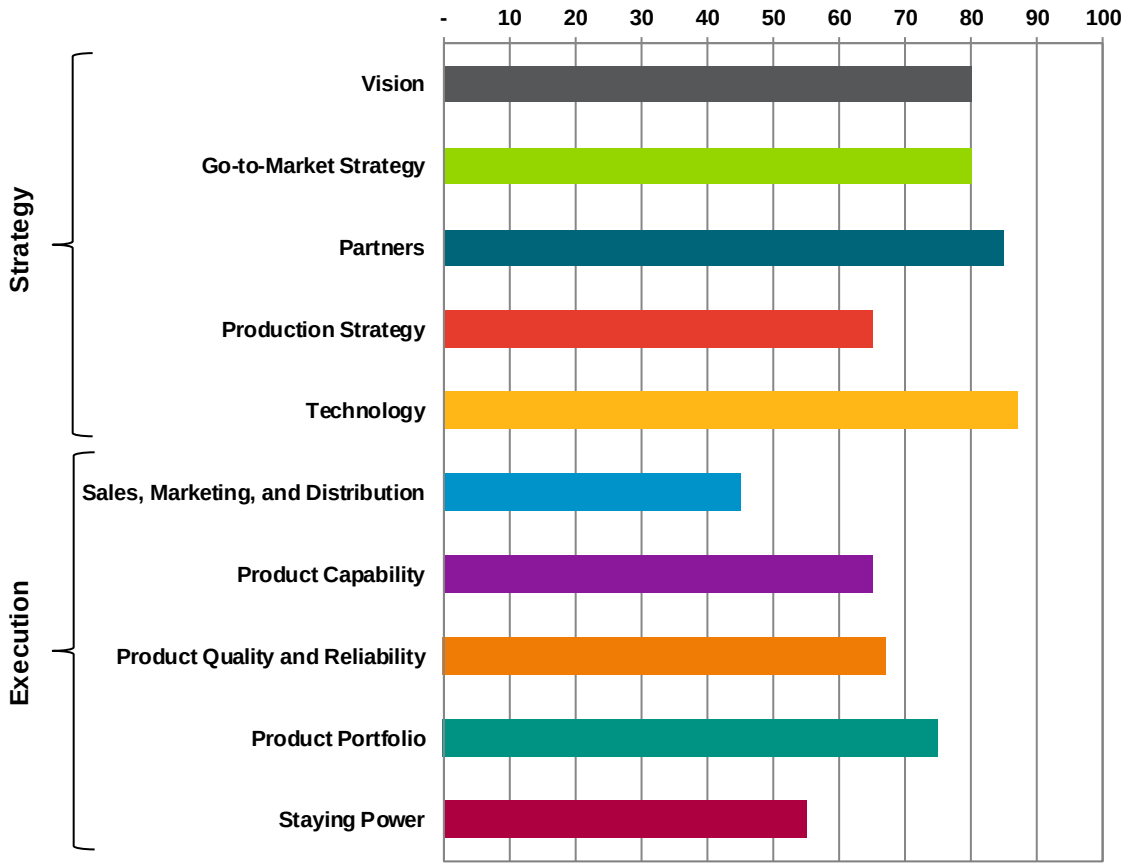
Delphi is the highest ranking automotive supplier in this edition of the *Leaderboard Report*, having rapidly moved to the forefront of automated driving development over the past 3 years. The Tier One supplier became an independent company when GM spun off its parts division in 1999. Delphi has narrowed its focus significantly in the past several years, spinning off many of its own units and leaving fuel systems, electronics, electrical architectures, and automated driving as the core businesses. Delphi has made a number of strategic investments related to automated driving, including the purchase of Ottomatika and seed investments in Quanergy systems, a developer of lidar technology.

In April 2015, Delphi engineers successfully completed the first cross-country drive in an automated vehicle, taking a prototype Audi SQ5 from Palo Alto, California to New York, with 99% of the miles reportedly in automated mode. In August 2016, Delphi and nuTonomy were named to lead a pilot project in Singapore to test first-mile/last-mile automated taxi services. The first Delphi vehicle for the multiyear project went into service in September 2016, with five more set to join in early 2017. 2016 also brought the formation of Delphi's services business unit to develop new revenue streams around mobility services.

In November 2016, Delphi announced a partnership with Intel and Mobileye to integrate chips from those companies into its multi-domain controller along with its software from Ottomatika. The Mobileye EyeQ4 and EyeQ5 chips will also enable the deployment of Ottomatika's Road Experience Management system to crowdsource real world data to produce high-definition maps for navigation and localization. Delphi hopes to be able to offer OEMs a turnkey automated driving stack consisting of sensors, electronics, and software by 2019 for introduction on vehicles coming to market by 2021.

www.delphi.com

Chart 4.9 Delphi Strategy and Execution Scores



(Source: Navigant Research)

4.2.6 Hyundai Motor Group

Overall Score: 66.4

Strategy: 62.0

Execution: 70.6

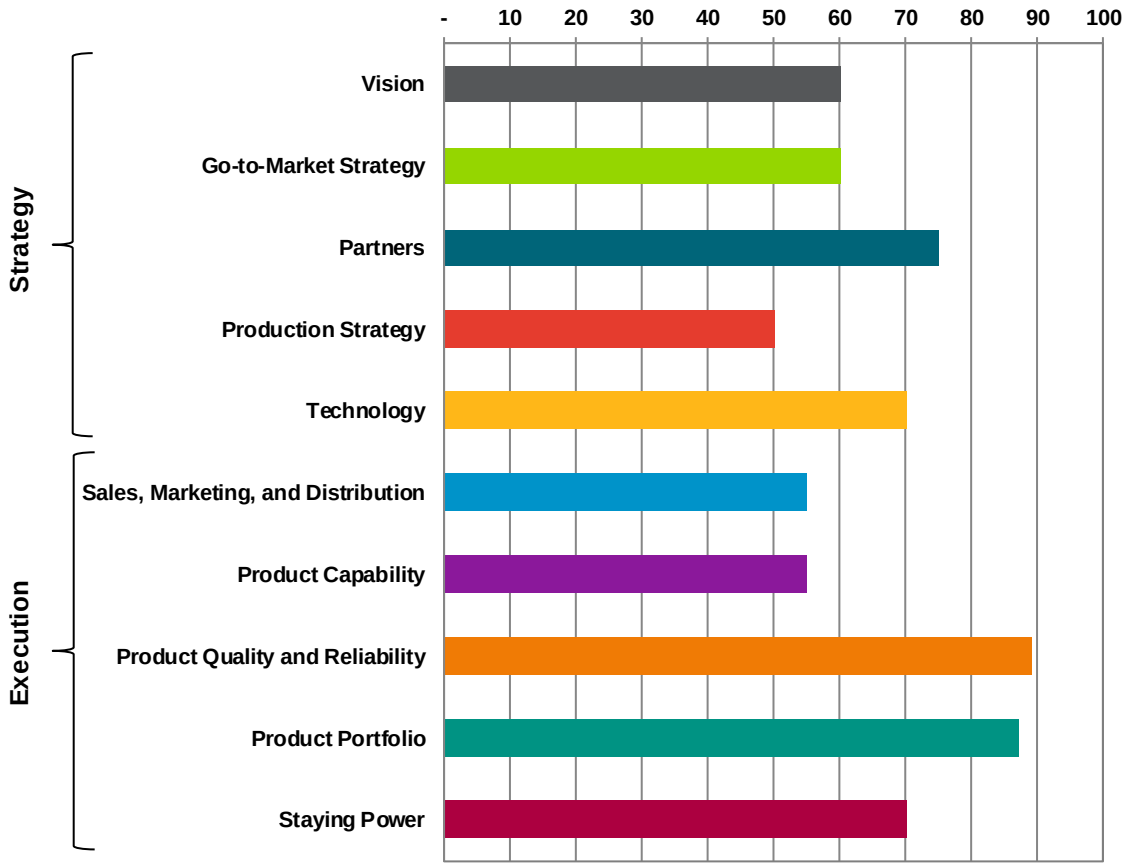
Through its Hyundai and Kia brands, Hyundai Motor Group has been developing automated driving technologies for several years now, and is targeting a production launch in the early 2020s. The most recent iteration of its automated development vehicle is based on the recently launched Ioniq battery EV, and is equipped with a sensor suite that includes three lidar sensors in the front along with short and long-range radars and a variety of cameras tuned for pedestrian detection, lane tracking, and reading traffic signals. The vehicles also use high-definition maps from the Hyundai MnSoft division of the group. Hyundai Motor Group conducted demonstrations of the automated Ioniq during the 2017 CES in Las Vegas.

However, before Hyundai Motor Group launches fully automated driving, like most mainstream OEMs it is rapidly deploying more capable ADAS systems. The lane keeping system in the 2016 Elantra compact is surprisingly capable compared to both segment competitors and more expensive vehicles, reliably detecting lane markings at speeds above 35 mph and using steering to keep the car centered nearly as well as the auto-steer functionality of Tesla's Autopilot. Most of the Hyundai, Kia, and Genesis lineup now offer similar capabilities.

Hyundai also showed off its vision for Mobility at the 2017 CES, with a smart home concept that features a dock for an automated car. The side of the car opens up, enabling its passenger cabin to become an extension of the home. One of the key drivers for automation and mobility services is to enable people who are unable to drive due to age or physical disabilities to maintain access to personal transportation. With this concept, someone could go directly from home to vehicle and off to a destination, even if they are unable to walk.

www.hyundaimotorgroup.com

Chart 4.10 Hyundai Motor Group Strategy and Execution Scores



(Source: Navigant Research)

4.2.7 PSA

Overall Score: 65.3

Strategy: 67.8

Execution: 62.8

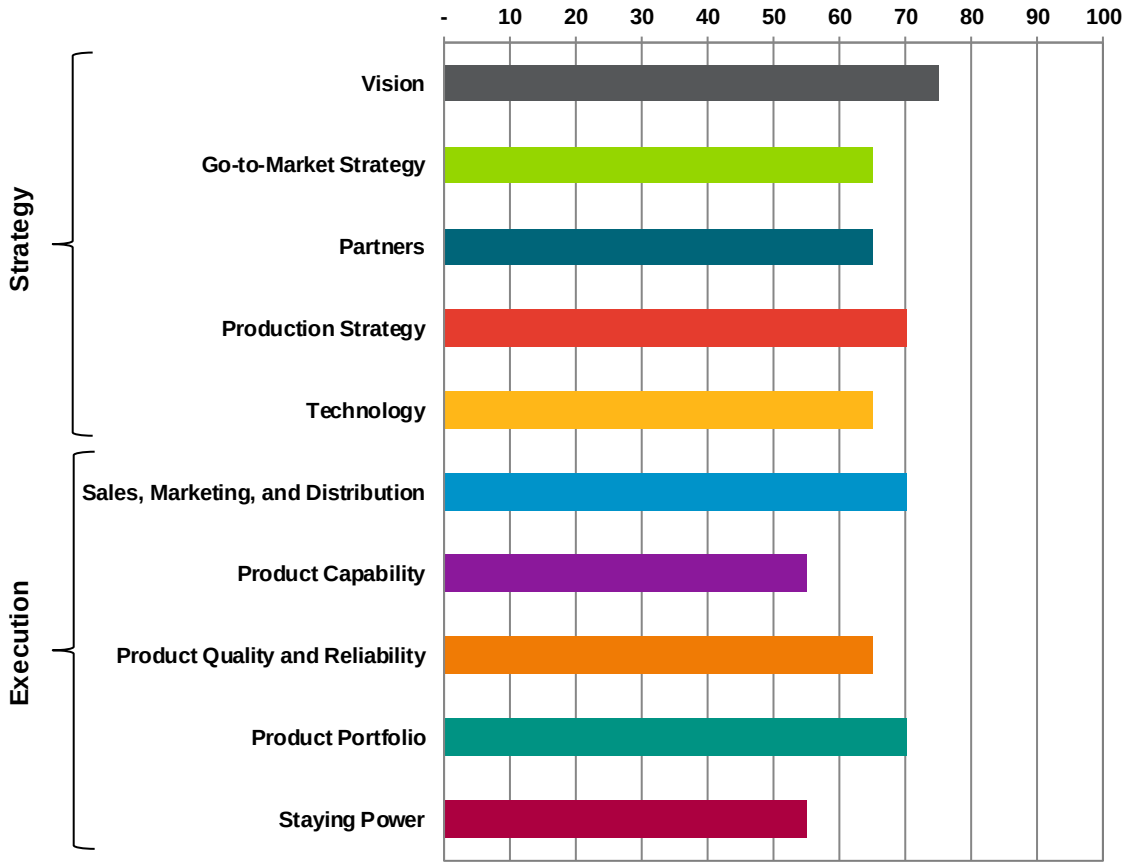
French manufacturer PSA Group produces vehicles under the Peugeot, Citroën, and DS brands. While not the first to implement ADAS on its vehicles or make public promises about automated driving, in October 2015, to coincide with the ITS World Congress, the PSA Group showed it was actively developing the technology when a specially prepared Citroën C4 Picasso completed the road trip between Paris and Bordeaux with no human intervention. In April 2016, two updated C4 Picasso cars drove from Paris to Amsterdam with the driver only monitoring for safety. PSA collaborated with TomTom for HD maps for this journey.

PSA was the first manufacturer to request permission from French authorities to conduct driverless technology testing in the country, getting approved in July 2015. To date, it has a fleet of 10 vehicles under testing. It is also working with the Automotive Technology Center of Galicia in Spain to validate interactions between drivers and self-driving cars, as well as projects with the System-X and Vedecom research institutes.

In November 2016, ZF announced that it would supply cameras, radar sensors, and software to PSA for a vehicle with self-driving features to be launched in 2018. Thought to be a new generation of the Peugeot 508, the Level 2 features are expected to include hands-free steering and braking control in congested traffic, on freeways, and for parking maneuvers. The company has announced plans to offer a more capable system by 2020, provided that European legislation allows Level 3 and 4 systems on the roads by then.

www.groupe-psa.com

Chart 4.11 PSA Strategy and Execution Scores



(Source: Navigant Research)

4.2.8 Tesla

Overall Score: 64.5

Strategy: 67.7

Execution: 61.2

Palo Alto, California-based Tesla has been the most aggressive of all OEMs in deploying automated driving technologies to its production vehicles. Beginning in September 2014, the company equipped its vehicles with a suite of radar, camera, and ultrasonic sensors to power its Autopilot Level 2 automation. In October 2015, Tesla deployed an over-the-air software update to enable the system. While Tesla has never officially called Autopilot a self-driving system, CEO Elon Musk has certainly implied that it was in presentations and interviews.

Within days after its release users began publishing videos of Autopilot driving the vehicle while they read books or in some cases even climbed into the back seat. Unfortunately, while the system was probably the most capable ADAS system available, the sensor suite was not capable of providing robust self-driving capability, especially in challenging light conditions. It also frequently disengaged without the driver being aware of it.

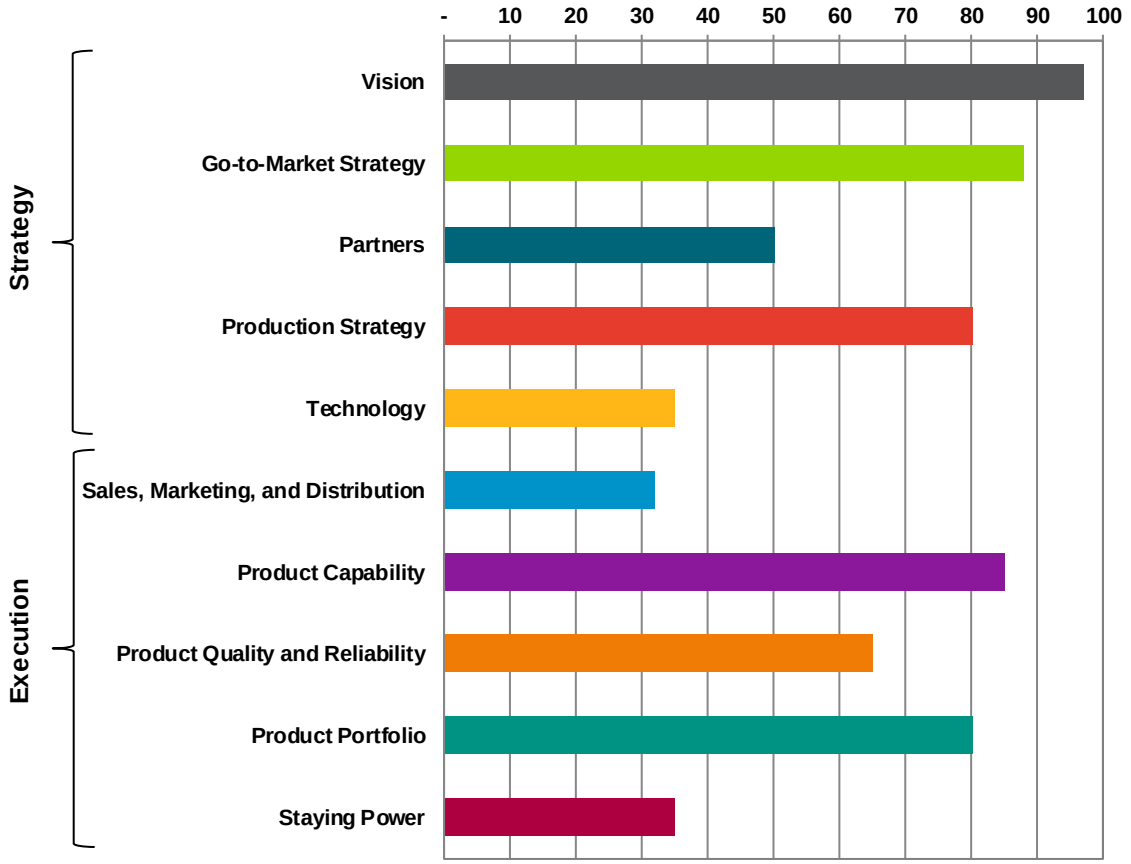
In May 2016, a fatal accident occurred when an owner operating a vehicle with Autopilot at a high speed collided with a truck turning left across his path. The truck was not detected by the camera or radar sensors. This led to a falling out between Tesla and imaging supplier Mobileye. Tesla then decided to develop its own image sensing system and deploy a second-generation Autopilot hardware suite in September 2016 using eight cameras around the car.

Yet, Tesla still does not utilize lidar technology and does not have any mechanism to keep the cameras clean in challenging weather. All of the other companies in this report use lidar as part of their sensor suite, considering it essential to provide a robust automated driving solution. While Tesla CEO Elon Musk has stated that he does not believe lidar is necessary, it is generally believed that the company aims to avoid the added cost of the technology and claim that its current vehicles will eventually be capable of full autonomy. Each type of sensor has its strengths and weaknesses, and the use of radar, cameras, ultrasonic, and lidar fused together with connectivity increases capabilities in a greater number of different conditions. As a result, Navigant Research believes that the current Tesla Autopilot 2 system will likely never be capable of Level 5 automation, and even Level 4 is likely to be more limited than other systems.

Musk has articulated a vision for providing mobility services direct from Tesla as well as a platform for individual owners to share their vehicles once they are automated. He has also made it clear that he believes automated driving is far safer than human drivers. However, the company has a limited distribution network and a history of losing money that may not improve as it moves down market.

www.tesla.com

Chart 4.12 Tesla Strategy and Execution Scores



(Source: Navigant Research)

4.2.9 Toyota

Overall Score: 64.2

Strategy: 60.8

Execution: 67.5

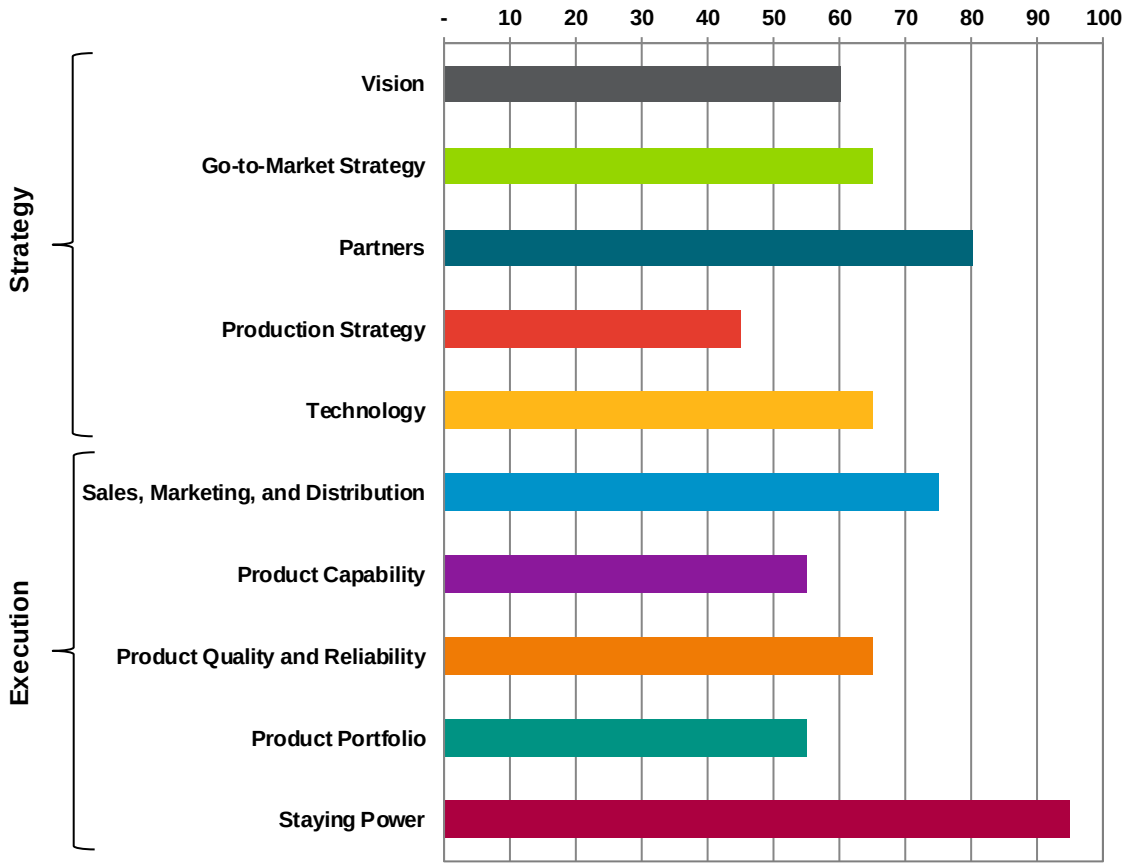
As one of the world's largest and most profitable automotive OEMs, Toyota has the resources and expertise to develop fully automated vehicles. Work on the technology has been ongoing for several years, and Toyota publicly demonstrated a Level 2 system at the 2014 ITS World Congress. In November 2015, Toyota announced the formation of the Toyota Research Institute (TRI) based in Palo Alto, California to focus on artificial intelligence (AI) and robotics with a $1 billion investment over 5 years. TRI staff will be collaborating with researchers at Stanford University and the Massachusetts Institute of Technology (MIT).

While Toyota does not want to be left behind in the race to develop automated driving technology, it is taking a much more conservative approach to deployment than many other OEMs. The company does not expect widespread deployment of high-level automation until the late 2020s.

However, it is now aggressively deploying ADAS on new models throughout its lineup. The 2018 Camry sedan that debuted at the 2017 NAIAS in Detroit, Michigan will feature a full suite of ADAS functions including adaptive cruise control, pedestrian detection, and lane keeping assist as standard equipment. In addition, the 2018 Lexus LS features a pedestrian detection system with active steering to help avoid striking a pedestrian. Toyota has invested in carsharing service Getaround and ride-hailing provider Uber. The company wants to be in the position to take advantage of when the market is ready for the technology without necessarily being the first to take the risk.

www.toyota.com

Chart 4.13 Toyota Strategy and Execution Scores



(Source: Navigant Research)

4.2.10 ZF

Overall Score: 64.0

Strategy: 53.3

Execution: 73.3

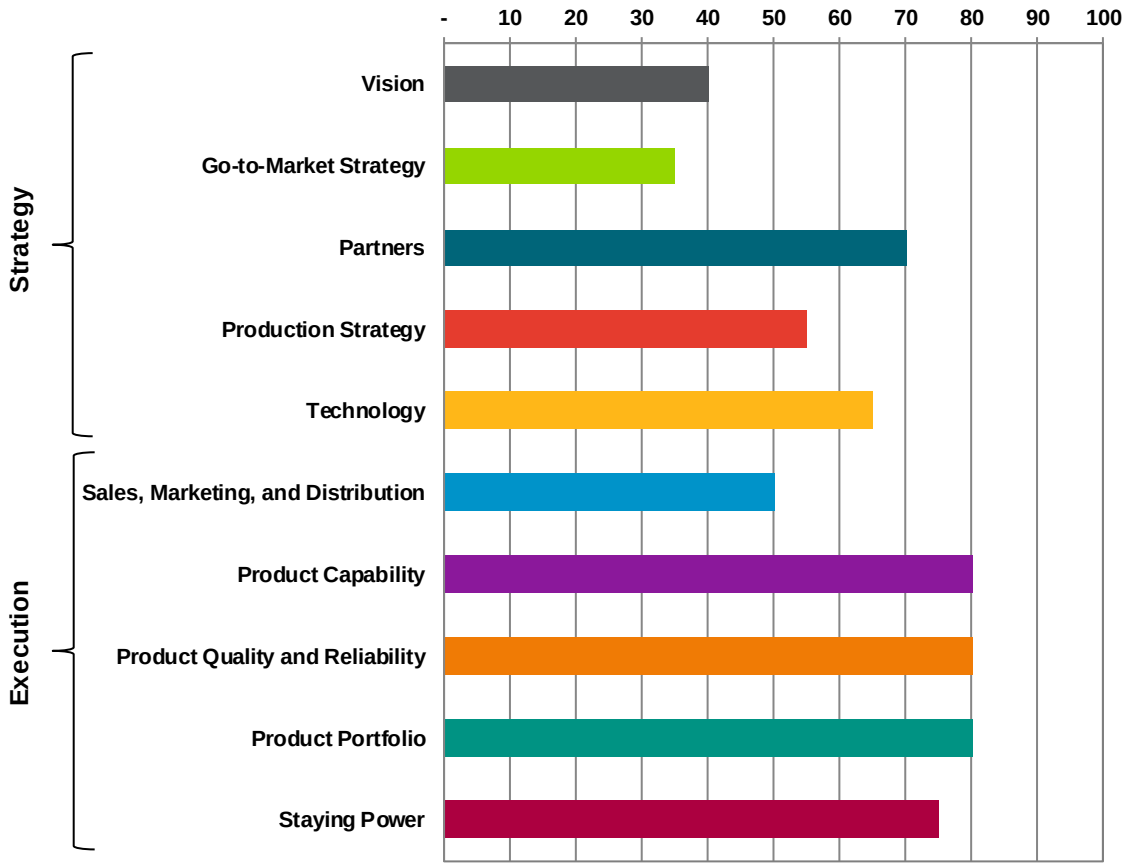
With its 2015 acquisition of TRW Automotive, ZF quickly moved into a prominent position in the development of automated driving solutions. ZF produces many of the actuators needed for automated driving, including steering systems, and TRW has long been one of the top suppliers of ADAS and active safety systems. TRW produces radar sensors for adaptive cruise control, electronic braking systems, and has a partnership with Mobileye for lane keeping systems.

At the 2017 CES, CEO Dr. Stefan Sommer announced that that ZF would be the first company to commercialize the Nvidia Drive PX2 processing platform with its upcoming ProAI electronic control unit (ECU) that will go into production in 2018. The Drive PX2 reference system is already widely used by many companies for the development of automated driving, and features two major processing units. A chip based on Nvidia's Pascal graphics processing unit (GPU) handles object detection from the sensor signals and fuses the suite of sensors into a coherent view of the world around the vehicle. The GPU is optimized for running neural network algorithms for machine learning to improve performance as the vehicle is used. The second processor is based on Nvidia's Parker chip architecture. The Parker chip is a general purpose processor handles path processing to determine where the vehicle should go and control of the actuators. This is a similar electronic architecture to the Mobileye/Intel approach utilized by Delphi and BMW.

ZF plans to utilize the ProAI ECU for a variety of applications starting with industrial equipment. Due to the longer development lead times for automotive applications, the ProAI is not expected to appear in production vehicles until about 2020. ZF specifically called out TRW's active safety technology and ZF's desire to integrate this with its own products for automated driving solutions at the time of the acquisition. However, compared to Delphi, ZF has not articulated a strong strategy to develop mobility services platforms.

www.zf.com

Chart 4.14 ZF Strategy and Execution Scores



(Source: Navigant Research)

4.3 Challengers

Companies that scored higher than 25 but less than 50 in both Strategy and Execution are considered Challengers. While all the Challengers in this *Leaderboard* have been actively developing automated driving technology, there has been less of a clear strategy to rollout the technology widely. In general, companies in this category need to start or expand public road testing and articulate a vision for deployment.

4.3.1 Honda

Overall Score: 55.1

Strategy: 46.5

Execution: 62.6

Like Toyota, Honda has taken a more conservative path toward deployment of high-level automation. Honda demonstrated a Level 2 system on the roads of Detroit in 2014, but has not indicated when it will make such a system available in a production application. Honda has been actively testing various levels of vehicle automation in Japan and the United States. While the company received a permit from the state of California for testing on public roads, it only tested on closed courses in 2016.

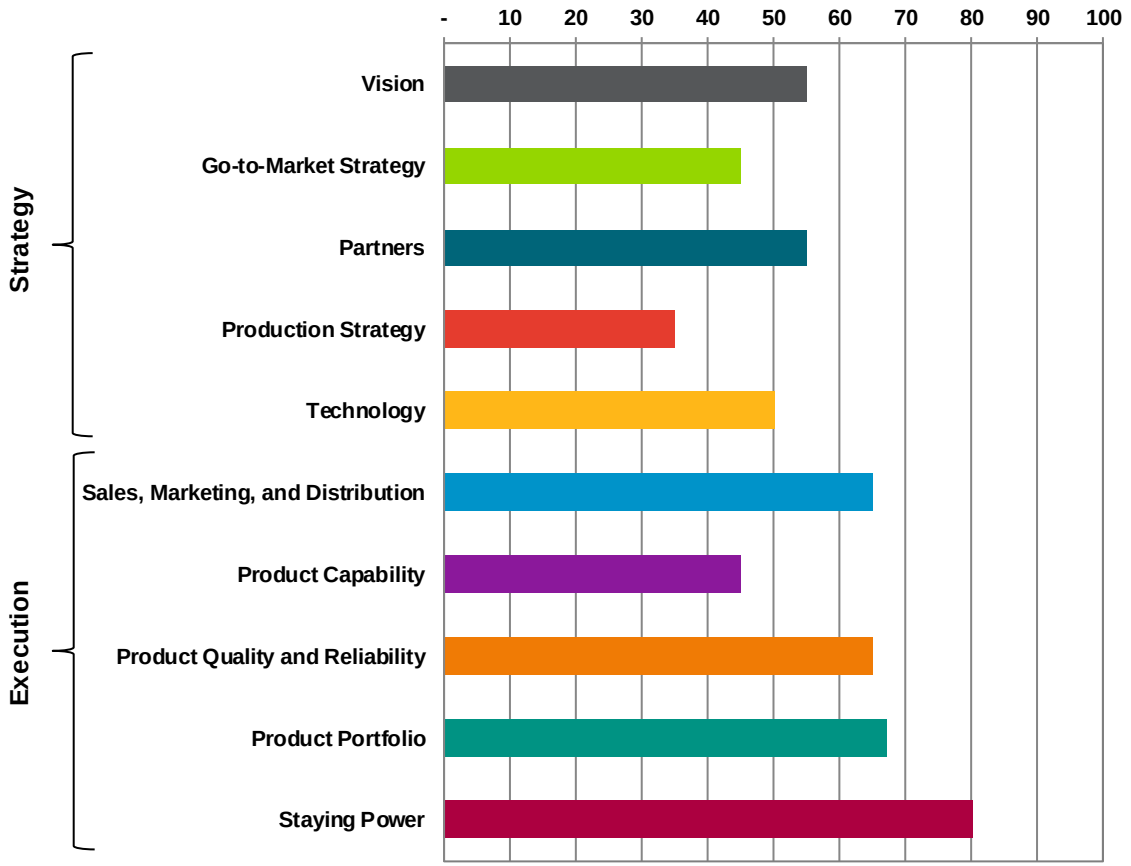
Rather than rushing into development of high-level automation, Honda is currently focused on expanding availability of ADAS systems across its mainstream lineup. Since 2015, each new model introduction has made an ADAS suite, branded as Honda Sensing, available on all trim levels at the price of $1,000. With the launch of the 2018 Odyssey minivan, the ADAS package will be optional on the base LX trim and standard on all others, with Honda projecting 95% of sales to have the Sensing package.

There is an indicator that Honda may be having issues developing some of its automation systems in-house. In December 2016, the company signed a memorandum of understanding with Waymo to discuss potential collaborations between the two companies. However, since Waymo has indicated that it is not seeking to supply its automation system to other OEMs, any partnership between Honda and Waymo may be limited to supplying base vehicles that Waymo would utilize to provide its own mobility services.

At the 2017 CES, Honda displayed the NeuV concept, a vision of a future automated urban mobility vehicle that could be utilized for on-demand services or peer-to-peer sharing. The NeuV was part of Honda's Cooperative Mobility ecosystem that also includes other types of vehicles, including a self-balancing motorcycle and integration with other services.

world.honda.com

Chart 4.15 Honda Strategy and Execution Scores



(Source: Navigant Research)

4.3.2 Uber

Overall Score: 54.5

Strategy: 67.0

Execution: 38.0

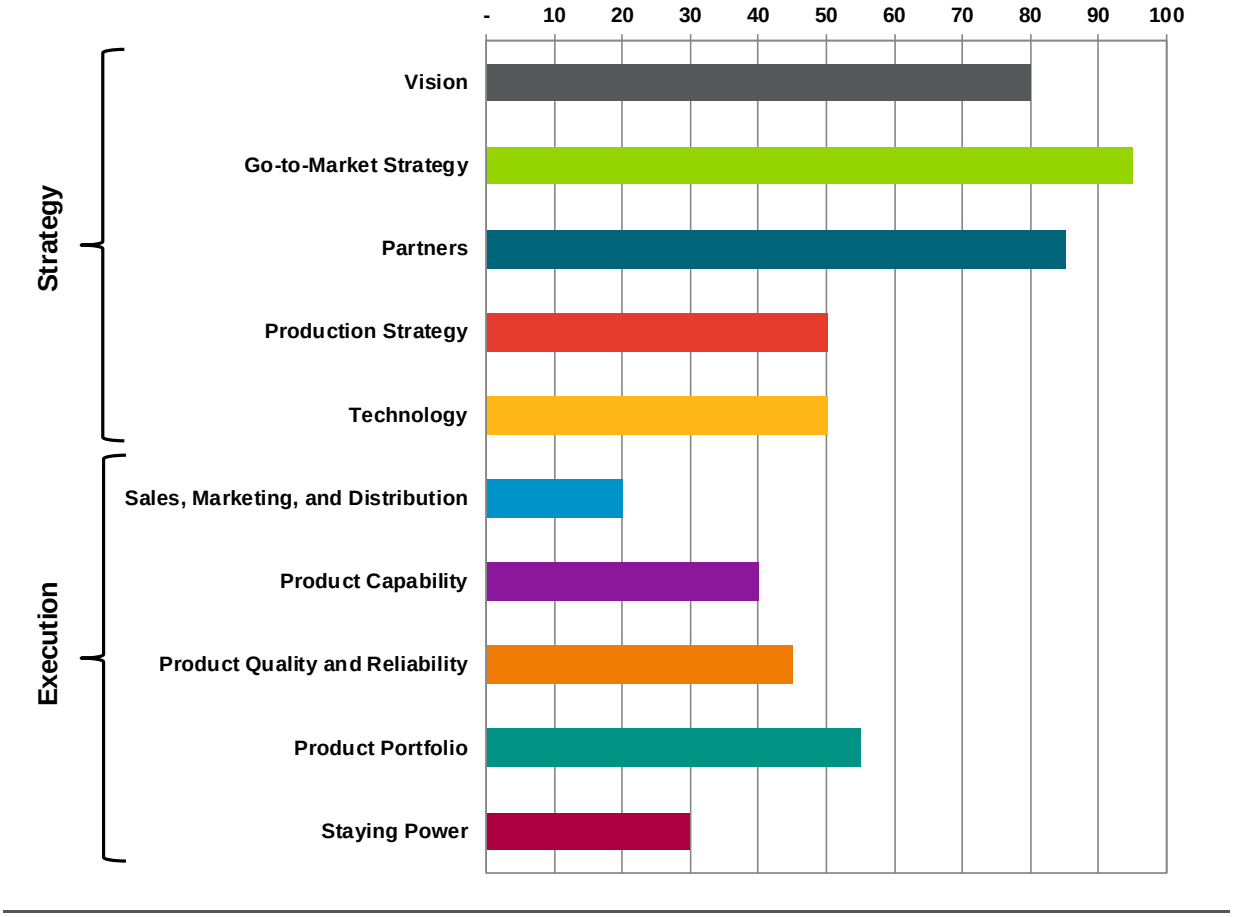
In early 2015, San Francisco-based ride-hailing pioneer Uber announced that it would begin developing its own automated driving technology. The company's goal is to ultimately replace the hundreds of thousands of human drivers that participate in its online dispatching system. Uber established an R&D facility in Pittsburgh, Pennsylvania, adjacent to Carnegie Mellon University, hiring many of the school's researchers to work on its development program. Within a few months, Uber was testing prototypes based on the Ford Fusion in Pittsburgh, and in September 2016, the company began a pilot program to pick up passengers that had opted in to the program.

In August 2016, Uber announced a partnership with Volvo to develop an automated vehicle platform for its service based on the Swedish OEM's scalable platform architecture. Subsequently, Uber began testing a new generation of prototypes based on the Volvo XC90. In December 2016, Uber launched a pilot passenger pickup program in San Francisco. The test was shut down within a few days after videos emerged of the Uber vehicles running red lights and having other problems. The company refused to sign up for a California permit for testing self-driving cars, prompting the state to revoke the registration for the test vehicles. Uber has a history of seeking to sidestep regulations covering taxi services. While this strategy has allowed it to expand its business rapidly, this desire to operate outside regulatory oversight could also put it in the crosshairs of regulators concerned about automated vehicles.

In January 2017, Uber also formed a partnership with Daimler for the automaker to operate its automated vehicles on the Uber platform. This could be a hedge by Uber in the event that its in-house technology development does not work out—or if it proves to be too expensive to operate its own fleet of vehicles.

www.uber.com

Chart 4.16 Uber Strategy and Execution Scores



(Source: Navigant Research)

4.3.3 nuTonomy

Overall Score: 51.6

Strategy: 56.5

Execution: 46.3

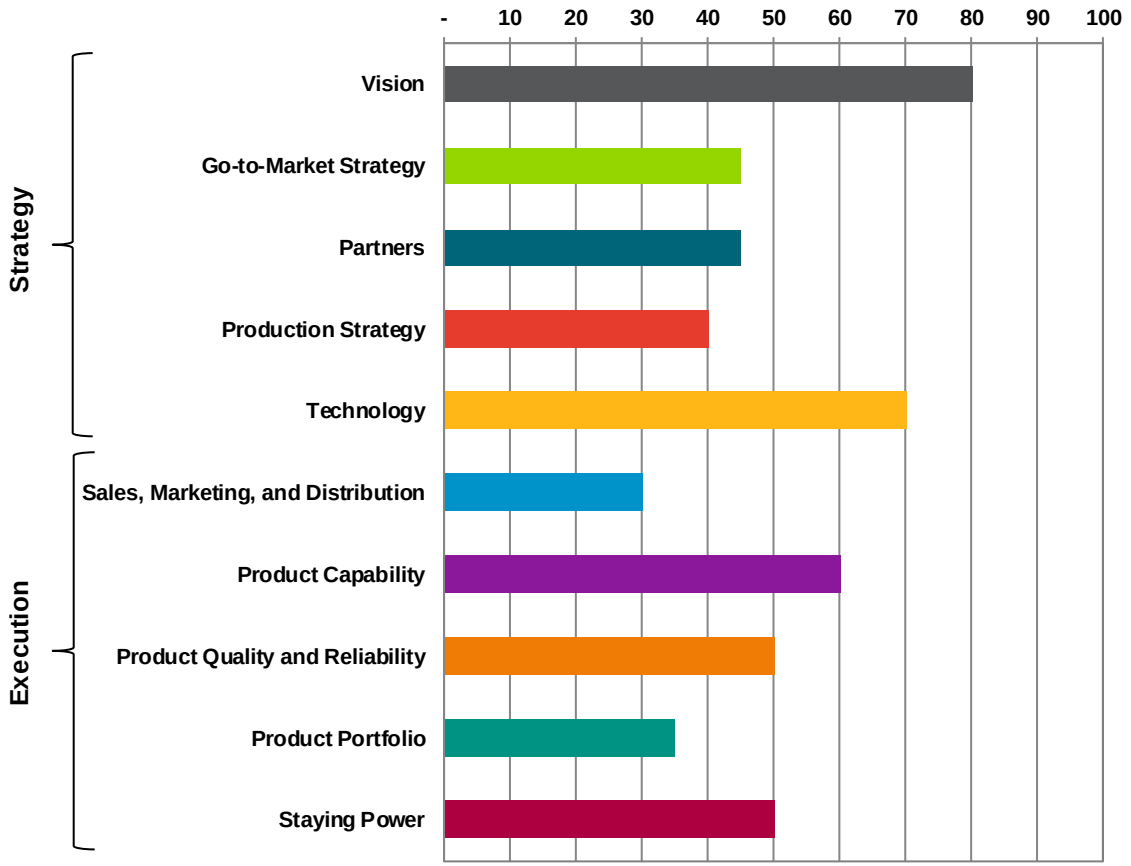
Boston-based nuTonomy spun off from MIT in 2013 to develop automated driving systems. The company's main focus is on developing the control software for sensing and path planning, but it has integrated a full suite of sensors and actuators into its fleet of test vehicles which include the Mitsubishi i-MiEV and Renault Zoe.

In August 2016, nuTonomy became the first company to launch testing under a pilot program run by the Land Transport Authority in Singapore. The pilot test involves a fleet of six automated vehicles that are providing first-mile/last-mile automated taxi services in the one-north district of the city. In November 2016, nuTonomy expanded its public test program to its hometown of Boston where it has encountered new challenges to deal with, including flocks of seagulls that its control system must learn to recognize and operate around. Unlike many others that are relying on deep machine learning and neural networks, nuTonomy uses a different approach to its system. Instead, it is using formal logic with a set of rules and preference ranking. The key distinguishing feature is that it is more deterministic and verifiable, although it may not evolve as quickly.

As a small startup, nuTonomy certainly faces challenges in commercializing its technology. The company raised $20 million in venture funding through the end of 2016, with investors that included the government of Singapore and Fontinalis Partners, a venture fund founded by Ford Motor Company executive chairman Bill Ford. nuTonomy aims to raise more money in 2017. The company already has a partnership with Jaguar Land Rover to develop automated driving technologies and is targeting further OEM deals. At this time, nuTonomy does not plan to develop the hardware for automated driving, instead focusing on the software and systems integration as well as the services platform that is being tested in Singapore.

www.nutonomy.com

Chart 4.17 nuTonomy Strategy and Execution Scores



(Source: Navigant Research)

4.3.4 Baidu

Overall Score: 47.1

Strategy: 53.8

Execution: 39.3

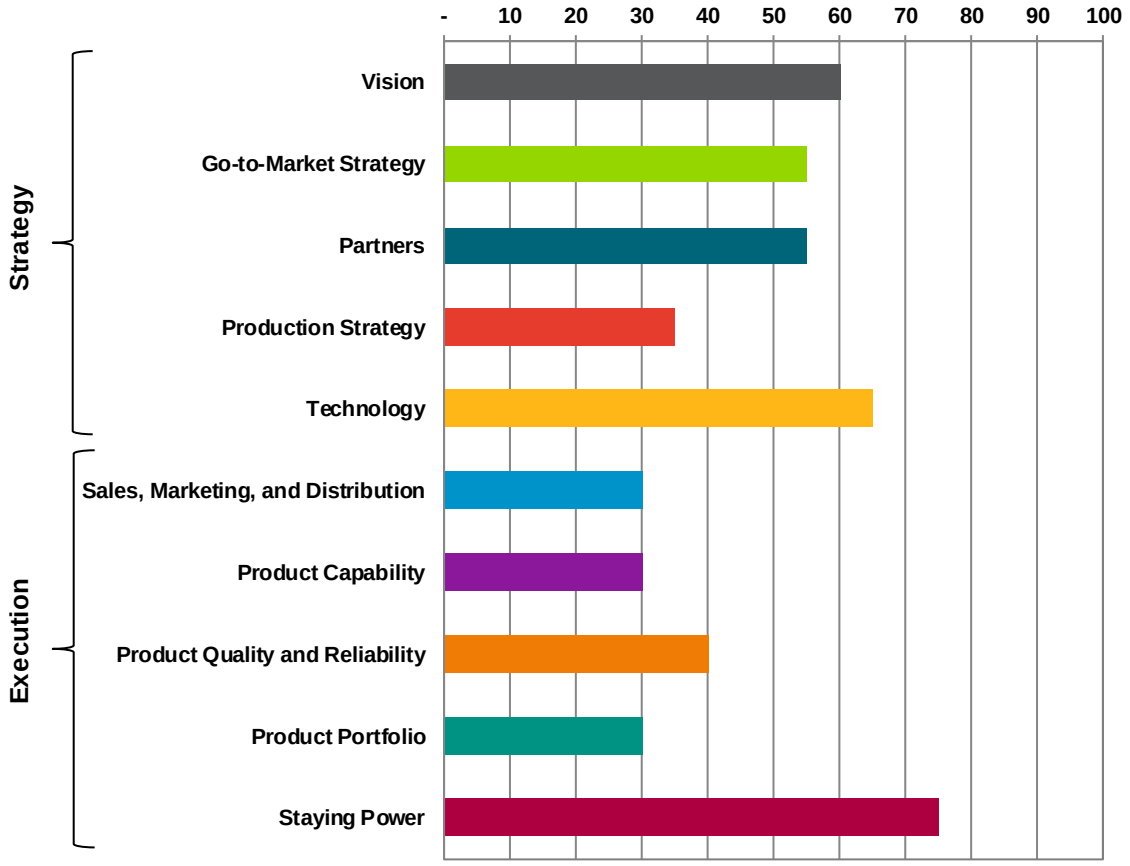
In 2014, Chinese internet technology company Baidu announced a partnership with BMW to develop self-driving technology to assist drivers rather than replace them, and conduct testing in the United States and China. The company saw this as a way to use its data mapping and AI capabilities. However, in November 2016, the two companies decided to end the cooperation, reportedly because they held different opinions on how to proceed with research. The partnership jointly developed an automatic overtaking capability, and the two companies will continue to be partners on high-definition maps.

In July 2016, Baidu announced that it had opened a new Silicon Valley division dedicated to self-driving cars. In September 2016, the company said it would soon begin testing driverless cars on US roads after California issued Baidu USA an automated vehicle testing permit. Baidu completed its first fully automated road test in China in December 2015, and it plans a small-scale commercial launch of fully automated cars in 2018, with mass production likely to follow in 2021.

Baidu has recently invested in lidar company Velodyne, and announced a partnership with US graphics processor maker Nvidia to accelerate its self-driving car program. The stated goal is to create a fleet of driverless taxis that use a cloud-to-car architecture platform and build on Baidu's AI expertise.

www.baidu.com

Chart 4.18 Baidu Strategy and Execution Scores



(Source: Navigant Research)

Section 5
ACRONYM AND ABBREVIATION LIST

ADAS.....Advanced Driver Assist System

AI ..... Artificial Intelligence

AMS..... Automated Mobility Service

AV.....Automated Vehicle

CEO..... Chief Executive Officer

CES .....Consumer Electronics Show

DARPA .....Defense Advanced Research Projects Agency (United States)

ECU ..... Electronic Control Unit

EV..... Electric Vehicle

FCA .....Fiat Chrysler Automobiles

GM..... General Motors

GPU..... Graphics Processing Unit

lidar..... Light Detection and Ranging

MIT .....Massachusetts Institute of Technology

mph .....Miles per Hour

NAIAS.....North American International Auto Show

NASA..... National Aeronautics and Space Administration (United States)

NHTSA ..... National Highway Traffic Safety Administration (United States)

OEM .....Original Equipment Manufacturer

R&D ..... Research and Development

TRI ..... Toyota Research Institute

US ..... United States

VW ..... Volkswagen

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Section 8
SCOPE OF STUDY AND METHODOLOGY

8.1 Scope of Study

Navigant Research has prepared this report to assess the relative strengths of the global participants in the emerging market for automated driving systems. The report is intended to help potential end users of those vehicles, including municipalities, fleet owners, and Tier One and Tier Two suppliers, to better understand which companies are leading the rollout of self-driving technology and which are lagging.

This *Navigant Research Leaderboard Report* focuses on current automotive manufacturers and suppliers, as well as new entrants in the field of automated driving. The companies selected are developing full-stack solutions that in most cases also include mobility services solutions for the deployment of this technology. The report is not exhaustive, as there are many smaller players in the market that were not included because of their lack of geographic reach or technological capability.

The major objective of this *Leaderboard* is to provide a timely overview of the companies involved in this market, as well as their Strategy and Execution in developing, manufacturing, and marketing automated driving features. Note that the company rankings capture each company's standing at the time of the report. They also take into account a retrospective of past accomplishments and an expectation of future business moves based on public statements and Navigant Research evaluations of the technology in development. The ratings are likely to change further over time as this market matures and business models continue to evolve.

8.2 Sources and Methodology

Navigant Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Navigant Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Navigant Research's analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Navigant Research's reports. Great care is taken in making sure that all analysis is well-

supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

Navigant Research is a market research group whose goal is to present an objective, unbiased view of market opportunities within its coverage areas. Navigant Research is not beholden to any special interests and is thus able to offer clear, actionable advice to help clients succeed in the industry, unfettered by technology hype, political agendas, or emotional factors that are inherent in cleantech markets.

8.2.1 Vendor Selection

The companies included in this report were chosen based on their activities and capabilities related to developing all the major components of complete automated driving stacks, including perception systems, processing, control software, and services platforms. While many startup companies are developing a variety of solutions for automated driving, most are not well known or are focusing only on specific aspects of the systems—such as machine vision, path management, or sensor fusion—and were thus excluded. Most of these companies are likely to either go out of business or be acquired by a larger company. Some major suppliers (such as Bosch, Continental, and Denso) that produce many of the subsystems and components but are not focused on providing full turnkey solutions and services were also excluded. OEMs that have not demonstrated automated driving solutions or were not deemed to be far enough along in internal development have been excluded, as well.

8.2.2 Ratings Scale

Companies are rated relative to each other using the following point system. The ratings are a snapshot in time, showing the current state of the company. These scores are likely to be fluid as new competitors enter the market and customer requirements evolve.

- Very Strong 91 – 100
- Strong 76 – 90
- Strong Moderate 56 – 75
- Moderate 36 – 55
- Weak Moderate 21 – 35
- Weak 11 – 20
- Very Weak 1 – 10

8.2.2.1 Score Calculations

The scores for Strategy and Execution are weighted averages based on the subcategories. The overall score is calculated based on the root mean square of the Strategy and Execution scores.

8.2.3 Criteria Definitions

8.2.3.1 Strategy

- **Vision:** Measures the company's stated goals in designing automated solutions for today and tomorrow. Clear and compelling visions for both short and long term that are effectively communicated to the public result in higher scores.
- **Go-to-Market Strategy:** Evaluates the company's strategy for reaching the target market, including the sales and marketing channels to be used, as well as the processes established for informing the target market about brand differentiation and unique product value.
- **Partners:** Measures the company's established partnerships with key suppliers or other OEMs that will provide an advantage in financial backing, sales, business, and product development. Part ownership of other companies with recognized strength in advanced technology will increase scores.
- **Production Strategy:** Evaluates the long-term competitiveness of the manufacturing plan as an effective solution that satisfies market requirements and meets market capacity needs. A component of this is an evaluation of the ability of the manufacturing base to supply product quality to meet market expectations and demand.
- **Technology:** Evaluates whether the company has developed and/or implemented ADAS technology that provides a significant business advantage over competitors and is likely to have an enduring effect on its success. Higher scores are given if the company's technology is already a proven market success or delivers unique product attributes.

8.2.3.2 Execution

- **Sales, Marketing, and Distribution:** Evaluates the company’s marketing and sales performance and current distribution channel. Higher scores are given to companies with a large global dealer network with specific support for ADAS and self-driving products.
- **Product Capability:** Evaluates the competitive performance of the features. Higher scores are given to companies that provide more autonomy within legal limits while delivering on customer expectations.
- **Product Quality and Reliability:** Evaluates the quality and reliability of the systems in vehicles delivered to customers and the company’s track record on quality with the current product line.

- **Product Portfolio:** Addresses the products' relative competitiveness in the market. Points are awarded for product features (operational speed range, obstacle detection distance, target identification, etc.), uniqueness, and benefits for the target market.
- **Staying Power:** Evaluates whether the company has the financial resources to withstand weak or variable markets and price-based assaults by competitors. Also measures the company's likelihood to continue to pursue advanced vehicle technology in the event of market softening. Higher scores are given to companies with better financial performance and a greater capability to survive market downturns.

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