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MORGAN STANLEY BLUE PAPER

MORGAN STANLEY RESEARCH
Global

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Morgan Stanley Blue Papers focus on critical investment themes that require coordinated perspectives across industry sectors, regions, or asset classes.

Autonomous Cars

Self-Driving the New Auto Industry Paradigm

Autonomous cars are no longer just the realm of science fiction. They are real and will be on roads sooner than you think. Cars with basic autonomous capability are in showrooms today, semi-autonomous cars are coming in 12-18 months, and completely autonomous cars are set to be available before the end of the decade.

This is not a toy—the social and economic implications are enormous: Beyond the practical benefits, we estimate autonomous cars can contribute $1.3 trillion in annual savings to the US economy alone, with global savings estimated at over $5.6 trillion. There will undoubtedly be bumps in the road as well, including the issues of liability, infrastructure, and consumer acceptance. However, none of these issues appears insurmountable.

The auto industry business model could be transformed—and the collateral impact to other sectors could be significant as well. Like the PC/smartphone industry today, we see the auto industry reorganized into dedicated "hardware" OEMs, "software / systems" OEMs/suppliers, and integrated "experience" creators. Selling content to the occupants of the car (who now have nothing else to do) could be a significant new revenue stream. We believe early leaders in the space have a critical head start including Audi, Mercedes-Benz, BMW and Nissan among auto OEMs, Delphi, Continental, Autoliv and TRW among suppliers and tech players like Google, IBM and Cisco. Non-auto industries with high stakes in this market include telecom services, software, media, freight transportation, semiconductors and insurance.

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MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

Autonomous Cars: The Basics

Executive Summary

A few decades from now, a child from today will hardly believe that people used to drive vehicles manually. The march toward autonomous vehicles or self-driving cars is well underway and though it may be a few years until we get there, the destination may be closer than most people think. It also means that, as a society, we need to start now to fathom the enormous implications of this transition, so that we are ready for it when it comes.

Over the course of several months, we held intense brain storming sessions and interviewed futurists and top executives within the auto industry and potential disruptors outside the industry, to develop a vision of what a future with autonomous cars will look like. The result is this Blue Paper, a collaborative effort across ten global research teams at Morgan Stanley Research.

This Blue Paper is *not* meant to be a comprehensive list of every advantage and disadvantage, use of, and obstacle to adoption of autonomous vehicles. That already has been well-covered in other places, and we may write on such topics in more detail in future follow-up reports.

Rather than focus on the topic of “what is an autonomous vehicle”, we have instead focused on areas that have not been addressed so far. We have attempted to lay out a timeline for adoption, determine what the global implications might be, quantify the socio-economic benefits, and—most importantly—examine the investment implications of autonomous vehicles. We have attempted to make *a practical case* for the adoption of autonomous vehicles and present solutions to the most pressing concerns/obstacles, with the goal of sparking the debate about whether we need to be preparing for the future, starting now.

We prefer to use the term “autonomous car” rather than “self-driving car” or “driverless car” in this report, because we believe the term “autonomous” best conveys the amount of technology and engineering that goes into making this system work. It also avoids the negative images of rogue, self-aware vehicles that the term “self-driving” or “driverless” can imply.

Autonomous cars are real and will be ready for prime time sooner than you think

In any discussion of cars, mention the terms “autonomous” or “self-driving” and most people conjure up images of science fiction movies or television shows, like *Knight Rider* and *Batman*. The idea of a driverless car is still so fantastical that this topic struggles to get respect even today. Broaching the concept as something real is still met with eye-rolling and deep skepticism, even among people within the auto industry who are actively working on autonomous car technology. It is true that there has been a significant amount of print media devoted to the topic recently, but we believe there has been little serious dialogue. Even starting work on this Blue Paper drew a lot of debate within our own teams as to whether this was a topic of relevance, in terms of size of the impact, the timing of potential realization, and the ability to generate actionable investment implications.

However, it is now clear to us that not only are autonomous cars real but they are likely to come around sooner than most people think. With US drivers driving 75 billion hours a year, autonomous cars are also poised to have a much greater impact on society as a whole than most people give them credit for.

Getting the cars to drive themselves may be the easiest part

Why are we so convinced when even people closest to the technology within the auto industry sound so deeply skeptical? Simply because the uncertainty around timelines of adoption for most new technologies in the auto industry is largely due to having to solve complex technological problems. That is not the case for autonomous vehicles—the technology to make a self-driving car happen is largely available today and only incremental R&D is required, mostly in the area of testing, durability, reliability, and cost reduction, all of which have largely visible paths. This is one of the few areas where there is agreement across the auto industry, the futurists, and adjacent market players.

Basic autonomous capability is available in cars today, with semi-autonomous capability coming in 12-18 months and full autonomous capability (which exists in prototype form today) on the path to commercialization by the end of the decade. The technology to make it happen is not a stretch and neither is the cost premium. We estimate full autonomous capability will add only about $10,000 to the cost of a car, at today’s prices (which we expect will fall significantly by the time the technology is ready to be commercialized). In fact, we believe autonomous vehicle technology is a smaller leap than full electric vehicles—which still need unknown battery breakthroughs in a lab or significant macro disruption to make them viable beyond being niche vehicles.

"It won't happen because it’s too hard"

Rather than the technology itself, we believe most of the concerns or obstacles to mass adoption of autonomous vehicles are largely practical or procedural in nature. What’s more, these issues appear relatively easy to solve and we have suggested our own likely solutions to a number of the most pressing issues.

The main barrier to autonomous vehicle growth is the question of liability—"who is responsible in the event of an autonomous vehicle crash, the occupants, the OEM, the supplier, or someone else?” We do not see this as an insurmountable issue—in fact, we believe the solutions are relatively straightforward. We talk about all states in the US going to "no fault" to eliminate the need to answer the above question in the first place and believe the economics of insurance can support the liability in the event of a crash. We note that the liability issue has often been presented as a deal breaker ahead of most of the biggest technological leaps taken by mankind, but that has not stopped us from flying on airplanes or building an electric grid or, indeed, inventing the automobile in the first place. Other potential obstacles often mentioned include gaining customer acceptance, building sufficient infrastructure, government regulation, and ethical issues.

We believe the potential socio-economic benefits of autonomous cars are so great that most of the practical issues will be quickly solved to clear the path to their implementation. There will be offsetting unfavorable impacts as well—for example, whether we will need as many EMTs, paramedics, and law enforcement officers, if there are no accidents? However, as with other innovations in the history of mankind, we believe society must and will adapt.

Global or bust

One of the potential obstacles to the success of autonomous vehicles that does not come up often enough, in our opinion, is whether it can succeed in emerging markets or be limited to developed markets only. Almost every stakeholder we have spoken to seems to believe that if autonomous vehicles were to achieve significant penetration at all, it will only be in developed markets, given the additional challenges facing the technology in emerging markets, on top of the challenges faced in developed markets.

We strongly believe that autonomous vehicles cannot be limited to developed markets alone if they are to become the fundamental business model shift we envision. The OEMs' recent move to common platforms and the need to sell similar cars across all markets will ultimately mean that cars will either be autonomous everywhere or nowhere, especially given the vast changes in the design and engineering of a vehicle that are required to give it autonomous capability. In this Blue Paper, we discuss many of the obstacles that autonomous vehicles in emerging markets face, and explain why we believe not only that none of them are deal-breakers but also that there are many EM-specific reasons why autonomous vehicles will actually work better in those markets.

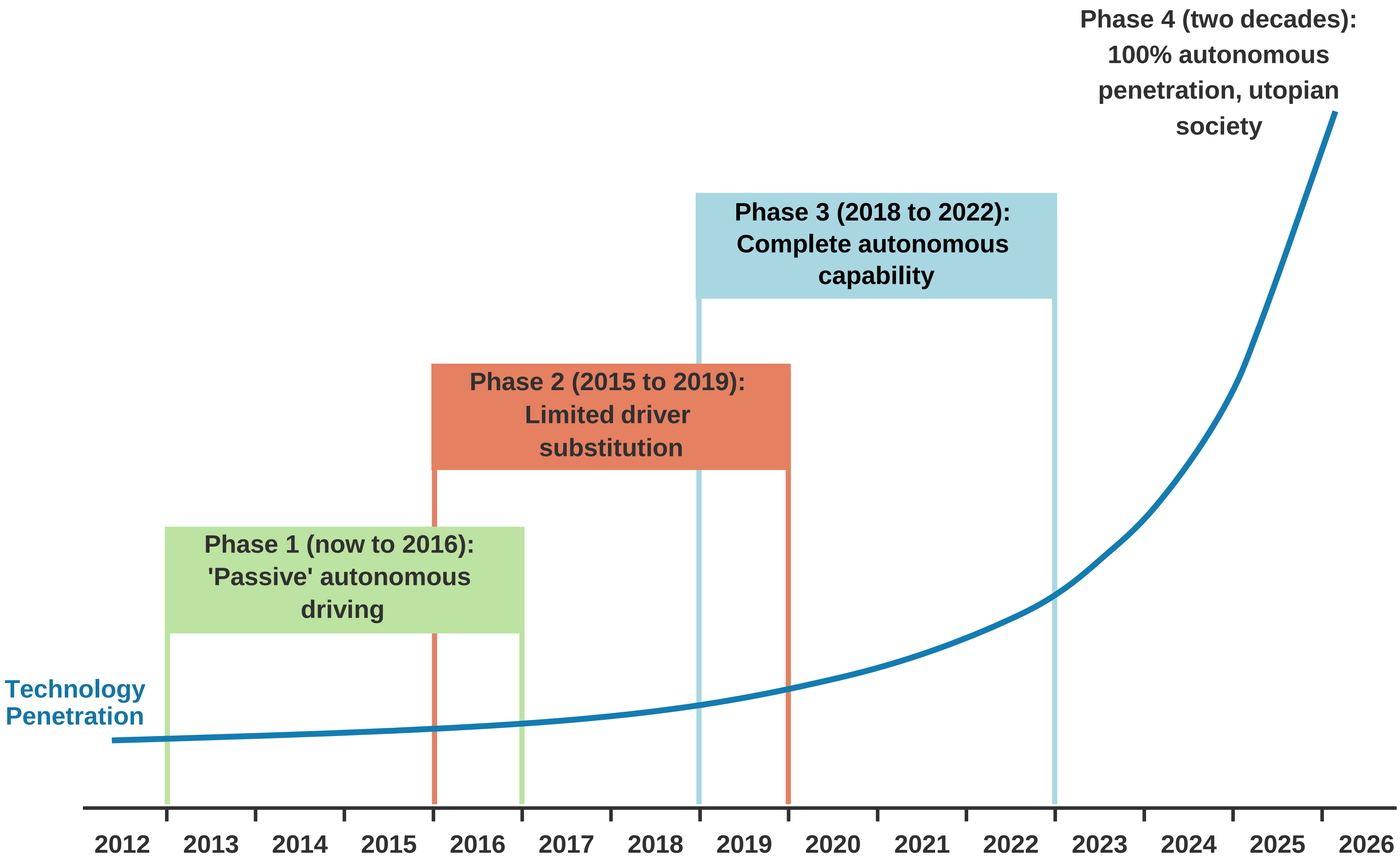
Your time starts now

We see five phases in the autonomous vehicle adoption curve, starting with basic active safety capability today and ending at a utopian world in which every car on the road will be autonomous. While this utopia looks to be a couple of decades out, we envision a scenario in which mass adoption and full penetration could come much more quickly, if the need to achieve the socio-economic benefits of autonomous cars compels the industry and governments to force the adoption of the technology. And the socio-economic benefits are indeed significant.

Not just about making the world a better place

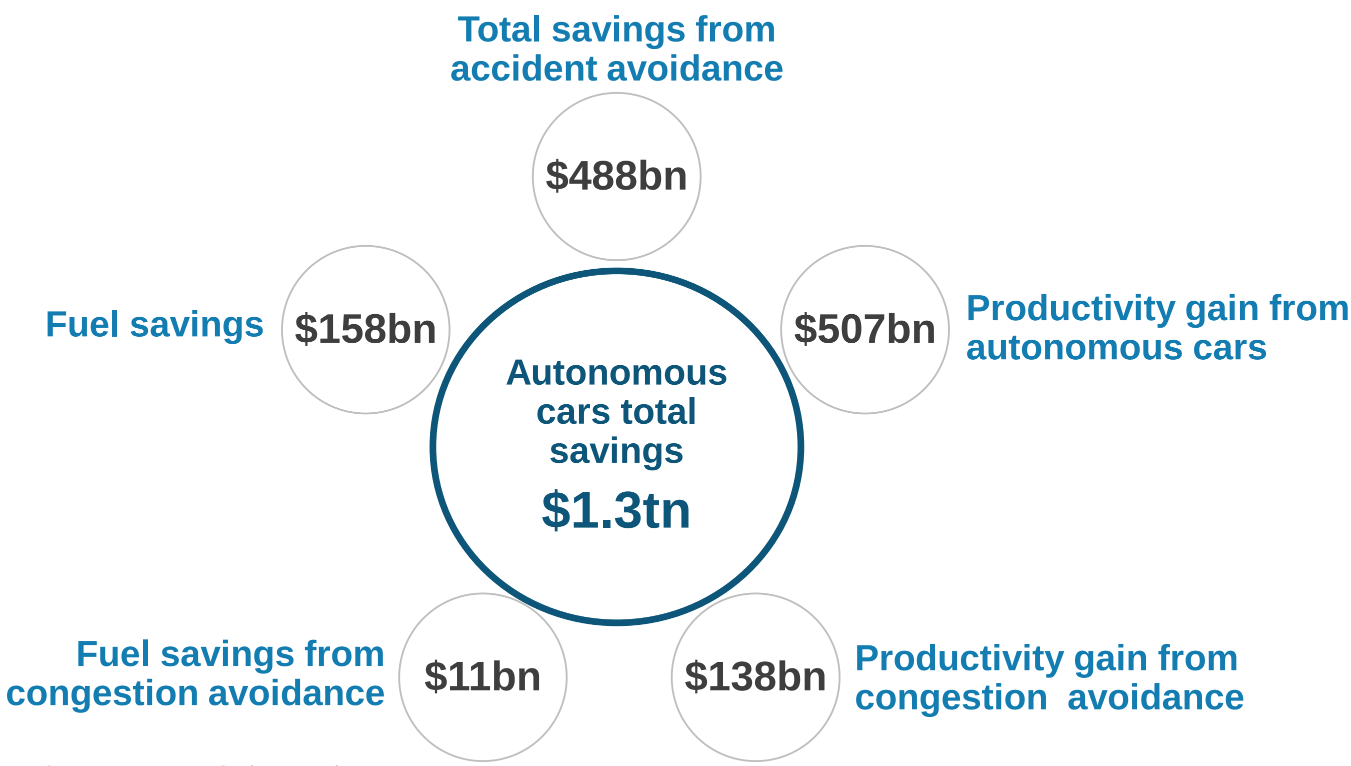
Autonomous cars bring obvious social benefits—fewer (if any) road accidents, reduced traffic congestion, higher occupant productivity, fuel savings, and many, many more. However, while the social benefits may be nice, autonomous vehicles need to generate a real economic return for both the consumers paying for the technology as well as the industry/governments that will invest billions of dollars in developing it. Happily, though, the economic benefits of these social gains promise to be great. We have made a high-level attempt to quantify these gains—we believe the US economy can save $1.3 trillion per year, once autonomous cars become fully penetrated. To put that number in context, it represents 8% of US GDP. Extrapolating these savings to a global level by applying the ratio of US savings / US GDP to global GDP, we estimate global savings from autonomous vehicles to be in the region of $5.6 trillion per year. We believe the promise of achieving this level of savings will compel the penetration of autonomous capability in vehicles, at a pace quicker than natural demand pull.

Exhibit 1
Adoption Timeline



Source: Company Data, Morgan Stanley Research

Exhibit 2
Potential US Cost Savings



Source: Company Data, Morgan Stanley Research

The investment implications are also great

Autonomous capability is not just a cool new feature to add to car's brochure. We believe this technology can drive one of the most significant transformations of the automobile in its history. A change of this magnitude is likely to drive a paradigm shift in the auto industry as well. We highlight two fundamental changes that we see coming to the auto industry

(a) The growth of software as a value-added part of the car is likely to divide the industry into dedicated "hardware" makers (similar to OEMs today), dedicated "software" makers (includes OEMs, suppliers and external entities new to the auto industry), and vertically integrated "experience" makers, who control every aspect of the automobile. This industry structure is analogous to the smartphone or PC industry structure of today.

(b) The consumption of content in the car by occupants (who now are free to do what they want) opens up a new revenue stream for whoever it is that wants to control it. This could be the OEM itself, the autonomous system supplier, or a third party.

We believe the move to autonomous vehicles could present an existential threat to OEMs who are lagging behind with the technology or do not have the balance sheets to keep up. These OEMs could either go away entirely or become low-cost assemblers of cars.

Traditional vs. non-traditional players: The importance of thinking big

The main advantages for the traditional players here are their familiarity with the automobile, their control over the industry, and their very high standards for testing and reliability that make them unlikely to go to market with a half-baked product. The main challenge that the traditional players face, in our view, is sustaining an ability to think outside the box and beyond a rigid structure of innovation and adoption. In our conversations, we found many traditional players unable or unwilling to think (or at least share their thoughts) about a future with autonomous vehicles in it, and how those vehicles might be game changing, beyond a general expectation that they are relatively inevitable. The traditional industry appears to be thinking of the autonomous car as “just another feature.” Strapped to an adoption curve, they appear to be unwilling to think beyond it and, in our view, therefore risk being left behind.

It is the exact opposite for the new entrants—companies like Google, IBM, Cisco Systems, and start-ups. These companies (while playing their cards equally close to their vests) seem to be aiming for the same utopia of universal adoption of autonomous vehicle technology that we envision, with merely achieving a high degree of penetration being the downside proposition. Unencumbered by the adoption curve planning of the traditional auto industry, these players seem to want to embrace risk and push the boundaries of disruption, and seem to have little fear of failure. In our view, this may free them to leapfrog the traditional auto industry players as creators of value. This approach mirrors Tesla’s attitude to building cars, which so far has achieved remarkable success in a very short period of time. However, this approach carries risk—these non-traditional players need to learn the automobile and how its occupants like to interact with it, build their products and systems to be automotive-grade, and embrace the cyclicality of the industry.

Autonomous cars can have significant implications for a number of adjacent sectors. The Morgan Stanley Freight Transportation team believes that autonomous and semi-autonomous driving technology will be adopted far faster in the cargo markets than in passenger markets. Long-haul freight delivery is one of the most obvious and compelling areas for the application of autonomous and semi-autonomous driving technology The Telecom Services team believes the industry could see a ~$100 bn revenue opportunity, while the Semiconductor team expects a significant increase in semi usage. The MS Media team sees an incremental $5 bn of potential revenue for the media companies, and the Software team sees opportunity for complex software use and Big Data. The insurance and car rental sectors may see binary outcomes from autonomous cars.

Exhibit 3

Bull-Base-Bear Cases for Potential Savings in the US

		Bull Case	Base Case	Bear Case
	Autonomous Cars Total Savings	**$2.2tn**	**$1.3tn**	**$0.7tn**

Key Assumptions		Bull Case	Base Case	Bear Case
	Fuel Price Per Gallon:	$6.00	$4.00	$3.00
	Improvement in Fuel Efficiency:	50%	30%	15%
	Cost of Life:	$9mm	$8mm	$6mm
	Median Income per	$32.5	$25.0	$19.0
	Work as % of Total Time Spent in a Car:	50%	30%	10%

Source: Company Data, Morgan Stanley Research

SUMMARY OF KEY TAKEAWAYS BY INDUSTRY

Auto OEMs & Suppliers	**Autonomous driving capability could change the auto industry in fundamental ways:** • Shifting the "value" of the car away from predominantly hardware to a software component as well, thereby allowing new players to enter and forcing existing players to reinvent themselves or cede share. This could allow OEMs to shift away from a vertically integrated, asset heavy business model, thereby changing the profitability structure of the industry. • Introducing a new revenue model that monetizes the new "drive time" content opportunity within the car. **Ultimately, we see the industry structure going the way of the PC/smartphone industry.**
Freight Transportation	**Autonomous and semi-autonomous driving technology will be adopted far faster in the cargo markets than in passenger markets**: • We conservatively estimate the potential savings to the freight transportation industry at $168 bn annually • Collateral implications include competitive advantage to large, well capitalized fleets
Media: TV	**Autonomous vehicles have the potential to materially increase total media consumption. generating over $5 bn of net new media revenue. Video should take disproportionate share of liberated drive-time, while radio and recorded music may lose a key captive audience:** • We expect TV to be the largest beneficiary on a total dollar basis and Home Video to benefit the most on a % basis. As likely relative time share losers, roughly 10-15% of radio and recorded music revenues could be at risk. • Unclear impact to outdoor advertising: While the newly liberated driver may have more capacity to view outdoor advertising, outdoor ads will need to compete with more immersive media (e.g. TV) for the driver's attention.
Telecom Equipment	**Today, connected cars are a modest near-term revenue opportunity. This could potentially reach ~$100 bn with the rise of autonomous driving. Positive for towers, while carriers face opportunities and risks:** • Towers should benefit from the carrier capex requirements of a higher-capacity, broader coverage network, further adding to the potential duration of revenue growth. • This could be a significant opportunity for carriers. These customers could have low churn (average life of car) and strong ARPU, though the network investments may be quite costly.
Semiconductors	**The increasing importance of semiconductors in car manufacture and operation has two key implications:** • Chip providers in the compute, networking and communications, and data storage segments should benefit. • New wireless inter-vehicle communication standards could provide significant opportunities.
Software	**We see three principal areas of opportunity for software vendors.** *Near-term:* • A demand for increasingly complex software in auto design and manufacturing. *Longer-term:* • Standardization of custom-built software on packaged platforms or application sets. • Managing "big data" resulting from increasing sensor counts in vehicles.
Insurance	**The autonomous car is unlikely to be the death knell for auto insurance, but the assignment of Insurance liability is a key unknown. Two key implications:** • Insurance prices are likely to decline due to lower accident frequency. • However, accident severity costs may continue to rise as car complexity rises.
Medical	**Autonomous vehicles should have limited impact on hospital volumes and revenues, with only 8% of car accidents resulting in an in-patient admission:** Motor Vehicle Accidents (MVA) account for $23 bn in hospital spending, which translates to ~1.5% of all total hospital care and physician services costs.
Car Rental	**Two highly polarizing scenarios seem plausible:** • Transforming cars into workplaces or leisure venues could Increase the benefits of private ownership, to the detriment of rental companies. • The fleet management/customer service opportunities in the world of the roving autonomous car parc could be significant.

Potential Net Beneficiaries, or 'The Autonomous 40'

The below names were chosen for being either early leaders in autonomous vehicles or dominant players within industries positioned to be net beneficiaries of autonomous vehicles, or both. This list is not, and should not be considered, a portfolio.

Company	Early Adopter	Dominant in Vertical
Auto OEMs		
BMW	●	●
Daimler	●	●
General Motors	●	●
Nissan	●	●
Toyota	●	●
Volkswagen/Audi	●	●
Auto Suppliers		
Autoliv	●	●
Continental	●	●
Delphi	●	●
Denso	●	●
TRW Automotive	●	●
Tech Hardware / networking		
Cisco Systems*	●	●
IBM	●	●
Software		
Dassault Systèmes		●
Google	●	●
PTC*		
Big Data		
EMC		
HP		
Oracle		●
SAP		●
Teradata		

Company	Early Adopter	Dominant in Vertical
Semiconductors		
Ambarella	●	
Intel	●	●
Linear Technology	●	●
NVIDIA	●	
NXP Semiconductors	●	●
Telecom Services		
American Tower Corp.		●
AT&T		●
Crown Castle International		●
SBA Communications		●
Sprint		
T-Mobile		
Verizon		●
Freight Transportation**		
Con-way		●
FedEx		●
Heartland Express		●
Knight Transportation		●
Old Dominion Freight Lines		●
Saia		●
Swift Transportation		●
United Parcel Service		●
Werner Enterprises		●
Media		
In our view, the entire vertical could benefit		

* Not covered by Morgan Stanley Research
**Important freight carriers with large trucking fleets
Source: Morgan Stanley Research

Exhibit 4

History of Autonomous Cars

1970 · 1980 · 1990 · 2000 · 2010 · 2020 · 2030

1977	First truly autonomous car unveiled by S. Tsugawa at Japan's Tsukuba Mechanical Engineering Laboratory
1980s	Ernst Dickmanns' vision-guided Mercedes-Benz van achieves 39 mph on streets without traffic
	The US Department of Defense funds the DARPA Autonomous Land Vehicles (ALV) project
1987 (to 1995)	The European Commission funds the €800 million EUREKA Prometheus Project on autonomous vehicles
1994	Dickmanns / Daimler-Benz vehicles, VaMP and Vita-2, drive more than 620 miles in Paris
1995	Carnegie Mellon University Navlab project ("No Hands Across America") achieves 98.2% semi-autonomous driving over 3,100 miles
1996	Alberto Broggi's ARGO Project achieves 94% fully autonomous driving on a 1,200 mile journey across Northern Italy
2004 to 2005	DARPA starts long distance competitions; In 2005 $2 million prize awarded to Stanford University
2007	DARPA Urban Challenge focuses on 60-mile urban environment, Carnegie Mellon's team takes first place
2010	Google starts their Driverless Car program using a mix of Google Maps data, radars and LIDAR

Source: Company Data, Morgan Stanley Research

Part 1: Autonomous Vehicles – Basics

An autonomous vehicle can drive itself with no input from the driver. While the technology needed to achieve real autonomous driving has only emerged in recent years, test prototypes of autonomous cars date back to the 1940s and 1950s.

Autonomous cars can have many advantages. Chief among them are lives saved, fuel savings, reduced traffic congestion, improved user productivity, economic stimulus, and military applications.

Autonomous cars also face challenges. They include consumer acceptance, high cost, liability concerns, legislative uncertainty, the need to convert a large car parc of non-autonomous vehicles, as well as security and ethical issues.

None of these challenges appear insurmountable. We believe autonomous cars can change the world as we know it by increasing miles driven, car usage, and suburbanization, as well as promoting emerging market/rural area connectivity.

What is an Autonomous Vehicle?

An autonomous vehicle can drive itself from Point A to Point B with no manual input from the driver. The vehicle uses a combination of cameras, radar systems, sensors, and global positioning system (GPS) receivers to determine its surroundings and uses artificial intelligence to determine the quickest and safest path to its destination. Mechatronic units and actuators allow the "brain" of the car to accelerate, brake, and steer as necessary.

History of the autonomous car

Much like electric vehicles, autonomous cars may seem like a very recent initiative but were first developed decades ago. These included both OEM driven initiatives like the GM Futurama exhibit at the 1940 World's Fair and running autonomous prototypes from GM and Ford in the 1950s. There have also been several independent attempts to build autonomous cars over the years in the US, Japan, and Europe, in the 1960s through the 1980s. Most of the early attempts at autonomous driving needed significant help from infrastructure (like special roads with metal guide strips and radio sensors to point out the right of way to the cars), but some also used early cameras, remote sensors, and actuators to allow the cars to control themselves—in much the same way as semi-autonomous cars can today. The early "self-driving" cars were able to complete test routes but were largely untested in real world traffic conditions.

The big breakthrough that brought autonomous driving out of the fringes of "skunkworks" programs and the odd science class project was the DARPA Grand Challenge. Organized by the US Defense Department's Defense Advanced Research Project Agency (DARPA), this competition brought a number of schools, OEMs, and innovators together to create the autonomous vehicle of the future—initially aimed for potential military use, but eventually with crossover to civilian applications.

The DARPA Grand Challenges were held in 2004 (open desert), 2005 (desert course), and 2007 (urban course). While the participants had varying degrees of success (the first Grand Challenge saw no participant complete the course and had no winner), the reliability and capability of the machines improved dramatically with each iteration. The first Grand Challenge winner was Stanford's Stanley vehicle in 2007—a modified Volkswagen Touareg that earned the team the $2 million winning purse. The Grand Challenges got many of the OEMs and other participants in the autonomous vehicle field today, including Google and Cisco Systems, seriously thinking about the technology. Many members of participating teams are spearheading autonomous vehicle development at the auto OEMs and other companies today.

Exhibit 5
2005 DARPA Grand Challenge Winner

Source: Carnegie Mellon Tartan Racing

Advantages of autonomous vehicles

The main advantages come from the assumption that once artificially intelligent robots take over a formulaic and mundane task like driving, they will make fewer mistakes than human drivers. This should result in several socio-economic benefits.

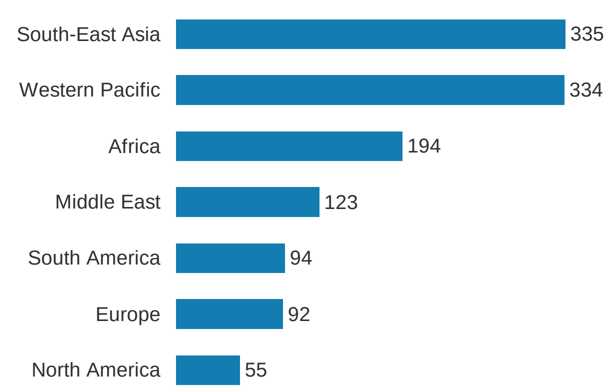
1. **Lives saved**. Each year 30,000 to 40,000 people are killed on the roads in the US alone. Despite a recent decline, there were 11 mm road accidents in the US in 2009 (latest data from the US Census). Most of these

accidents are caused by driver error or mechanical failure. Driver errors are, in turn, caused by lack of knowledge, failure to follow traffic rules, driver distraction, or driver incapacity (DUI or fatigue). Arguably, an autonomous car should be more capable and consistent with its computer-driven ability to determine and interpret its surrounding environment and apply traffic laws. This should result in significantly fewer accidents, especially if a high percentage of cars on the road are autonomous. This could be even more beneficial in emerging markets where limited driver experience, weakly enforced traffic laws, and poor road conditions result in a significantly higher ratio of traffic deaths to car population than in the developed world.

Exhibit 6

World Traffic Deaths by Region (2010)

(000s)

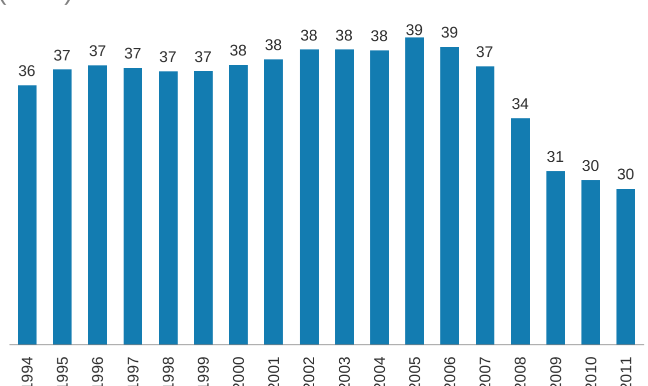


Source: Euromonitor Data, Morgan Stanley Research

Exhibit 7

US Traffic Deaths per Year

(000s)



Source: National Highway Traffic and Safety Administration Data, Morgan Stanley Research

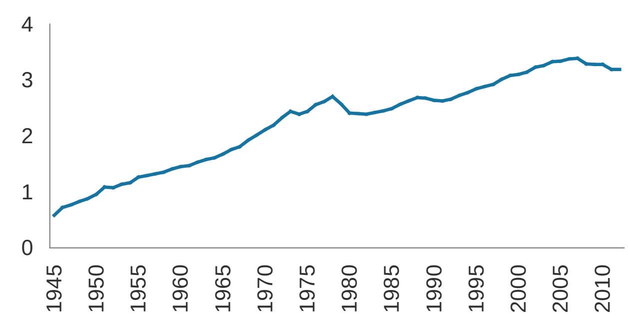
2. **Gasoline saved—**In the US alone, automobiles consume 143 bn gallons of oil per year use at a cost of over $500 bn. Cars that drive themselves based on predictive capability and the ability to alter the state of the car based on anticipated load conditions should be significantly more efficient than manually operated vehicles. Just using cruise control in a car of today can easily result in a 15-30% fuel economy improvement vs. manually operating the throttle. This is because the car knows what kind of load will be placed on the engine and adapts accordingly.

   In the future, autonomous cars with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communication ability will have a far greater understanding of road and traffic conditions and should be able to predict even anticipated loads on the engine allowing them to operate in "cruise" mode all the time. This could result in a similar level of fuel economy savings as using cruise control all the time. Combined with a push for more fuel-efficient internal combustion engines and light electrification, corporate average fuel economy could run up to 75 mpg and above. In a utopian world where all cars are self-driving, cars can theoretically be made significantly lighter (why reinforce a car that is not going to crash?), potentially driving fuel economy north of 100 mpg.

Exhibit 8

US Gas Usage – Gallons per Year

(bn)

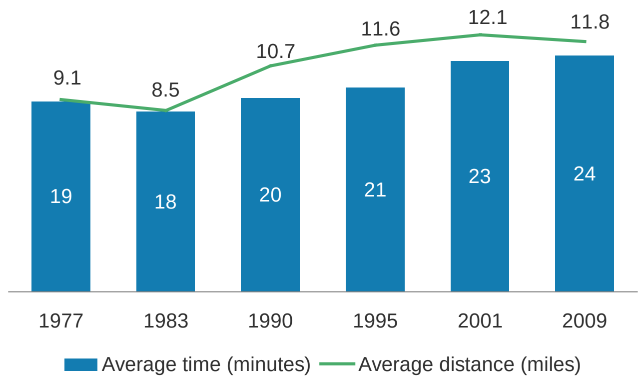


Source: EIA, Morgan Stanley Research

3. **Traffic patterns**—V2V and V2X capability should enable autonomous cars to know the position of surrounding traffic and create significantly more efficient traffic flow. Every year, the existing US car parc burns 3 billion gallons of gas sitting in traffic jams. Autonomous cars should be able to not only dynamically re-route themselves based on anticipated traffic conditions (similar to advanced GPS systems today), but also to avoid creating traffic jams in the first place. Car

positioning based on V2V/V2X communications should allow traffic to negotiate intersections without stopping, and cars should be able to travel at higher speeds and in closer proximity to each other (the aerodynamic efficiency of this should further boost fuel economy).

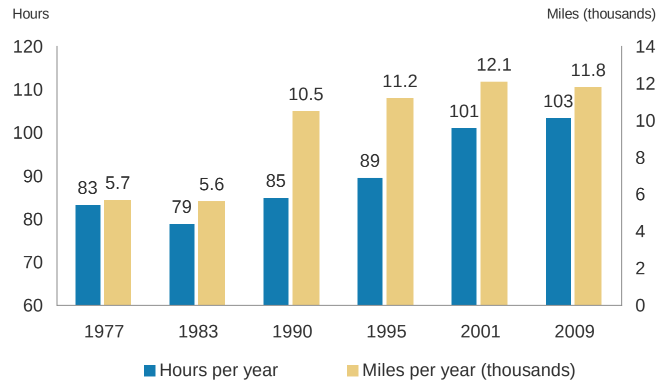
Exhibit 9
Historic Average Commute Time vs. Average Travel Length



Source: US Department of Transportation, Federal Highway Administration, Morgan Stanley Research

4. **Consumer productivity.** One benefit of smoother traffic flow, we believe, is less time spent on the road getting from Point A to Point B, which should significantly boost commuter productivity. The bigger gains could come from not having to manually drive the car, freeing up the occupants' time spent *in* the car for other pursuits. US drivers spend an average of 75 billion hours each year on the road, which can now be put to good use. Whether people choose to spend this time eating, sleeping, watching TV, reading the newspaper, working, or simply conversing, it should result in significantly de-stressing the average commute and life in general.

Exhibit 10
Average Yearly Hours Commuting vs. Miles Driven



Source: Euromonitor and Department of Transportation, Morgan Stanley Research

5. **Boost to the economy**. If, as we expect, autonomous cars do end up converting commuters into consumers, the resulting enhanced consumer productivity could drive economic value creation, which could conceivably help boost the economy. More importantly, more time to consume…anything—movies, TV, books, news, food, YouTube videos… in the car, means more opportunity to buy stuff. Expect to see a massive increase in the number of billboards by the side of the road, location-based advertising (such as an in-car tweet notifying you in real time that you are now driving past the highest-rated steakhouse in all of Dallas!).

6. **Military applications.** Aerial defense has already gone unmanned with the use of drones and spy planes. We believe ground warfare could do the same with autonomous vehicles. The connection between autonomous vehicle capability and defense applications is strong—the DARPA challenge was one of the first modern attempts at developing self-driving capability. Autonomous military vehicles can keep troops out of harm's way by scoping for IEDs, conducting reconnaissance, or even engaging in basic combat operations in dangerous situations.

Exhibit 11

US Army's Unmanned Stryker Combat Armored Vehicle

Source: Digital Journal

Between the lives and dollars saved and general improvement in the quality of life through fewer traffic jams, stress-free travel, and higher productivity, autonomous cars have the potential to effect the biggest transformation in society since the internet.

Obstacles to adoption

Consumer acceptance—At first, many consumers may be reluctant to put their lives in the hands of a robot. Recent studies and surveys have shown a split in opinion on whether people would like autonomous capability to be available in their vehicles or not. Therefore, mass acceptance of this technology could take a long time. This could be the case particularly if there are accidents involving even semi-autonomous vehicles early in the adoption phase, whether it was the fault of the autonomous system or not.

Just in the course of researching this Blue Paper, we have had discussions with people about autonomous vehicles that usually elicits two reactions: "that's awesome" quickly followed by "that's scary. What if I don't want to share the road with an autonomous car?" Over time, we believe the autonomous capability in cars will get more capable and reliable (see our adoption curve in Part 4), increasing the public's faith in and acceptance of the system.

Logically, as autonomous vehicles continue to penetrate, we would soon approach a point where to ensure complete reliability of phase 4 vehicles, all vehicles on the road would need to be at least partly autonomous. This could mean that autonomous vehicles could be mandated by law and manual driving disallowed in order to reduce the number of variables on the road. Suddenly, the question of "what if I don't want to share the road with an autonomous car" could become "what if I don't want to share the road with someone driving his own car?" There could be significant issues with telling people that they cannot drive their own cars. There could be significant privacy concerns as well if V2V/V2X systems can "track" every car on the road and store vehicle/road/traffic conditions in central databases for long-term access. We see a few potential solutions to this problem, which we discuss in Part 6.

Cost—In our view, the above is a reasonably high quality problem to have because it would mean the other obstacles on this list mostly would have been resolved, penetration of autonomous vehicles among the early adopters/tech fans/wealthy consumers would be full, and the technology would be knocking on the door of the mass market. To first get the early adopters on board, however, the costs of the system need to come down. At each point in our adoption curve (Part 5), the ongoing phase should add no more than $1,000-2,000 to the cost of the car, with the next phase adding not more than $3,000-5,000. Even with such limited cost premiums, penetration could be low and restricted to high-end trim levels of mass market vehicles rather than across the board.

According to a recent JD Power survey, 37% of respondents at first said they were interested in purchasing an autonomous vehicle, but that percentage dropped to 20% once they were told it would cost an additional $3,000. OEMs are already concerned that consumers may balk at paying a similar premium for new fuel efficiency technologies, despite the lower running costs that would result in a net payoff over time. In addition, newly mandated safety and consumer-demanded infotainment systems, together with the aforementioned fuel efficiency technologies, could already add $5,000 to $6,000 to the cost of the car, before the cost of autonomous systems, which may be seen as a convenient indulgence and not as "necessary" as the other features.

Technology—The practical hurdles to widespread adoption of autonomous vehicles may be great but to even get to that point, we must solve several technological challenges first. Almost every constituent we have spoken with believes that the path to fully autonomous vehicles contains many technological challenges—but none are insurmountable. In fact, some believe that a cost-is-no-object, fully autonomous vehicle can be put on the road today.

Some of the key technological challenges to be resolved are

(1) What to do in the snow/fog/rain when radar/sensor capabilities today are rendered ineffective

(2) How to manage LIDAR systems for real-time changes in roadside "profiles" (see Part 2: Technology for details on LIDAR and "profiles")

(3) How to integrate the army of sensors and radars in cars today without dramatically changing the styling and practicality of vehicles

(4) How to handle the human-machine interface (how does the car get the driver to take over in emergency situations)

(5) The chicken-and-egg quandary of having enough autonomous cars o the road to make V2V/V2X possible and relevant, but getting those early adopters on the road in the first place.

Again, these issues are not insurmountable, in our view. In fact, many in the industry believe that the leap to make fully autonomous vehicles commercially viable today would be *smaller* than the leap to commercialize fully electric vehicles. Many industry observers, OEMs, and suppliers also think that the greatest technological challenge is to bring those solutions down the cost curve for widespread adoption. In the end, we believe that the success or failure of autonomous vehicles and the timeframe for adoption will be determined not by the ability to clear the technology hurdle but by overcoming the other obstacles listed here.

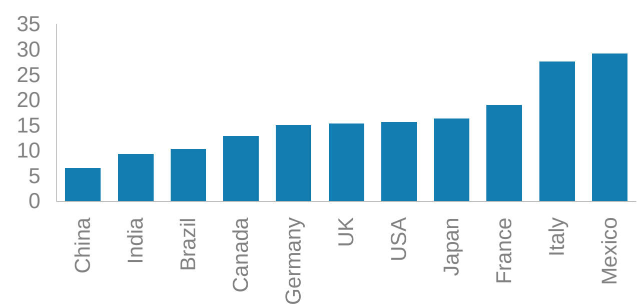
Liability——We have noted earlier that we believe customer acceptance is likely to be the biggest obstacle to autonomous vehicle penetration, but industry constituents that we have spoken with list the liability factor as the number one concern. Put simply, if there is an accident involving an autonomous vehicle, who is liable for the consequences? Legally, the OEMs can cover their liability in partially autonomous vehicles (stages One through Four, as listed in Part 5: Timeline for Adoption) because the driver is still behind the wheel and therefore ultimately liable for the safety of the vehicle. But even this point may be intensely debatable, if a "feature" of a car cannot be relied upon at all times. The insurance industry needs to get fully on board with autonomous vehicles and lay down strict rules of "at fault" before we can commercialize fully autonomous vehicles. We have explored this topic in more detail in Part 6: What Happens Next.

Legislation—National and state governments will need to develop laws that allow cars to drive themselves on the streets. Among the potential implications of this, people who otherwise are not able/allowed to drive could "get behind the wheel" of autonomous cars, and cars could technically drive from one place to another with no occupants. There are concerns over privacy and how to manage the enormous mount of private data that will be generated. The initial steps appear relatively promising. In the US, California and Nevada have granted "licenses" to self-driving autonomous vehicles and the US Department of Transportation has issued guidelines for the implementation of autonomous vehicles.

Existing car parc—Autonomous cars will be most effective when all cars on the road have the capability, which will then act as a universal, crowd-sourced traffic management system and drive predictable reactions to different driving scenarios. However, with 250 million cars on the road in the US alone (and 1 billion worldwide), full penetration of autonomous vehicles could take decades. At a rate of 13-14 mm cars scrapped in the US per year, turning over the US car parc alone would take almost 20 years. Having manually driven cars along with autonomous cars could dramatically increase the number of unpredictable outcomes and reduce the reliability, effectiveness, and safety of autonomous cars in the initial years—which could set off a vicious circle of limited acceptance. There could be a solution, however. Once there is a large enough penetration of autonomous cars (more than 25%, approaching 50% of cars on the road), we believe the obvious and quantifiable social and economic benefits of full penetration could accelerate the scrappage or retrofitting of existing cars with autonomous systems, via government or industry aided funding and/or mandates. This could cut the time needed to achieve full penetration by half. *See Part 4 for more detail.*

Exhibit 12

Car Parc Turnover (Parc/2013 Sales) for Major Countries



Source: IHS AutoInsight, Eurodata, Morgan Stanley Research

Infrastructure/EM—While autonomous cars' dependence on dedicated infrastructure is much lower than it was in the early prototype stages several years ago, we still need some basic level of infrastructure including road markings and signage, GPS mapping, strong telecom networks and ideally some level of vehicle-to-grid (V2X) communication. Lack of infrastructure in EM and even some DM markets could be a challenge to accelerating penetration of autonomous vehicles. *Please see Part 3 for more detail.*

Security—The prospect of cars that can drive themselves inevitably raises security concerns. What if an autonomous car can be hacked into and taken over? While a real issue, we believe autonomous cars are probably not as vulnerable as some people think. Recent reports of individuals "hacking into" cars have raised concerns about future connected cars. However, we note that every instance of a "car hack" so far has been physical—wires connected from the hackers' computer to the cars OBD system with the "hacker" physically inside the car. The "risk" in this situation is the same as the risk that a burglar is sitting in the back seat with a gun to your head. Hacking a car wirelessly is much more difficult. That does not mean it is impossible, however, and future technological development theoretically could allow someone to wirelessly enter a car through its connectivity systems. The auto industry recognizes this and is moving to address it. The current AUTOSAR automotive software development standards are being fortified to prevent break-ins and the industry is moving toward protecting each ECU in the car from being hacked.

The ethical issue—Autonomous cars raise two kinds of ethical issues

(a) Can we program an autonomous car to respond to *every single conceivable scenario* on the road, including instances when it may be necessary to break or circumvent existing laws or rules to achieve a favorable outcome (breaking the speed limit on the way to the ER, for example, or driving recklessly to get out of a dangerous situation)?

(b) While autonomous cars are likely to deliver significant socio-economic benefits, there is also a flipside in terms of a number of jobs being rendered obsolete.

Regarding (a) we note that those same ethical issues exist today—what happens if the police stop the aforementioned driver speeding to the ER? Does he get a ticket? Also, there could be workarounds—the occupant could call 911 to get a special dispensation, and that car could then be "permitted' via special instructions to drive under a different set of protocols.

Regarding (b), this is an unfortunate potential outcome of the adoption of the driverless car, but we note that this has been an issue since the Industrial Revolution, and every single technological breakthrough ever since. In addition, the enormous savings generated by autonomous cars should help pay for compensation and/or training for those negatively affected by it.

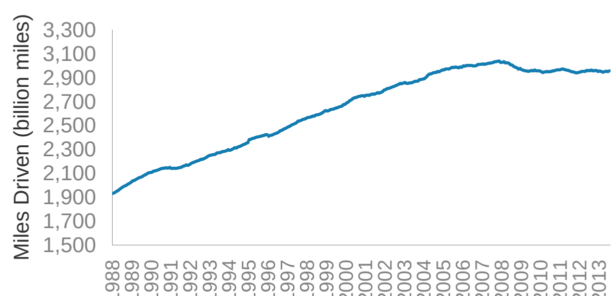
How autonomous cars can change the world

Miles driven should increase—US drivers drive approximately 3 trillion miles a year. This number had increased in almost a straight line over the past 30 years but peaked in 2008, then declined sharply in the economic downturn, before stabilizing more recently. However, during the period of growth, the number of cars on the road rose at an even faster pace and miles driven per car peaked in 2004. Simply put, Americans today are driving less, on both an absolute and relative basis, than they were before 2008.

There could be a number of reasons for this. The relative decline could be a result of too many cars on the road, while the absolute decline could reflect macro weakness/high unemployment, high gas prices, environmental awareness, the rise of internet services (Facebook, Seamless, Netflix etc., which give people fewer reasons to venture outside) and declining youth interest in the car. The consensus view appears to be that miles driven will continue to remain stable or decline because most of the above factors (except macro) are structural and not cyclical.

Exhibit 13

US Miles Driven – Trailing 12 Months

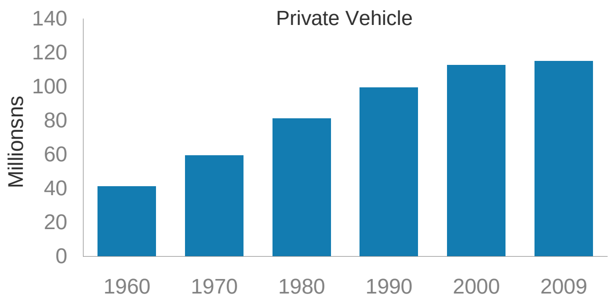


Source: Federal Highway Administration, Morgan Stanley Research

We believe autonomous cars can change this trend and boost miles driven significantly. If driving—whether as a work commute or an interstate vacation—is a comfortable, stress-free experience that gives consumers their own private space and flexibility of schedule, with little actual involvement in the driving activity, we believe consumers may be willing to switch away from the inconveniences of public transportation to "driving" their own autonomous vehicles.

Usage increase—Another factor resulting in higher miles driven will be the use of autonomous vehicles in driverless situations. Autonomous capability is perfectly suited for fixed route applications including public transportation (buses, taxis), delivery (mail, package, commercial) or even long-haul. Over time, autonomous vehicles in these applications could dramatically increase usage and lower cost vs. having human drivers. Autonomous cars also lend flexibility to occupants who are too young or too old (or too incapacitated) to drive but need to travel anyway and now will not have to depend on someone to drive them around.

Exhibit 14
Commuters in the US



Source: US Department of Transportation, Federal Highway Administration, Morgan Stanley Research

More suburbanization—If drivers are more comfortable traveling long distances in a car because of higher productivity and the new ability to put that time to better use, we may see a trend toward moving away from dense, expensive urban areas to increasingly remote suburbs. Local governments may encourage this move (through tax incentives and other) because it may reduce the need to build expensive public transportation systems, reduce the resource load on urban centers, and increase tax revenues from gentrification of remote suburbs.

Car ownership—There are polar opposite views on what autonomous vehicles will do to car ownership. One school of thought is that the higher optionality now provided by an autonomous car could dramatically increase car ownership. People who previously relied on public transit for time management, cost, safety, or other reasons could now choose to own their own cars instead. The other school of thought says that car ownership could collapse if driverless cars could serve multiple purposes (why own two cars in a household when one car can drop a spouse at work and then return on its own to pick up the other spouse). In an extreme scenario, car ownership could fall to virtually zero to be replaced by roving fleets of driverless droids to take you to your destination.

Our view is that the final outcome is likely to be something in between. We do not see the extreme scenario of almost no car ownership playing out simply because we have not seen car ownership today replaced by massive fleets of "driver-ed" taxis or car-sharing services. The desire to own your own personal, clean, reliable method of transportation is too great, in our opinion. We believe the tendencies to either downsize the household car fleet or expand it—because of the higher flexibility of autonomous cars—will largely offset each other. We expect car ownership to remain largely stable, with more households having cars but with fewer cars per household.

Cars will look different—An autonomous car needs to look nothing like the cars of today, in our view. A car of today is built around the driver and maximizes that person’s physical ability to drive the car. An autonomous car needs to be built around the comfort and entertainment of the occupants, with the car doing its own driving. What will cars of the future look like? Look up. We see airplanes as a good benchmark. Cars will have highly aerodynamic bodies with built-in sensors and cameras around the edges. We will no longer need large and potentially dangerous windows apart from small portholes for occasional sightseeing. The interior will mimic first class airline cabins with large, comfortable, reclining seats for all occupants and several displays (including on what used to be the windscreen?), since we will not need a traditional steering wheel, pedals or instrument panels. Cars will be lighter through use of advanced materials and less need for crash reinforcement/passive safety and mechanical controls. Why do cars need to have lights, apart from airplane-like strobes, since there will be no need to signal and the cars will have infrared cameras with which to see?

Exhibit 15
The car of the future? Maybe…

Source: Morgan Stanley Research

New revenue model for the auto industry—From an investment perspective, it is understandable that the auto industry will see the biggest impacts, both positive and negative. We see two fundamental changes. First, while the traditional OEM/supplier relationship will continue for some time, we see the industry eventually coalescing around three main components: 1) companies that specialize in making the car (traditional OEMs/suppliers or "hardware" makers); 2) companies that specialize in making software that will be the brains of these cars, including autonomous driving capability (hi-tech suppliers, in-house OEMs or third parties called "software" suppliers); and 3) companies that try to be vertically integrated and control every aspect of the automotive "experience," including the content consumed by the occupants of the autonomous cars. This potential industry structure closely parallels the PC/smartphone industries. See our detailed analysis of this business model in Part 7.

This new industry structure—with the growing importance of software and content that the traditional players have little knowledge of—could effect the second fundamental change we foresee. It could render obsolete traditional players who cannot evolve, replacing them with new players from outside the industry (such as, hypothetically, Google, IBM, Cisco Systems, smartphone makers, and startups).

EM/remote connectivity—While most of the above changes seem to relate mostly to developed markets, they are equally applicable to EM, in our view. However, where the EM markets could see the most game-changing impact from autonomous cars could be in remote and poor regions. Autonomous vehicles can be used as regular convoys to supply food, water, and resources to remote but populated areas, serve as an alternative to non-existent and/or difficult mass transportation. Even in urban areas, we believe autonomous cars can bring driving discipline, ease traffic management and reduce accident rates. Please see Part 3 for more detail.

Is this the end of the auto enthusiast?

Not necessarily, in our opinion, and things may possibly get even better. One of the issues frequently presented to us as an obstacle to the penetration of autonomous cars is that people love driving too much to give up the wheel, especially in Europe. We disagree. In our opinion, the vast majority of people driving today are trying to get from Point A to Point B as quickly, safely, and comfortably as they can, and are not attempting to carve up canyon roads. For those that do enjoy such things, the move to autonomous vehicles is only another step on a path that began with the slow death of the manual transmission. The new generation of automatic transmissions are so objectively superior to manual transmissions in every way, that only a small group of hard-core enthusiasts still lament the imminent extinction of manual. Furthermore, we believe that in an autonomous car world, enthusiasts can still enjoy track days where they can drive select cars manually or take “classic cars” for a spirited drive. The takeaway is that, as car enthusiasts, we may be living in a golden age *today.* Go buy a top-of-the-line luxury/performance model today and store it in a garage for the next 20 years.

MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

Which Technology Wins?

Technology

The technology to enable fully autonomous car capability already exists. Active safety systems that are commercially available today represent a basic level of autonomous driving. Fully autonomous functionality does not need much more incremental hardware.

Software and testing is where most of the work needs to be done. Autonomous cars use sophisticated algorithms to decipher the input received from sensory hardware to determine the course of action to be taken and how to execute that action. This will also need extensive testing to ensure every possible scenario has been accounted for.

The cost premium is not that high. We estimate that a fully autonomous systems will add about $10,000 to the cost of the car, with the cost expected to be cut in half by the time the technology is ready to be commercialized by the end of the decade.

The first step toward getting autonomous cars on the road is to get them to work. This may not be as large a challenge as some think because much of the technology already exists. In our discussions with the players involved, a few things have become quite clear

1. **The hardware is not the hurdle.** Most of the technology needed to get fully autonomous cars to work in the real world already exists today and many fully functional prototypes have already been built and are being tested. Active safety systems, which offer a very basic level of autonomous functionality, have been on sale for a few years and are just starting to enter the mass market. Full autonomous capability only needs automakers to walk further down that path. We look at many of the hardware components that make up the autonomous driving system in this section.

2. **Software will be the "secret sauce" here**. While the hardware situation appears relatively settled, much of the development work taking place today appears to revolve around software. Autonomous vehicles use incredibly sophisticated algorithms to interpret the sensory input coming in from the hardware to (a) interpret the car's surroundings (b) anticipate upcoming events and predict the necessary reactions (c) instruct the various hardware components of the car to perform the necessary actions. This exponential increase in the amount and sophistication of software needed to achieve autonomous capability is probably the biggest change in the functionality of the automobile.

3. **Practical considerations are the main impediment.** While the engineers put the final tweaks on the hardware and software needed to deliver full autonomous capability in labs, the long lead time to commercial implementation is likely to be the result of practical considerations. There are two levels of practical considerations (a) solving non-technical issues like liability and regulation, as discussed elsewhere in this report, and (b) making sure that the hardware and software have accounted for virtually every possible real-life driving scenario. The only solution for (b) is extensive testing in the real world and in simulations, which takes a lot of time and resources and needs some level of (a) to be solved.

The industry's poker face

The section on Technology was both the easiest and the toughest part of this Blue Paper for us to write, and came together at the very end. The easy part was that most of the content for this section physically exists, is already commercialized, and is easy to write about, with little need for the projection we employ in many other parts of this report. The hard part was trying to penetrate the wall of secrecy surrounding industry activities on the technology side. We spoke with many companies currently operating autonomous vehicle prototypes and while most were eager to discuss their broad vision of a future with autonomous cars, there was little visibility into specific technological approaches, even at a 10,000-foot level. Some of this, understandably, could be a result of competitive concerns. But we believe the secrecy may also indicate a lack of clarity on the precise path ahead. We found many of the suppliers, including Autoliv, Delphi, Denso, and TRW, to be much more forthcoming about their technological solutions.

There appear to be two broad approaches to getting the car to be able to drive itself

The old adage "Give a man a fish and feed him for a day or teach a man to fish and feed him for a lifetime" is a good way to describe it.

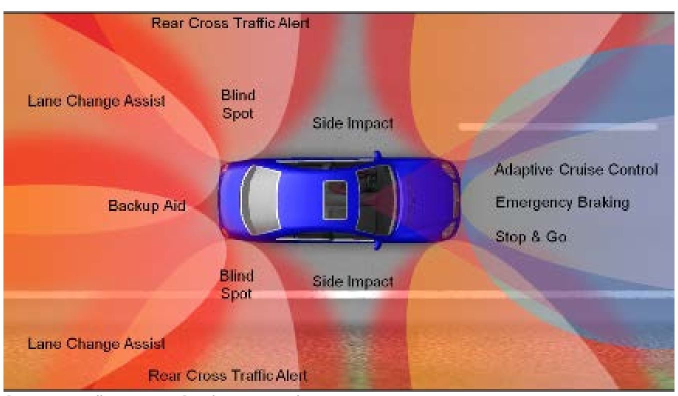
The first approach is the "give a man a fish approach" where the car is told where to go. Imagine being blind-folded and having to walk through an obstacle course with an external observer passing on instructions like "turn left, walk 10 steps, stop, turn right," etc.—that is approximately what this approach is like. The input comes from infrastructure (along the road sensors, intersection management systems, and other V2X communication) and from comparing a LIDAR-obtained profile of the 360° surroundings of the car, comparing that image to a map database, and identifying any differences between the two images as "obstacles" that need to be navigated around.

The advantages to this approach are that it can be made quite reliable over time, covers relatively large distances and is relatively low cost (from the car's perspective). The disadvantages are high initial cost (because of the need to build out infrastructure and a detailed street-view map database) and potentially, the car's ability to react to sudden changes.

The second approach is the "teach a man to fish approach," which is similar to tackling the obstacle course by feeling your way around the course while blind-folded, without external navigation instructions. This is achieved by stuffing the car with a battery of cameras, radar, and sensors that give the car a 360° knowledge of the surrounding environment and allowing it to react proactively to obstacles.

This approach allows the vehicle to react quickly to situations and focus only on what is important, while ignoring everything else—which is one of the most important and fundamental rules of autonomous driving. The downside is relatively high car cost (at least in the near term) and sensitivity to weather and other sources of electronic signal blockage.

Exhibit 16
Building a sensory buffer around the car



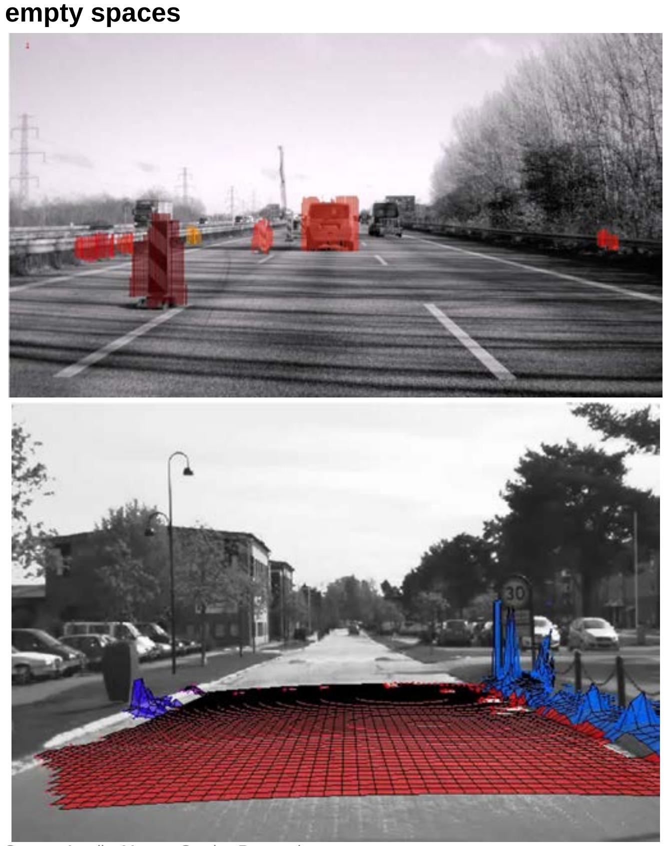
Source: Autoliv, Morgan Stanley Research

Neither approach is the "right" or "wrong" one. In reality, the final approach is likely to be a combination of the two—or an "all-of-the-above" approach to achieve maximum reliability and redundancy for the system.

Hardware components of an autonomous driving system

1. **Cameras:** Cameras need to be at least monovision cameras, which means they have one source of vision. Monovision cameras are very simple devices and the video feed is usually used for understanding basic surroundings—typically fixed infrastructure like lane markings, speed limit signs, etc. The hardware itself is pretty simple and cheap. Automotive monovision cameras are less sophisticated and have lower pixel density than cameras on smartphones. However, the challenge is on the software side, which involves fast image processing to recognize common roadside infrastructure from a simple black and white relatively low-resolution image. The next stage up is stereovision cameras, which use two video sources, similar to human eyesight. This incorporates depth perception and can help the car better understand the relative position of moving traffic and potential obstacles.

Exhibit 17
Stereovision cameras use depth perception to differentiate between moving and still objects and empty spaces



Source: Autoliv, Morgan Stanley Research

Apart from object detection, the cameras can be used for various other applications, including reading speed limit signs, headlight high beam de-activation in case of an approaching vehicle, light sensing, etc.

Exhibit 18
Monovision camera

Source: Autoliv, Morgan Stanley Research

2. Radar: in addition to visual confirmation of its surroundings, the car also collects sensory images using radar systems. There are two typical types of radar systems— short-range and long-range, which are usually mutually exclusive. Short-range radar, as the name indicates, "feels" around the car's immediate surroundings, especially at low speeds, while long-range radar is used at high speeds and over relatively long distances. It is the combination of long distance radar plus algorithm-based processing of images from stereovision cameras that gives the autonomous car the capability of knowing, with a reasonably high degree of accuracy, exactly what is in front of it and how the positions and profiles of external objects are changing at all times.

An autonomous car is also likely to have short-range side radar (already used in blind spot detection systems) and short- and long-range rear radar (already used in advanced active safety systems for pre-crash warning and avoidance) to create a 360° view of what is around the car. Ultra wideband radar is probably best suited for autonomous applications but the challenge with the technology today is that standards are not harmonized and it is difficult to secure permission to use the spectrum needed for its operation. However, we expect this to change over time as the technology matures and there is more pressure on governments to approve, monitor, and secure communications bandwidth for autonomous cars.

Exhibit 19
Automotive radar systems

Source: Autoliv, Morgan Stanley Research

The weather issue: One of the concerns surrounding an autonomous car's ability to be effective in a broad range of circumstances is the whether it can be reliable in bad weather. It is true that in conditions of heavy rain, fog or snow, the autonomous car's cameras would struggle to pick up familiar patterns or objects while radar systems could become confused. In such cases, an autonomous car may not be able to function.

However, there are a few things to keep in mind:

1. This only happens in cases of really extreme weather, where visibility drops to very low distances similar to whiteout conditions. It can be argued that the human driver's ability to see may be no better than the car's in such circumstances and the best course of action may indeed be to pull over and not drive at all

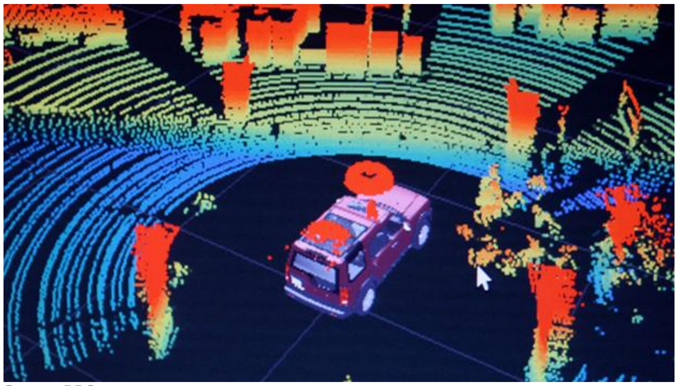
2. Vehicle to vehicle communication makes driving in poor weather conditions safer than with manual driving. Cars know exactly where they and other cars are on the road and differing speeds and driving styles will not be an issue. Autonomous cars will also be unlikely to drive in a manner unsuitable to the conditions, causing fewer bad weather accidents.

   In the end, driving probably becomes like other modes of transportation, including air and train travel—if the weather conditions are so bad that even a car with advanced stereo and infrared cameras and long distance radar cannot see, it is probably too dangerous to drive in the first place.

3. **LIDAR:** LIDAR uses a combination of reflected laser/light (LI) and radar (DAR) to create a 3D profile of the surroundings of the car. LIDAR is extensively used today in marine, archeological, and mapping applications.

LIDAR does not technically detect a moving object but rather creates a rapid series of 360° profiles and compares them to each other and to a stored database to detect changes (i.e., movement). One of the issues faced by this system in real life is that temporary changes (like snow or new traffic patterns) could disrupt the surrounding profile. Also, given the nature of the output, this system may not work for some aspects of autonomous driving like lane and sign tracking, which will need camera / vision systems.

Exhibit 20
LIDAR image creates a 3D profile of the car's surroundings



Source: BBC

4. **Sensors:** While the cameras, radar, and LIDAR are used for obstacle and environment monitoring, sensors are used extensively to understand what is happening with the car itself. In addition to navigating the roads, the autonomous car also needs to monitor itself to know that it is not traveling over the speed limit or if something is wrong with the car and it has to pull over. Sensors of all kinds are already extensively used in cars, including acceleration sensors, pressure sensors, light sensors, etc. We expect a meaningful step up in sensor content in the car, especially in the active safety and human-machine interface (HMI) areas.

5. **GPS receiver/communications:** Autonomous cars will need reliable, high-speed two-way data communications equipment for navigation, V2V/V2X communication, and content reception. This will include antennas, 4G receivers, and GPS receivers. Autonomous cars will also likely need to have sophisticated event data recorders or black boxes, similar to planes, given the high level of automation, in the event of an accident or failure.

6. **Human-machine interface (HMI):** The HMI could be one of the most sophisticated and complex systems within an autonomous car. The HMI refers to the combination of systems in the interior of the vehicle, including the infotainment/entertainment system, instrument panel, and controls that act as an interface between the car and the occupants. The HMI in an autonomous vehicle will be very different from that of a vehicle today. The priority for the HMI will move away from driver information and control and toward infotainment/entertainment. However, the HMI also needs to be aware of the internal environment of the car, in case of emergency situations. In exceptional cases, the car may need to alert the occupants that it needs to be manually controlled or that it is pulling over. The HMI is likely to be comprised of an array of in-cabin sensors, screens, and controls.

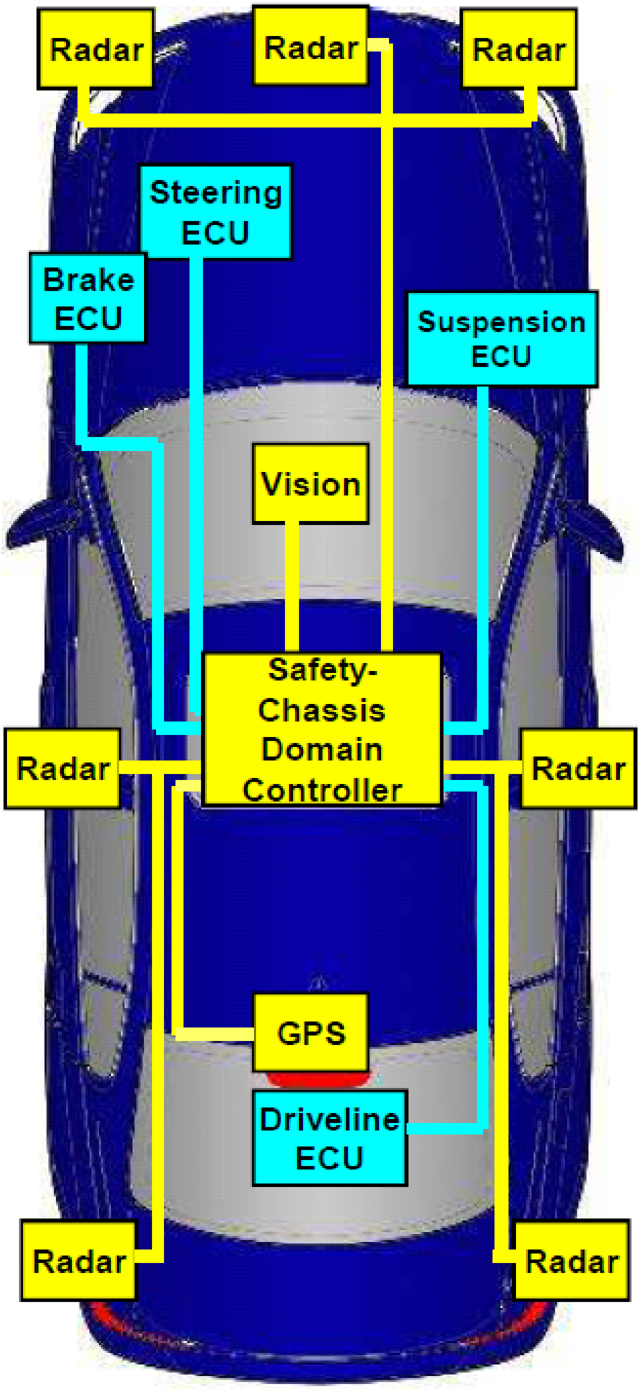
Exhibit 21
Acceleration sensor

Source: Autoliv, Morgan Stanley Research

7. **Domain controller:** The domain controller functions as the hardware "brain" of the autonomous driving system. It acts as the crossover between the input and output systems of the car by receiving signals from the various cameras, radar, and sensors, determining what action is to be taken and then communicating with the car's drivetrain to execute the necessary actions. The domain controller is also likely to be where the software brain / operating system of the car resides (see Part 7 for more detail on the car's operating system). The battle over who controls the domain controller—the OEM, the safety supplier, the chassis supplier, the autonomous system supplier—will determine who controls the value of the car.

Exhibit 22

The Domain controller performs a critical central control function in the car



Source: Autoliv, Morgan Stanley Research

8. **Motion control systems/actuators/mechatronic units**. Once the domain controller has decided what action is to be executed based on inputs received by the sensing units, it passes instructions to mechatronic units/actuators, which physically control the drivetrain components, such as the steering wheel, throttle, brakes, suspension, etc. Actuators are already present in cars with active safety systems today, as these are the components that make the steering wheel turn and the car accelerate or brake without human input.

Exhibit 23

Actuators control the steering and other mechanical components in the drivetrain

Source: TRW, Morgan Stanley Research

We believe that the auto industry will collectively come together to establish standards for V2V/V2X communication, autonomous system hardware, and software to ensure commonality, consistency, and safety of systems across OEMs, geographies, and vehicle types. This process may already be underway.

There needs to be a high level of redundancy

The price of system failure in an autonomous car is unacceptably high, similar to the aviation industry. One way to minimize the impact of mechanical failure is to have redundant systems, again, similar to the aviation industry. Failure of one system could then be made up by backup systems, at least in a fail-safe mode. Autonomous cars will approach redundancy in two ways.

(1) For sensory inputs, to determine the environment around them, autonomous cars use multiple overlapping data sources to ensure that the quality of the sensory input is as accurate as possible. The multiple cameras, radar, LIDAR, and GPS systems are all used to look around the vehicle—each in slightly different ways—to ensure that all possible variables in the surrounding environment are captured.

(2) The mechanical systems in an autonomous car, however, will likely need multiple hardware systems to ensure that failure of one does not compromise the safety of the vehicle. If the actuator that controls the steering fails, for example, there needs to be an electronic or mechanical backup, at least until the car has been brought safely under control. We note that the odds of failure for an autonomous car are just as high as for a car today (which does not have redundant systems) or even lower, given the high level of system monitoring and V2V communication that can notify following cars of even an impending failure and make sure they avoid a collision. However, in the event that a failure does result in a collision the consequences could be catastrophic (given the likely speeds and traffic density at the time), making the need for redundant systems a vital one. Redundant systems also add significant cost and weight to the vehicle, which might be the ultimate determinant of the level of redundancy built in.

The cost is not that high, in a broader context

It doesn't matter what this technology is capable of, if no one is able to afford it. We were surprised to find out that autonomous systems are likely to cost significantly less than we initially thought. At today's prices, we estimate that the various hardware components needed to achieve *full* autonomous capability cost less than $5,000 per car, which means that, together with R&D and other costs, the customer would pay a premium less than $10,000. We believe this is a reasonable premium to pay over a regular car given the benefits to the customer of a car that can drive itself. By the time fully autonomous cars are ready to be commercialized in 5-7 years, we expect the cost to be cut at least in half, with higher volumes and more mature technology. Pressure from tougher safety standards that compel the OEMs to put these technologies into their cars (even if not mandated by the government) could see the OEMs squeeze profit margins on the incremental content and bring cost down even further.

MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

Regional Differences

Regional Differences in Autonomous Car Development

Many industry observers believe that even if autonomous cars were to be successful, they are likely to remain a developed market (DM) phenomenon only.

We disagree. We think emerging market (EM) penetration of autonomous cars is essential because the volume boost would bring down the cost of the technology and would support the strong push by every OEM to achieve platform consolidation.

We see several catalysts that can aid the adoption of autonomous vehicles in emerging markets.

Basic infrastructure is a necessity to make autonomous cars work. The latest technology aims to make autonomous vehicles independent of fixed dedicated infrastructure. Several decades ago, the early prototypes and experimental models relied upon roadside and connectivity infrastructure (such as under-road metal strips and radio transmitters along roadways) to make the car aware of its surroundings and path of travel. Autonomous vehicles today seek to use a battery of on-board cameras, radar, and GPS to get an independent sense of the surrounding environment. This, in theory, reduces the autonomous vehicle's dependence on infrastructure, giving it relative flexibility of use.

However, while the autonomous car of today can see by itself, there still needs to be something to be seen and this necessitates a basic level of infrastructure development. Even fully autonomous cars will depend on road and lane markings, and global positioning systems loaded with pre-mapped roads. They will also require a sufficient field of vision and connectivity for V2V and V2X communication.

It appears autonomous vehicles are therefore best-suited for developed markets—at least in the near term. DM are more likely to have fully developed and mature road and communications infrastructure. Furthermore, given higher average transaction prices and traditional familiarity with a technology penetration curve in developed markets, acceptance of and willingness/ability to pay for autonomous vehicles could also be higher than in emerging markets. Almost everyone in the industry that we have spoken with seems to believe that if and when autonomous cars start to penetrate the car parc, their growth will likely remain restricted to developed markets only.

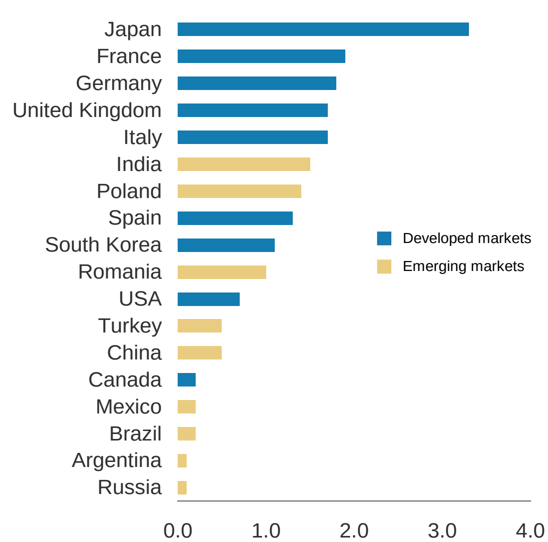
This is certainly the way the early days of autonomous cars are panning out. The US appears to be the most willing to embrace the concept of autonomous vehicles, with two states (California and Nevada) granting licenses to OEMs and suppliers to test-run autonomous vehicles on public roads (Florida and Michigan have also been supportive). Various US government bodies like the National Highway Traffic Safety Administration (NHTSA), the Department of Transportation (DOT), and the Environmental Protection Agency (EPA) are thinking about future legislation already, and several other corporate constituents appear open to the concept.

Europe appears to be proceeding more slowly on this path, which is unusual given that Europe traditionally has been the incubator or birthplace of cutting-edge automotive technologies, including active safety, the predecessor of autonomous driving. Indeed, many European OEMs, including Audi, BMW, Mercedes-Benz, and Volvo, are among the pioneers in the field of autonomous driving. But while much of the R&D may be in Europe, the US is also becoming an R&D center, and increasingly the predominant test-bed for the OEMs, although these are signs that Europe may be starting to catch up as well. In July 2013, the Department of Transportation of the United Kingdom issued a report approving the testing of autonomous cars as part of a GBP28 billion plan to ease traffic congestion. Japan also recently issued its first autonomous driving license to Nissan.

Exhibit 24

Global road density—Developed markets have a more developed road network, giving them a better platform for autonomous cars

Kilometers of Road per km^2 of Land



Note: KM of roads per KM2 of land area 2012
Source: Euromonitor Data, Morgan Stanley Research.

Why is the regional development relevant?

Does it matter whether autonomous vehicles remain a DM phenomenon only and cannot make inroads into the EM markets? Indeed, there is no technical reason why we cannot have a vast network of autonomous cars in DM with regular cars in EM. **However, we think it is critical that autonomous cars gain acceptance in emerging markets as well.** In fact, we believe autonomous cars may struggle to fully penetrate even DM, if EM volumes do not catch up.

For starters, if autonomous cars can achieve penetration in EM markets, the volume boost should help defray the development costs. However, that is merely a collateral benefit. The primary reason why we believe EM penetration is critical is the structural push toward platform consolidation—the top strategic priority of most global OEMs today. OEMs are looking to reduce the number of architectures and engine platforms on which they build cars globally to minimize engineering costs and gain economies of scale over the largest volume possible. We expect this to be the top driver of structural cost savings for the OEMs over the next decade. What this also means is that OEMs will be looking to sell virtually the same model of car with a similar engine lineup in all regions of the world.

A purpose designed and built autonomous car may have many characteristics that differentiate it from a non-autonomous car. As discussed in Part 1, an autonomous car can be lighter, look different inside and out, and have different design and engineering priorities than a regular car. The differences can be even greater under the skin, with a network of radars/sensors and different electrical architecture and hardware/software relationships. This could make common platforms extremely difficult to achieve between autonomous and non-autonomous cars. Making a non-autonomous car on an autonomous architecture could result in massive redundancies and cost inflation for no benefit at all.

If OEMs now need to develop separate platforms for EM and DM markets, it could completely negate any cost savings that the OEMs seek to generate from platform consolidation. It is critical that the OEM can sell the same car in all markets—so either autonomous cars penetrate EM as well or the whole exercise could be a non-starter in DM as well. Fortunately, we do not see this being a significant problem.

We think autonomous cars can thrive in Emerging Markets

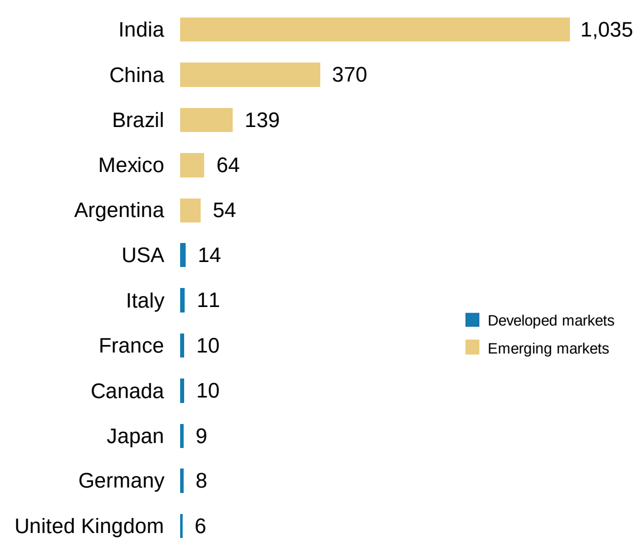
Despite the early start and inherent bias toward autonomous vehicles remaining largely a developed market phenomenon, we believe emerging markets will eventually become the primary markets for autonomous vehicles. Developed markets may well take the lead and see high penetration in the initial years, but over time, we see a number of reasons why developing markets should quickly catch up.

1. More people = more traffic deaths. While the existing car parc in most EM countries is still small compared to DM countries, the number of traffic deaths as a percentage of cars on the road is significantly higher. According to the latest data from Euromonitor, over 1,000 people are killed per 100,000 cars in India and 370 in China vs. 10-15 in most developed markets. By the end of this decade, the number of cars on the road in China will approach today's levels in the US. Assuming a similar ratio of traffic deaths to car parc (where the fatalities per 100,000 cars in China is 30x the rate in the US), almost one million people will be killed on the roads in China every year.

Exhibit 25

Total number of road deaths per 100K vehicles

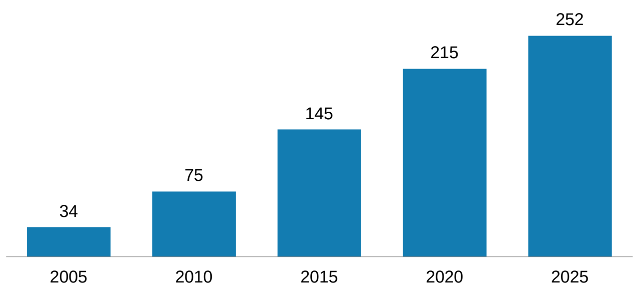
World Traffic Deaths by Country (2010)



Source: World Health Organization, Morgan Stanley Research. Note: * Death rates calculated using light vehicle car parc excluding two wheeler. Emerging markets of India, Brazil, China, Mexico and Argentina have higher two wheeler mix in death rates.

Exhibit 26
Projected Car Parc Growth in China through 2020

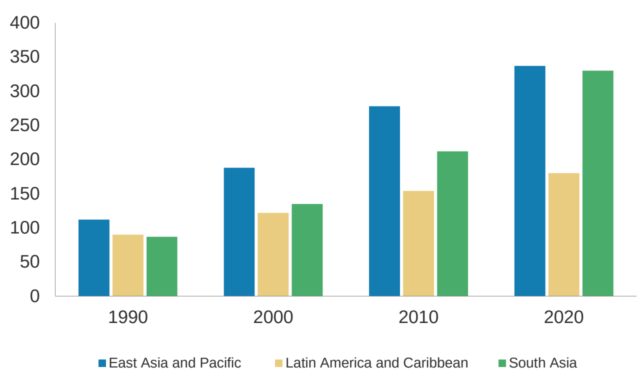
(mm)



Source: IHS AutoInsight, Eurodata, Morgan Stanley Research

Exhibit 27
Projected Road Fatalities Growth in EM through 2020

(000s)



Source: GBI Research Data, Morgan Stanley Research

2. Less stringent driving tests/standards and higher congestion: Standards for driving in EM markets tend to be lower than DM markets. This may be the result of driving licenses that are easier to obtain, greater congestion, less strict enforcement of driving laws, problematic traffic planning, and insufficient driving infrastructure.

This is initially going to be a challenge to penetration of autonomous vehicles, which need a certain degree of uniformity/predictability of traffic flows. However, over time, deeper penetration of autonomous vehicles should, by itself, improve driving standards if the cars are controlling the flow of traffic.

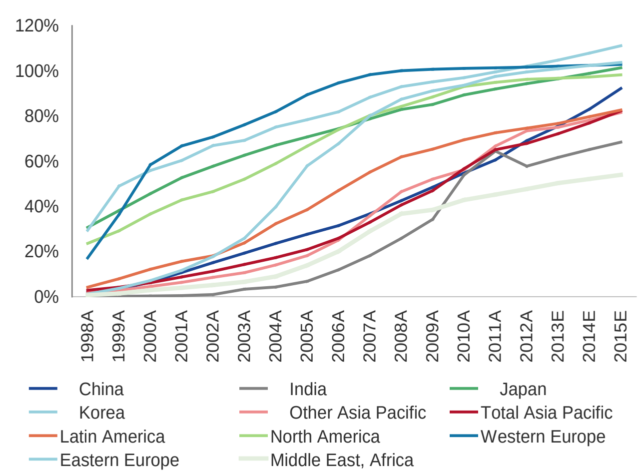
To facilitate the changeover, we may need designated "autonomous car-friendly zones" in some countries. Autonomous vehicles seem very well-suited to urban areas in emerging markets but face enormous challenges in less developed rural areas. It is possible to envision a scenario where cars may be required to switch to autonomous mode to enter parts of the cities that are prone to congestion and grid lock, similar to low pollution “congestion zones” in some cities today.

3. Higher penetration of chauffeur driven cars...which is getting more expensive. The high congestion and poor driving standards together with low car penetration (a family may only have one car but needs to run multiple trips during the day) and hitherto cheap labor has driven a significantly higher proportion of chauffeur-driven cars in EM than in DM. It is not uncommon to see even ultra-compact cars being chauffeur driven in EM. However, rising labor/wage rates and a tight labor pool are making it increasingly difficult and expensive to retain chauffeurs in growing emerging markets. Autonomous cars can cost effectively solve this problem (at least partly, at first).

4. Quicker to adapt to new technology: EM countries have been very receptive to new technologies and conveniences. For example; smartphone penetration in China, India, and other EM countries has outpaced Western Europe and other developed countries in recent years. While the EM markets are typically a generation or two behind the DM markets with adoption of safety and emissions standards, technological content is quickly catching up. We believe EM markets could embrace autonomous driving if it can cost effectively solve a number of practical issues facing driving in EM countries.

Exhibit 28
Smartphone Wireless Penetration Globally

India and China have amongst the fastest growth rates



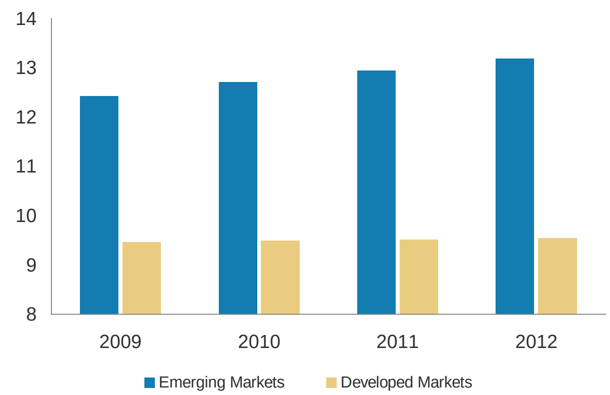
Source: Morgan Stanley Research

5. Fewer legal/government constraints. Given the severe and immediate concerns facing the economies and societies of many emerging markets—from overdependence on oil to higher rates of traffic fatalities, congestion and pollution—we believe that the many social and economic benefits of autonomous vehicles may be more readily embraced by the governments of EM countries than by their DM counterparts, who may not face such large and near-term threats or as severe a threat of litigation/liability.

6. Newer infrastructure in many urban areas. While one of the constraints to quick adoption of autonomous cars in EM could be the lack of road and infrastructure networks, in many urban areas, EM countries actually have newer and better roads and telecom networks than many developed markets. In addition, the sharp growth of new infrastructure projects in the coming years could result in support for autonomous vehicles being built in from the start.

Exhibit 29
Miles of Roadway: Emerging vs. Developed Countries

(total miles of road, mm)



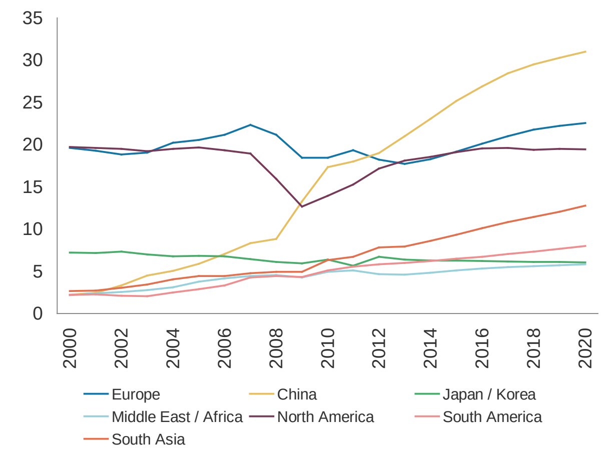
Source: Euromonitor Data, Morgan Stanley Research

7. Limited driving range/standard driving patterns. Autonomous vehicles excel in conditions that are either stop-and-go urban traffic or very long distance highway cruises with few variables. *It is the intermediate suburban-highway-urban cycle that presents challenging conditions*. Drivers in EM countries tend to use cars mainly for intra-urban commuting, for which autonomous cars are well suited. There isn't really a "driving culture" in most emerging markets, unlike the US or even Europe, which is likely a function of legacy low car penetration/ownership, smaller/less powerful vehicles, a poor road network, excellent public transport alternatives and high gas prices. Autonomous vehicles could be good commuter cars.

8. EM is where the growth is. Car ownership is mostly fully penetrated in DM, but has significant room to grow in EM markets. Almost all the growth in global car sales in the next decade is expected to come from EM.

Exhibit 30
Auto Sales Growth by Region through 2020

(mm)



Source: IHS Data, Morgan Stanley Research

Achieving EM penetration is not going to be easy. We do not gloss over the fact that many of these opportunities can themselves initially present significant challenges to penetration of autonomous cars in emerging markets. This includes the aforementioned poor infrastructure outside of select urban areas, poor driver training/driving discipline of the existing car parc, cost considerations, and other priorities that compete for incremental auto content per vehicle before the car needs to drive itself. However, we feel confident that strong demand for the latest technology in EM markets, coupled with the push for platform commonality by the global OEMs and innovation at EM OEMs / suppliers, will create a significant market for autonomous vehicles a few years in.

China’s self-driving car test

China is one of the first emerging market countries to show acceptance of autonomous cars. In 2011, the National University of Defense Technology in China, in partnership with First Auto Works, created an autonomous vehicle using a Hongqi HQ3 sedan. The autonomous vehicle completed a 154-mile journey on a busy freeway from the Hunan province's capital of Changsha to Wuhan, the capital of the Hubei province, in 3 hours and 20 minutes.

Researchers reportedly set the top speed of the vehicle at 68 mph, which was fast enough to permit the car to overtake 67 other vehicles on the expressway, and let the car loose to figure out how to get to its destination. Along the way, the HQ3 navigated through fog, thundershowers, and unclear lane markings without incident. FAW says that it has been working on autonomous car technology since 2001.

Exhibit 31
Autonomous Hongqi HQ3 sedan

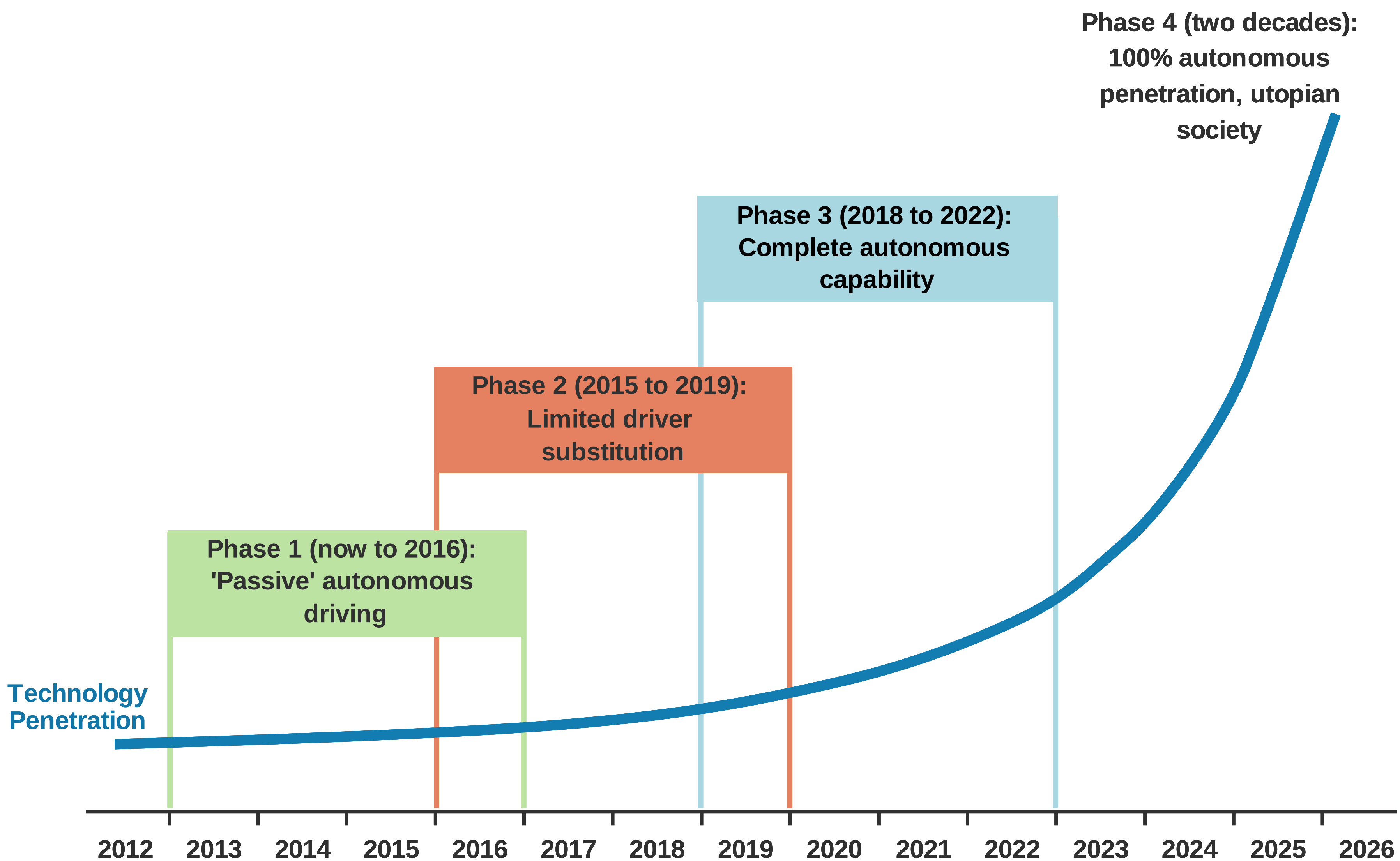
Source: FAW

MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

Timeline for Adoption

Exhibit 32
Timeline for Adoption



Source: Company data, Morgan Stanley Research

Exhibit 33

The Four Phases of Autonomous Vehicle Adoption

Phase 1 – Passive Autonomous Driving (0-3 years)	Phase 2 – Limited Driver Substitution (3-5 years)	Phase 3 – Complete Autonomous Capability (5-10 years)	Phase 4 – 100% Penetration, Utopian Society (Two decades)
Capability: Autonomous capability is not meant to control the car but only acts as a second line of defense in the event that a mistake by the driver is about to cause an accident.	**Capability**: The driver is still the primary operator of the vehicle under all conditions though he can give up some duties to the vehicle. This also includes limited external self park capability.	**Capability**: The car can accelerate, brake and steer by itself in mixed and transitional driving conditions but the driver should remain in the driver's seat ready to take over in the event of an emergency or system failure.	**Capability**: This is an "ideal" world in which all cars on the road have at least a Phase 3 level of autonomous capability and full V2V/V2X capability, and the cars are capable of driving themselves with zero human intervention.
Functions: adaptive cruise control, crash sensing, blind spot detection, lane departure warning, night vision with automatic pedestrian highlighting	**Functions**: All Phase 1 features plus automated braking/throttle/steering with GPS driven forward vision.	**Functions**: All Phase 2 features plus capability to manage transitions, lane changes, navigate intersections, etc.	**Functions**: All Phase 3 features plus focus on lifestyle/entertainment of occupants with car control as a backup/supporting function, cars can also travel with no occupants. Remote control/disable feature necessary
Tech needed: radar, front camera, infrared camera, AV display, mechatronic controls	**Tech needed**: All Phase 1 tech plus more advanced forward radar (with multi-level forward sensing), GPS connectivity to map database.	**Tech needed**: All Phase 2 tech plus redundant capabilities, advanced sensors to interpret surroundings, basic V2V/V2X system, access to a vast database of roads and other infrastructure	**Tech needed**: All Phase 3 functions with advanced human machine interface, artificial intelligence, fully networked road and vehicle infrastructure
Cost: CPV ~ $100-200 each; total cost to customer of about $1000-1,500.	**Cost**: Cost to customer ~ $2,000-5,000 (at today's prices).	**Cost**: Cost to customer ~ $5,000-7,000. (at today's prices)	**Cost**: Cost to customer ~ $10,000. (at today's prices).
Our View: These systems are already available as optional extras on high end luxury vehicles and even some mid-line cars today. As the cost of these systems comes down, early adopters spread positive feedback and safety agencies like Euro NCAP mandate adoption of active safety systems, we could see mass penetration of these technologies ramp in 3 years.	**Our View**: This type of limited autonomous vehicle should hit the road first in the 2014 Mercedes Benz S-Class, which allows autonomous driving in traffic and high-speed (but limited) highway conditions. Next gen self park systems will allow the driver to exit the vehicle while it parks. However, the driver may still have to drive up to a vacant spot.	**Our View**: Prototypes of such vehicles exist today though mass introduction with an automotive grade of reliability will need a certain level of infrastructure development(for V2X), certain minimum penetration level of Phase 1/Phase 2 systems (for V2V) and widespread acceptance of the concept of autonomous driving	**Our View**: Despite the relatively small technological leap vs. Phase 4, we believe this will take much longer due to required high penetration of the existing car parc and some infrastructure development. However, this phase could be realized sooner than we think.

Source: Company data, Morgan Stanley Research

Timeline for Adoption

We expect fully autonomous vehicles on the road by the end of the decade. This view is more bullish than the traditional auto industry but slightly more conservative than some of the external players.

We see four phases of adoption of autonomous vehicles. Phase 1 is already underway, Phase 3 will see introduction of fully autonomous vehicles in 5-10 years, Phase 4 may take a couple of decades until full penetration is achieved.

However, Phase 4 could come sooner than we think. If the government, the auto industry and other entities choose to accelerate adoption to access the full socioeconomic benefits of autonomous cars.

There appears to be broad consensus that we are not heading toward a "Minority Report" world of self-driving modules zipping around autonomously in a highly coordinated pattern ferrying blissfully ignorant occupants to their destinations, any time soon. While that may be the ultimate utopian goal, the first target is to get fully autonomous vehicles on the road. Here is where we see more diversion of opinion. The most aggressive bulls on autonomous vehicles see the first fully autonomous vehicles on sale in 4-5 years with a steady penetration through the car parc from that point on. It is probably not a coincidence that most of these bulls are outside the traditional auto industry. Most auto OEMs and suppliers, on the other hand, are in agreement that the first fully autonomous cars are at least 10 years away.

Exhibit 34

Robohighway of the Future?
Sorry…this is not happening any time soon

Source: Engadget.com

So why bother reading this report? For two reasons:

1. Our own view on timing is somewhere in between the bulls and bears—we believe a confluence of supply push and demand pull will see fully autonomous vehicles on the road by the end of the decade
2. Penetration of autonomous functionality in the vehicle is not binary but rather a curve that started *a few years ago*

These factors make autonomous vehicles a relevant investible topic *today.*

The autonomous vehicle adoption curve

The path to fully autonomous cars is unlikely to be a straight one. In a way, we already have a certain level of autonomous driving capability available in cars today, in the form of sophisticated and usually optional active safety systems. The traditional auto industry is likely to implement a path to full autonomous capability by incrementally increasing the capabilities and independence of currently available systems.

We see the following phases in the adoption curve of autonomous vehicles. Our phases mostly coincide with the US Department of Transportation's recently issued "levels" of autonomous vehicles.

Phase 1: 0-3 years: Autonomous driving as a safety feature

Autonomous capability: The main purpose of autonomous driving in this scenario is to act as a back-up for the driver in order to avoid an accident. The autonomous capability is *not* meant to control the car but acts only as a second line of defense in the event that a mistake by the driver is imminently going to cause an accident. Despite being "active" safety, the autonomous driving capability is "passive" in nature.

Scenario 1: A driver is cruising on the highway at 70 mph when he comes upon traffic that is backed up at a construction zone. The driver is distracted and does not notice that traffic is moving at a considerably slower speed ahead of him. The car detects this and warns the driver and if he or she does not apply the brakes, the car automatically initiates emergency braking.

Scenario 2: A driver is driving home from a long day at work and is exhausted. On a long stretch of road, the driver loses focus and the car begins to drift off the road. The car warns the driver via an audible/visual alert that he is leaving the lane, and then nudges the car back into the lane.

Functions: Adaptive cruise control (cruise control that adjusts vehicle speed based on traffic conditions, and that can bring the car to a full stop and start moving again), front crash sensing, rear crash sensing, blind spot detection, lane departure warning, night vision/infrared systems with automatic pedestrian highlighting.

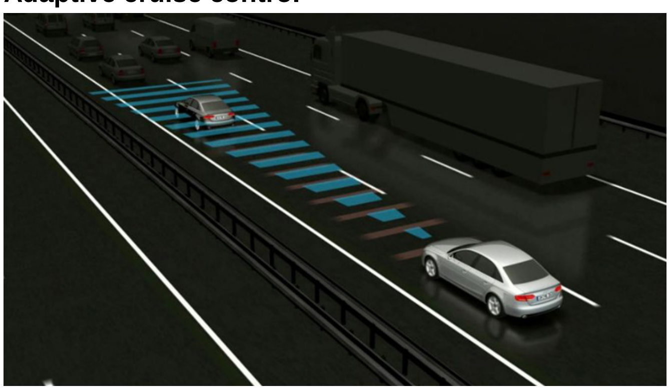
Technology needed: Forward radar, rear radar, side radar, front camera, infrared camera, AV display, mechatronic controls/actuators.

Cost: We estimate that *each* of the above functionalities will include content per vehicle of approximately $100-200 with a cost to customer of approx. $1,000-1,500.

Why this will take 0-3 years. These systems are already available as optional extras on high-end luxury vehicles and even some mid-line cars today. As the cost of these systems comes down, early adopters spread positive feedback and safety agencies like Euro NCAP mandate adoption of active safety systems, we could see mass penetration of these technologies ramp in three years.

Exhibit 35

Adaptive cruise control



Source: Audi

Phase 2: 3-5 years: autonomous driving in limited/controlled conditions

Autonomous capability: The main purpose of autonomous driving in this scenario is to move beyond basic active safety and assist/substitute for the driver under limited, controlled driving conditions, reducing stress for the driver. In this scenario, the driver is still the primary operator of the vehicle under all conditions though he can give up some duties to the vehicle. This also includes limited external self parking capability.

Scenario: If a car is stuck in stop-and-go traffic, the driver can allow the car to creep ahead and stop as necessary and relax for a while until traffic conditions improve.

Scenario 2: If a driver is driving on the highway at speed over long distances with little traffic, he can allow the car to control the throttle and steering and any emergency actions.

Scenario 3: A driver pulls up to a parking spot, puts the car in autonomous park mode and exits the vehicle. The car automatically parks itself in the chosen spot and shuts off.

Functions: all Phase 1 features plus automated braking/throttle/steering with GPS driven forward vision.

Technology needed: All Phase 1 technologies, plus more advanced forward radar (with multi-level forward sensing), GPS connectivity to map databases that provide upcoming road directions and conditions, speed limits, and other basic pre-determined information.

Cost: This is an incremental step over Phase 1. We estimate the cumulative costs of these technologies to be in the $2,000-5,000 range, *at today's prices.* We expect the prices to decline sharply over time.

Why this will take 3-5 years: Such a type of limited autonomous vehicle should hit the road first in the 2014 Mercedes Benz S-Class, which allows autonomous driving in traffic and high speed (but limited) highway conditions. Cadillac's Super Cruise feature set to become available on the XTS and CTS in a couple of years performs similar functions on the highway. Next-gen competitors to the S-Class (Audi A8, BMW 7Series and others) are likely to offer these features when launched within the next 3-5 years. While "self-parking" is already available in some vehicles, only steering is autonomous while the driver still controls the throttle and needs to be in the vehicle. Next generation self-park systems will allow the driver to exit the vehicle while it parks. However, the driver may still have to drive up to a vacant spot. For truly automated parking, where the car finds its own spot, we may have to wait 5-10 years.

Exhibit 36

2014 Mercedes Benz S-Class – autonomous driving capability

Source: Company data

Phase 3: 5-10: years autonomous driving in mixed conditions / fully autonomous driving

Autonomous capability: This scenario envisions true autonomous driving. The car can accelerate, brake and steer by itself in mixed and transitional driving conditions. However, the driver should remain in the driver's seat at least semi-attentive, ready to take the wheel in the event of an emergency or system failure.

Scenario: Driver gets into the car in his suburban driveway, sets the destination as his workplace in the nearby downtown area, and proceeds to read the newspaper (on his personal smart device, of course), while the car drives him to work. Once he is there, he alights at the front door to the building, while the car drives around to the parking garage, finds an empty spot, and parks itself, until summoned to the front door again, at the end of the day.

Functions: All Phase 2 features, plus fully autonomous driving capability with ability to manage transitions including dense traffic to highway, lane changes, navigate intersections, urban-highway cycle etc. True remote self parking capability.

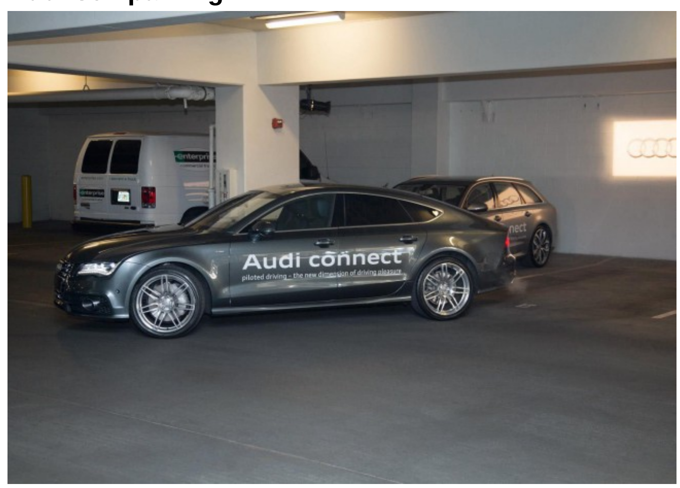
Technology needed: All Phase 2 features at a highly advanced level with redundant capabilities, highly advanced radar/laser sensors to capture surroundings, basic human machine interface to monitor occupants and make sure the driver is at least semi-attentive, basic V2V/V2X capabilities to be fully aware of the surroundings, big data capability with access to a vast database of roads and other infrastructure.

Cost: We estimate the cost of a fully autonomous system without V2V/V2X communication to be around $5,000-7,000, at today's prices. We expect the cost to come down significantly by the time we get to this phase.

Why this will take 5-10 years: Prototypes of vehicles with such capabilities exist today, although commercial introduction with an automotive grade of reliability will need a certain level of infrastructure development (for V2X), a minimum penetration level of Phase 1/Phase 2 systems (for V2V), and widespread acceptance of the concept of autonomous driving (to solve liability, regulatory and other concerns raised elsewhere in this report).

Exhibit 37

Audi self parking A7



Source: Audi.com

Phase 4: 20+ years: 'Autopia'

Autonomous capability: This is an "ideal" world akin to common science fiction in which all cars on the road have at least a Phase 3 level of autonomous capability (including retrofitting older cars), full V2V/V2X capability and the ability to drive from Point A to Point B with zero human intervention.

Scenario: A family of four wants to travel from New York to Chicago. They have dinner at home, climb into the vehicle at 9 pm, watch a movie projected on the windscreen, and then go to sleep in their fold-flat seats, waking up at their destination the next morning.

Functions: Fully autonomous driving with no human intervention, with the focus likely to be on lifestyle/entertainment of occupants and manual car control as a back-up/supporting function (or disallowed). Cars will look very different from cars of today. Cars can also travel with no occupants. Remote control/disable functionality necessary.

Technology needed: All Phase 3 functions with advanced human machine interface, artificial intelligence, fully networked road and vehicle infrastructure.

Cost: With additional infotainment content and full V2V/V2X communication, we estimate a completely autonomous car in a utopian world will carry a $10,000 cost premium at today's prices. We expect cost to fall by half by the time this Phase comes to fruition.

Why this will take 20+ years: The large time gap between Phase 3 and Phase 4 is because we will need a critical mass of autonomous cars on the roads before this scenario can play out. In fact, we believe a significant majority of, if not all, cars on the road need to have basic autonomous and V2V/V2X capability before we can think of the "utopian" environment. They will also require a significant infrastructure build-out that will take a lot of time and money to complete. This infrastructure will include "side lanes" on highways where autonomous vehicles can pull out in case of technical issues, fully networked intersections and traffic monitoring capability, fully mapped roads with real-time updates, and massive network capability to handle the data needs of several hundred million autonomous vehicles on the roads, etc. However, as we mentioned earlier in this report, we believe the significant socioeconomic benefits of autonomous cars could accelerate their adoption, and this Phase could be realized sooner than we expect.

The adoption curve

We see these four Phases of autonomous vehicles being implemented across an adoption curve. The first three phases will be incremental increases in the content and capability, with a steep increase to get to the Utopian world in Phase 4. The sharp slope of the curve reflects the challenge that we expect the industry to face as it attempts to achieve full penetration of autonomous vehicles.

The risk of settling for incremental active safety vs. going for step-function change

The steep curve in the last phase of autonomous vehicle adoption also represents a grey area at the inflection point between Phase 3 and Phase 4. This is the point of crossover, where the "training wheels" and "adult supervision" are removed from the autonomous vehicle and it is allowed to drive on its own. The cars do not really become "self-aware" at this point—it's just that they do not need human intervention and can decide their own course of action even in the case of emergencies or one-in-a-million chance circumstances. This is a critical step that distinguishes between a true autonomous vehicle and a car that can drive itself on auto-pilot. **Achieving this final step is also an *extremely* important juncture in the new business model, where the winners can be sorted from the losers in the race for autonomous cars.**

The traditional industry approach. It appears that most of the auto OEMs and suppliers working on the autonomous car are aiming at late Phase 3 technology—cars that can drive themselves in a variety of circumstances, without regard to whether they are fully (Phase 4) autonomous or not. These entities view the combined hurdles of customer acceptance, liability, infrastructure, and mass penetration as too great to overcome in the foreseeable future. While they acknowledge that there is a chance we may ultimately get to such a utopian world, they believe it is equally likely that we do not, which makes it not something they need to worry about at this point in time. What this means is that they can adapt existing cars/architectures for self-driving capability without having to design an autonomous car from the ground up. This is the incremental approach, where active safety gets better and better until the customers decide at which point they want the cars to take over.

The outsiders' approach. Unlike the traditional auto industry, the "outsiders," like Google and some start-ups, are *directly aiming to get to Phase 4 as fast as possible.* They acknowledge that there might be an adoption curve initially, but want to skip over Phases 2 and 3.

There could be three reasons for this.

1. Giving customers the full benefit of autonomous capability will drive maximum penetration: Once people have experienced the full benefits of a fully autonomous vehicle and what they can (and what they don't have to) do behind the wheel, this will automatically create a positive feedback loop that can drive mass penetration. Incremental steps in active safety may not accomplish this.

2. New entrants cannot really capitalize in the intermediate Phases: Being external to the auto industry, the Googles and start-ups of the world cannot really participate in the trickle up penetration of active safety in the same way that traditional auto suppliers can. This drives them to reinvent the automobile on their own terms. It helps that the approach toward the utopian vision needs extensive use of mapping and big data capabilities—something they are very good at and the OEMs/suppliers are not.

3. You need full autonomy in order to monetize it: We extensively delve into the monetization opportunity and the new business model for autos in Part 7, but, in short, we expect a new revenue stream to the generated from fully autonomous cars in terms of the content that can be sold to the occupants when they are in the car and on the road. To truly be able to achieve this, the occupants need to be able to concentrate on *the content* and not *on the road*.

We believe the traditional OEMs/suppliers may miss the opportunity to monetize the content angle, if they "settle" for getting the autonomous car to Phase 3 and do not push for Phase 4.

THE SARTRE PROJECT – How autonomous and manually driven cars can co-exist

The SARTRE (SAfe Road TRains for the Environment) Project is an initiative funded by the European Union that studies the feasibility of implementing a road-train system on highways. A road-train would comprise of a number of cars in formation, closely following each other as a "platoon" until cars need to peel out of the pack to different destinations. The cars will be in semi-autonomous mode when in the platoon. In its current form, each platoon would be led by a bus or truck. The cars can merge into / out of the platoon with relatively small gaps (10 meters, expected to come down) through V2V communication and coordination.

The advantages of this concept are that cars can drive autonomously in safety, achieve significant fuel economy improvements as a result of the "drafting effect" of the platoon and reduce congestion.

We think the SARTRE project is a good example of how autonomous and non-autonomous cars can coexist on roads for a few years until autonomous cars achieve full penetration. Dedicated lanes for autonomous vehicles or periodic "platoon lead" vehicles could be used to shepherd autonomous cars around manually driven ones.

Department of Transportation's "Levels" of an autonomous car

Another way of looking at the expected evolution of autonomous vehicles is to divide it into different levels based on capability. This is what the US Department of Transportation has done in its initial guideline note on autonomous vehicles. This note is meant to be a guide for the states and government agencies when they have to deal with the issue, in any context.

NHTSA defines vehicle automation as having five levels:

No Automation (Level 0): The driver is in complete and sole control of the primary vehicle controls—brake, steering, throttle, and motive power—at all times.

Function-specific Automation (Level 1): Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.

Combined Function Automation (Level 2): This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.

Limited Self-Driving Automation (Level 3): Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.

Full Self-Driving Automation (Level 4): The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

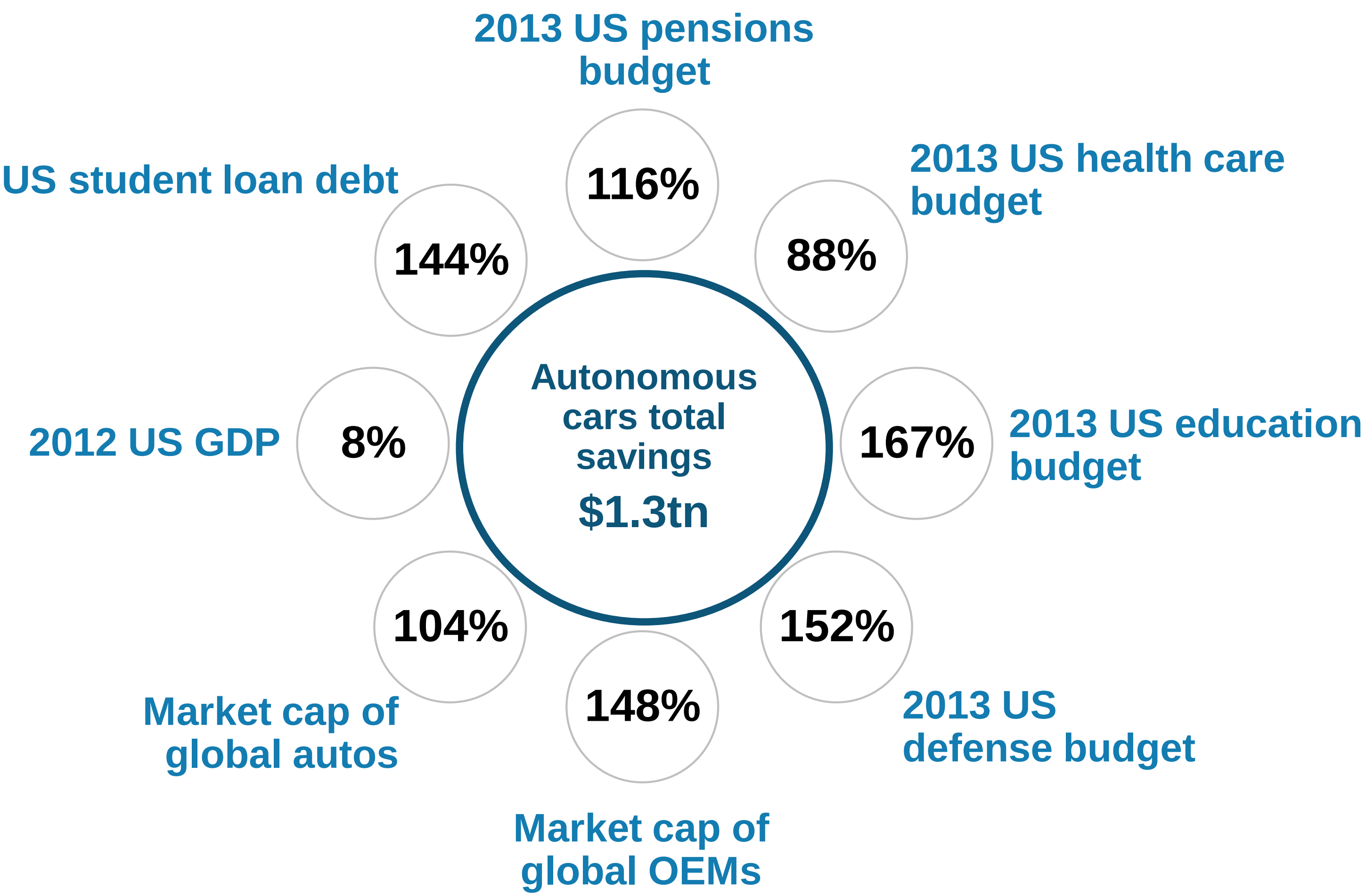
MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

Quantifying the Economic Benefits

Exhibit 9

Medical, Fuel Costs and Productivity Gains Drive Significant Savings



Source: US Department of Transportation, National Highway Traffic Safety Administration, Federal Highway Administration, EPA, FDA, AAA, Census, Texas Traffic Institute, usgovernmentspending.com, Thomson Reuters, Morgan Stanley Research

Exhibit 38

Bull-Base-Bear Cases for Potential Savings in the US

	Bull Case	Base Case	Bear Case
Autonomous Cars Total Savings	$2.2tn	$1.3tn	$0.7tn

Key Assumptions		Bull Case	Base Case	Bear Case
	Fuel Price Per Gallon:	$6.00	$4.00	$3.00
	Improvement in Fuel Efficiency:	50%	30%	15%
	Cost of Life:	$9mm	$8mm	$6mm
	Median Income per	$32.5	$25.0	$19.0
	Work as % of Total Time Spent in a Car:	50%	30%	10%

Source: Company Data, Morgan Stanley Research

Quantifying the Economic Benefits of Autonomous Vehicles

We estimate that autonomous vehicles can save the US economy $1.3 trillion per year. We believe the large potential savings can help accelerate the adoption of autonomous vehicles.

We see five drivers of the cost savings: Fuel cost savings ($158 bn), accident costs ($488 bn), productivity gain ($507 bn), fuel loss from congestion ($11 bn), productivity savings from congestion ($138 bn).

This is our base case estimate. Our bull case estimate of savings is $2.2 tn/year and a bear case is $0.7 tn/year

- This is a rough estimate. It does not account for the cost of implementing autonomous vehicles (one-time), offsetting losses, and investment implications. It also assumes 100% penetration of autonomous vehicles to achieve the full run-rate of potential savings.

The key selling point of autonomous cars is their potential to reduce the adverse social and economic impacts of transportation infrastructure. Here we have attempted to calculate the total potential economic cost savings that autonomous cars represent. In our view, putting a dollar figure on the potential savings impact can help crystallize the benefits of a technology that is viewed by some, even industry insiders, as pie-in-the-sky science fiction.

Autonomous vehicles can save the US economy *$1.3 trillion per year*

These cost savings would come from the improvement in fuel economy of the car parc, improved productivity for autonomous cars occupants, and the near elimination of accidents and the resultant injuries and loss of life. If autonomous cars can penetrate globally, the global economic savings could be many multiples higher. Applying the ratio of US savings / US GDP to global GDP of about $70 trillion, nets a global savings estimate of about $5.6 tn per year from autonomous vehicles.

But here comes the fine print

There are a number of disclaimers that we must make very clear, however.

1. **This is a very rough estimate.** The $1.3 tn savings figure makes a number of assumptions based on data from a variety of government and non-government agencies and studies. Furthermore, some of the sources date back to 2010, as the most recently available information. This estimate is also by no means comprehensive and only represents an attempt to quantify the biggest areas of savings.

2. **We do not include the cost of autonomous vehicles.** This analysis is obviously one-sided and only looks at the benefits of autonomous cars and not the costs. This was done for two reasons: (a) for the sake of simplicity, the benefits being a little more obvious than the infrastructure, legal, and other costs needed to get the cars on the road; and (b) we view most of the costs related to autonomous cars as up-front or one-time in nature, while the savings should be ongoing, making this more relevant.

3. **We do not consider the offsetting losses.** There are two sides to every story and as has been the case since the Industrial Revolution, every automated/mechanized activity potentially eliminates existing jobs. Our analysis does not account for such offsetting losses. For example; if there are virtually no motor vehicle accidents there could be fewer emergency rooms at hospitals, which could result in less employment for EMTs/doctors/nurses. In another instance, self-parking cars could eliminate the need for valets.

4. **We do not include the investment implications of autonomous vehicles.** The $1.3 tn number only includes the dollar cost of the social savings and does not consider the value accrued to the auto OEMs, suppliers, and external corporate entities directly or indirectly involved with autonomous vehicles. *We have attempted a separate assessment of investment implications in Part 7 of this report.*

5. **This will only happen in a Phase 4 utopian world.** The most important thing to keep in mind about our $1.3 tn savings estimate is that it can be achieved only in a Phase 4 utopian scenario, as laid out in Part 4 of this Blue Paper. This means that the $1.3 tn figure could be purely theoretical until we get to a point where 100% of cars on the road are autonomous and manual driving is virtually banned from the roads. However, we could see incremental savings along the adoption curve.

Fuel savings: $158 billion per year

There are currently 251 mm vehicles on the road in the US, which travel a total of approximately 3 trillion miles per year, for an average of about 11,700 miles per vehicle per year. In 2012, the US alone consumed 134 billion gallons of gasoline for transportation use, according to the US Energy Information Administration (EIA), at a cost of $535 billion at $4/gallon. Divided over 251 mm vehicles, that works out to 532 gallons of gasoline per year for an effective fuel economy of 22 mpg. *We can do better.* The corporate average fuel economy for the vehicle fleet in 2011 is almost 30 mpg or 36% above the car parc average number. As per the new fuel economy standards, set forth by the NHTSA and the EPA, the CAFE standard needs to go to 54.5 mpg by 2025. Clearly, cars are set to become massively more fuel efficient in the coming years and the country's gasoline bill is set to drop significantly.

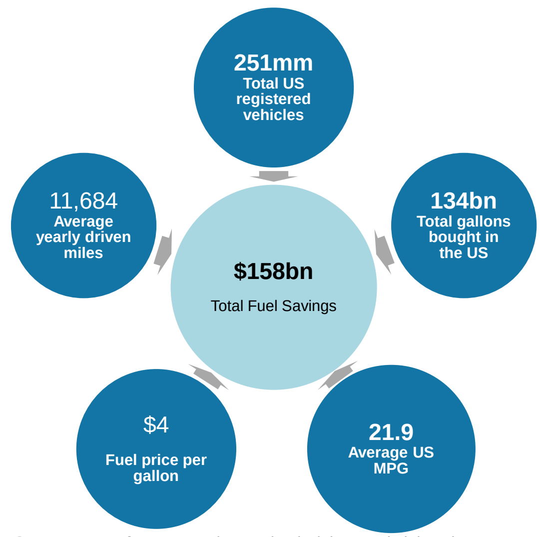
None of this has anything to do with autonomous cars…yet. We think autonomous cars can add a further leg up to fuel efficiency. In today's cars, even using cruise control / driving smoothly can easily deliver a 20-30% improvement in fuel economy vs. a manually controlled "surging" brake / throttle. Autonomous cars will run on cruise control 100% of the time. Add to this aerodynamic styling and light weight, plus active traffic management, and **we can potentially get up to a 50% improvement in fuel economy from autonomous cars *on top of* the fuel economy improvement from new engine and transmission technologies that are going to be incorporated in cars anyway.** In order to be conservative, we assume an autonomous car can be 30% more efficient than an equivalent non-autonomous car. Empirical tests have demonstrated that level of fuel savings from cruise control use / smooth driving styles alone. If we were to reduce the nation's $535 gasoline bill by 30%, that would save us $158 bn.

There is a catch here…Because these savings would be realized over a span of several years, the parallel increase in fuel efficiency of the cars will already reduce that fuel bill and potentially reduce the apparent benefit of autonomous vehicles. For example; if the average miles per gallon in the US goes to 30 by the end of the decade, from 22 today, the total gasoline bill would go from $535 bn to $392 bn. Thirty percent autonomous car savings on this figure is only $118 bn—still significant but less than the $158 bn we have considered. However, we believe the $158 bn number is relevant because it is based on today's $4/gallon cost of gasoline, a cost we believe is likely to increase in the coming years. We also assume that the convenience of autonomous cars will result in more miles driven and therefore higher gasoline consumption by the car parc. *Note that the $158 bn estimate is adjusted for congestion improvement, which we include as a separate category to avoid double counting.*

Exhibit 39

Total Dollar Spent on Fuel (2012)

US data



Source: US Department of Transportation, Federal Highway Administration, Morgan Stanley Research

Accident savings (including injuries and fatalities) $488 billion per year

The largest vehicle costs to society are the billions that are lost to injuries and fatalities. In 2010, the World Health Organization (WHO) estimated 1.2 million deaths globally due to vehicle accidents. A report by the WHO confirmed that nearly a million children are killed worldwide as a result of unintentional injuries, and the biggest killers are traffic accidents. According to the US Census, there were 10.8 million motor vehicle accidents in the US in 2009 (the last year for which data is available). According to the US DOT, these accidents resulted in over 2 million injuries and 32,000 deaths. Over 90% of these accidents have been determined to be caused by human error, according to the International Organization for Road Accident Prevention.

Accidents are very expensive. The Federal Highway Administration (FHWA) calculates the cost per vehicle crash injury, adjusted for inflation, to be around $126,000, and the cost per fatality at almost $6 million. The FHWA places dollar values on 11 components and excludes property damage-only crashes. The comprehensive costs include property damage; lost earnings; lost household production (non-market activities occurring in the home); medical costs; emergency services; travel delay; vocational rehabilitation; workplace costs; administrative costs; legal costs; and pain and reduced quality of life. The EPA and FDA also have calculations for the statistical value of life, $9.1 mm and $8 mm, respectively (we use the “midpoint” FDA number as the basis for our base case calculations). Costs from injuries represent $282 billion, and costs from fatalities represent $260 billion per year. There is a total cost of $542 billion per year in the US due to motor vehicle-related accidents.

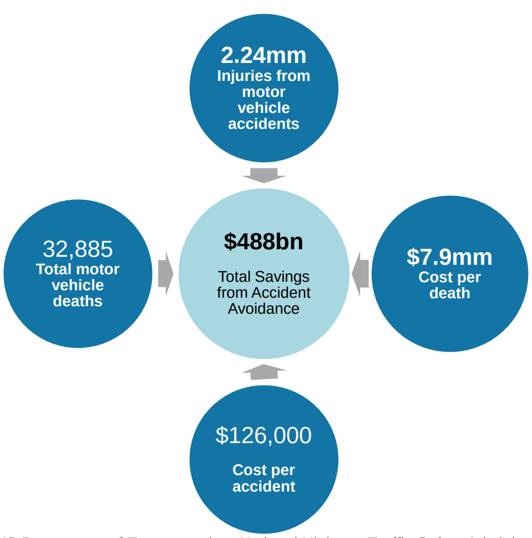
If 90% of accidents are caused by driver error, taking the driver out of the equation could theoretically reduce the cost of accidents by 90%. This could save $488 bn (90% of $542 bn) per year. While autonomous vehicles could still be involved in accidents due to mechanical failure, we believe V2V/V2X communication and instant reaction times would greatly reduce the collateral damage in that instance.

Again, there is a catch… We are not going to achieve these savings until we have completely eliminated the human factor behind the wheel. This means that almost 100% of the cars on the road need to be autonomous at all times to prevent the one guy who is still driving his car himself from causing an accident. As mentioned earlier, this will only happen in the utopian scenario.

Exhibit 40

Cost of Motor Vehicles-related Fatal and Non-fatal Injuries

US data



Source: US Department of Transportation, National Highway Traffic Safety Administration, Federal Highway Administration, EPA, FDA, AAA, Morgan Stanley Research

Productivity gains: $507 bn per year

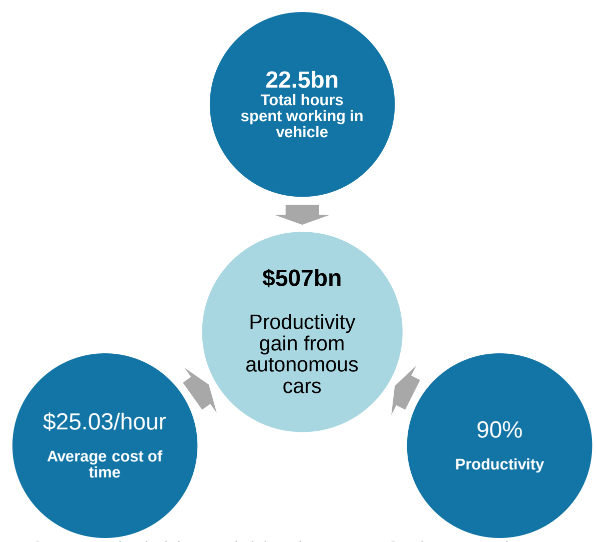
One of the main advantages of autonomous cars is that occupants are freed from the chore of driving to do whatever else they want. For instance, people can work in their cars while commuting to work or at any other time. We have tried to estimate the value generated from people now being able to work during a time they could not earlier.

US drivers drive approximately 3 trillion miles a year. According to the DOT/FHWA, in 2009, the average speed of a commute in the US was 27.5 mph. For the purposes of our calculation, we are assuming 40 mph (for simplicity’s sake, a blend of average urban speed limit of 30 mph and highway speed limit of 55 mph). Three trillion miles driven at 40 mph equals 75 billion hours spent in a car (again, conservatively assuming only one occupant in a car at all times). If we assume that people work 30% of the time that they are in a car, that equals 18.75 bn hours. We assume the “cost of time” is $25 per hour (based on US median income of $50k/year) and that people are 90% as productive in the car as behind a work desk. This means the value of the productivity generated from being able to work in the car is $507 bn (22.5 bn x $25 x 90%).

Exhibit 41

Productivity Gain from Autonomous Cars

US data



Source: Census, Federal Highway Administration, Morgan Stanley Research

Congestion savings: $149 bn per year

Productivity loss from congestion is something every driver can feel in real time. There is no escaping the dreaded morning commute, or the rush to beat after-work traffic. The

European Commission for Mobility and Transport estimates that congestion costs Europe about 1% of GDP each year. According to the Texas Traffic Institute's Urban Mobility Report, supported by the US DOT, in 2011 the average US driver lost 38 hours to congestion, way up from 16 hours in 1982. This was calculated as the difference between traveling at congested speeds rather than free-flowing speeds. That is the equivalent to almost five vacation days. In areas with over three million people, commuters experienced higher congestion delays and lost an average of 52 hours in 2011. The report analyzed over 600 million speeds on 875,000 roads across the US. The speed data was collected every 15 minutes, 24 hours a day, at hundreds of points along almost every mile of major road in North America.

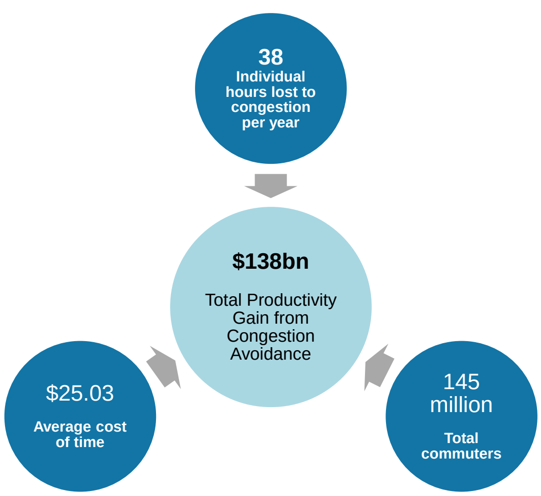
The report also estimates that there are about 145 mm commuters in the US, which means they are collectively losing to congestion around 5.5 billion hours a year (38 hours x 145 million commuters).

Autonomous cars should be able to largely eliminate congestion due to smoother driving styles and actively managed intersections and traffic patterns. Autonomous cars (and especially driverless cars) should also strongly encourage traffic pooling. Again, assuming the cost of time is $25 per hour, 5.5 bn hours saved in congestion is worth $138 bn of potential productivity generated.

Exhibit 42

Productivity Gain from Vehicle Traffic Congestion Avoidance

US data



Source: Census, Texas Traffic Institute, Morgan Stanley Research

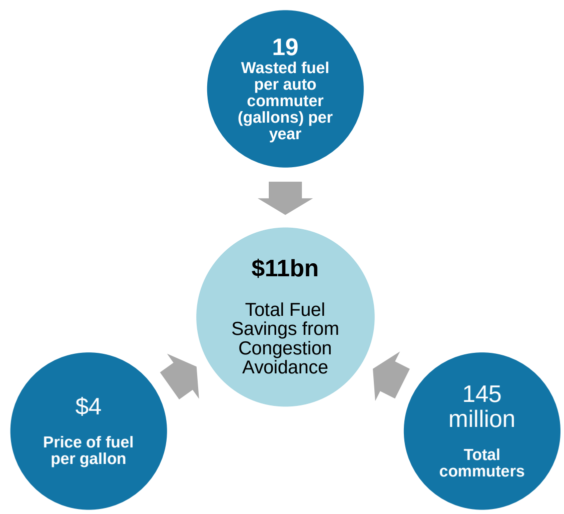
We assert that this is *not* double-counting against the productivity gains bucket. The productivity gains math uses only the time spent *moving* on the road, whereas the above congestion math uses only time spent stuck in congestion when not moving.

There is another aspect to congestion saving—the fuel wasted by being stuck in traffic will no longer be needed. This was also calculated by the Texas Traffic Institute's report, which quantified congestion by taking the free-flow results and subtracting them from congested results. First, TTI calculated the emissions and fuel consumption during congested conditions by combining speed, volume, and emission rates. Then it estimated the amount of gas needed to produce those $C0_2$ emissions. The average fuel wasted was 19 gallons per commuter and a total of 2.7 bn gallons for the entire US in 2011. $10.8 billion dollars were wasted by just sitting in traffic. This waste could also be eliminated by moving to a congestion-free autonomous car world.

Exhibit 43

Fuel Savings from Vehicle Traffic Congestion Avoidance

US data



Source: Texas Traffic Institute, Morgan Stanley Research

In conclusion, we believe that full penetration of autonomous cars could result in social benefits such as saving lives, reducing frustration from traffic jams, and giving people more flexibility with commuting or leisure driving. These social benefits also have significant potential economic implications. And the implications are truly significant—the $1.3 tn of value potentially generated by autonomous cars amounts to over 8% of the entire US GDP, as well as 152% of the US Defense budget and 144% of all student loans outstanding. In a different context, it is about 150% of the global auto OEM market cap and 100% of the global auto industry market cap.

The best part is that while we may have to wait for the Utopian scenario to get the entire savings, we can still get partial savings in the same ratio as the adoption curve with incremental penetration of autonomous capability until we get to 100% penetration. This by itself, makes the pursuit of autonomous vehicles entirely worth it, in our opinion.

What If We Are Wrong?

What happens if our views here do not come to pass and autonomous cars remain a niche vehicle feature at best? This is certainly possible given the number of headwinds facing autonomous vehicle penetration discussed elsewhere in this Blue Paper.

If autonomous vehicles fail to gain traction, then little will change vs. the industry of today. The push toward widespread in-car connectivity is well underway and should continue until all cars are connected devices, but with drivers still at the wheel, the incremental benefits from moving from Phase 3 to Phase 4 would not be realized. This means there would still be modest gains in safety as active safety systems achieve full penetration, but fuel economy, productivity, and economic gains would likely be relatively limited.

MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

Next Steps

- Government
- Auto Insurance
- Telecom Services

Morgan Stanley

Next Steps — The Path to Get There

So what are the next steps to get there? Before we see full penetration of autonomous cars, we need to resolve a few issues outside of the technology needed to get there. Some of these issues are relevant in the near term, some are longer-term issues, but all of them probably need to kick off now to be resolved in time for the autonomous car ramp-up.

We highlight four next steps:

Building consumer awareness

Getting regulatory support

Resolving the liability issue

Building out the network infrastructure

While the industry works to perfect autonomous vehicle technology, there are steps that need to be taken outside the industry to ensure that the rollout will be smooth and successful. While these actions do not necessarily have to be completed before the first autonomous car hits the road, they will be a necessity to achieve full penetration of autonomous vehicles.

Step 1: Building consumer awareness

It is going to take a lot of coaxing to get people to give up control of the steering wheel. Even the use of cruise control is viewed with skepticism by many drivers today so getting them to give up complete control is not going to be easy. That said, we probably do have an epidemic of too many people driving while impaired, whether it is texting or some other distraction. It may be easier to get people to embrace autonomous cars than to give up their smartphone in the car.

We believe the OEMs need to begin 1) familiarizing consumers with autonomous car technology and 2) retraining their car-related behaviors. In our view, the best way to do this is by conducting road shows at which people are driven around small tracks in autonomous cars at low speeds, to get them used to the feeling. OEMs can also set up simulators at dealers so that customers can try out the autonomous experience in a safe environment.

Step 2: Getting regulatory support

The US government is going to have to get on board with autonomous cars at some point during the ramp up phase. We believe the government can have a large role in the process, including accommodating autonomous cars in legislation, issuing special licenses to autonomous vehicles in the early stage, helping resolve the liability issue, building out V2X infrastructure, and ultimately speeding up adoption through a mandate, if necessary.

Step 3: Resolving the liability issue

This is the most frequently cited impediment to autonomous vehicle penetration. We believe the liability issue needs to be comprehensively addressed soon. This is actually a critical issue for even early adoption of autonomous vehicles.

Step 4: Building out the network infrastructure

While a vast V2V/V2X is only needed for part of Phase 3 and Phase 4 of the adoption curve, the long lead times necessary for build-out and spectrum approval means we have to get started pretty soon.

Government's Role: The Silent Referee

The two hurdles to the adoption of autonomous vehicles that we come across most often are 1) determining liability and 2) government acceptance of the technology. While the first is very real and will need to be comprehensively addressed, we believe the second is less of an obstacle than many people think.

Stage 1: We do not think the US government will be an impediment to autonomous vehicle adoption/penetration

The US government rarely tends to be ahead of the curve when it comes to adoption or penetration of new technologies. Sometimes it is an impediment, such as in the case of Audi's active-matrix LED headlamps. These are illegal in the US because of a 1968 law requiring that the driver must be in control of switching headlights between high and low beams. Another example is the lag time in the EPA’s ability to adapt its fuel economy testing methods to keep pace with new fuel-efficient technologies.

In the case of autonomous vehicles, however, it may not be a bad thing. This is because we believe very little intervention is needed from the government for early adoption of autonomous systems. While we are still very early in the process and there are several areas of uncertainty, there appear to be few laws or regulations that prevent or inhibit the use of autonomous systems in cars.

The "driver's" license issue. The biggest sticking point is likely to be how to handle licensing for cars without drivers. So far, Nevada, California, Florida, Michigan, and the District of Columbia have explicitly permitted and/or licensed fully autonomous cars for use on their roads (with a few other states considering similar approvals). However, for the other states, it is unclear whether driverless cars are legal, and not having an explicit approval does not necessarily mean it cannot be done. Simply put, if there are no laws that specifically forbid the use of autonomous cars, there may be no legal impediment to their adoption and the government might not need to officially approve the technology ahead of time for it to proceed and develop.

Legal issues aside, however, there are practical considerations that governments may need to address over time.

Stage 2: We believe the US government will eventually help facilitate rapid adoption of autonomous vehicles

While we need little government intervention to initially get autonomous cars on the road, the government may well have an important role to play over time (between phases 3 and 5 as stated in Part 4).

Where autonomous cars will need US government support:

1. Stepping in with intervention if necessary. The US government is unlikely to ignore autonomous vehicles, in our view. The DOT has already issued guidelines for autonomous vehicles and the NHTSA and the federal government are working with individual states on rules and regulations. We believe the government's approach to autonomous driving will be similar to its approach to distracted driving/connected cars, that is staying at arm’s length and letting the technology evolve at its own pace unless there are real-world concerns or adverse implications of the technology that need policing or regulation. In the case of autonomous vehicles, if early self-driving cars are involved in an unacceptably high rate of accidents caused by system unreliability and the general public becomes fearful of sharing the road with autonomous vehicles, then the government could step in to regulate the technology.

But if the technology works as hoped for and demand is high, the government could help accelerate adoption.

2. New automotive technologies typically penetrate fastest when they are mandated. The government usually mandates technology when the benefits are clearly demonstrated and undeniable and the overall cost/benefit of a mandate is positive. If the actual socio-economic benefits of autonomous vehicle technology is even remotely in the ballpark of our estimate in Part 5, we believe the cost/benefit analysis will be quite clear. This could be a few years after fully autonomous vehicles first become available. As we mentioned in Part 5, to get the full benefit, we need 100% penetration of the car parc, which could take two decades or more at a natural run rate. A government mandate (in the form of an accelerated scrappage program, an electric vehicle-like cost rebate, or a ratings/cost penalty on cars without the technology) could significantly accelerate full penetration and, consequently, the realization of full economic savings.

3. Helping resolve the liability issue. "Who is at fault in the event of an autonomous car crash?" appears to be the number one issue facing autonomous vehicles. While part of this needs to be resolved by the insurance companies (please see insurance implications elsewhere in this Blue Paper), the government could also help resolve this in a number of ways. (We note that we are not attorneys and that the following discussion is purely hypothetical.)

From a tort perspective and to help lay the groundwork for the insurance companies, we might see all states adopting "no fault" insurance regimens. Currently 12 states are "no fault," meaning the blame for an accident and the insurance implications are equally shared by the parties involved, irrespective of who caused the accident. Applying such a regimen to autonomous cars may remove the very need to answer the question of "who is responsible..."—at least from an insurance/tort perspective.

From a criminal liability perspective, because autonomous cars will carry an array of cameras, sensors, radar, GPS, and data tracking technologies, reconstruction of accident scenes likely will be easier to achieve. This should help make it easier to apportion blame in the event of an accident. We also believe the OEMs and suppliers will carry ample liability reserves in the early years of autonomous vehicles, to defray litigation risk. This could help determine which companies succeed in the world of autonomous vehicles—if your system is good enough, you will not need to worry about your liability reserve. In addition, as we discuss in the insurance, keeping individual auto insurance premiums at current levels, despite the large reduction in the frequency of accidents, could help create a large liability pool with which to settle accident claims when they do occur.

Comments from Morgan Stanley Property & Casualty Insurance analyst Greg Locraft: While this is speculation at this time—moving to a “no fault” regime might be an answer especially because it eliminates the complexity from the at-fault equation. It is also possible that when a concentrated group is trying to insure a risk, a lot of times they will “pool” their premiums/dollars and create their own insurance company (including off-shore) and self-insure for smaller losses and use reinsurance to manage tail risk exposure. The insurance industry has had a long history of innovating product to solve for issues of companies/ consumers, especially on s mass scale. Insurance is a product that "follows" the growth curve of other industries as a necessary evil. It is a utility in the business world. Autonomous car insurance may be costly for those that bear the risk, especially in the early years...but a solution is likely to be found.

4. Regulating the V2V/V2X frequency spectrum. Autonomous cars will need to communicate both among themselves and with nearby infrastructure to be most efficient in their operation. To help facilitate this, the government may need to open up and safeguard enough telecommunications frequency. This need not wait until critical mass is achieved, and could be one of the earliest actions the government can take to enable adoption. The government would also need to lay down guidelines to ensure the security and privacy of the collected data.

5. Infrastructure/city planning. In the long run, the government could enhance the safety and success of autonomous vehicles by adequately developing infrastructure suited to them. This includes improving road marking and signage, installing V2I communication infrastructure along roads and intersections, dedicating lanes for autonomous cars to pull into when experiencing mechanical failure, creating "no human driving" zones that reduce the likelihood of "black swan" events, rewriting building codes to mandate the support of autonomous capability in parking garages, and, of course, buying large fleets of autonomous vehicles for government use.

Auto Insurance: Fewer Accidents but Who Is Liable?

Gregory W. Locraft

Assignment of Insurance liability a key unknown. In a driver-less autonomous car world, the blame may potentially be placed on the auto manufacturer or perhaps the software provider; however, it is unlikely the owner of the autonomous vehicle would escape liability in an accident.

Insurance prices likely to decline due to lower accident frequency. P&C industry loss frequency has declined 22% over the past 30 years as cars have become safer. The autonomous car would be expected to utilize advanced technology to avoid crashes, thus saving on auto insurance claim payouts.

However, accident severity costs may continue to rise as car complexity rises. P&C accident loss severity (i.e., cost per accident) has risen 56% the last 30 years. The technological complexity of the autonomous car means that when accidents happen they could be much more costly to repair, driving insurance costs higher.

The autonomous car is unlikely to be the death knell for auto insurance. Auto insurance has evolved through significant new technology adoptions that were once thought to point to a world of lower insurance premiums, including seat belts, anti-lock braking, and air bags. While insurance will not deter autonomous car evolution, the multi-decade adoption for each of these innovations points to any material impact from the autonomous car on auto insurance being 20+ years away.

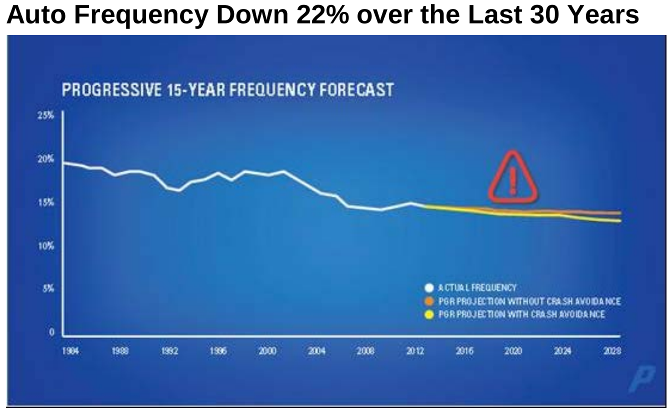
The $200 bn US auto insurance market is competitive and highly regulated. Auto insurance is the second biggest line of business (workers compensation is the first) and accounts for 38% of US premiums. The product is mandatory. If one wants to drive a car, one must be insured. Auto insurers are highly regulated at the state level in order to protect the interests of policyholders (i.e., drivers). Regulators review pricing and profitability, and have the power to seize control of companies that fail to meet minimum capital hurdles. The industry is fragmented, with many competitors, but the Top 5 garner 53% market share and include, in order, State Farm, Geico, Allstate, Progressive, and Farmers.

Assigning blame is a key unknown insurance consideration in a driver-less world. Core to an insurance claim is the designation of "fault" or blame for the damage. In a driver-less autonomous car world, blame may potentially be placed on the auto manufacturer or perhaps the software provider; however, it is unlikely the owner of the autonomous vehicle would escape liability in an accident.

The battle for assigning blame in autonomous cars accidents is likely to be waged in the courts. Our industry sources agree it is too early to assess auto insurance in a driver-less world. Robert Hartwig, president of the Insurance Information Institute, said at a recent Society of Automotive Engineers (SAE) panel, "It's a legal morass right now, and unfortunately it will take court decisions to work this out."[1] At its May 16 investor day, Progressive executives discussed the adoption of future driver-assisted technologies such as automatic braking and lane assistance. They even discussed the eventual uptake of V2V and/or V2X systems. However, they refrained from discussing who would be responsible for the insured costs in the event of an autonomous car crash.

Insurance costs benefitting from a structural decline in auto accident frequency that should continue with the autonomous car: P&C industry loss frequency (i.e., number of accidents) has declined 22% over the past 30 years as cars have become safer (air bags, etc.). The autonomous car would be expected to use advanced technology to avoid crashes and eliminate some of the more common accident-inducing behaviors, such as tailgating, dozing off at the wheel, texting while driving, etc. In a perfect world, we would see a step-function improvement in the number of auto accidents as human drivers are removed from the equation.

Exhibit 44
Auto Frequency Down 22% over the Last 30 Years



Source: Progressive Investor Day presentation

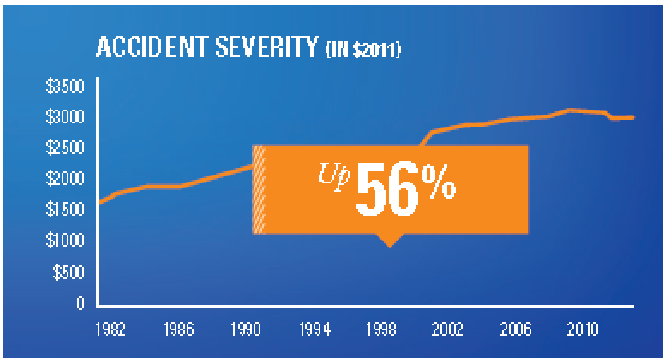
Accident severity costs, however, should continue to rise as car complexity and medical costs rise: P&C accident loss severity (i.e., cost per accident) has risen 56% over the last 30 years. Key drivers of rising severity are medical inflation and higher-cost car repairs due to more valuable

[1] http://www.bloomberg.com/news/2013-02-06/self-driving-cars-more-jetsons-than-reality-for-google-designers.html

content within autos. The complexity of the autonomous car means that when accidents happen they will be more costly to repair, driving insurance costs higher.

Exhibit 45

Auto Severity +56% over the Last 30 Years



Source: Progressive Investor Day presentation, Best's Aggregates and Averages, Bureau of Labor Statistics, USDOT Federal Highway Administration, P&C Insurers Association of America

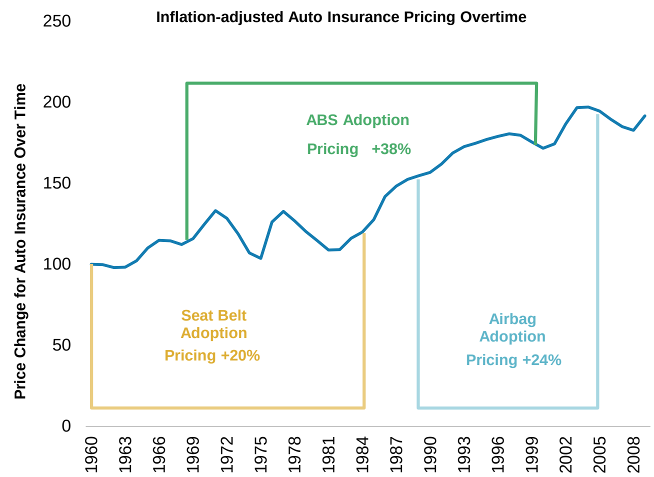
The autonomous car is unlikely to be the death knell for auto insurance. Auto insurance has evolved through decades of new technology adoptions that were once thought to point to a world of lower insurance premiums. Although accident frequency declined, the auto insurance industry adapted and grew as the desire for protection by owners amidst rising severity costs held firm. Advances in safety and their impact on auto insurance rates include:

1. **The seat belt:** The 20-year introduction of the seat belt saw insured rates increase by 20%.
2. **Anti-lock Braking Systems (ABS):** During the 30-year implementation of ABS (which are now standard in many automobiles), pricing actually increased by 38%.
3. **The air bag:** The 15-year adoption of the air bag corresponded to rate increases of 24%

Note: All rate increases are given on an inflation-adjusted basis.

Exhibit 46

Insurance Pricing Has Risen During Major Auto Safety Adoption Curves



Source: DOT, Bureau of Labor Statistics, Morgan Stanley Research

Insurance will not deter autonomous car adoption as early policies emerge in specialty markets in the next 10 years. As with other emerging technologies, specialty writers tend to initially dissect and price risk that is less homogenous and more unknown, as would be the case with the autonomous car (i.e., Lloyds of London). These carriers typically charge higher rates. In time, as loss experience emerges, competition enters the higher-priced/higher-return insurance segments and drives prices lower for end users. We have little doubt carriers will embrace the provision of insurance for autonomous cars and will be ready to adapt to whatever timeline the autonomous car industry follows.

A material impact from the autonomous car on auto insurance is 20+ years away. We believe the complexity of each of the previous innovations we mention pales in comparison to that of widespread autonomous car adoption, so any material impact in auto insurance is likely 20+ years away, at a minimum. Indeed, Progressive estimates a long timeline for adoption. They note that with other new auto technologies, such as ABS, airbags, or electronic stability control systems, full-scale adoption took up to 30 years, with 50%+ penetration achieved in 15-20 years.

Telecom Services: Ubiquitous LTE Coverage Is Essential

Simon Flannery
John Mark Warren, CFA

Today, carriers are working with manufacturers to enable connected cars. Though connected cars are a modest near-term revenue opportunity, in the long term they could represent ~$100 bn.

Autonomous driving would dramatically increase the role and importance of wireless networks.

- The drivers' network usage will rise. US drivers spend 75 billion hours in the car per year, and moving to autonomous driving would mean much of this time may be used to consume content.
- The cars themselves will continuously use the network. The interactions between autonomous cars and wireless networks will be near constant as the vehicles navigate the driving environment.

Traffic patterns will change the geography and timing of data consumption.

- Today, data consumption is concentrated in urban markets. Autonomous driving could expand the high data usage areas from urban to suburban and rural markets, following traffic patterns.
- Today, network usage rises through the day, peaking in the evening. Network utilization should rise in an autonomous driving environment, as usage during the morning and evening commutes grows significantly and adds to peak loading periods. Even the low-usage night-time hours provide an opportunity for OTA updates.

The volume and criticality of network usage will require additional investment.

- Coverage needs will grow in suburban and rural markets as cars demand uninterrupted network contact to navigate safely. Low-band spectrum is ideal, given its breadth of coverage per cell site.
- Capacity needs will grow in urban markets as the driver consumes more data. High-band spectrum is ideal, given its higher capacity.

Industry Implications: Another positive for towers, while carriers face opportunities and risks.

- Towers should benefit from the carrier capex requirements of a higher-capacity, broader coverage network, further adding to the potential duration of revenue growth for AMT, CCI, and SBAC.
- This could be a significant opportunity for carriers. These customers could have low churn (average life of car) and strong ARPU, though the network investments may be quite costly. T and VZ are advantaged, with network leadership and the best low-band spectrum. The broadcast auction is an opportunity for TMUS and S.

Autonomous Driving Will Dramatically Increase the Role and Importance of Wireless Networks

A strong and reliable wireless signal is increasingly becoming essential, as our daily lives grow more connected and the content we generate and consume becomes richer.

This could significantly change in an autonomous driving environment. The hours spent in a car go from largely unconnected to doubly connected, with both the driver and the car using the network.

Exhibit 47
Today's Vehicles Are Increasingly Connected

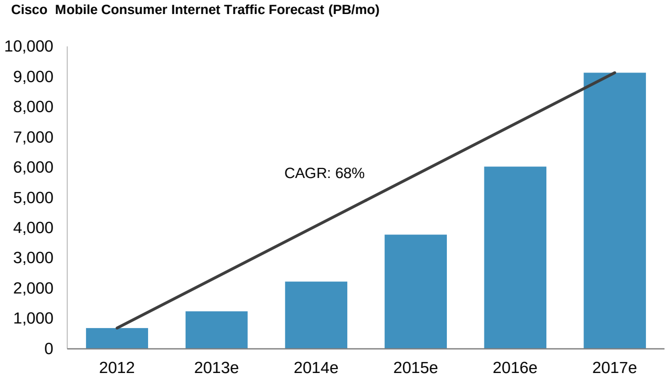
Source: Morgan Stanley Research

Drivers will have one hour of additional free time to surf each day. Today, the average American spends about an hour in a vehicle every day. The average vehicle carries 1.6 people and the non-driving passengers are likely already using mobile devices in the vehicle. However, an autonomous car will free up the driver's time, increasing potential in-car mobile usage by 167% as the driver will no longer need to be engaged in navigating the vehicle.

Cisco forecasts that mobile internet traffic will rise at a 68% CAGR through 2017, while internet video use will rise at a 29% rate over the same time period. Growth in data demand from autonomous vehicle usage may become a key contributor to continued mobile and internet video growth beyond 2017.

Exhibit 48

Mobile Data Driven by Video, Social, and Web

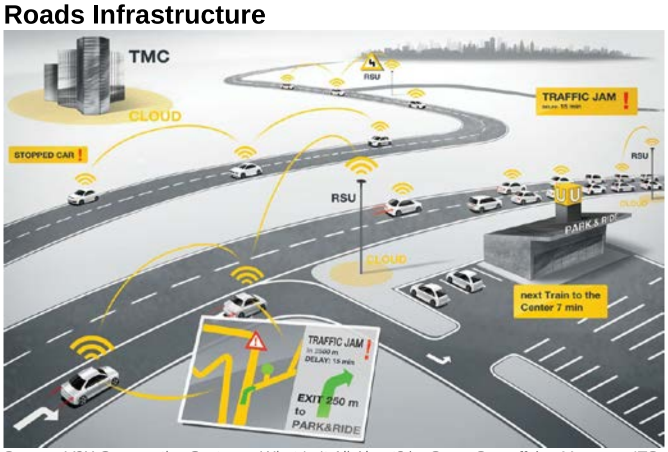


Source: Cisco Visual Network Index Forecast – 2013, Morgan Stanley Research

The car will continuously use the network. In order to safely navigate from point A to point B, the autonomous car will simultaneously communicate with all nearby other vehicles, traffic signals, overhead signs, and toll booths, get real-time updates on road conditions and traffic patterns, and constantly evaluate its surroundings to adapt to any unpredictable activity. This suggests the car will likely be in constant contact with the wireless network. Therefore, the network must have full coverage of all highways and roads, and high latency will be unacceptable.

Exhibit 49

Cars Will Communicate with Each Other and the Roads Infrastructure



Source: *V2X Cooperative Systems: What Is It All About?* by Steve Sprouffske, Manager, ITS Solutions and Presale Group

The FCC has allocated 75 Mhz of spectrum in the 5.9 GHz band for use by the transportation industry. This spectrum would be used for dedicated short-range communications (DSRC). The idea would be to have cars, traffic lights, road signs, and other elements communicating with each other. This would enable collision avoidance systems, cooperative cruise control, real time traffic management, and many other applications. Given the short range of 5.9 GHz spectrum, we could see backhaul via LTE networks.

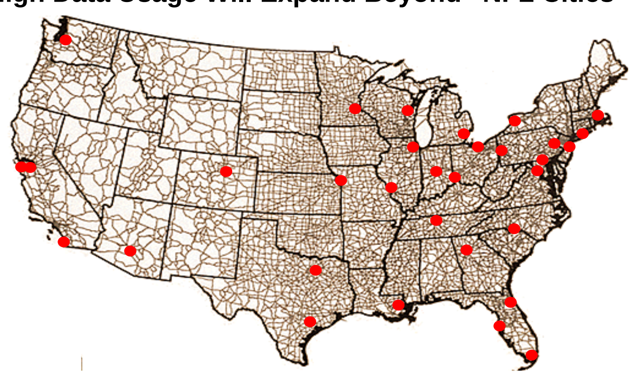
Traffic Patterns Will Change the Geography and Timing of Data Consumption

The adoption of a connected and autonomous car will have implications for when and where data is consumed. From a geographic perspective, we would expect data usage to broaden from the urban environment toward suburban and rural markets. From a timing perspective, we would expect network utilization to rise as high usage broadens from the mid to late evening hours to the peak commuting hours.

Data consumption will broaden from urban markets. Today, usage is concentrated in urban markets, largely driven by population density. In an autonomous driving environment in which data is consumed on roads and highways by both the driver and vehicle, traffic patterns dictate that data usage will broaden from urban centers to suburban markets and rural areas.

Exhibit 50

High Data Usage Will Expand Beyond "NFL Cities"

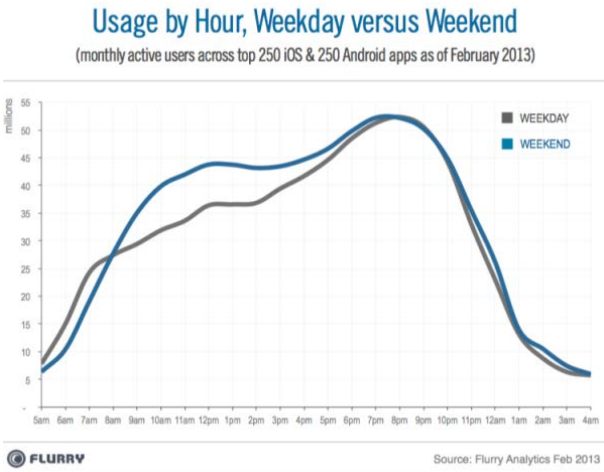


Source: Morgan Stanley Research, fhwa.dot.gov

Network utilization should improve. Today, network usage is lower in the morning and grows steadily throughout the day, peaking in the late evening. Networks are largely built to accommodate peak usage, meaning there are significant periods of under-utilization, though some self-optimizing network capabilities are improving carriers' abilities to better balance peak and off-peak demands.

Exhibit 4

Today, Mobile Usage Peaks in the Late Evening



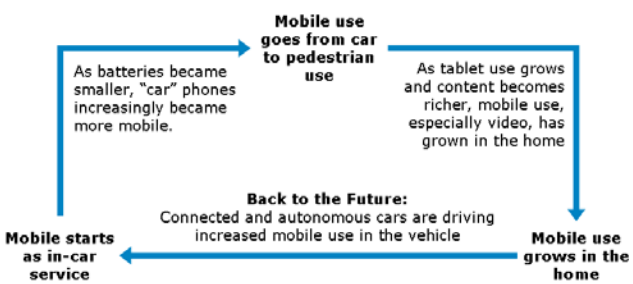
Source: Chart from blog.flurry.com, Morgan Stanley Research

An autonomous driving environment will likely change this usage pattern. Network usage will grow during high-commute times, such as rush hour in the mid-morning and early evening. This should lead to higher network optimization for carriers.

Even the early morning hours (midnight to 5am), when network usage is largely dormant, may be better utilized by the network as carriers can take advantage of these times to roll out over-the-air (OTA) software updates to the vehicle. We already see this occurring in the Tesla Model S.

Exhibit 51

It's "Back to the Future" for Mobile



Source: Morgan Stanley Research

The Volume and Criticality of Network Usage Will Require Additional Investment

To take advantage of the opportunities that autonomous vehicles may offer, carriers will need to significantly bolster their networks. Coverage needs will grow, as every highway and road will need to have uninterrupted, low-latency network coverage for vehicles to safely navigate. Capacity needs will grow, particularly in urban markets, where connected vehicles will drive data growth in already high-usage areas as both drivers and cars access the networks.

Exhibit 52

Carrier Partnerships Are Largely Focused on Telematics and Infotainment Today

Carrier	OEM	Capabilities	Timing
AT&T	GM	Diagnostics, infotainment, connectivity, security, navigation, etc.	Late 2014
	Tesla	Diagnostics, infotainment, connectivity, security, navigation, OTA updates, etc.	Current
	Nissan / Sirius XM	Diagnostics, infotainment, roadside support, etc.	Announced July '13
	Ford Focus Electric	Mobile network services, smartphone integration, etc.	Current
	Nissan Leaf	Mobile network services, smartphone integration, etc	Current
Sprint	Chrysler (certain models)	"Sprint Velocity" platform - Diagnostics, connectivity, infotainment, etc.	Current
T-Mobile	Audi	WiFi connectivity & navigation, etc.	Current
verizon	Mercedes (Hughes)	Concierge, navigation, security, etc.	Current
	VW (Hughes)	Concierge, security, diagnostics, etc.	Current
	On-Star	Concierge, etc.	Through Model Yr 2013

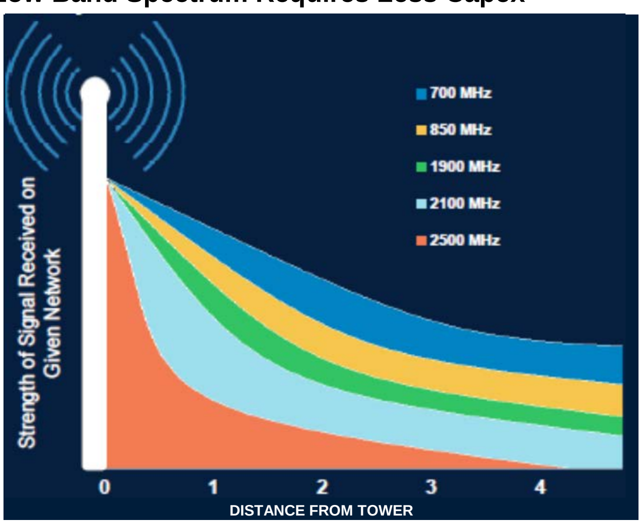
Source: Company Data
Listed capabilities may not be inclusive of all services provided.
Listed partnerships may not be inclusive all arrangements

Coverage needs will grow in suburban and rural markets. To enable autonomous driving, wireless networks will need to seamlessly cover every road and highway, significantly broadening the geography over which wireless networks must have uninterrupted coverage. This should increase the value of low-band spectrum, given the significantly lower cell site density required to achieve full coverage.

Data can travel significantly farther between cell sites when transmitted over low band spectrum (<850MHz) than over high-band spectrum (>2.3GHz), meaning that required cell site density is much lower.

Cell site density can be as much as 2x higher for high-band spectrum than for low-band spectrum. This, along with superior propagation characteristics of low-band spectrum, is why AT&T and Verizon have rolled out their initial LTE networks in low-band spectrum. In an autonomous driving environment, this attribute may become even more valuable as the economics of offering flawless coverage in low-density and rural areas could be difficult with high-band spectrum, given the capex needed.

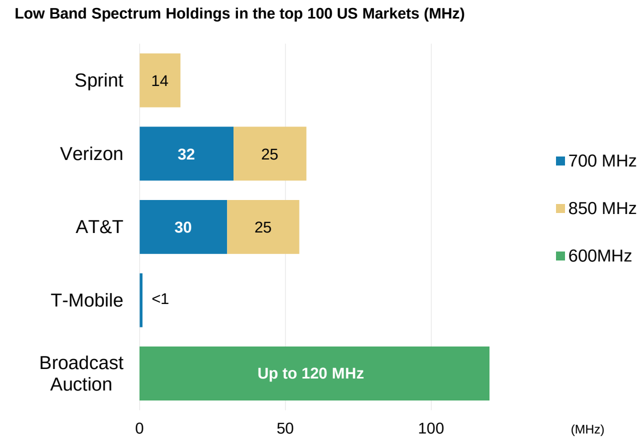
Exhibit 53
Low Band Spectrum Requires Less Capex



Source: Company Data, Morgan Stanley Research

Bells' Have Low-Band Advantage, but Auction Offers a Reset. AT&T and Verizon hold the most low-band spectrum today, with 55MHz and 57MHz, respectively. However, the FCC plans to auction up to 120MHz of additional low-band spectrum currently occupied by television broadcasters in 2014. This offers an opportunity for all of the national carriers to potentially bolster their low-band spectrum position.

Exhibit 54
Low-Band Spectrum Up for Auction in 2014/2015



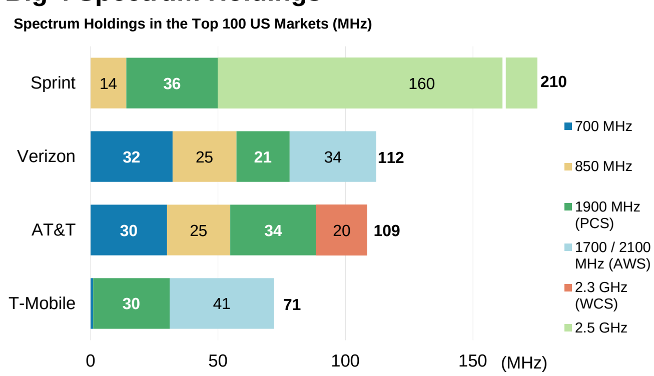
Source: Company Data, Morgan Stanley Research

Capacity needs will grow in urban markets. As network usage grows in urban markets from the addition of connected cars and drivers, carriers will need to ensure that they have sufficient network depth to accommodate even higher usage than today.

High-band spectrum that complements a low-band network will be ideally suited to handle this increased traffic, particularly if autonomous vehicles induce higher mobile video usage, which we would expect.

Today, most mobile video is consumed in static locations with WiFi. If drivers begin to consume mobile video in transit, carriers may want high-band spectrum to accommodate this usage and to complement the base layer of the network built in the low-band.

Exhibit 55
Big 4 Spectrum Holdings



Source: Company Data, Morgan Stanley Research estimates, not adjusted for AT&T's proposed purchase of LEAP or AT&T's 3Q13 purchase of 700MHz B-Block spectrum from VZ.

Industry Implications:

Towers—Positive. Current LTE network build plans at the Big 4 carriers will not be completed for several years, giving the towers good visibility into near-to-mid-term growth. An autonomous driving environment could provide a platform for further growth beyond current plans, as the increased network breadth required would lead to further investment by the carriers.

Carriers –Opportunities and Risks: In an autonomous driving environment, wireless networks would be even more important and valuable than they are today. We estimate the rise of autonomous vehicles could be a ~$100 bn opportunity for the carriers. Autonomous cars would represent very low churn, potentially high-ARPU connections, while existing customers would continue to increase their data usage.

Exhibit 56

Autonomous Vehicles May Be a $100B Opportunity

Total Addressable Market			
Estimated Vehicles			300 million
	x	Incremental usage (Driver + Car)	5 GB/Mo
	x	Revenue per GB	$5-$7
Annual Revenue Opportunity			$90B - $125B

Source: Morgan Stanley Research estimate

The revenue model is still uncertain. Given the limited number of fully connected cars with diagnostics, infotainment, security, navigation, etc. today, we do not yet know what structure carriers will ultimately use to monetize the car and driver's network usage. One example we have today is the Audi connect product, in which consumers purchase data based on a monthly service agreement.

We understand that the average usage runs about 1-2 GB per month, even on an HSPA network, with some users consuming 30 GB per month. A mobile hotspot can enable kids to use WiFi tablets on the go; one can see how backseat DVD systems may become a thing of the past.

Exhibit 57

Audi Owners Pay for Monthly Data Plans

Audi connect® Data Plans Update

Service Term	Retail Price	Monthly Equivalent	Savings
1 month	$30	$30	-
12 months	$324	$27	10%
24 months	$600	$25	17%
30 months	**$450**	**$15**	**50%**

Source: Company Data, Morgan Stanley Research

Alternatively, the Tesla Model S does not have a monthly fee for the car owner, though buyers must pay $3,500 for the tech package, which includes GPS navigation and other features. Ultimately, there may be two revenue streams for carriers. One may be a wholesale arrangement with the automobile manufacturer for the vehicle's navigation and diagnostic services and ultimately its autonomous driving usage, while the carrier may deal directly with the consumer for infotainment services.

AT&T and Verizon have an early advantage given their data-centric pricing, leading national networks and strong spectrum holdings, particularly low-band, which is in short supply. That said, T-Mobile and Sprint are aggressively building out their networks and may be able to improve their low-band spectrum position via the broadcaster incentive auction expected next year.

This opportunity brings significant risk, as the increased investment in capex and spectrum required to make this technology viable may pressure cash flows, and it is not clear how many carriers will be able to participate in the opportunity at scale.

MORGAN STANLEY BLUE PAPER

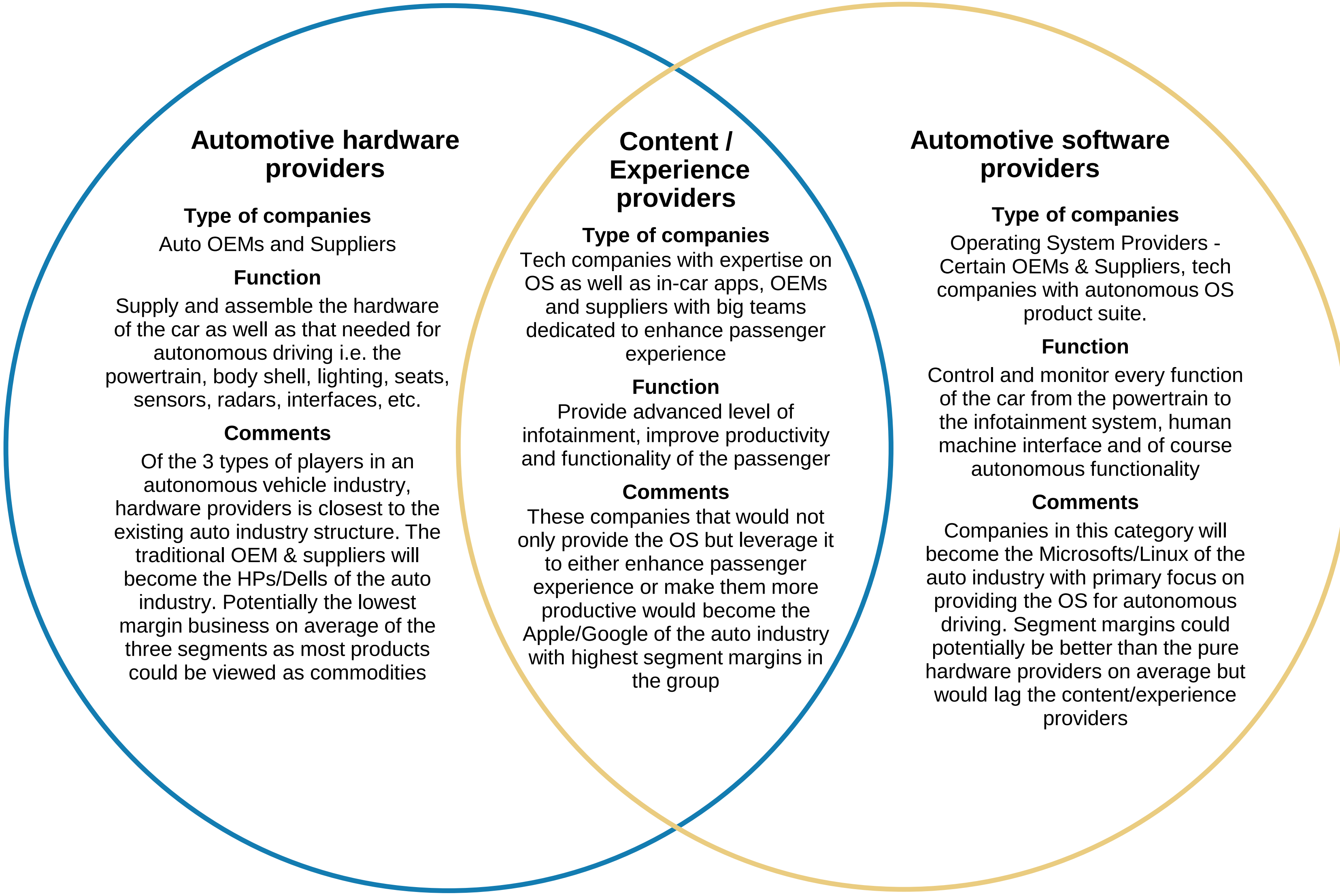
Autonomous Vehicles

The New Auto Industry Revenue Model

- **Lessons from the Technology Hardware Industry**
- **Global Auto Company Implications**

Morgan Stanley

Exhibit 58
The Future Structure of the Automotive Industry?



Source: Company Data, Morgan Stanley Research

The New Auto Industry Revenue Model

We believe autonomous cars will drive a paradigm shift in the traditional auto industry. We see the emergence of software as a key part of the "value" of the car, dividing the auto industry into "hardware" specialists, "software" specialists, and integrated "experience" providers. This is analogous to the PC hardware or smartphone industries.

This could be a binary event for many players. Some could see an existential threat from autonomous cars, some could reinvent themselves as leaders, and others could enter the industry for the first time.

There are implications for OEMs and suppliers. The traditional OEMs need to lead in the space or reinvent themselves as manufacturing specialists. The secular suppliers who provide autonomous vehicle systems and other growing parts of the car will get stronger, while suppliers who are exposed to static or no longer essential parts of the car will be challenged.

The content opportunity opens up a new potential revenue stream. The battle to control the content will be waged by the OEMs, the ,suppliers and the external content providers.

There are significant collateral implications for other sectors. We examine the read-across to the auto space from the PC hardware industry, Google's ambitions and the implications for media, software, car rental, healthcare, transportation, and the semiconductor spaces.

The move to autonomous vehicles is likely to bring significant social and economic consequences for the broad economy and even society in general. The investment implications are likely to be even greater. The advent of the autonomous car is likely to have investment implications for telecom, infrastructure, insurance, IT services, technology hardware, software, and, of course, autos.

A New Revenue Model for the Auto Industry

It may be easy to conclude that the reinvention of the automobile as autonomous will be a watershed event for the auto industry and that the automobile—which at one point in the last decade seemed destined to become insignificant—will play a new, important role in society. This should be significantly positive for the automotive OEMs and suppliers.

Not quite.

We see the emergence of autonomous cars as a binary event for the auto industry. Some players will face an existential threat from autonomous cars, some will reinvent themselves as leaders, and others will enter the industry for the first time.

The Battle for Content

Most of the attention surrounding autonomous cars so far has focused on the potential social and macroeconomic gains they represent. Autonomous cars seem to be all about making the world a better place. However, we do not believe that the social/practical gains necessarily will be the primary driver of the pursuit of autonomous vehicle penetration.

Social gains may be a good way to get some parties (like the government, insurance companies, and the general public) on board, but rarely pay the bills. The government might be able to use the social economic savings (Part 6) to justify spending significant resources building some level of infrastructure support and writing legislation that supports implementation. However, autonomous vehicles will need to deliver real economic returns to the companies and entities involved to be able to gain real traction.

On the business side of things, the various players within and outside the auto industry are expected to spend several billions of dollars on autonomous vehicle development over the next decade, without any guarantee that the customer is able and willing to pay for it. We have seen this with other penetration stories in the group—the OEMs typically tend to push back against fuel efficiency or safety or emissions legislation, until it is clear how they can monetize it.

We see are two primary reasons why the OEMs may be championing a push toward autonomous cars:

1. **Keeping up with the cutting edge of innovation**. In addition to the social benefits, this is the main reason we hear from the OEMs and suppliers for pursuing this opportunity. With even basic active safety systems and advanced infotainment systems—two areas where the luxury OEMs used to distinguish themselves—spreading to the mass market OEMs, the luxury OEMs need to move on to the next frontier, which they believe is cars the drive themselves.
   The existing auto players also, quite rightly, view this as one of the biggest steps up in the functionality of the automobile, significantly greater than higher fuel efficiency or infotainment. Once customers have experienced autonomous cars and have heard the positive word-of-mouth, the OEMs believe the demand-

pull for the feature is going to be very strong. And self-driving capability is not an LED daytime running light that can be slapped on the car in a hurry. Given the nature of the product—high levels of experience / knowledge required with extremely long lead times and very high level of R&D involved—if an OEM reacts and tries to get on the bandwagon *after* demand spikes, it may be too late.

2. **More importantly, we believe the real value here comes from selling content to the occupants of the car.** The emergence of the autonomous vehicle opens up a new avenue of revenue generation for all entities involved. As mentioned in Parts 1 and 4, we collectively spend over 75 bn hours per year in our cars. With the ability of the car to drive itself, that time can now be redirected to other pursuits, potentially creating a new revenue stream if the content can be monetized. In a way, this is a content provider's dream. Short of air travel, there are few other opportunities to have a captive audience for several hours at a time**.**

   However, to make this happen it is critical that the car be fully autonomous. It is not practical to have to keep pausing a movie every couple of minutes to manually take over the car and make a lane change. We believe this may be why some players are attempting to go straight for the ultimate goal of completely autonomous cars, bypassing the incremental stages.

The New Auto Industry Paradigm

Autonomous driving capability is not just a cool new feature in the car, but rather a powerful force that can fundamentally change the auto industry.

We see two paradigm shifts in the industry.

1. Shifting the "value" of the car away from predominantly hardware to a software component as well, thereby allowing new players to enter and forcing existing players to reinvent themselves or cede share. This could potentially allow OEMs to shift away from a vertically integrated, asset heavy business model, thereby changing the profitability structure of the industry

2. Introducing a new revenue model by being able to monetize the content opportunity within the car.

In short , we see the industry structure going the way of the PC/smartphone industry.

The value in the auto industry today is about the car as a holistic product. The OEM is the most important link in the supply chain as the biggest single contributor of content, which is why the OEMs have the most visible brands in the industry as well. The other parts of the value chain tend to be incidental to the automotive experience and do not usually have branding power.

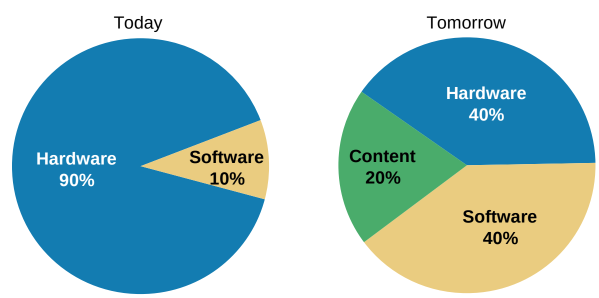
In a world of autonomous vehicles, we see the value in the auto industry coming from three different sources.

- **Hardware**: We define hardware as the car as we know it today, i.e. the powertrain, unibody, exterior panels, interior, lighting, seats, etc. Today, we estimate about 90% of the value of the car to the customer comes from the hardware. We see that falling to about 40% in an autonomous car environment.

- **Software**: We believe autonomous cars will need use an all-encompassing software operating system unlike cars of today. These operating systems will control and monitor every function of the car from the powertrain to the infotainment system, human machine interface and of course autonomous functionality—effectively replacing the human driver in the car. Today, we estimate that about 10% of the value of the car comes from the software. We see that rising to about 40% in an autonomous car environment.

- **Content**: We see the emergence of in-house OEM and third party-created content for use in autonomous vehicles, including for entertainment, productivity, and functionality. This content could come in the form of audio, video, or apps, or in other forms. Today, very little value of the car to the customer comes from the media content—we see that increasing to about 20% in an autonomous car environment.

Exhibit 59
Value of the Car – Today vs. Tomorrow



Source: Morgan Stanley Research

The traditional OEM-supplier auto industry business model is also likely to change, with some companies trying to specialize in each of the three functions we describe, and with others trying to vertically integrate across the spectrum. This is likely to mirror the PC/smartphone industry, with hardware specialists, software specialists, and integrated experience creators.

The “hardware” business model

We believe the current auto industry structure can remain largely in place with OEMs and suppliers making great cars. Even if cars were to drive themselves–or perhaps even more so because of it–cars will have to remain safe, comfortable, quick, connected, quiet, and stylish. The OEMs will continue to be the most influential players in the industry through their design, assembly, distribution, marketing and service capabilities. The suppliers can continue to add value and build sustainable business models by focusing on the growth areas of fuel efficiency, safety, emissions, and interior content. However, the gap between the secular and cyclical suppliers could widen. With the value of the automotive hardware declining as part of the overall value provided by the autonomous car, only the most critical hardware components within the car can continue to command pricing power. The “metal-benders” and “widget makers,” who are already facing significant challenges within the industry, will particularly suffer if the value of the hardware as a whole declines.

The stability of the hardware business model, however, does not mean that there will not be major changes. As cars evolve from what they are today to fully autonomous vehicles in our utopian scenario, we envision several changes in the form and function of the various parts of the car, as we highlight in Part 1. Suppliers who make components that serve little to no function in an autonomous car will be particularly at risk.

The “software” business model

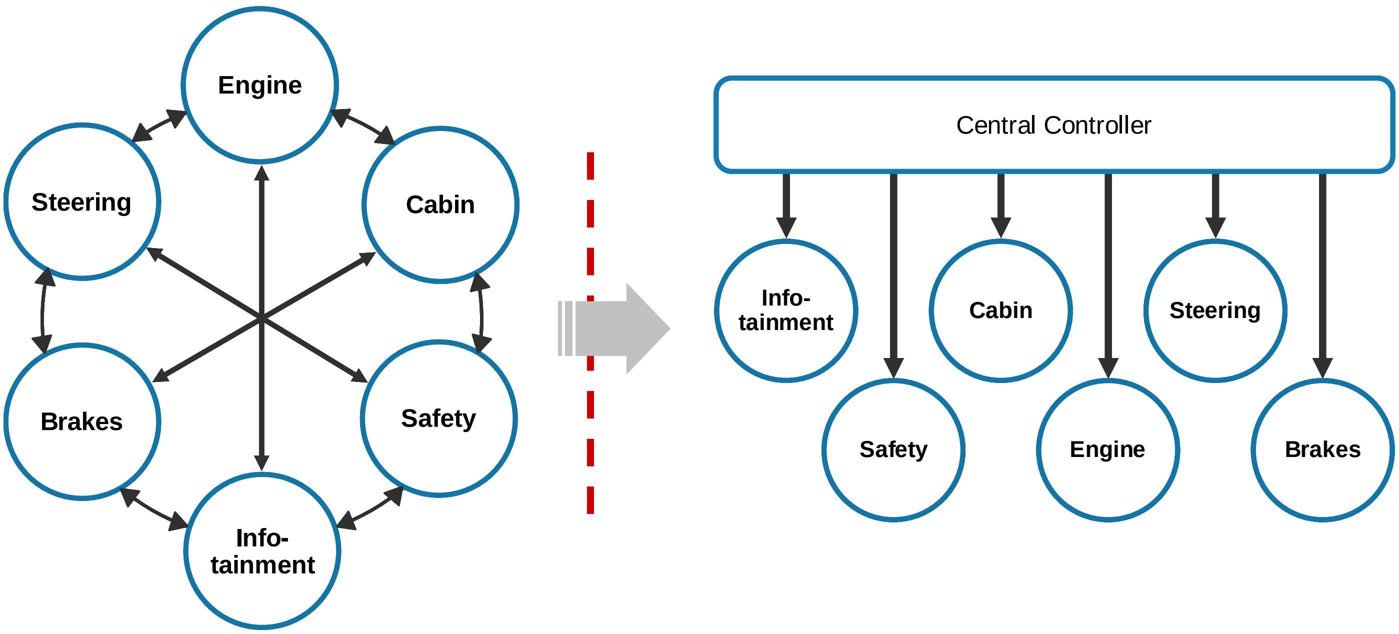
The average car today contains a reasonable amount of software—about 5-10 million lines of code. The software in a car today typically regulates independent functions of a car, including drive-by-wire, traction management, active safety and infotainment. However, these systems act largely as independent silos today, with only a few “handshakes” or exchanges between components. The autonomous car of the future cannot work like this. All the systems in an autonomous car will need to be brought together within a central managing “brain” that can supervise and control almost every function of the car at all times. The level of system monitoring in an autonomous car is *significantly* higher than that of a regular car, given the fact that the main controlling factor of a regular car—the driver—is absent in an autonomous vehicle. The autonomous vehicle also cannot risk different sets of code written by different suppliers of each component.

In effect, the central controller/operating system will be replacing the human driver as the primary operator of the vehicle. In an autonomous car, the car needs to know what every function and feature within the vehicle is doing at all times because the car is in charge and has to make decisions based on operating conditions. This means virtually very function of the car will now have a software component to it. In addition, every function within the car will now need to be supervised and controlled by the central computer, which runs an “operating system” similar to a personal computer, within with each of the different functions of the car reside. Unlike cars of today, with independent functions, the central controller/operating system (analogous to the domain controller that we described in part 2) will control all the other functions of the car. We envision the autonomous driving “brain” as being the most important part of this central controller/operating system.

We expect players within the auto industry to specialize in this newly important software component—i.e., to build operating systems for cars. These could be existing auto OEMs, auto suppliers or quite possibly players from outside the industry, such as Google, Apple, Microsoft, or other companies with computer operating system expertise. We see the automotive software/operating industry as being parallel to the hardware industry, where suppliers sell and install their operating systems into cars made by different automakers, in much the same manner as PCs today ship with options of different operating systems. These operating systems will then interact with the hardware components installed in the vehicle using industry standard communication protocols (similar to how a certain make of computer can work with a printer or keyboard of another make).

Exhibit 60

Current System Architecture vs. Autonomous Vehicle System Architecture



Source: Morgan Stanley Research

The "Experience" creator. In addition to the software business model that revolves around the operating system for the car, we also an emerging content opportunity. One of the key objectives of getting cars to drive themselves is so that the occupants of the car, including the driver, can be freed up to sell them content. This allows several content creators who have only had limited access to the car until now, through infotainment systems such as internet radio, to make full inroads into the car. Most content is not car-specific (YouTube, Netflix, blogs, news, TV, social media, etc.) that is developed for smartphones can be piped into the car as well, with little incremental change. This does not mean that YouTube and Netflix will now have an automotive division and will become players in the auto industry. This does mean that these companies will be able to gain access to a new revenue stream, in addition to smartphones and computers.

We do not believe that the traditional auto industry players will be locked out of the content opportunity or that the hardware and the software business models are mutually exclusive, however. We see some existing industry players trying to offer a comprehensive solution, including hardware, software and content, to give customers the most cohesive, integrated experience possible. For example; an auto OEM will make its own car, powered by its own proprietary operating system developed in-house or in close relation with a supplier. It will also control the content available within its cars. This is closest to the Apple model for smartphones and desktop computers. We see this as being limited to the most advanced and successful OEMs, the ones with powerful brands, large balance sheets, and extensive R&D resources that will allow them to venture into areas they will have little expertise in, especially on the software/content side.

But why do this? Why not let the software/content be handled by those outside of the traditional auto industry who know it best? We do think outsourcing the software will still be the most common business model, but the few OEMs who want the best experience for the customers will at least attempt to vertically integrate, for two reasons;

1. ***The value/importance of the software/content component:*** the OEMs so far have stayed out of software largely because it has been a relatively small part of the value of the car and has been restricted to components typically purchased from suppliers. This will no longer be the case with autonomous cars, with the software+content angle accounting for 60% of the value of the car, in our view. In addition, selling the software/autonomous capability to other, less vertically integrated automakers as well as monetizing the content opportunity within the car are two new revenue streams that the OEM may be unwilling to ignore.

2. ***The temptation of replicating Apple' success with smartphones.*** Apple's success as a design-focused company that controls every part of the hardware, software, and content in its products, and its ability to translate that into better products, quality, and pricing should be the goal of every automaker, in an industry where pricing and uniqueness have been hard to come by, despite high transaction prices.

This may not be as farfetched as it sounds. With many OEMs already developing in-house autonomous vehicle capability, as well as infotainment system development, their software capabilities may already be much farther along than most people give them credit for. For example; GM recently decided to stop outsourcing all its IT development and is hiring 10,000 computer professionals in the next three to five years, to bring ~90% of all its capability in house.

The OEMs are also not strangers to the content business, either. Recall that many OEMs already have smartphone apps available that allow basic car functions to be controlled via smartphone. In the past few years, both BMW and Audi have commissioned independent filmmakers to direct indie/art movies that feature their cars as part of marketing campaign, and both OEMs have internal TV channels as part of their corporate/dealer network.

While we do not expect an OEM to emulate Netflix and commission a top Hollywood director to develop a TV series for their vehicles only, we point out that this is not impossible. We think it is more likely that certain OEMs team up with media partners to allow exclusive availability of content on their vehicles (especially in the case of multi-brand conglomerates like VW or GM), and generally act as gatekeepers for what goes into their vehicles.

What does this mean for:

OEMs. The OEMs will have a range of choices as to how vertically integrated they want their cars to be. They can make fully integrated vehicles by designing, developing, and assembling the body and the operating system (including the autonomous capability), and controlling the content available in the car. The other extreme would be an extremely asset-light, completely outsourced model, in which the OEM sells a car under its brand and distribution network but, apart from designing the vehicle in its studios, every other component is outsourced. This would include sourcing the engine, transmission, battery, and other interior/exterior components from other OEMs or suppliers; using software and autonomous capability developed by other OEMs, suppliers, or third parties, and outsourcing assembly (such as Magna Steyr) and maybe even distribution (such as a third-party distribution arrangement like Penske-Smart).

While the OEMs could certainly adopt a business model that looks like something in between these two extremes, over time we see the industry coalescing at one or the other end of the vertical integration spectrum. In the early years, we expect the OEMs that to date have not been early leaders in the development of autonomous vehicle systems to be "hardware specialists" and design, develop, and build the cars themselves, but purchase the software from outside suppliers. Those OEMs who have been autonomous vehicle leaders from the start are likely to pursue full vertically integration as soon as possible, in our view.

The three OEM business models:

The business models will be quite different at either end, of course. The fully integrated OEMs will have massive upfront fixed costs for R&D but will also likely have the strongest brands, margins, and ROIC, given the value of the automobile that they control. The "hardware specialist" business model will likely come down to a cost model determined by how cheaply a car can be designed and built, while keeping capacity utilization at the highest possible levels in order to generate adequate returns after outsourcing 60% of the value of the car from external entities. This is a likely business model for brands that are not strong or operate mostly in emerging markets. The fully outsourced business model would be basically a brand-licensing model, where an OEM with a strong brand and design capabilities would choose an extremely asset -light model which can be relatively easily monetized even with outsourcing everything.

Suppliers. When we first started thinking about autonomous vehicles, we had expected that the OEMs and companies outside the traditional auto industry (like Google) would be most successful and the existing auto suppliers would be the most severely challenged. This was driven by our view of a shift in the value generated by the different components of the car vs. today, and the relative exposure of the suppliers today.

While we remain convinced the shift in value will occur, our conclusion about winners and losers could not be more different than our initial view. We see autonomous vehicles as being highly beneficial to auto suppliers and believe certain suppliers will see tremendous value creation from being early leaders in the space. These suppliers are likely to enjoy an extremely close relationship with the OEMs and will be involved in the design and development of a vehicle at an even earlier stage than they are today. This will be especially true if the supplier is a conglomerate that is also a leader in other parts of the car that will see rapid content growth, such as fuel economy/electrification, active safety, and comfort/convenience (the latter two being closely tied to autonomous vehicle capability).

The less vertically integrated the OEM chooses to be, the greater will be the value accrued to the suppliers—and we expect to see a significantly higher level of outsourcing over time. We could also see the emergence of a new breed of suppliers that specializes in low-cost manufacturing (like a Foxconn for smartphones). Finally, we expect to see value erode at existing suppliers of components that will be less important or relevant in the car (exhausts, drivetrains, tires, or any component that is not highly engineered).

External entities. External entities could come into the auto industry in three ways: 1) Software—through development of proprietary autonomous vehicle systems (Google, Mobileye, start-ups, etc.), 2) Software—through supplying content for in-car consumption (YouTube, Netflix, social media); and 3) Hardware—suppliers of new components related to autonomous capability or low-cost assemblers taking advantage of the new outsourcing business model.

Entering the automobile will be seen as a game-changing event for the companies that are from outside the industry—in both good and bad ways. The positive perspective is that the automobile is the most expensive item purchased by an individual after his home, and the place where he spends the most free time, after his home. The automobile is also the last place that neither traditional nor new media have significantly penetrated. We still hear protests from some people about the death of the car radio as internet radio takes hold in infotainment systems. This could accrue tremendous value to entities that can sell content to the consumers within the automobile.

The downside is that the global auto industry is one of the most cyclical, price-sensitive industries in the world, with significant overcapacity and inefficiencies, and a powerful supply/value-chain. Exposing the likes of Google and Silicon Valley start-ups to annual contractual price-downs and supplier support payments likely will be seen in a dim light by shareholders of those companies. The learning curve will be steep, however; given the tremendous value that these entities are likely to generate and the software-centric nature of their products, they should be relatively insulated from the worst tendencies of the industry.

Lessons from the Technology Hardware Industry

Katy Huberty
Scott Schmitz

We see three primary lessons from prior technology cycles that apply to potential changes in the auto industry during the development of autonomous vehicles:

1) Value-added services that cause most of the disruption are preceded by periods of infrastructure investment.
2) Closed systems are often more successful in early product development, but open systems eventually lower costs and gain more market share, albeit at lower profitability levels.
3) Controlling the platform is the key to long-term success. Operating system software and key semiconductor components are among the few areas of competitive edge, while OEM competition and lack of differentiation pressures margins.

Starting with mainframes in the 1960s, technology cycles last roughly 10 years and start with an infrastructure build-out followed by value-added services that lead to major changes in user behavior. Each cycle brings new winners, improved functionality/interfaces, lower prices, and expanded services, leading to a ten-fold increase in the number of devices.

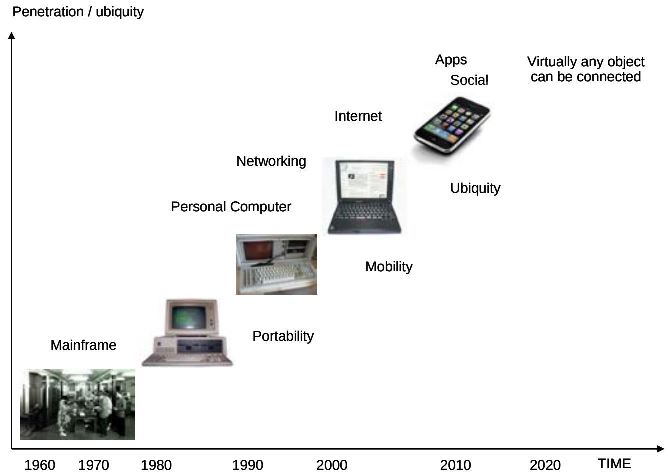
We are in the early days of the next computing cycle—the “Internet of Things”—in which sensors embedded in everything from mobile devices to stores and automobiles will change the way consumers interact with their environment. We view the autonomous car as an extension of this trend, contributing to a ten-fold increase in the number of devices (in this case cars) that communicate with one another through sensor technology, including Bluetooth, GPS, and WiFi. The first step in this process is the connected car—where 3G/4G connectivity powers infotainment systems, leading all the way up to autonomous cars.

Key lessons from prior technology cycles

Infrastructure comes first, followed by value-added services that change user behavior

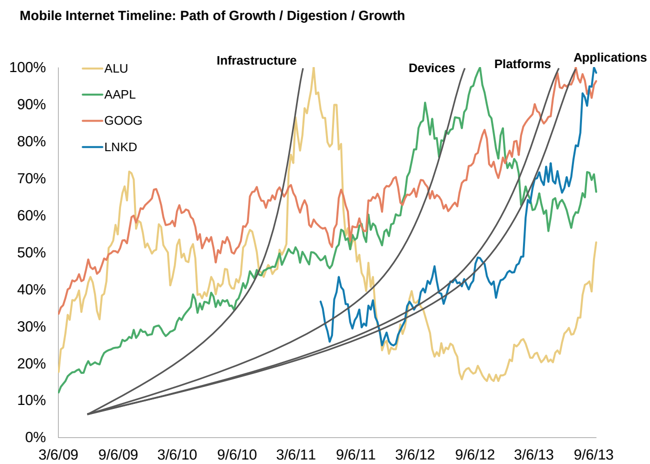
Technology cycles follow a logical growth pattern that begins with infrastructure development, evolves with software and services, and ultimately causes the major disruption. For example, the Mobile Internet cycle required ubiquitous wireless connectivity, which was followed by the rapid growth of mobile phones, use of applications, and broad changes in computing behavior.

Exhibit 61
Technology Cycles over the Past 50 Years



Source: Morgan Stanley Research

Exhibit 62
Autonomous Vehicles Require Significant Infrastructure Investments before Disruption from Valued-added Services Change User Behavior

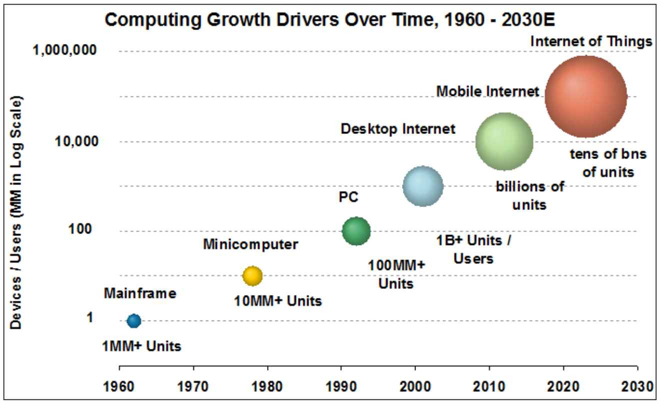


Source: Thomson Reuters, Morgan Stanley Research

The advancement of wireless speeds, improved smartphone functionality, and value-added services led to an explosion in the number of devices. Consistent with prior technology cycles, the mobile internet cycle is driving a 10x increase in the number of computing devices compared to the desktop internet era. Since the introduction of the first iPhone in 2007, smartphones grew at a 42% CAGR, reaching 723M units in 2012.

Exhibit 63

Each Successive Computing Cycle Has Yielded 10x More Cumulative Devices



Source: ITU, Morgan Stanley Research

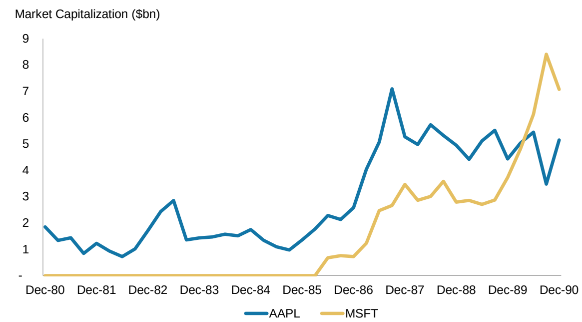
Closed systems launch new industries, but open systems eventually lower costs and gain more market share, albeit at lower profitability levels

Some of the most successful technology innovation cycles occur when a single person or company has full control of all aspects of product development (hardware and software) in order to best complete the vision. We refer to this as the closed approach, which is common in the early stages of new product cycles. Apple and AOL are some of the most well-known examples of a closed approach during the early stages of the personal computer, desktop Internet, and mobile Internet cycles. However, as the initial vision materializes, standards are set that typically lead to lower cost and broader adoption. Microsoft proved this with Windows, and Google is beginning to prove it with Android in smartphones and tablets. However, closed system participants do not necessarily lose value in later stages, they simply grow at slower rates because they demand higher prices.

The closed approach is often required in the early stages of a new product category, given the lack of standards and uncertain market adoption that may require constant changes to the product. The closed approach limits market share, but allows for premium pricing and higher profitability (Apple). The closed approach typically yields a better user experience but reduced economies of scale as building each component internally raises costs.

Exhibit 64

Apple's Closed System Led to the Early Success of the Personal Computer, but as Standards Evolved Open Systems Dominated the Market



Source: Reuters, Morgan Stanley Research

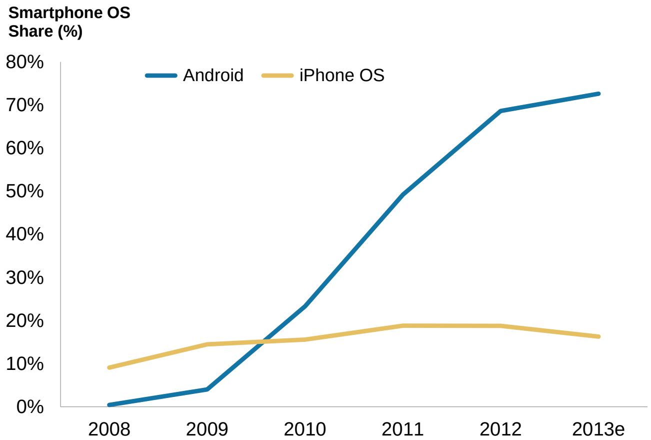
Auto industry—closed vs. open approach

The traditional auto industry is fiercely protective of its technologies, patents, engineering, and production techniques. While cooperation between OEMs currently exists, it is relatively limited, rarely successful, and comes either in the form of one OEM buying a complete powertrain or vehicle platform from another or joint technology development from scratch (GM and Ford on six- and nine-speed transmissions, for example). Neither sort of cooperation applies in the case of true open source. There are rare cases of open source in today's auto industry from independent design studios—a good example is legendary designer Gordon Murray's T-27 and T-25 city cars.

With the emergence of autonomous vehicles, however, the auto industry may have to start embracing an open source world. This would be particularly true if certain suppliers adopt a business model of offering up their autonomous vehicle systems for free, in exchange for supplying the hardware or controlling in-car content. Eventually, if the hardware of a car becomes so commoditized that most of the car's value comes from the software, even the hardware could become open source, especially in emerging markets. At the end of the day, however, there is a relatively low limit to how open source a vehicle can be given the unacceptably high risk of failure and security concerns.

Exhibit 65

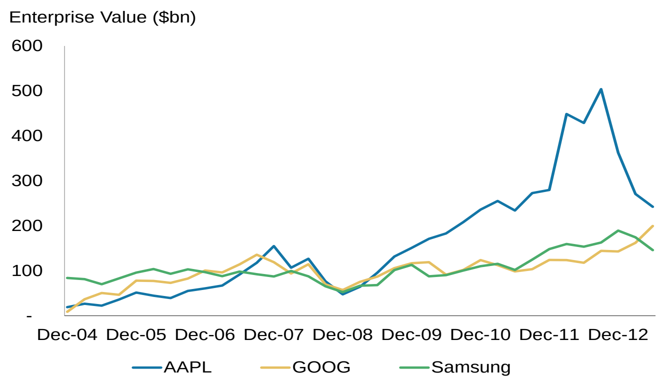
Apple's Innovation Also Changed the Smartphone Industry, but Fast Followers and Open Solutions Drove Down Costs and Gained Market Share



Source: IDC, Morgan Stanley Research

Exhibit 66

Open Systems Account for 80% of the Market, but Apple Still Leads Profitability and Valuation



Source Thomson Reuters, Morgan Stanley Research

Apple's market share peaked at 19% in 2012, before falling slightly in 2013 as low-cost Android-based units quickly flooded the market with wide OEM distribution. However, Apple still commands a premium for its more fluid user experience, helped by its tight control of the hardware and software functionality. Additionally, Apple's installed based, with over 575 million credit card-linked accounts and portfolio of music, photos, and videos that easily tether to Apple devices, makes Apple's platform very sticky. Apple's premium solutions continue to yield margins significantly above the industry average. Despite accounting for only 19% of the smartphone units in 2012, Apple generated more than twice the operating profit of the next five largest players who control 48% of the market.

Exhibit 67

Apple Has Less than Half the Revenue and Market Share of the Smartphone Market, but Earns >2x the Profit and Is Twice as Valuable

2012	Apple	Next 5 Largest Players	Apple Delta
Revenue ($bn)	85	165	-0.5x
Unit Market Share	19%	48%	-0.6x
OP ($bn)	37	16	1.3x
OPM (%)	43%	10%	3.4x
Market Cap ($bn)	456	219	1.1x

Source: Reuters, Company data, Morgan Stanley Research

A similar trend is playing out in tablets, with Apple accounting for half the industry revenue but only 33% market share vs. nearly 100% in early 2010.

Operating System Software and Key Semiconductor Components Among the Few Areas of Differentiation in the PC Food Chain

High market share and control of the primary functionality of a PC have helped Microsoft and Intel consistently draw value from the PC supply chain. The fragmented market for most other components as well as a large variety of PC brands pressures pricing and profitability. Most PCs contain the same components (WinTel architecture), leading to a lack of differentiation, commoditized pricing and elongating life spans.

Exhibit 68

CPU and OS Account for Nearly Half of the PC Bill of Materials with the Highest Profitability Levels

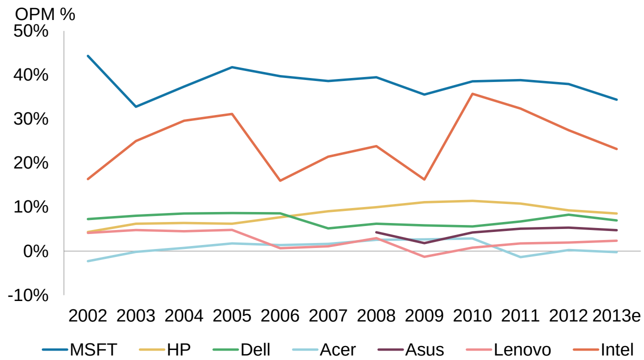
Notebook	US$	% of BOM	Approx. GM%
CPU & Chipset	150	31%	60%
OS	60	13%	75%
Assembly (MVA)	45	9%	10%
Panel/Display	41	9%	-2%
HDD	40	8%	28%
Connectors, IC, and others	38	8%	40%
Battery	28	6%	10%
Casing	20	4%	10%
Power adaptor	12	3%	20%
PCB	12	3%	10%
Memory	8	2%	15%
WiFi/Bluetooth	7	1%	50%
Keyboard, Camera, Speaker, Oth	19	4%	15%
Total	**480**	**100%**	

Source: Source: Gartner, IDC, Morgan Stanley Research

Most of the profit sits with the software providers. Software providers not only benefit from high margins, but also have lower capital intensity, yielding ROICs well above most other suppliers.

Exhibit 69

OEMs Extract Little Value from PCs Compared to Key Suppliers

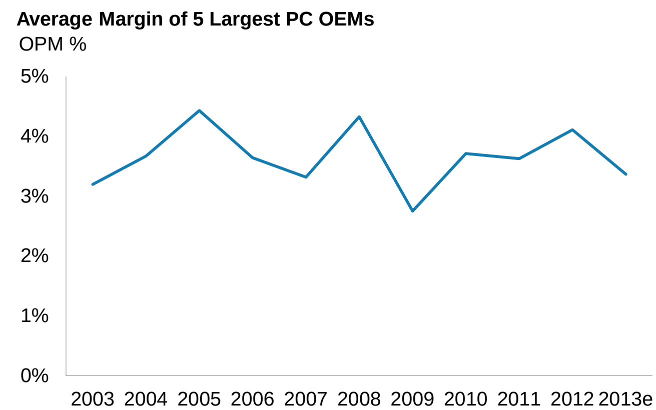


Source: Company data, Morgan Stanley Research

New computing devices in the form of tablets and smartphones are further pressuring the PC industry. As the user experience matures and product differentiation narrows, less emphasis is placed on the individual components and more on the price. By removing the driver control, a vehicle's performance becomes slightly less relevant, which could pressure the hardware OEMs' ability to differentiate. Users generally do not care who makes the processor in their PC, tablet, or smartphone, and similarly "passengers" may not care who makes the "processor" in their car.

Exhibit 70

PC Margins Pressured as Lack of Product Differentiation and Alternative Computing Platforms Forces Aggressive Price Competition



Note: for HP, only PC segment is included
Source: Company data, Morgan Stanley Research

Global Auto Company Implications

Auto OEMs

The biggest impact within the auto industry from the move to autonomous cars is arguably going to be on the OEMs. The OEMs that have the most reliable and feature-rich autonomous capabilities in their cars are likely to be the ones that succeed, while the ones that do not will either be forced out of business or will have to reinvent their business models to be "hardware only" / assemblers while buying the autonomous systems from other OEMs/suppliers/third party players. We believe this could really be existential for the OEMs—at least, once we get to a world where autonomous capability is so widespread that non-autonomous cars are no longer allowed on roads.

Getting a head start is critical. As we have outlined earlier in this Blue Paper, the technology to enable full autonomous driving capability is not really a hurdle apart from bringing it somewhat down the cost curve. However, there is a significant amount of development work still needed, particularly in the areas of reliability and scenario testing. This is something that can only be gained with experience—namely racking up millions of test miles on prototypes in controlled test and real world scenarios. This could take several years to complete and there is no short cut to this.

In this setup, getting a head start on the testing and development is critical. While it may tempting to wait until the path forward is a little clearer in a few years, we believe that a late entrant into the space will find playing catch-up either very expensive or nearly impossible, if they are caught 5-7 development years behind some competitors. It is true that the OEMs may be reluctant to repeat their recent experience of the electric vehicle arms race, when gas prices were rising sharply before the economic downturn, only to reward the OEMs with weak demand, little technological progress, and underutilized battery capacity in recent years. However, we believe autonomous vehicles arguably have a clearer path ahead than EVs, making them a smaller leap of faith.

The early movers will likely be the most successful. Fortunately, the race to be the early leader in the OEM race is intense. Almost every major OEM has at least expressed interest in the field of autonomous vehicles, if not committed significant R&D resources behind the project.

The German luxury OEMs are typically amongst the leaders in innovation when it comes to most major technologies that have debuted in the auto industry, at least in the past 50 years. Autonomous vehicles are no different. Audi, Mercedes Benz, and BMW each have running prototypes of autonomous vehicles on the road, with firm plans/targets of commercial roll-out. All three have been leaders in implementation of active safety—the precursor to autonomous driving—over the past several years, and the rest of the industry is in the process of catching up. In the meantime, the German OEMs have their sights set on full autonomous capability.

Audi was one of the first OEMs to obtain a license for an autonomous vehicle for its driverless A7 prototype in the state of Nevada. Its TT Pikes Peak prototype tackled the grueling and incredibly treacherous Pikes Peak Hill Climb challenge in 2010, without a driver at the wheel. Audi parent Volkswagen's recent autonomous vehicle initiatives go back even further. The winner of the 2007 DARPA challenge was Stanley, a VW Touareg retrofitted with driverless capability in collaboration with Stanford University.

Mercedes-Benz, however, will become the first OEM to commercialize semi-autonomous driving. Its 2015 S-Class will be able to autonomously navigate slow speed traffic jam situations as well as high-speed highway cruising (up to 124 mph). Mercedes-Benz also recently demonstrated its completely autonomous S500 Intelligent Drive vehicle, which covered the 60-mile journey between Mannheim and Pforzheim in Germany—replicating the route driven by the first automobile made by Karl Benz 125 years ago. We note that almost all the hardware used by the S500 Intelligent Drive is already production-based.

BMW demonstrated its ConnectedDrive Connect (CDC) system on a 5-Series in 2012 and engineers have racked up several thousand test miles on autonomous cars already. While BMW says that the technology is about 10-15 years away from commercial production, it continues to work with suppliers like Continental to further develop the system.

Volvo is trying to make sure that the early lead in the autonomous car field is not exclusively German. The upcoming 2015 XC90 is expected to come equipped with a traffic jam and highway cruise assistant. Volvo has also demonstrated a self-parking car and is a participant in the SARTRE autonomous road train project in Europe.

General Motors' autonomous car history goes back several decades, with some of the earliest self-driving prototypes developed in the 1940-60s. GM has not fallen behind the Germans since then, either. Cadillac will debut its Super Cruise feature around 2016, which can drive at highway speeds and take corners. This ability would make it one of the most advanced early autonomous systems on the road.

Ford was the first mass OEM to offer hands-free parking in its cars, as early as five years ago. Since then, it has taken somewhat of a back seat, so to speak, in the development of fully autonomous cars compared to some peers, at least in the public domain. However, in early October 2013 Ford demonstrated self-parking and obstacle avoidance technologies in new prototypes. Earlier this year, Ford Chairman Bill Ford, Jr., stated at a conference that self-driving cars will soon become reality.

Toyota was the first OEM to commercialize hands-free parking back in 2007 with the Lexus LS and continues down that path with a small fleet of autonomous prototypes, including a Lexus LS and RX450h. In October 2013, Toyota announced it had developed an advanced, next-gen driving support system for highway (including car-only highway) driving that uses automated driving technologies. The system is called Automated Highway Driving Assist, or AHDA. AHDA goes beyond technology currently on the market, such as adaptive cruise control based on, e.g., cameras and millimeter-radar, to provide an advanced technology package that supports drivers by, for instance, wirelessly communicating with vehicles traveling ahead. It plans to commercialize AHDA by around the mid-2010s.

Nissan, much like it did with its EV strategy, appears to have the most concrete and aggressive autonomous vehicle rollout plan. Despite being off to a relatively slow start, Nissan not only has a prototype of an autonomous Nissan Leaf on the road but has also announced a target to deliver the first "commercially viable self-driving system" by 2020, across several models in its lineup—and at a "realistic price". While the details on what exactly this means are unclear, Nissan is one of the only OEMs to set a clear timetable for commercial introduction of autonomous vehicles.

Honda also unveiled a self-driving car based on the Accord Hybrid at the ITS World Congress in October. The car utilizes Honda's unique technology developed in its humanoid robot, ASIMO, a well-known "face" in Japan. ASIMO analyzes the movements of people in its vicinity, and this technology has been adapted to vehicles. It tracks the movements of pedestrians (e.g., judges whether they are attempting to cross the road or not) and provides feedback to the driver, and also uses the information to control the vehicle and avoid collisions. While it apparently does not currently have a fully independent driverless car such as that pursued by Google, it is engaged in advanced research.

Beyond the J3, we also focus on **Fuji Heavy Industries** (Subaru), for its highly developed technology in adaptive cruise control, a fundamental technology in self-driving systems. Over the last 24 years, FHI has developed driving-assist systems that use stereo cameras. Its adaptive cruise control system, known as EyeSight, is very popular in Japan, and models featuring EyeSight now make up around 80% of FHI's domestic sales. When the US-based IIHS (Insurance Institute for Highway Safety) recently tested front-crash prevention systems for the first time, the EyeSight-equipped Legacy/Outback received the highest ratings among the 74 models tested. At the recent ITS World Congress, FHI exhibited an EyeSight vehicle also fitted with its cooperative driving assistance system, which features inter-vehicle and pedestrian-to-vehicle communications systems.

While these OEMs appear to be the early movers in the autonomous vehicle space, several others, including Fiat, PSA, the small Japanese OEMs and other emerging market OEMs continue to either adopt a wait-and-watch attitude or do not have this on their radars for the time being. There currently are about 25 major global OEMs ex-China and about another 100 or so in China. With the leap to autonomous technology looming over the next decade, we are not sure everyone can (and should) make it.

In the end, it comes down to balance sheets and priorities. OEMs that are dealing with severe macro declines in their home markets and are barely able to keep their regular product line-up profitable appear unlikely to be able to invest significant resources on what is still regarded in many circles as a fantasy, especially when there are many other calls on their cash, including investing in fuel efficiency, safety and infotainment technology, developing common platforms, and EM growth. As we concluded in a prior Blue Paper on global auto scenarios in 2022, the OEMs with the biggest balance sheets are likely to be the long-term success stories, while the smallest ones are likely to face existential threats over time.

In our view the "haves and have-nots" will evolve such that the early start and the heavy investment made by the "haves" will lead them eventually to become "experience" makers and licensees of their autonomous technologies.

The have-nots, on the other hand, could either go away or become "hardware specialists/assemblers" who license the autonomous system from other OEMs/suppliers.

Auto Suppliers

We see suppliers fulfilling two roles within the autonomous vehicle space.

1. Being a Tier-1 supplier working with the OEMs on their autonomous systems by providing technology, software and expertise

2. Independently developing their own autonomous vehicle systems to license to OEMs who are lagging behind the leaders and need to bring the technology to market quickly.

Irrespective of the role, the diversified electronics and active safety suppliers have the best chance of being the long-term winners here. Companies that are already well down the path to developing fully autonomous driver assistance systems in conjunction with the OEMs include Delphi, Continental, TRW, Denso and Autoliv. These companies are active safety suppliers who already make the cameras, radar, sensors, and mechatronic units which will enable the autonomous car to "see" and drive itself. The suppliers who also do infotainment/telematics/connectivity in addition to active safety (Delphi, Continental, Denso) have an additional leg up with being able to develop the HMI and content delivery systems.

Continental has perhaps been the most vocal supplier when it comes to autonomous cars. The company’s booth at the 2013 Frankfurt auto show was centered around the concept and Continental announced partnerships with Google and IBM for further development. This is not a new venture for Continental—it also has a partnership with BMW to get autonomous vehicles on the road by 2025. Continental has also put interim stakes in the ground with a goal of having “partially automated” cars on the road by 2016 and “highly automated” cars by 2020. Continental also has a license to operate its autonomous vehicle in the state of Nevada.

Delphi Automotive PLC has also devoted considerable resources (relatively speaking) to the autonomous car project. It has been working with Google on its fleet of self-driving Priuses. We believe Delphi can benefit from its strong presence in both the active safety and infotainment spaces together with its software expertise.

Autoliv is a leader in the passive and active safety space today (along with TRW) so a progressive move into autonomous capability is a logical step for them. While ALV is still approaching the technology from a safety perspective (increase the capability of active safety enough to remove the driver from the equation potentially) and its main focus is to be the owner of the domain controller within the car, it remains to be seen whether ALV will move out of the safety domain into adjacent areas like infotainment and HMI, which it needs to become an end-to-end autonomous vehicle system supplier (that can license a system in a box to an OEM).

TRW is another safety leader that is keenly interested in autonomous vehicles and driver assistance systems (DAS). TRW is working with Mobileye, a private company that specializes in vision-assisted DAS.

Sensata Technologies Holding is a leader in automotive sensors though it is unclear what role they will play in an autonomous world. While there is likely to be a meaningful increase in the number of sensors in an autonomous car, most of the incremental sensors are likely to be for active safety or HMI applications, which Sensata does not participate in. Sensata’s specialty is in the engine/transmission/powertrain area, which could see modest incremental content increase but is unlikely to see a big lift from the move to autonomous vehicles.

Non-traditional supplies: The autonomous vehicle opportunity also allows players who have not traditionally been part of the autos space to have a look in. While Google is probably the most well-known "external" player here, others potentially include Cisco Systems, IBM, Intel and others from the IT world as well as—for probably the first time in several decades within the auto industry—start-ups. These companies are effectively on the path to becoming Tier-1 automotive suppliers with a focus on electronic systems and software that will drive autonomous capability.

These external entities are not going to have it easy. The traditional auto industry historically has been tightly knit and highly skeptical of outsiders, believing that "automotive grade" is very difficult standard to achieve. Indeed, in our discussions with various members of the traditional auto industry about the role external entities play have in the future, we encountered an enormous degree of skepticism, dismissal and even hostility directed toward their ambitions. However, we do not believe "automotive grade" is an insurmountable moat around the industry.

It is likely true that the external entities cannot go it alone—they will most likely have to work with the traditional OEMs and suppliers to find their way around the automobile.

However, the expertise they can bring on the software side of the business—which has hardly been a forte of the traditional industry can be critical to the success or failure of this endeavor.

Impact on Japanese Auto Suppliers

Shinji Kakiuchi

Of the Japanese auto parts makers, we expect **Denso** to benefit from wider adoption of self-driving systems. Among global suppliers, we think Denso and German companies Robert Bosch and Continental are able to deliver high value-added in this field.

In terms of anti-collision system hardware, per-vehicle use of sensors, sonar, radar and cameras can be expected to rise. Suppliers of these parts are likely to benefit from the increased volume. However, standardization of the systems by automakers and legally mandated installation (e.g., as occurred with airbags and ABS) could lead to commoditization and lower prices.

We see scope, meanwhile, for companies to maintain and enhance value-added via development capabilities and technology. The key to advanced driving technology is in analyzing driving data from sensors and the like and determining how to control the actual vehicle. Automakers essentially have the knowhow here. Many suppliers supply ECUs that control individual systems, such as brakes, airbags or steering, but only the major Tier 1 suppliers offer ECUs that integrate control of multiple systems that enable, for instance, safe driving. And even within this group, companies need software development capabilities to build the architecture that links the systems together.

Denso has the development and technological capabilities, including software circuit design capabilities, to build integrated ECUs that link navigation, engine control, brake control, transmission, steering and other systems.

On September 26, Denso revealed that it aims to carve out a global share of around 20% in the safety/anti-hazard sensor business by 2020—it had around 10% in 2012. Denso expects the market for anti-collision systems to grow eight-fold in the next eight years as use becomes widespread and regulations tighten. It aims to expand orders by enhancing its individual sensors and also offering sensor packages tailored to specific functions.

Denso roughly estimates the size of the global market for such sensors at ¥100-150bn per year. It expects this to balloon to ¥800-1,200bn by 2020. Denso aims to grow sales from the ¥10-20bn it had in F3/13 to around ¥200bn in F3/21.

Denso has packaged its sensor systems into three types, standard (for mass-produced autos: image sensors + millimeter-wave radar (long-range)), basic (for small cars: image sensors + LIDAR), and advanced (for high-end autos: stereo image sensors + millimeter-wave radar). With this base lineup, it is pursuing orders for safety/anti-hazard systems to aid in, for example, avoiding collisions, keeping the vehicle within lane boundaries, ensuring nighttime visibility, and regulating speed.

Denso announced on September 26 its decision to invest in Adasens Automotive, which develops image recognition technology for safety/anti-hazard systems. Adasens is part of the Spain-based Ficosa International group. Denso is slated to acquire 50% of Adasens shares from Ficosa.

Within the Toyota group, **Aisin Seiki** is also set to enhance its self-driving technology, its plan being to build on the concept of its IPA (Intelligent Parking Assist) system, a world-first system jointly developed with Toyota in 2003.

Potentially challenged: The growth of autonomous vehicles could bring the involved suppliers greater power and relevance within the industry, resulting in faster growth, stronger CPV/margins and eventually higher stock multiples. On the other hand, with the hardware components of the car decreasing in relevance, the non-secular suppliers who do not serve the growth areas of efficiency, safety and comfort/convenience could go the other direction and see their decline in relevance accelerate, especially if autonomous capability renders their parts virtually obsolete. Some of these areas could be body panels/frames, drivetrain (axles), exhaust, lighting, some interior components, glass, tires etc.

We also note that the barriers to entry in the supplier space are high—map databases, tech hardware, and software expertise will take years of experience and several billion dollars of investment to replicate from scratch. New/late entrants will also have to convince the OEMs—who may already have a long history of working together with the early suppliers and deeply integrating their systems into the car—to start over, take a risk and give them a chance. But this is not a technology where the OEM can take a chance as the risk of failure is unacceptably high.

MORGAN STANLEY BLUE PAPER

Autonomous Vehicles

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Google: An Early Leader in Autonomous Vehicle Research

Scott Devitt
Jordan Monahan

Google's autonomous vehicle program may be the earliest, highest-profile program in the US today. Google's autonomous vehicle team has been developing self-driving cars since at least 2005, and Google has been actively promotional about the program over the past 1-2 years. While Google's business case for autonomous vehicles is currently open to speculation, these vehicles fit into the GoogleX R&D laboratory mandate. Google X attempts to make a few targeted bets on technologies that have a low initial probability of success, but a high expected payoff upon achieving success. Google has vocally championed these "10X" products and the company's "10X" thinking since co-founder Larry Page took over as CEO in 2011.

A dozen autonomous cars in three states today

Google's self-driving car program consists of around a dozen vehicles, primarily Toyota hybrid vehicles, each supervised by a driver and an engineer in the front two seats. Google has successfully sponsored legislation legalizing self-driving cars (with human caretakers) in three US states: California, Florida, and Nevada. As of August 2012, Google's autonomous vehicles had driven more than 500,000 accident-free kilometers.

According to various media sources, each of Google's vehicles contain around $150,000 of computer and sensor equipment, including a $70,000 LIDAR system that measures objects and distances via a combination of laser imaging and reflected light. While initial costs seem prohibitive for mainstream vehicles, a former Google engineer has commented to *USA Today* that "reasonably-priced LIDAR systems are coming relatively soon." Indeed, the sales director of Ibeo, a German automotive supplier, announced the firm's plans to sell a lower-powered LIDAR system for around $250 starting in 2014.

Commercial possibilities may include the following:

- ***Google using self-driving vehicles continuously to improve its market-leading maps and local directory products:*** Robotic vehicles may be able inexpensively to traverse a variety of roads to collect precision location data, Street View data, and business data. Google would then be able to provide the most up-to-date data to consumers of its web-based informational and advertising products.

- ***Google perfecting and then licensing its proprietary vehicle operation software to vehicle OEMs:*** Google may decide to license or sell software and/or a package of hardware/software to traditional vehicle manufacturers, similar to its Android and Chrome OS programs that provide software to electronic equipment OEMs. Advantages include Google gathering a large amount of mapping and other data, along with the ability to "close the loop" between online ads and offline purchase behavior. For example, Google may benefit from being able to show an advertising agency that a consumer who viewed an online ad for Nordstrom, for instance, later that day drove to a Nordstrom retail location.

- ***Google producing vehicles to sell to consumers:*** Various Google executives have expressed a desire to solve traffic congestion, fatality, and natural resource problems by reducing driver error and increasing vehicle efficiency. By replacing fallible human operators with computers and sensors, Google may believe that it can reduce or eliminate collisions, injuries, and deaths associated with human driver error. Also, Google may believe that computerized drivers are more likely to choose efficient routes and minimize fuel consumption. Google may see these as public goods, but ones that it can most effectively deliver by producing a fully integrated hardware/software vehicle.

- ***Google producing a fleet of for-hire vehicles:*** Google has also discussed the potential to replace inefficient taxis (which spend time and waste fuel looking for customers) with fleets of self-driving taxis that operate on demand. According to media reports, Google has been in discussions with automotive suppliers Continental and Magna International about assembling a "Model G" self-driving car or taxi.

While each of these commercial options (or others) may become potentially interesting businesses over time, Google may also find other projects that it is even more interested in pursuing and discontinue autonomous vehicle research at any time. We therefore remain excited about the potential for Google to reinvent transportation, but hesitate to quantify the opportunity at such an early stage.

How Does the Auto Industry View Google?

Ravi Shanker

The traditional auto industry views Google's efforts with a mix of suspicion and enthusiasm. On the one hand, having a company like Google and its track record of innovation enter the auto world could be a shot in the arm for one of the most mature and cyclical industries in the world. OEMs might also be eager to partner with Google and potentially use its experience with the autonomous car systems. On the other hand, if Google chooses to make its own way in the industry or partner with an "outsider" like Tesla, the entrenched OEMs could be facing a formidable new competitor.

The traditional auto industry is watching Google very closely. The high level of interest is driven by a number of factors: 1) Google's early lead with its autonomous vehicle initiative, which probably forced a number of automakers to follow suit; 2) interest in what exactly Google's plans are, and whether Google can disrupt the automobile OEM space, much as Tesla has done with electric vehicles; and 3) the hope of partnering with Google to use its expertise, experience, and especially its map database, Street View.

Make no mistake. The traditional auto industry is by no means dismissing Google's autonomous vehicle efforts as misguided or doomed and is instead tracking them as a real competitor, even if there is some skepticism as to whether Google will ever actually become an OEM.

Can Google ever make its own car? It may not be as crazy as it sounds. Google is pursuing the development of its autonomous driving system with enthusiasm and determination. While the perceived social benefits may be helping the project down its path, we believe the auto industry firmly believes that "the greater good" is not Google's only end-game here. One of the possible outcomes of this endeavor could be Google entering the auto business by making its own cars. As surprising as that might sound, we have spoken with top executives at auto OEMs who do not dismiss the idea out of hand.

While we have seen no evidence that Google intends to become an automobile OEM, there are a few factors that may make it easier for it to do so:

1. The growing importance of software that we discussed earlier would mean that if Google were to use its own proprietary autonomous driving and operating system for the car, it would control a significantly larger part of the value of the car in the future than just a software-based approach today.
2. As we discussed earlier, the actual hardware of the car could become more of a cost-driven assembly business that can be outsourced. Google need not build a single car plant but instead could have its cars built by third-party assemblers (similar to the Model G taxi mentioned on the previous page), or it could enter into partnerships with certain OEMs with excess capacity and design abilities (of which there are at least a few Europe today).
3. The Tesla factor. Google and Tesla appear to have a very close working relationship, given their common Silicon Valley roots, and already have a connection on the mapping/infotainment side. Tesla CEO Elon Musk has spoken of his intention to have "autopilot" functionality on future Teslas and has engaged in discussions with Google over the idea. It may not be farfetched to expect Google and Tesla to team up on car design and manufacturing.

Still, even though it is easier and more logical than ever for a company like Google to enter the car-making business, we do not think this is likely to be a near/medium term project.

It's like Android…for cars. We believe the auto industry may be more accepting of a near-term solution that sees Google license its autonomous driving system for other carmakers to use. Similar to Android for smartphones, we envision Google issuing guidance for the autonomous-capable hardware and design necessary for the OEMs to incorporate into their cars before the Google driving system is plug-and-played in. Similar to Android, this system could potentially be free for automakers to use, though it is unlikely to be open source given the security concerns.

In return for its system, the OEM may give Google exclusive access to the data into and from its cars. This is a sensitive area today and most OEMs control the data that is generated by the cars they manufacture, even if it is a supplier's component that generates it. However, in return for not having to spend billions of dollars and many years on autonomous vehicle development (especially if an OEM is already behind its peers in this area), the OEM could potentially give Google data exclusivity with the car. As we have discussed earlier, this is likely to move in two directions: 1) into the car, where Google may control / supply the content that is consumed by the occupants during travel, or 2) out of the car, where Google is anonymously given data about driving patterns and characteristics for its own use. This dual stream of data could open a third revenue front for Google, in addition to PCs and smartphones.

This is still entirely theoretical, of course. The last thing that a company of the size, caliber, and profitability of Google may want to do is to enter the traditional auto industry—an industry still challenged by extreme cyclicality, global overcapacity, fragmentation, and questionable pricing power. But that does not mean that Google cannot bring in an entirely new approach, especially as the automobile undergoes one of its most fundamental transformations in its history. As long as Google's fleet of self-driving Priuses keeps plying the highways of California, the traditional auto industry is going to be on its toes waiting to either welcome Google as a partner or face it as a competitor.

Not All Maps Lead to Google: Alternative Mapping Providers

Andrew Humphrey

Besides Google, there are just two other global companies that have proprietary mapping database: Tom Tom/Tele Atlas and Nokia/Navteq. These companies could be Tier 2 suppliers of their mapping databases to the Tier 1 suppliers of automotive in-vehicle software. TomTom, for example, has said it believes it will be a question of when, not if, autonomous cars will be commercialized. Management says that its focus is likely to be on software, content, and services rather than hardware because supplying hardware to the automotive industry is not a part of its strategy going forward.

Autonomous cars will need a very high level of accuracy in their mapping and positioning systems—far more than exists with GPS today. This also includes crowdsourcing of traffic and real-time data for route management as well as an extensive point-of-interest database. In addition to mapping, navigation, we observe that accurate positioning and handling real-time data are also part of TomTom's core competencies. TomTom has said it believes that it can extend into integration with the car's sensors to achieve an even greater level of position accuracy, though it does not intend to reach up into the Tier-1 level of full integration with the vehicle mechanics.

Autonomous Freight Vehicles: They're Heeeeere!

William Greene

The Morgan Stanley Freight team believes that autonomous and semi-autonomous driving technology will be adopted far faster in the cargo markets than in passenger markets. Long-haul freight delivery is one of the most obvious and compelling areas for the application of autonomous and semi-autonomous driving technology.

We conservatively estimate the potential savings to the freight transportation industry at $168 bn annually. The savings are expected to come from labor ($70 bn), fuel efficiency ($35 bn), productivity ($27 bn) and accident savings ($36 bn), before including any estimates from non-truck freight modes like air and rail.

Collateral implications include competitive advantage to large, well capitalized fleets and improved customer service.

While the focus of this Blue Paper is primarily on passenger vehicles, the Morgan Stanley Freight team believes that autonomous and semi-autonomous driving technology will be adopted far faster in the cargo markets than in passenger markets. Humans are far more comfortable with autonomous technology operating vehicles in circumstances when human life is not at risk. When a risk to human life is introduced into the equation, the bar on safety rises exponentially, while freight losses are rightfully viewed as costly, but acceptable, if within reason. This helps explain why autonomous driving technology has already been applied and is in operation in select non-passenger environments, such as dump trucks in Australia mines, military truck convoys in war zones, drone military aircraft, and automated warehousing operations.

We understand the excitement about the idea that everyone will have their own autonomous chauffeur some day, but we believe that freight companies are far more likely to embrace, refine, and apply autonomous technology in ways that will lead the passenger market. Where freight and passenger traffic interact, safety hurdles will remain high. This could limit the speed with which autonomous driving technology can be applied to Class 8 trucks on US interstate highways, for example. We would argue that broad and complete adoption of self-driving freight trucks cannot occur if passenger vehicles remain manually driven. But, there is scope for semi-autonomous technology and, outside the mixed use environment, we would expect cargo companies to move as fast as regulators allow the technology to be adopted.

Long-haul freight delivery is one of the most obvious and compelling areas for the application of autonomous and semi-autonomous driving technology. As our colleagues discuss elsewhere in this report, local and urban driving environments are particularly challenging for software engineers due to the difficulties of predicting the unpredictable behavior of human drivers (who occasionally choose to violate basic traffic rules like running a red light on the way to the emergency room). The US interstate highway system, on the other hand, generally has fewer unpredictable outcomes.

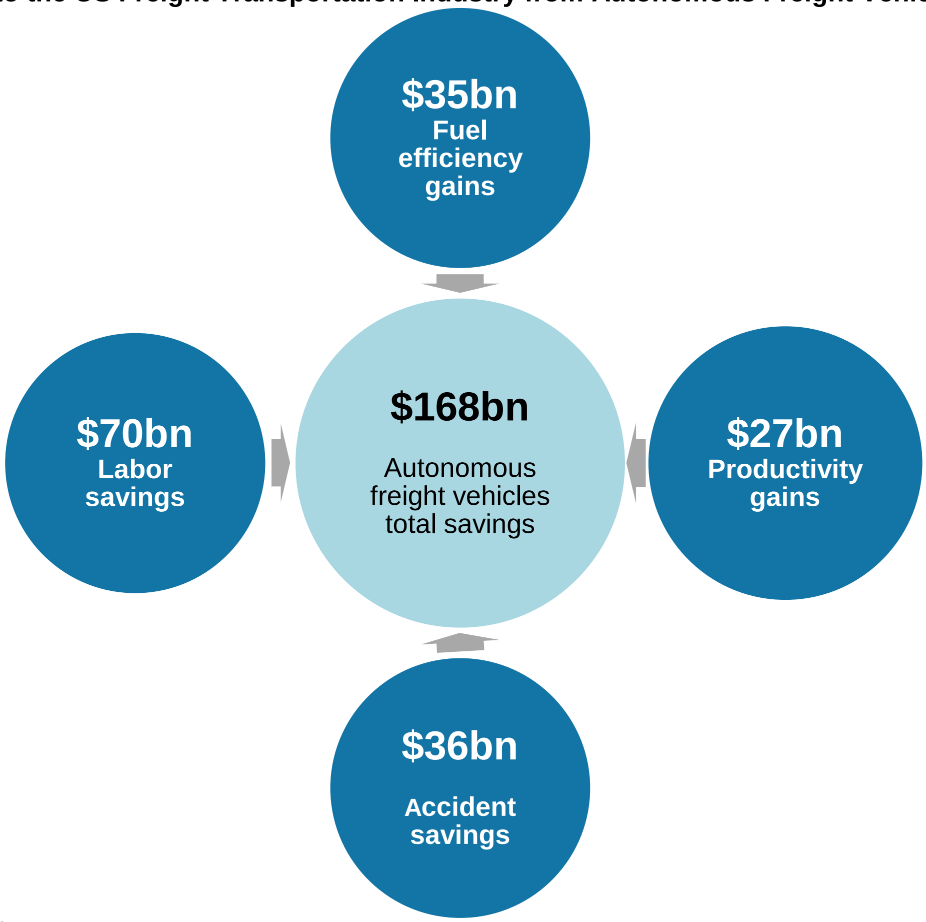
We believe that in such an environment we could see the introduction of semi-autonomous rigs and, potentially, broad adoption of the technology within 15 years. By using technology that exists today, truck operators could "tether" rigs together and move in convoy fashion over long distances. Initially, these convoys would involve a lead human driver (or driving team) followed in close formation by any number of trailing rigs, which are self-driven to follow the lead truck and are tethered through the technology (we call this semi-autonomous as it still requires a human lead manual driver team). The convoy works well in the monotonous environment of long-haul US interstate driving and eliminates much of the infrastructure needs addressed earlier in this report as the convoy's self-driving communication would be self-contained. Upon exiting the highway or entry into a congested urban interstate area, human drivers would likely need to be reintroduced, but the savings in labor, fuel, and safety costs from this semi-autonomous technology would be significant for truck operators.

Assessing the potential savings (conservatively, $168 billion annually)

The discussion below is intended to be mainly a thought exercise, rather than a definitive analysis of all the savings and investments required to implement autonomous driving technology to the freight markets. The savings we estimate are likely incomplete and reflect the utopian scenario in which autonomous driving technology is fully embraced and implemented in the trucking environment, and does not consider savings if the technology were applied to air or rail. Interim steps that involve semi-autonomous driving can also have significant, albeit smaller, savings than the utopian scenario.

Exhibit 71

Potential Savings to the US Freight Transportation Industry from Autonomous Freight Vehicles



Source: Morgan Stanley Research

Labor savings ($70 billion)—not as simple as eliminating the driver. Passenger vehicles transport the driver as passenger to his destination. Freight vehicles, however, require a driver to move the freight, but carriers view the driver as a cost, one that must eventually be returned to home base. As a result, most investors may believe that the concept of autonomous freight vehicles is a certain way to reduce or eliminate labor costs, which are the largest cost bucket for any freight carrier. However, based on our discussions with industry veterans and technology experts, we don't believe that the labor component is fully eliminated. While the number of drivers required in an autonomous driving environment would be drastically reduced, labor will not be entirely eliminated from carrier operations. There will still be a need for programmers, route planners, maintenance experts, fleet managers and, in most cases, some human oversight of the freight shipments. In the early years of the technology, these additional labor costs may run high. Moreover, the cost to introduce autonomous or semi-autonomous driving technology will be exceedingly high (some estimates put the cost at $200,000 per truck above the initial purchase price).

The real savings for carriers will come from fleet productivity. The savings generated by shifting to 24 hours per day, 7 days per week schedule for costly freight assets is compelling. Gone are the concerns about new hours of service rules (which mandate rest periods for drivers). Carriers will no longer need to plan routes that eventually return a truck (and the driver) home. Given that the US long-haul trucking industry faces driver turn-over rates that often exceed 100% annually, there are also significant savings to be found from reducing recruitment costs.

Given all of the above, labor savings are tricky to estimate. Moreover, it is unclear whether labor unions would have enough political clout to block or delay the introduction of autonomous truck technology in some jurisdictions. Over time, we do not believe unions will be able to prevent adoption of this technology, but it is certainly possible that they could delay it. For our purposes, we assume labor and regulatory issues are not impediments to adoption of the technology. According to the American Trucking Association (ATA), the US has approximately 3.5 million professional truck drivers. We estimate that the average truck driver earns roughly $40,000 in annual compensation and benefits, implying a total industry driver labor cost of ~$140 billion.

Unlike our colleagues' estimates for the utopian vision where no one drives, we do expect that some "driver" role will still be required even if all vehicles were driverless. There are many reasons some monitoring role for a "driver" won't be fully eliminated. Consider just a few of the issues. First, what happens if the vehicle breaks down (flat tire, engine issue, etc.)? If the vehicle is 100 miles from the nearest maintenance facility, that's still a long way to bring a maintenance engineer. A solution is to have a "driver" monitor the road convoy and, if there are issues with any of the vehicles, he is there to address on the spot and call for support if needed.

Another issue to consider is security. Some trucks haul extremely valuable inventory (e.g., a trailer full of iPads). If entrepreneurial thieves determined which trailers contain valuable inventory, they could arrange to hijack the vehicle and abscond with the inventory before any security could arrive. For this reason, we believe that a residual driver pool will remain, which means scheduling and recruiting challenges will not be fully eliminated.

Mundane items like bathroom breaks, rest periods, meals and deadheading will all still be required even if vehicles are fully automated. Moreover, some form of slip-seating scheduling would need to be introduced. Slip-seating scheduling has drivers share trucks so that the truck asset can realize improved operating utilization. Most truck drivers today strongly prefer to use only one truck ("their" truck) for driving.

Exhibit 72
An Autonomous Truck

Source: New Energy and Industrial Development Organization of Japan

strongly prefer to use only one truck ("their" truck) for driving.
Under an automated driving regime, technician drivers would need to share the operating vehicle with other drivers (again, much like pilots share planes). In any case, our best guess is that a fully automated driving regime could result in a two-thirds reduction in the current driver pool. This would imply that the trucking industry could still save ~$93 billion in annual driver costs, but there are other offsets to consider.

For example, the "driver" may need to be proficient in the technology, which could require a higher education level as well as technical certifications (much like a pilot). These certifications would restrict entry into the profession and would certainly result in higher wages for the remaining pool of driving technicians. In addition, it is entirely possible that this higher level of training eventually lead to some form of unionization. The current long-haul driver pool is not thoroughly unionized, given the large number of owner-operators and the high turnover of drivers. Unionization of technician drivers could significantly increase the average cost per employee. In fact, the carriers may look at allowing unions to play some role in the new environment as an acceptable cost for unions' agreement not to use political and legal maneuvers to delay and fight the technology's implementation. Lastly, there may be other highly paid professional positions (programmers, route planners, etc), that are required to manage these new high-tech autonomous fleets.

Given all of the offsets, we simplistically assume that in a full-adoption scenario, average "driver" wages increase by 50% to $60,000, implying an annual labor cost of $70 billion, resulting in still impressive 50% reduction in total driver labor costs.

Fuel efficiency gains could be large ($35 billion).
According to the ATA, there are more than 26 million trucks of all classes in the US truck fleet. Of this, approximately 2.4 million are Class 8 or tractor trailer trucks. The ATA estimated that the US truck fleet drove ~400 billion miles in 2011 (15,380 miles per unit). Class 8 trucks are estimated to drive ~100 billion miles annually (41,666 miles per unit). The ATA estimates that the US trucking industry consumed 52.3 billion gallons of diesel fuel in 2011 and spent ~$143 billion on fuel that year. Although these trucks are a variety of sizes and perform various roles in the freight economy, the implied fuel economy of the US truck fleet is ~7 gallons per mile. We should note that ton-mile per gallon is actually a better way to measure freight fuel economy, due to the concept of trip avoidance when using larger vehicles, but to remain consistent with the passenger vehicle section, we used miles per gallon.

We believe that autonomous or semi-autonomous driving technology can vastly improve the fuel economy of the US truck fleet. Like passenger vehicles, autonomous freight vehicles would operate primarily on “cruise control” mode, which under current technology can improve vehicle efficiency significantly. Moreover, freight vehicles could move in “convoy” format. By running large vehicles in close formation (tailgating), a carrier could effectively create a “train” of rigs on the highway, which results in a slipstream of lower air resistance, thereby improving fuel efficiency. Recent tests of driverless trucks in convoy format in Japan saw fuel efficiency gains in the 15-20% range, which would imply $21-28 billion in annual fuel cost savings in today’s dollars. The US Department of Energy estimates that “road-train” convoys, as are common in Australia, can improve ton-mile fuel efficiency by over 35%. For our purposes, we assume a 25% improvement in efficiency ($35B in annual savings), which is far lower than what our colleagues believe is possible in the passenger vehicle market, but we should note that our estimate fails to capture fuel savings from short-haul truck moves such as parcel delivery, local pick-up and delivery vehicles, and many other shorter moves. As such, the fuel savings in freight could me substantially larger.

Productivity gains come in many forms (savings difficult to estimate but should be $27 billion at a minimum). The productivity gains from the adoption of autonomous driving technology could be great, but are also difficult to estimate. According to a study by Texas A&M University, congestion cost the US trucking industry $27 billion in 2011. Presumably, this cost would be virtually eliminated by the broad adoption of autonomous vehicles.

But, there are other aspects to consider. Long-haul trucks could literally operate 24/7, though the nature of freight movements means that there will likely still be significant downtime for trucks. As noted above, the ATA estimates that the US Class 8 (long-haul) truck fleet logged ~100 billion miles in 2011, or 41,666 miles per truck. Assuming that the trucks operated ~250 days per year, this implies 166 miles per day per truck. This average clearly understates the productivity of dedicated long-haul trucks that can log well over 100,000 miles/year, though it may overstate the mileage driven by Class 8 trucks in local pick-up and delivery operations. The average also captures time when trucks are waiting to pick up or drop off freight, sitting on a congested highway, refueling, in a shop for maintenance, etc. Although autonomous technology may help alleviate some highway congestion once full adopted, refueling, time spent waiting on a customer and maintenance time are clearly unavoidable. For this reason, most industry experts on autonomous technology estimate that autonomous trucks would increase capacity by ~30%. If congestion is alleviated by the shift to autonomous vehicles, the capacity increase could be greater, but as a start, we agree with the estimate.

Even so, a 30% increase in truck productivity would be very significant. According to A.C.T., in 2012, US Class 8 truck sales were roughly 194,000 and the average price of a new rig ~$123,000. This implies that the industry spent ~$23 billion in capital on new trucks. In addition, the industry purchases ~237,000 trailers/year at ~$20,000 each, or $4.5 billion in total spend. A 30% increase in truck productivity implies that the industry would need far fewer trucks to haul the same freight, but this is too simplistic. Increasing trucking operations means each truck drives more miles each year, i.e., more wear and tear. Truck age is more a function of mileage than the passage of time and at ~500,000 miles most long-haul trucks are reaching maximum “age.” So, autonomous driving technology would certainly improve asset turns, but it would mean that the useful life of a truck would fall when measured in years.

Additionally, the cost of the trucks will be materially higher. Some technology experts estimate that the cost of a installing the technology in a truck would add $200,000 to the cost (in addition to the ~$123,000 cost for a manually driven truck). While these estimates are surely to fall over time as the technology becomes more commercial, this is still a significant investment for any carrier. Even if the cost per autonomous truck drops by one-third as the technology is commercialized, the implied cost to replace 70% of the current fleet (i.e., assuming a 30% productivity gain) would still be ~$336 billion (70% of 2.4 million trucks at $223,000 per unit). Obviously, the transition to a wholly autonomous truck fleet would take ~7-10 years AFTER the technology is tested, approved and commercialized. But, given the labor, fuel and productivity savings, the pay back from such a significant investment would still be impressive.

And, that leads to an interesting ancillary conclusion worth mentioning. According to the ATA, there are over 500,000 trucking companies in the US, over 80% of which have fewer than 20 trucks. Clearly, for these small truckers, a capital expenditure three times as high as a new Class 8 truck (and many small carriers buy used trucks at substantial discounts) is just prohibitive. We believe that this would give the large, well-capitalized carriers are significant opportunity to create a major barrier to entry in their business (for the first time in the history of the industry). A large carrier that transitioned quickly to an autonomous fleet would generate significant labor, fuel, safety, and maintenance savings as well as huge gains in fleet productivity. This cost advantage would allow the carrier to enjoy outsized and sustained market share gains. Moreover, managing the technology and a very large fleet of trucks would take professional management and a commitment and investment in IT, which would likely play into the strengths of the larger, well-capitalized truckers, such as Knight Transportation, Swift Transportation and Werner Enterprises, just to name a few examples. In other words, automated driving technology could theoretically turn the current long-haul truckload business into more of a networked model, resulting in significant scale advantages and barriers to entry.

Large transport companies like UPS and FedEx have long eschewed the long-haul truckload market given the difficult industry competitive dynamics. Autonomous technology would be a significant savings for them as well, given their very large fleet of trucks and package delivery cars. This could lead to a new business line for them as well (long-haul trucking).

Lastly, it's worth considering whether autonomous driving technology would improve customer service. We believe that autonomous driving, if adopted en masse, would lead to far less road congestion relative to today. Thus, it follows that truck carriers would improve on-time pick-up and delivery performance, which could lead share shift back to truck from other modes.

Accident savings ($36 billion). In 2010, the US DOT reported that 3,675 people were killed in large truck crashes, capping a long period of improving truck safety statistics. In March, 2007 the Federal Motor Carrier Safety Administration published a study which estimated that the average cost of reported crashes involving large trucks (gross weight exceeding 10,000 pounds) at $91,112 (in 2005 dollars—the latest date we found) and a total cost of ~$40 billion. The cost per fatal truck crash was estimated at ~$3.6 million per incident. According to the authors, the costs indicated above represented "the present value, computed at a 4 percent discount rate, of all costs over the victims' expected life span that result from a crash. They include medically related costs, emergency services costs, property damage costs, lost productivity, and the monetized value of the pain, suffering, and quality of life that the family loses because of a death or injury. The cost estimates exclude mental health care costs for crash victims, roadside furniture repair costs, cargo delays, earnings lost by family and friends caring for the injured, and the value of schoolwork lost."

Similar to passenger vehicles, most truck crashes involve some element of human error. Using a similar estimate as our passenger vehicle colleagues, namely that 90% of accidents are due to human error, autonomous truck (and car) technology could save ~$36 billion annually (when we reach full adoption).

What about other modes? Autonomous technology has already been applied in rail and air environments. One example of a driverless train is New York City's JFK AirTrain, which are fully automated and operate without a conductor. In aviation, military drones have been widely publicized. Given the heavy regulatory overlay in rail and air, government regulators will play a major role as a gatekeeper to autonomous driving technology and the speed with which it can be adopted. If the other modes fail to adopt the technology, but trucking does, it seems certain that the other modes would, over time, cede market share back to truck. As such, we fully expect that some close loop networks can quickly adopt the technology if regulators allow. The potential opportunities and savings from driverless trains and pilot-less planes are similarly large to carriers in those industries, but estimating the savings goes beyond the scope of this Blue Paper.

Media: More TV Time Means More Revenue Potential

Benjamin Swinburne
Ryan Fiftal

Autonomous vehicles have the potential to materially increase total media consumption: By freeing up ~75 billion hours of drive-time or 6-7 hours per week per licensed driver, we estimate total media consumption could materially increase, generating over $5 bn of new media revenue.

We expect video to take disproportionate share of liberated drive-time, while radio and recorded music may lose a key captive audience: We expect TV to be the largest beneficiary on a total dollar basis and Home Video to benefit the most on a % basis. As likely relative time share losers, roughly 10-15% of radio and recorded music revenues could be at risk.

Unclear impact to outdoor advertising: While the newly liberated driver may have more capacity to view outdoor advertising, outdoor ads will need to compete with more immersive media (e.g. TV) for the driver's attention. This fragmentation is likely to pressure ad rates. Outdoor platforms will have opportunities to leverage location-based technology to better deliver advertising to passengers, but will be competing with more options than before.

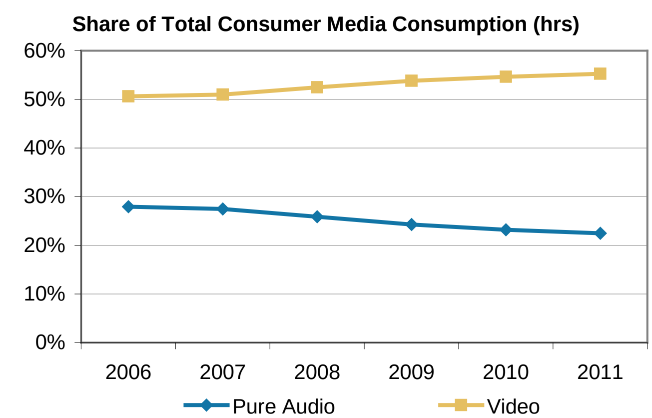
With Robust Media Delivery Enabled by the Connected Car, the Autonomous Car Could Materially Increase Total Media Consumption

As stated earlier, we estimate that fully autonomous vehicles could free up ~75 billion hours of time currently spent by drivers each year, equating to roughly 6-7 hours per week per licensed driver. Putting this into context, Veronis Suhler Stevenson (VSS) estimates the average American consumes ~65 hours of total consumer media per week, indicating a substantial increase to total media consumption is possible. Based on our analysis, *we estimate autonomous vehicles could in total generate over $5 bn of new media industry revenue,* with TV the largest beneficiary in total dollars, Home Video the largest beneficiary by % of market growth and Radio / Recorded Music losing share.

TV and Home Video Most Likely Beneficiaries; Radio / Recorded Music Hours Most At Risk

Over the last few years, we have seen a general shift in media consumption (measured by time spent) away from pure audio services and toward video-based media (TV, Home Video, Video Games). We believe the proliferation of video-capable devices and increases in bandwidth delivered to the home, most notably to smartphones and tablets but increasingly connected TVs and game consoles, have caused the shift by significantly expanding the opportunity to consume video. Autonomous cars could further expand the video use-case, and *we expect video-based media to disproportionately win share of hours freed from driving.* Therefore, while television currently accounts for roughly 50% of total media hours consumed (according to VSS), we believe it could take a higher share of hours liberated by autonomous vehicles. Assuming (1) ~25% of former drive-time is spent on non-consumer-media activities (e.g. work) and (2) TV wins ~60% of the remaining hours, this could increase total TV consumption by 6-7%, potentially increasing TV ad revenue by ~$2B (assuming 6-7% more viewing drives 3-4% greater ad revenue at the industry level). Similarly, Home Video accounts for ~1.5% of total media time spent (VSS), though again we would expect disproportionate share. If 3% of drive time is redirected to movie consumption, we estimate the total number of home video units consumed could increase by 15-20%, potentially expanding the home video market by $1.5-2B depending on distribution platform.

Exhibit 73
Autonomous Vehicles Would Likely Continue the Shift of Media Consumption toward Video



Source: Veronis Suhler Stevenson. Video includes TV, Home Video, and Video Games. Pure Audio includes Radio and Recorded Music

However, some of this video consumption will come at the expense of audio-based media—most notably radio, secondarily recoded music—which will lose a "captive audience" of drivers. Assuming that roughly 75% of current drive-time is spent listening to audio today, we estimate that roughly 25% of total Radio and Recorded Music listening time could be at risk of transitioning to other media. In our Autonomous Vehicle scenario, we assume that while pure audio media accounts for 20-25% of total media consumption hours today (VSS), audio services would win only 15-20% of liberated drive-time, reducing total Radio and Recorded Music hours of consumption by ~20%, potentially reducing the radio advertising market by ~10% or $1-2B and recorded music sales by ~$1B.

Advertising Most Likely Form of Monetization, Though New Subscription Services Are Possible

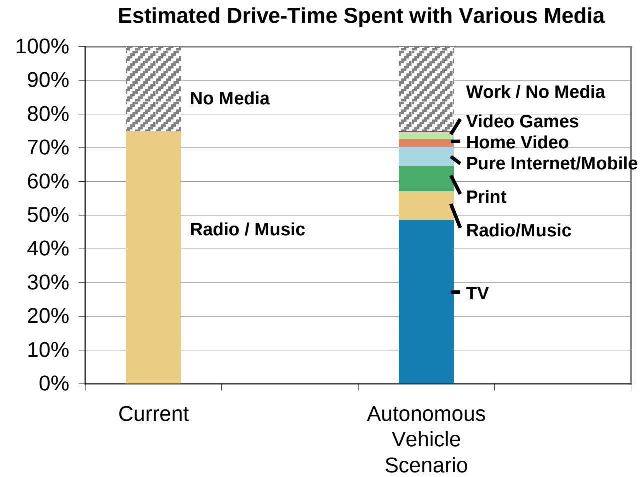
Given that the Pay TV subscription bundle is already moving toward an any device, anywhere model (with no additional direct fees to the consumer), there is risk that increased TV consumption in the car will not directly increase subscription revenues (though increased TV consumption in theory should increase customer willingness to pay and support pricing power). Therefore, we expect increased advertising to be the primary method of monetizing increased media consumption, though other direct or transactional fees (e.g. pay per view movies, book and magazine sales) should also increase.

Unclear impact to Outdoor Advertising

The autonomous car's potential impact on Outdoor Advertising is somewhat less clear. On one hand, the newly liberated driver could have increased capacity to view outdoor advertising. However, similar to radio, Outdoor may lose a key captive audience—if the driver is immersed in video content, he or she is less likely to view outdoor advertising. There will be opportunities to innovate in the Outdoor industry, leveraging location-based technologies to deliver more targeted advertising to passengers. However, fragmentation of audience and attention will increase, which tends to put downward pressure on ad pricing.

Exhibit 74

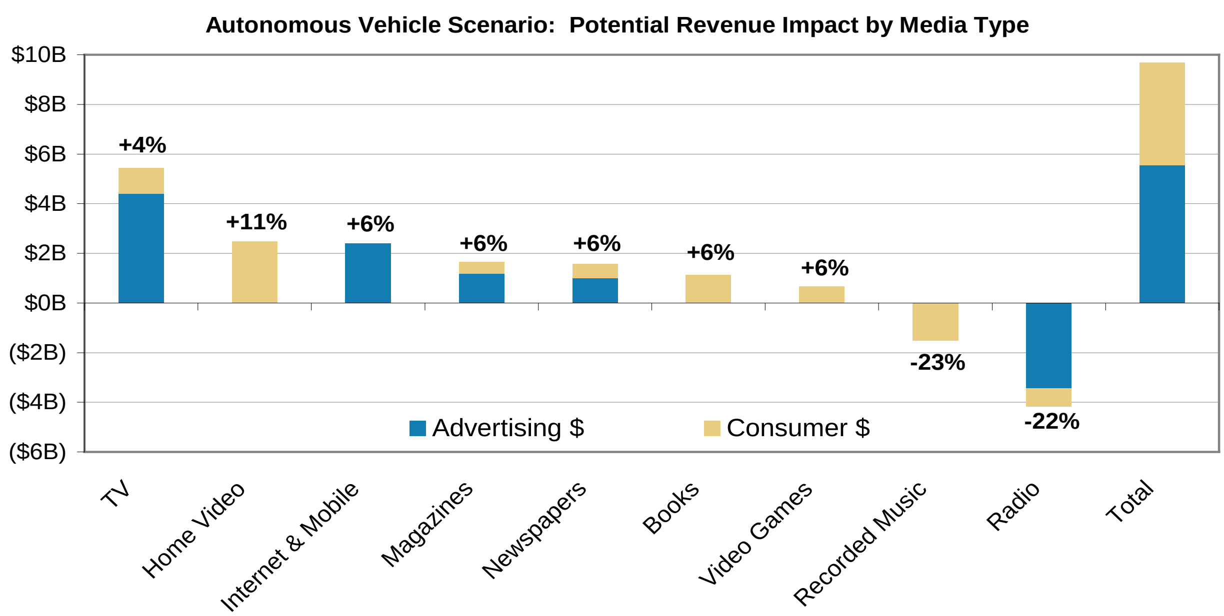
We Expect Video-based Media to Win Disproportionate Share of Freed Drive Time, at the Expense of Radio and Recorded Music



Source: Morgan Stanley Research Estimates, based in part on Veronis Suhler Stevenson market size and consumer media consumption data

Exhibit 75

The autonomous car could create $10B in new media revenue and shift share from audio to video media



Source: Morgan Stanley Research Estimates, based in part on Veronis Suhler Stevenson market size and consumer media consumption data

Semiconductors: Driving Innovation in Automobiles

Joe Moore
Craig Hettenbach

Key Takeaways

- Automotive is currently the fastest growing market for semiconductors, with a CAGR of 17% over the last three years
- Emerging technologies such as telematics, vision enhancement, lane control, and advanced driver assist should drive further semiconductor content on the way to fully autonomous vehicles
- Compute, video processing, and analog/microcontrollers are key growth segments.
- Intel, Nvidia, Ambarella, NXP Semiconductor, and Linear Technology appear best-positioned

Many of the companies in our coverage stand to benefit from the increased semiconductor content that autonomous cars one day will require, but a few stand out as best-positioned, in our view. In the compute area, we highlight Intel and Nvidia; in video processing, Ambarella; and in the analog/ microcontroller space, NXP Semiconductor and Linear Technology.

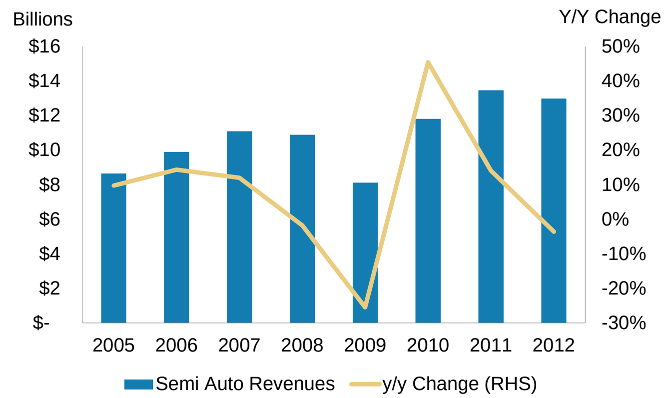
Growing Market, both in Terms of Units…

Before we discuss semiconductor potential in autonomous vehicles, we feel it is important to understand the proliferation of semiconductors already happening in the automotive segment. Today, the automotive semiconductor market is driven by growth in both the number of vehicles, and semiconductor content per vehicle. As more and more vehicles are sold, particularly in emerging nations, the demand for semiconductors from these nations increases as well, albeit at a reduced pace compared to those in developed nations.

In fact, the automotive market is the fastest growing end market for semiconductors, with a CAGR of ~17% over the last three years (2009-12). More than 70% of that comes from the growth in semi content per vehicle (three-year CAGR of 12.3%).

Exhibit 76

Semiconductor Auto Revenues on the Rise, Driven by Units…



Source: SIA Data, IHS, Morgan Stanley Research

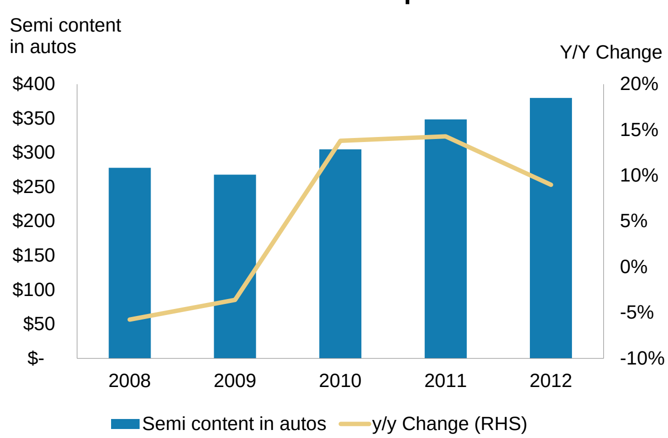
..as Well as Content per Unit

Given the intensity of technology adoption in new vehicles, semi content per vehicle has increased from under $300 in 2007 to close to $380 in 2012. We expect this secular trend to continue as consumers take advantage of new features enabled by advances in semiconductor devices (sensors, display, compute, connectivity, etc.).

Emerging applications such as telematics, vision enhancement, lane-control, advanced driver assist systems, etc. are likely drive the market, closing the gap with a fully functional autonomous vehicle down the road.

Exhibit 77

….and Semiconductor Content per Vehicle



Source: PwC, Morgan Stanley Research

Automotive Requirements Are Much More Stringent

Unlike the requirements for consumer and industrial markets, automotive requirements are much more stringent with much wider operating range- i.e., -40 to 160 deg. C and 0 to 100% humidity compared to -10 to 70 deg. C and ambient for industrial applications. Requirements for consumer are even less demanding. In addition, given the long life cycle of the products, products for the automotive sector require long operation times and failure rates close to 0%.

The Autonomous Vehicle Is Not Just a Concept Anymore

As the rest of this Blue Paper has shown, the self-driving car is no longer just a concept, and is rapidly moving closer to reality as the industry embraces more and more features into the vehicle related to safety, infotainment, and traffic management. Active safety systems include airbags, curtain restraint systems; braking, steering, and lane departure warning systems; electronic stability control; park assist; and tire pressure monitoring. The infotainment category includes audio, video, navigation, and other information from the myriad of sensors brought into the dashboard console, which are increasingly moving toward capacitive touch. In terms of traffic management, most connectivity and onboard telematics solutions are nascent and should evolve as the infrastructure develops. In addition, new technologies in the drive train, such as in hybrid and electric cars, are driving increased demand for semiconductors.

Exhibit 3 lists key feature enhancements in automobiles and the potential timeline for mainstream adoption. Note that the path to autonomous vehicles is transformational and will take more than five years to be realized.

Semiconductors Instrumental to Autonomous Evolution

Although a fully autonomous car could be years away, we expect to see the industry increasingly embrace functions that assist the driver. As autonomous vehicles evolve, we expect to see an increase in the amount and frequency of data collected, transmitted, processed, and stored. These activities directly or indirectly benefit companies in the compute, networking and communications, and data storage segments. Communicating data between vehicles (V2V) and the cloud (V2I) requires a combination of technologies including cellular baseband and WiFi, with standards continuing to evolve. We could see new wireless inter-vehicle communication standards, e.g., IEEE 802.11p, be widely adopted by automakers.

A cloud-based system with sensors in automobiles and a supporting roadside infrastructure would demand high bandwidth to collect and transmit data from the myriad of sensors present in the vehicle. In addition to the sensors within the vehicles (temperature, optical, navigation, proximity, etc.), we expect to see a rise in environmental sensors such as LIDAR, infrared cameras, and other video capturing device.

Semiconductor companies exposed to the network and communications infrastructure include Intel, Qualcomm, Broadcom, Cavium Networks, Inphi Corp, and LSI Corp. Those in our coverage in the compute infrastructure include Intel, Advanced Micro Devices, Nvidia, and Cavium. SanDisk and Micron Technology also could potentially benefit from the growing need for storage, particularly in solid-state drives (SSDs) where low latency is very important.

Exhibit 78

Features and Expected Timeline for Mainstream Adoption

Benefit	<2 years	2 to 5 years	5 to 10 years	>10 years
Transformational			- Autonomous Vehicles - Embedded Hypervisor - Natural-Language Q&A	
High	- CMOS Image Sensors - ESP/ESC - LED Lighting	- Gesture Control - High Brightness LED - Supercapacitors - Silicon Anode Batteries	- 802.11p - Automobile IP nodes - ISO 26262 - System Proptotyping	- Electric Vehicles - In-Vehicle Ethernet - Wireless EV Charging
Moderate	- Automotive Radar - Electric Power Steering - Video EDR	- Adaptive Cruise Control - Biometric Driver ID - Haptics - OLED Displays - Speech Recognition - Wireless Power	- Eye Tracking - Gaze Control - Head-Up Displays - ICE Start/Stop System - Lane Departure Warning - Night Vision Enhancement	- EV Charging Infrastructure - Smart Fabrics - Virtual Prototypes

Note: Lane departure warning is available in some premium models today. Source: Gartner, Morgan Stanley Research

Video processor maker Ambarella is a likely beneficiary as the demand for video capture, processing, and compression rises. At present, cameras powered by Ambarella's chips are installed in cars to record driving footage. Ambarella's latest processors are capable of delivering Super HD (and Full HD images at high frame rates (30 and 60fps, respectively). Insurance companies have promoted the use of these cameras as it helps them arbitrate cases in a transparent way, potentially bringing down the cost to them. In some cases, insurance companies offer incentives such as lower premiums to encourage customers to install the cameras. This practice is currently prevalent in markets with high accident rates, such as Russia and China, but not in the US.

As the automotive needs evolve, we expect AMBA's single chip solution to be compelling when it comes to processing multiple video streams from surround cameras, but also from other devices such as RADAR and LIDAR.

On the compute front, we also highlight Intel and Nvidia as potential beneficiaries of the increasing use of on-board analytics. Given the amount of redundant effort among automakers and the challenges associated with long product cycles, it makes sense, hypothetically, for a third party such as Intel or Nvidia to develop these solutions.

Intel currently is active in developing in-car technology for in-vehicle infotainment, targeting solutions that mimic user experience similar to what we see in smartphones and tablets. Its approach is to develop standard components/building blocks for elements such as CPUs, storage, displays, operating systems, and software to accelerate the development process and facilitate future upgrades. Intel is collaborating with automakers such as Nissan, Kia, Toyota, and a few others to develop the next generation infotainment systems. Nvidia's Tegra processor powers the infotainment system of the Tesla Model S sedan. The company has already garnered over $2bn in design wins (7 makers, 34 models) in the auto segment and expects to generate $450mm in revenues by FY16.

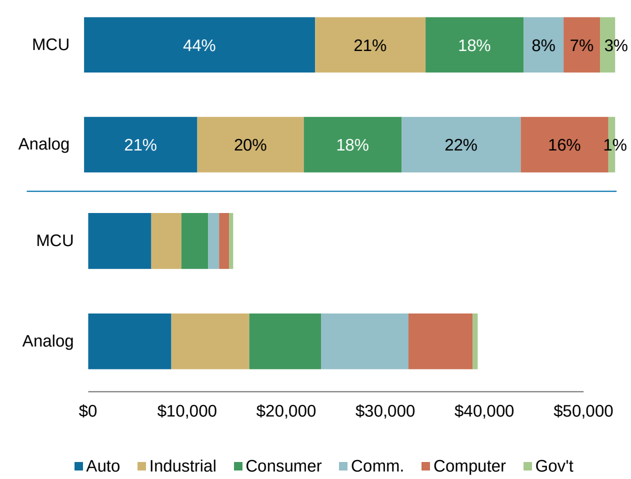
Programmable logic device (PLD) companies Xilinx and Altera also supply field programmable gate arrays (FPGAs) and PLDs for a variety of automotive applications. These include driver assistance systems (front, rear, and surround cameras), infotainment, real-time analytics (object detection, lane departure warning, etc.), and battery monitoring systems. Some of the key benefits of using PLDs over ASICs and ASSPs are that they can help lower overall development costs, bring down time to market, and leverage a single-chip solution. The rise in data gathering invariably demands storage, both local and cloud, a trend to which the memory companies Micron Technology and SanDisk are exposed.

Microcontrollers and Analog Exposure to Automotive

According to data from the Semiconductor Industry Association (SIA), the automotive exposure of microcontroller units (MCUs) is 44% of overall MCU sales, more than twice the 21% exposure of the analog industry. We expect MCUs to continue to be strong in autos because of increased demand and the rise in 32-bit MCUs.

Exhibit 79

Analog, MCU Revenues and End Market Exposures

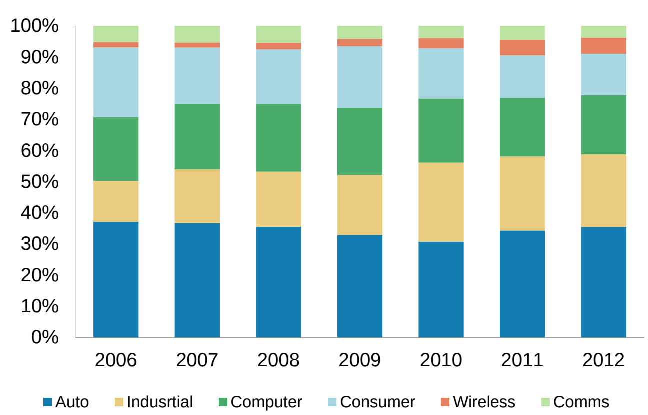


Source: SIA End User Survey, Morgan Stanley Research

Exhibit 80

Autos Is the Largest Market for MCUs

% of MCU Revenue



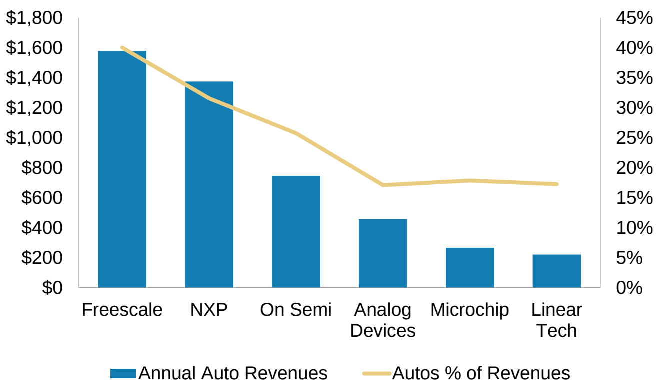
Source: Gartner, Morgan Stanley Research

Freescale, NXP Semiconductor, ON Semiconductor, Analog Devices, Microchip Technology, and Linear Technology are some of the companies in our coverage with substantial exposure to the automotive market.

Of those, we highlight Linear Tech and NXP Semiconductor as particularly well-positioned to benefit from the increasing semi content in vehicles .

Exhibit 81

Automotive Market Exposure by Company



Source: Company Data, Morgan Stanley Research

Exhibit 82

LLTC and NXPI's leading products

Company	Leading Products
Linear Tech	Battery management systems Navigation and safety systems Hybrid/electric vehicle systems Electric Steering and braking
NXP	In vehicle networking Car Access Lighting & entertainment Transmission / throttle control

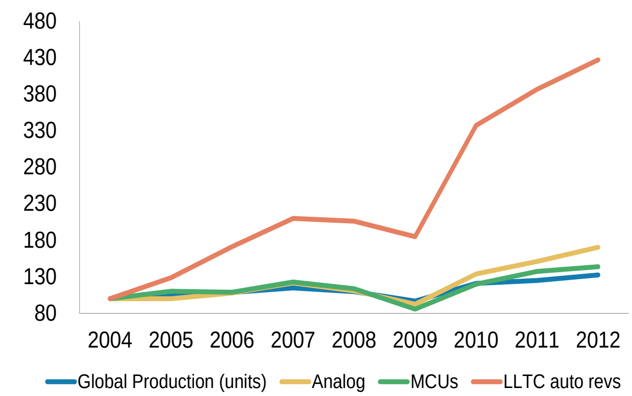
Source: Company Data, Morgan Stanley Research

Linear is seeing the strongest growth in autos among its peers, outgrowing production by a factor of 5x and analog industry auto revenues by 2x since 2007. The company has grown its automotive business at a five-year CAGR of 15% and eight-year CAGR of 20%, compared to automotive production of 3% and 4%, analog industry auto sales of 7% and 7%, and MCU industry auto sales of 3% and 5%.

Exhibit 83

LLTC: Substantially Higher Growth in Autos Relative to the Broader Analog Market

Indexed Autos Growth



Source: Company Data, Morgan Stanley Research

Over the last seven years, Linear intensified its efforts in autos. This has paid off handsomely to date, as the company was early to identify the increasing proliferation of electronics in autos and had the technology and technical sales personnel in place to meet the trend. Linear's strong portfolio of products, led by its battery management systems, has helped the company develop entrenched relationships with OEMs worldwide. Given the stringent qualifications set upon automotive component suppliers and Linear's growing position in this market, we are confident in the company's ability to maintain its lead.

NXP Semiconductors is a market leader in in-vehicle networking, passive keyless entry, and radio and audio amplifiers, and has an emerging business in telematics and solid-state lighting drivers. NXP's automotive revenue has grown at a CAGR of 15% over the last four years, nearly 2x the pace of analog auto revenue growth. NXP is benefitting from key auto trends such as increased energy efficiency (as mandated by government regulations), connectedness (entertainment and traffic management), and security (theft and hacking prevention).

We expect the company to continue to gain share in the analog auto space, as it increases penetration in its core market and as its emerging businesses, such as LED lighting and telematics, begin to ramp. Interestingly, the company recently gave a thumbs up to self-driven cars by making a strategic investment in autonomous car start-up Cohda, which specializes in inter-vehicle networking.

Software: From Design Today to Integrating Sensors Tomorrow

Adam Wood
Keith Weiss

The move toward autonomous cars present three opportunities for software vendors:

- OEM design
- Standardization of software content within autos
- Management and analysis of large data sets generated by increasing sensor count in cars

Software has emerged as a key competitive dynamic as hardware manufacturers seek to differentiate their offerings. We see evidence of this trend in many verticals including automotive today. The move towards autonomous cars would likely compound this effect.

We see three principal areas of opportunity for software vendors around the autonomous car trend: 1) near-term, automotive firms are dealing with the increasing complexity of adding software functionality to their design processes. Longer-term we see opportunities around firms 2) standardizing today's largely custom-built automotive software environment on packaged platforms or application sets, and 3) leveraging the large amounts of data likely to be generated by increasing sensor counts in vehicles.

Dealing with Software Complexity

Software today has already become very important to automobile manufacturers, even without considering the potential from autonomous vehicles. The increasing amounts of software embedded in products add huge complexity for manufacturers. Even before we discuss the challenges of the autonomous car, we see this increasing software mix providing a large opportunity for certain software companies. Indeed, at companies such as BMW and Jaguar Land Rover half the engineers are already dedicated to software and systems, and the rest to traditional mechanical design. The challenge for manufacturers today is that most of this software is custom-developed and manually installed. We see a significant opportunity for software companies to help automate and standardize the software development processes already in place at automakers. Clearly, this opportunity would likely expand significantly as the industry moves towards autonomous cars.

What is being done today? Traditional design software companies like Dassault Systèmes and PTC are already moving into the automotive software development market. Their design software has traditionally been used to design the mechanical parts of cars and the body-in-white. These vendors have also developed and acquired technologies to help OEM customers develop and test software and systems along with the mechanical design. Their products aid manufacturers with specifications, software and systems architecture, and the connections between the electronics software and control systems and the mechanical parts.

For example, Dassault Systèmes offers CATIA Systems, which covers system architecture and engineering. The technology is partly internally developed and partly a combination with the AUTOSAR embedded software tool developed by recently acquired Geensoft. AUTOSAR is already a standard in the German automotive industry. DS has seen its penetration of leading automotive OEMs increase +50% due to the CATIA Systems offering, which DS acknowledges probably covers only half of the functionality required by OEMs today. This leaves a significant market opportunity still to come for the company.

PTC also has a software and systems offering that, post its acquisition of MKS, includes the Integrity software development (ALM - application life cycle management) suite, now branded as PTC Integrity. PTC also highlights the already significant software complexity in many products and the risk of failure that software bugs can bring in what were purely mechanical products 15-20 years ago. The company also believes that compliance will be an increasingly significant driver in the space and should benefit from greater regulatory focus.

So what opportunity does the autonomous vehicle offer? As we consider the autonomous car we're looking at a moving set of goal posts as the software component in cars should increase materially from current levels.

How do they succeed? We believe that among the design software companies, DS and PTC stand to benefit most if is the OEMs and OE suppliers that try to develop the technology for autonomous cars and end up dominating the market. Of course, it is highly likely that the OEMs and their suppliers will try to build the systems needed for autonomous cars and so the technology providers like DS and PTC likely face a period during which these products grow quickly irrespective, of the end outcome of the battle for control of the autonomous car.

We also believe operating system integration will be a significant challenge. Technology providers such as DS, which already have experience in the much more automated aerospace industry, may have an advantage in helping auto OEMs design these systems.

Standardizing and Connecting a Custom Software World

The move from custom development toward the use of more packaged infrastructure and application components may represent an expanding opportunity for packaged software vendors.

This is a playbook we've seen in many markets before: As requirements and standards quickly evolve, firms requiring new software functionality remain largely focused on custom development in the short to mid-term (as you are seeing today within the car industry). As the market matures, 1) vendors are less able to drive differentiation from larger parts of their software functionality, 2) the costs of maintaining custom code rises, and 3) the need for interoperability with other functionalities and platforms drives software increasingly toward standards. For instance, today most vendors are developing their own in-dash infotainment systems Over time, we would not be surprised to see use of a standard platform underpinning these systems (analogous to mobile phone operating systems like Android).

Within our software coverage group, several vendors might benefit from this standardization trend. Microsoft and Oracle both offer platforms for embedding software functionality in non-general purpose compute devices—Windows CE Platform from Microsoft and the Java ME platform from Oracle. As we've seen with the Sync initiative, where Microsoft built out a broader infotainment platform now used in many Ford, Fiat, Nissan, and Kia models, vertical market functionality can be achieved. In addition, the open source Linux operating system underpins a large proportion of custom software work today.

In the medium term, we may see automotive firms look to a supported or security hardened Linux distribution like that offered by Red Hat. A recent collaboration between Red Hat and Meteorcomm shows what that type of standardization may look like, as the two vendors deployed a Interoperable Positive Train Control communication systems for the railroad industry based on Red Hat's Linux and messaging technologies.

These changes might be seen as a challenge to the providers of tools that support a more custom-developed approach. In response to that, we make two points: 1) It is very unlikely in our view that any one vendor will be able to dominate all the electronics, software, and systems in a car. So even if we move from totally custom to partly modular there will still be a need to integrate the different modules with each other and with the mechanical parts. 2) The software vendors that help support system architecture and engineering may choose between continuing to provide software to support modules or whether they could have a role providing the module itself—whether standalone or in partnership with others.

Big Data and the Autonomous Car

With a significant increase in on-board computing power and the number of sensors collecting data, cars will generate an even greater volume of data over time. This data is likely to be utilized in a more connected way than it is today—data collected and analyzed in real-time rather than at service intervals.

In the near term, product lifecycle management (PLM) software vendors like DS and PTC are already thinking about how this data could be used for more proactive servicing of vehicles. A part that has failed on a number of cars could be identified much earlier and then replaced. The idea of PLM is that the design teams could also learn from the experience of cars "in the wild" and incorporate live data on performance into the design of new vehicles. Analysis of the data sets could also be used to predict potential failures and order preventive maintenance.

We could also see this approach open up new business models for the manufacturers. Recently we have seen John Deere add sensors to its tractors and use analytics (SAP HANA) on the data these sensors collect in order to help predict when problems will occur and to add a services / maintenance business model to their existing manufacturing model. We could imagine a similar opportunity in automotive.

Longer-term, we see big data analysis used to lessen congestion of the roads, help drivers avoid hazardous conditions, and more effectively find roadside amenities, amongst other use cases. The beneficiaries within software would be companies involved in providing the technology to store, analyze, and use that data — particularly in real-time. In the case of store and analyze, we believe Splunk, Tibco, Oracle, SAP, Teradata, HP, EMC, PTC (not covered by Morgan Stanley), and Dassault Systèmes (Exalead) appear well-positioned. They have the capabilities to either ingest and analyze data in real time or work with massive quantities of data.

Car Rental: Potentially Polarizing Impact

Adam Jonas

- Autonomous cars could have significant, polarizing impact on rental car companies, but a highly connected car could be a sweet spot

The implications for autonomous driving on the car rental industry are likely very significant (if not transformational). That said, the direction of the outcome could potentially be very positive or negative. We can think of highly polarized scenarios ranging from a world in which self-driving vehicles increase the benefits of private ownership and usage, cannibalizing the need to rent vehicles, to one in which a roving parc of public transportation vehicles is controlled by firms with fleet management and customer service expertise.

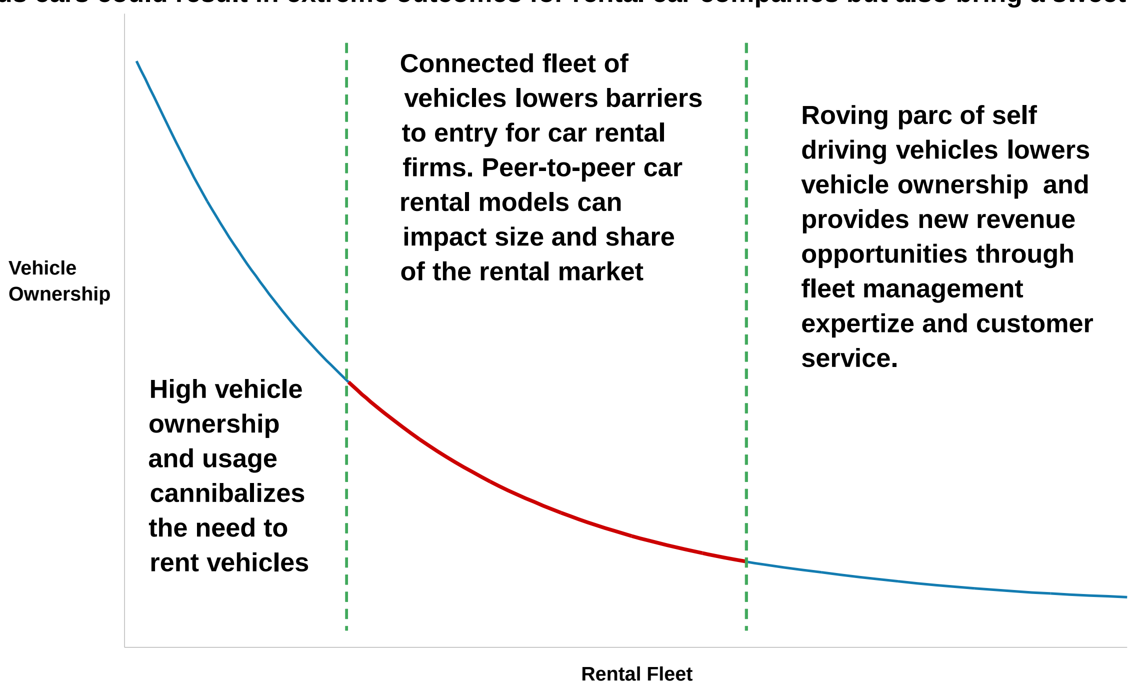
A further outcome could be lowered barriers to entry for car rental firms as all vehicles become connected devices, representing constantly mobile capacity, potentially disrupting such traditional strengths as the location of their available fleet at key spots, such as airports. Peer-to-peer car rental models could conceivably become even easier to implement, impacting both the size and share division of the car rental pie.

While we are convinced autonomous driving provides a powerful encouragement for car usage and miles driven (by reducing many of the hazards and inconveniences of human-controlled driving), there is far greater uncertainty over its potential effect on private car ownership. *See Part 1 for more detail on the impact on car ownership.*

Car rental companies have a history of adapting the latest technology to improve the convenience of the rental experience. Currently, the industry is making the shift to connected cars and kiosks in various forms. Avis Budget's purchase of Zipcar offers new avenues for expanding the hourly rental experience in convenient locations. Hertz's 24-7 program is aimed ultimately at turning 100% of its car rental fleet into a vehicle that can be reserved on line and rented by the hour, with minimal or no human interface. Precisely how the car rental industry's efforts to adapt new technology dovetails with the broader powerful shift in the 250m vehicles on US roads and more than 1 billion globally is less clear.

Exhibit 84

Autonomous cars could result in extreme outcomes for rental car companies but also bring a sweet spot



Source: Morgan Stanley Research

The Healthcare Angle: Impact on Medical Costs

Andrew Schenker
Cornelia Miller

Key Takeaways

- We believe autonomous vehicles would have a limited impact on hospital volumes and revenues. However, the social costs related to injuries and accidents go beyond just the medical costs.
- Motor Vehicle Accidents (MVA) account for $23 bn in hospital spending, which translates to ~1.5% of all total hospital care and physician services costs.
- Only 8% of car accidents result in an in-patient admission.
- Private insurance covers 55% of motor vehicle accidents, while 25% of accident victims do not have insurance.
- Among all MVA-related visits, the most common procedures include sutures of the skin and subcutaneous tissue, splints and wound care, and CT head scans.
- Health insurance policies typically pay medical claims after auto policy medical payments have been exhausted.

The direct impact to hospitals and insurers is quite small but the social costs are much larger. Motor vehicle accidents remain a major cause of injury-related hospitalizations and emergency department visits. Specifically motor vehicle-related accidents represent ~3% of all ED visits and 12.5% of injury-related ED visits in the US. However, the related healthcare costs still represent a small portion of health care spend in this country. Therefore, the economic impact to the industry would be limited as a result of the increased safety related to autonomous vehicles. In addition, for the full safety benefits to be realized, all vehicles would need to be autonomous.

The expenses associated with MVA-related injuries is nearly $24 bn by our estimates. Our analysis excludes the lost productivity related to the accidents. This compares with over $2.5 trillion in national health expenditures and $1.5 tn in hospital and physician related spending per year. By our estimates, car accidents account for approximately 0.9% and 1.6% of all national health expenditures and total hospital and related services costs, respectively. In addition, the CDC estimates the cost of lost work and productivity at $114 bn per year.

Exhibit 85

Motor Vehicle Accidents Represent Less than 2% of Medical Spend

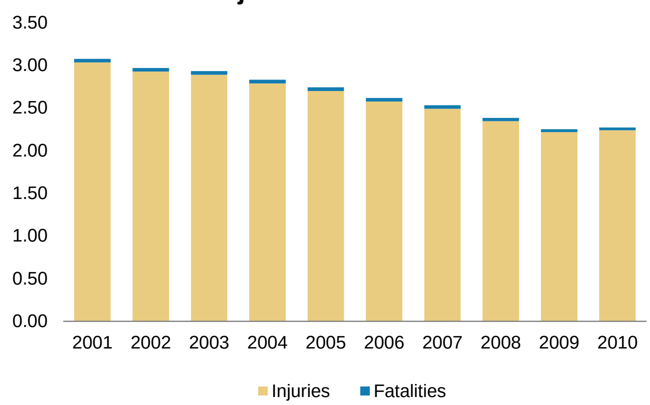
	Spend ($B)	Medical Costs % of Spend
Fatal injuries	$0.7	3.0%
Nonfatal hospitalized injuries	$17.4	73.3%
Nonfatal Ed-treated and released injuries	$5.6	23.8%
Total Medical Costs	$23.7	100.0%
Hospital Care	$814.0	2.9%
Professional Services	$688.6	3.4%
Total Hospitalizations & Services	$1,502.6	1.6%
National Health Expenditures	$2,593.6	0.9%

Source: CDC; CMS; Traffic Injury Prevention, 11:353–360, 2010; Morgan Stanley Research

Motor vehicle crashes lead to almost 2.3M annual injuries and fatalities resulting in medical care, with injuries accounting for the vast majority (~98%). Of those injured or killed in a motor vehicle accident approximately 4% were motorcyclists and another 6% were non-occupants, either pedestrians or cyclists. Not surprisingly, nearly 30% of fatalities include a motorcyclist or non-occupant. The data does not indicate who caused the accident.

Exhibit 86

Injuries Account for the Majority of All Motor Vehicle Related Injuries and Fatalities



Source: Federal Highway Administration, Census, US Department of Transportation

Only 8% of motor vehicle accidents result in an inpatient admission. Roughly 85% of individuals that are treated in an emergency room for an injury related to a motor vehicle accident are treated and released. Notably, only 8% are admitted to the hospital, which results in higher healthcare costs. Another 1.2% are transferred to another acute care hospital, and 5.8% go to another location for care such as a rehabilitation center.

Exhibit 87

Only 8% of MVA-Related Visits Result in In-patient

	MVA-Related ED Visits		
	# of Visits	%	Rate per 1,000
Discharge Status			
Treat-and-release	2,963,759	84.7%	9.9
Admitted for care	281,060	8.0%	0.9
Transferred to another acute care hospital	40,363	1.2%	0.1
Died in the ED	8,002	0.2%	0.0
Other	204,223	5.87%	0.7

Source: AHRQ, Center for Delivery, Organizations, and Markets, Healthcare and Utilization Project, Nationwide Emergency Department Sample (NEDS), 2006

Among those admitted to an emergency department as a result of a motor vehicle accident, the most common injuries include sprains, contusions, superficial injuries, open wounds, intracranial injuries, and neck and limb fractures. Approximately 20% MVA-related ED visits resulted in some kind of procedure. The most common procedures associated with these types of injuries are sutures of skin and subcutaneous tissues, splints and wound care, CT head scans, and routine X-rays.

Exhibit 88

Top Procedures Related to Auto Injuries

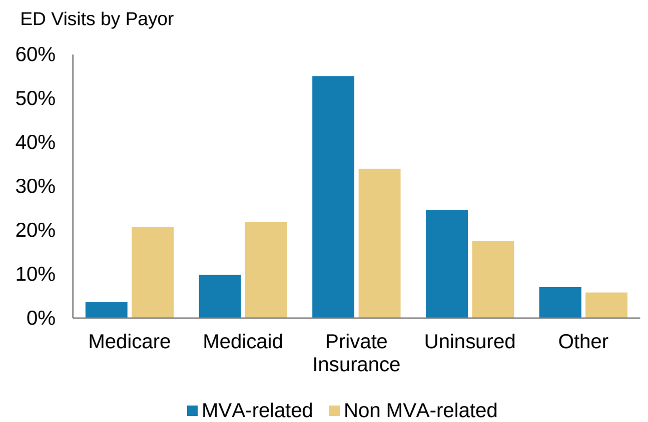
Top 10 Procedures in All MVA-related ED visits, 2006	# of visits with each procedure	% of All MVA-Related ED Visits
Other diagnostic procedures (consultation)	181,977	5.2%
Suture of skin and subcutaneous tissue	148,845	4.3%
Other diagnostic radiology and related techniques	131,092	3.7%
Traction; splints; other wound care	114,334	3.3%
Other therapeutic procedures	92,663	2.6%
Computerized axial tomography (CT) scan of head	51,781	1.5%
Treatment of fracture or dislocation of lower extremity	45,436	1.3%
Prophylactic vaccinations and inoculations	45,342	1.3%
Respiratory intubation and mechanical ventilation	39,880	1.1%
Routine chest X-ray	38,925	1.1%

Source: AHRQ, Center for Delivery, Organizations, and Markets, Healthcare and Utilization Project, Nationwide Emergency Department Sample (NEDS), 2006

Private insurance covers the majority (~55%) of motor vehicle accidents. However, ~25% of MVA-related visits are made by individuals without insurance and Medicaid covers approximately 10% of MVA ED visits. This compares with non-MVA related visits whereby only 34% of visits are covered by private insurance, 22% of visits are covered by Medicaid, 21% are covered by Medicare, and 18% are not covered by any insurance.

Exhibit 89

Private Insurance Covers 55% of All MVA-related ED Visits



Source: AHRQ, Center for Delivery, Organizations, and Markets, Healthcare and Utilization Project, Nationwide Emergency Department Sample (NEDS), 2006

Auto insurance typically pays before health insurance. Auto insurance companies generally make the first payments for medical care related to motor vehicle accidents. Auto policies most likely include personal injury protection (PIP), which will cover many of the same services as medical payments. Drivers can also add medical payments coverage to their auto policy. Most car insurance plans will not cover car accidents unless the driver has supplemental health insurance. Health insurance typically pays for medical claims after the auto policy's limit has been exhausted.

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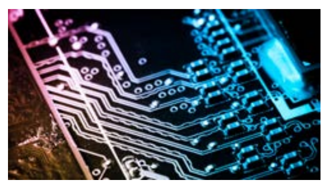

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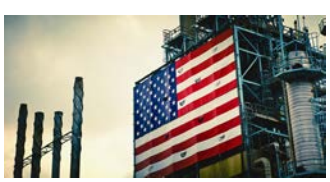

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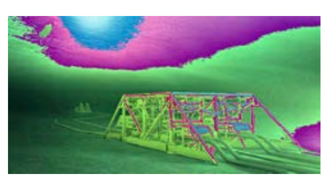

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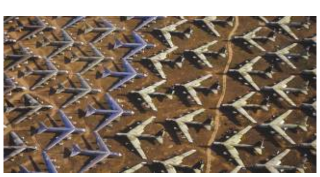

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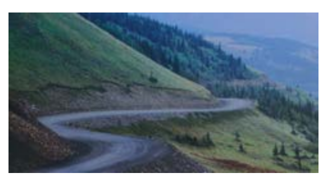

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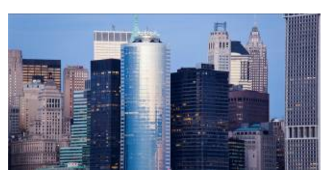

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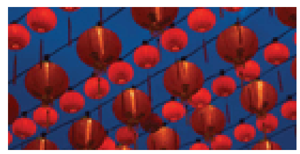

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(as of October 31, 2013)

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	Coverage Universe		Investment Banking Clients (IBC)		
Stock Rating Category	Count	% of Total	Count	% of Total IBC	% of Rating Category
Overweight/Buy	**988**	**34%**	**400**	**37%**	**40%**
Equal-weight/Hold	**1296**	**44%**	**496**	**46%**	**38%**
Not-Rated/Hold	**109**	**4%**	**28**	**3%**	**26%**
Underweight/Sell	**541**	**18%**	**152**	**14%**	**28%**
Total	**2,934**		**1076**		

Data include common stock and ADRs currently assigned ratings. An investor's decision to buy or sell a stock should depend on individual circumstances (such as the investor's existing holdings) and other considerations. Investment Banking Clients are companies from whom Morgan Stanley received investment banking compensation in the last 12 months.

Analyst Stock Ratings

Overweight (O). The stock's total return is expected to exceed the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis, over the next 12-18 months.
Equal-weight (E). The stock's total return is expected to be in line with the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis, over the next 12-18 months.
Not-Rated (NR). Currently the analyst does not have adequate conviction about the stock's total return relative to the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis, over the next 12-18 months.
Underweight (U). The stock's total return is expected to be below the average total return of the analyst's industry (or industry team's) coverage universe, on a risk-adjusted basis, over the next 12-18 months.
Unless otherwise specified, the time frame for price targets included in Morgan Stanley Research is 12 to 18 months.

Analyst Industry Views

Attractive (A): The analyst expects the performance of his or her industry coverage universe over the next 12-18 months to be attractive vs. the relevant broad market benchmark, as indicated below.
In-Line (I): The analyst expects the performance of his or her industry coverage universe over the next 12-18 months to be in line with the relevant broad market benchmark, as indicated below.
Cautious (C): The analyst views the performance of his or her industry coverage universe over the next 12-18 months with caution vs. the relevant broad market benchmark, as indicated below.
Benchmarks for each region are as follows: North America - S&P 500; Latin America - relevant MSCI country index or MSCI Latin America Index; Europe - MSCI Europe; Japan - TOPIX; Asia - relevant MSCI country index.
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Ticker	Company Name	Close Price (as of 11/5/2013
ABFS.O	Arkansas Best Corporation	USD28.04
ALL.N	Allstate Corporation	USD36.79
AMBA.O	Ambarella Inc	USD20.58
AMT.N	American Tower Corp.	USD78.6
AOL.N	AOL Inc.	USD38.54
AAPL.O	Apple, Inc.	USD525.449
T.N	AT&T, Inc.	USD22.83
CAR.O	Avis Budget Group Inc	USD31.06
BMWG.DE	BMW	EUR81.2
BRKa.N	Berkshire Hathaway Inc.	USD172,980.00
CSCO.O	Cisco Systems Inc.	USD23.07
CNW.N	Con-Way Inc.	USD41.32
CONG.DE	Continental	EUR136.05
CCI.N	Crown Castle Corp.	USD76.14
DAIGn.DE	Daimler	EUR5.67
DAST.PA	Dassault Systemes SA	EUR86.39
DLPH.N	Delphi Automotive PLC	USD55.01
6902.T	Denso	JPY4755
EMC.N	EMC Corp.	USD23.55
FDX.N	FedEx Corporation	USD136.23
FIA.MI	Fiat SpA	EUR5.71
F.N	Ford Motor Company	USD17.09
GM.N	General Motors Company	USD37.09
GOOG.O	Google	USD1021.52
HPQ.N	Hewlett-Packard	USD25.47
HTLD.O	Heartland Express Inc.	INR55.75
HTZ.N	Hertz Global Holdings Inc	USD21.3
IBM.N	IBM	USD177.85
INTC.O	Intel Corporation	USD24.03
KNX.N	Knight Transportation Inc.	USD32.28
LLTC.O	Linear Technology Corp.	USD40.94

Ticker	Company Name	Close Price (as of 11/5/2013
7201.T	Nissan Motor	JPY885
NVDA.O	NVIDIA Corp.	USD14.8
NXPI.O	NXP Semiconductor NV	USD42.44
ODFL.O	Old Dominion Freight Line Inc	USD47.68
ORCL.N	Oracle Corporation	USD24.86
PGR.N	Progressive Corp	USD26.24
PEUP.PA	PSA Peugeot-Citroen	EUR10.08
PMTC.O	PTC Inc.	USD27.92
RHT.N	Red Hat, Inc.	USD42.93
RRTS.N	Roadrunner Transportation Systems Inc	USD25.6
SAIA.O	Saia, Inc.	USD32.46
SAPG.DE	SAP AG	EUR57.6
SBAC.O	SBA Communications	USD90.96
ST.N	Sensata Technologies Holding NV	USD37.47
SPLK.O	Splunk Inc	USD63.98
S.N	Sprint Nextel Corporation	USD7.19
SWFT.N	Swift Transportation	USD21.88
TAMO.NS	Tata Motors	INR395.3
TDC.N	Teradata	USD42.63
TSLA.O	Tesla Motors Inc.	USD176.81
TIBX.O	TIBCO Software Inc.	USD24.01
TMUS.N	T-Mobile US, Inc.	USD28.12
TOM2.AS	TomTom NV	EUR5.749
7203.T	Toyota Motor	JPY6350
TRW.N	TRW Automotive Holdings Corp.	USD75.07
UPS.N	United Parcel Service	USD100.3
VZ.N	Verizon Communications	USD50.1
VOWG_p.DE	Volkswagen	EUR190.9
VOLVb.ST	Volvo	SEK82.05
WERN.O	Werner Enterprises	USD23.3
ZURN.VX	Zurich Insurance	CHF249.29