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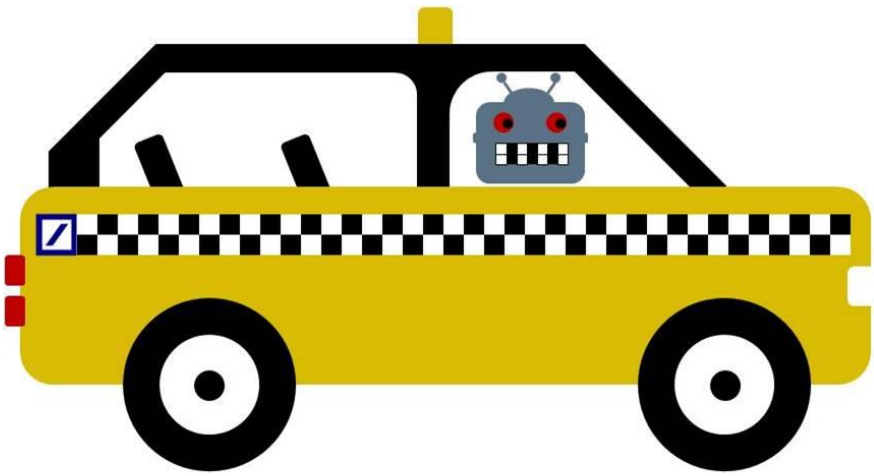
Industry

Pricing the Car of Tomorrow, Part II

Date
28 March 2016

Global

Consumer
Autos & Auto Parts



Rod Lache
Research Analyst
(+1) 212 250-5551
rod.lache@db.com

Tim Rokossa
Research Analyst
(+49) 69 910-31998
tim.rokossa@db.com

Kurt Sanger, CFA
Research Analyst
(+81) 3 5156-6692
kurt.sanger@db.com

Hiroshi Kuriu
Research Analyst
(+81) 3 5156-6703
hiroshi.kuriu@db.com

Ross Seymore
Research Analyst
(+1) 415 617-3268
ross.seymore@db.com

Johannes Schaller
Research Analyst
(+49) 69 910-31731
johannes.schaller@db.com

Robert Sanders
Research Analyst
(+44) 20 754-58394
rob.sanders@db.com

Kirill Babikov
Research Associate
(+1) 212 250-3738
kirill.babikov@db.com

Patrick Nolan, CFA
Associate Analyst
(+1) 212 250-5267
patrick.nolan@db.com

Mike Levin, CFA
Research Associate
(+1) 212 250-5317
michael.levin@db.com

Christoph Laskawi
Research Analyst
(+49) 69 910-31924
christoph.laskawi@db.com

Matt Diamond, CFA
Research Associate
(+1) 415 617-3345
matt.diamond@db.com

F.I.T.T. for investors

Autonomous Vehicles, Vehicle Ownership, and Transportation

Analyzing the impact of Autonomous Driving and On-Demand Mobility

Nearly every 5-10 year forecast for the Auto Industry today includes the word "disruptive". In this report we expand on the impact of Autonomously Driving Vehicles and On-Demand Mobility. Our work suggests that there are significant misconceptions about the impact of these trends on Vehicle Ownership and Auto Demand. We believe Auto Sales are more likely to increase than decrease, even as the population of vehicles declines. We believe that opportunities may outweigh risks for U.S. Mass Market and European Luxury Automakers. We also discuss the technological path being taken, and which Auto Suppliers and Semiconductor Companies should benefit.

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Kurt Sanger, CFA
Research Analyst
(+81) 3 5156-6692
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Research Analyst
(+81) 3 5156-6703
hiroshi.kuriu@db.com

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Research Analyst
(+1) 415 617-3268
ross.seymore@db.com

Johannes Schaller
Research Analyst
(+49) 69 910-31731
johannes.schaller@db.com

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Research Analyst
(+44) 20 754-58394
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Research Associate
(+1) 212 250-3738
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Associate Analyst
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michael.levin@db.com

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We estimate the magnitude of these potential changes

On-demand mobility services such as Uber and Lyft have tremendous potential for growth, but they will not replace private ownership everywhere. Our analysis suggests that these will be practical and financially attractive in the densest sub-sections of the top 20 MSAs (13.2MM households owning 15.5MM vehicles). Within these regions up to 61% of households may find it financially attractive to switch to On-Demand Mobility. Ultimately, we believe that network owned autonomous vehicles (e.g. operated by Uber, Lyft, Maven, Google, FordPass) may ultimately reduce the U.S. Parc by 7MM vehicles. Autonomous privately owned vehicles could further reduce the Parc by an additional 18.5MM.

The consensus view is that Auto Sales will decline, and that this will be negative for U.S. OEMs. We believe that the consensus view may be wrong.

Our analysis suggests that Autonomous Driving and On-Demand Mobility will result in more miles driven. This should lead to increased annual vehicle scrappage (life expectancy is dependent on miles driven). Annual sales will likely increase and the Auto Industry will likely become somewhat less cyclical. Moreover, we see more upside vs. downside risk for U.S. mass market OEMs. They are not profitable in the segments that are most likely to be disrupted. And they have potential to generate significant recurring earnings streams from mobility services (every 1% of NA volume shifted to this market could contribute $1.4-$1.7bn to earnings).

We see a significant market opportunity for Suppliers & Semi-co's

McKinsey recently estimated that by 2030, approximately 50% of all vehicles sold globally will have semi-autonomous driving capability and 15% will be Fully Autonomous. We believe that most of the remaining 35% will have significant active safety content (i.e. autonomous braking). Based on these forecasts, we believe that the market for Automation alone (hardware and software) could climb to $120bn sometime between 2025 and 2030. We also expect this phenomenon to increase demand for Vehicle Electrification. We believe suppliers best positioned to take advantage of this opportunity include Mobileye, Delphi, Continental, Autoliv, and Denso. Semiconductor content per vehicle could expand up to $1k (~$400 from ADAS alone) vs. $350 today, making for a 15-year Automotive semiconductor CAGR of +6% (roughly half from ADAS). Top picks in global semiconductors to play this theme include Buy-rated Infineon, Maxim Integrated, and NXP.

Companies Featured

General Motors Co (GM.N),USD31.31	Hold
Ford Motor (F.N),USD13.06	Hold
Mobileye (MBLY.N),USD34.40	Buy
Delphi Automotive (DLPH.N),USD72.37	Buy
Autoliv (ALV.N),USD114.05	Hold
Continental AG (CONG.DE),EUR193.45	Buy
Denso (6902.T),¥4,435	Buy
Infineon Technologies (IFXGn.DE),EUR12.25	Buy
Maxim Integrated Pdts (MXIM.OQ),USD35.62	Buy
NXP Semiconductors (NXPI.OQ),USD81.22	Buy

Source: Deutsche Bank

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Executive Summary

Nearly every 5-10 year forecast for the Auto Industry today includes the word "disruptive". Electrification, Automation, and Vehicle Connectivity are all key industry themes. In this report we expand on another key aspect of "Pricing the Car of Tomorrow" – The impact of Autonomously Driving Vehicles, On-Demand Mobility, Ride Sharing, and changing Consumer Preferences on vehicle ownership. There is abundant speculation regarding these trends. But we have also found that there has been relatively little data driven analysis. While we acknowledge that this is uncharted territory, and that forecasts and predictions should be viewed as having abundant room for error, we thought it worthwhile to provide a framework based on data and insights that are available today. We believe that the implications for Automakers and Suppliers may be surprising.

Key Points...

- How On-Demand Mobility and Autonomous Driving will promote new transportation paradigms. We estimate the magnitude of potential changes to the U.S. market through an analysis of the cost of private vehicle ownership in the top 20 U.S. Metropolitan Statistical Areas (MSAs) and the projected cost of operating Autonomous Vehicles.
- We illustrate why Autonomous Driving and On-Demand Mobility is likely to increase annual auto sales, and reduce the industry's cyclicality even as it shrinks the population of vehicles in operation.
- We discuss why the opportunities appear to outweigh the risks for U.S. Automakers and European premium OEMs.
- We discuss the technological path being taken for Advanced Driver Assistance Systems (ADAS) and Autonomous Vehicles, and the opportunities for Suppliers from a brand new market that we expect will reach $120bn per year.
- We detail how the advent of autonomous driving and ADAS underscores the ongoing secular increase in automotive semiconductor content.

Pricing the Car of Tomorrow II

Advancements in the computational power of semiconductors, new artificial intelligence development tools, improvements to sensor technologies, innovations in 3D road mapping, wide dissemination of GPS equipped smart phones, new tools for efficient deployment/dispatching of vehicles, changing consumer preferences, and (in many cases) government support are converging to set the stage for dramatic changes for the Auto Industry. These changes have already begun: On-demand transportation services such as Uber, Lyft, BlaBlaCar, Didi Kuaidi, Via, and Gett have taken off over the past 5 years, reaching ~$30 bn in gross revenue in 2015; largely at the expense of traditional on-demand livery services in many cities. These are still relatively small compared with consumers' preferred approach to vehicular transportation—individually owned cars and light trucks (Within the U.S. On Demand Mobility services account for <0.1% of miles driven; in Germany shared cars only account for 0.04% of the fleet). The cost of using these services as a primary means of transportation, even in dense urban areas, is still quite high compared with conventional vehicle ownership. But we believe that this is likely to change as the networks benefit from increased utilization, deploy innovative products that reduce costs, and ultimately automate the driving function (which will eliminate the cost of a human driver). Once the driver is removed from the car and utilization increases, there will be cases in which it will become significantly cheaper (and in major cities more practical and convenient) to hail an Uber, Lyft, or possibly a Google car vs. using a privately owned vehicle.

The purpose of this report is to provide our view on the magnitude of the potential changes based on our analysis of costs for individual mobility vs. on-demand mobility. We have interviewed numerous industry participants, and we have used publicly available data from Uber, Lyft, the NYC Taxi and Limousine Commission, U.S. government agencies (Census, DOT, etc), and published academic research to estimate the cost of various modes of transportation. Based on our work, we have concluded that in major cities around the world, autonomously driven vehicles and on-demand mobility has the potential to profoundly change commonly accepted norms of vehicle ownership and transportation. We have also concluded that there are significant misconceptions about the implications of these trends for Automakers and Suppliers alike. Key takeaways include the following:

- **Consumer behavior is already changing.** While more than 75% of U.S. and 80% of German consumers still see a personally owned car as their preferred transportation option, there are significant socio-demographic changes underway. Only 64% of Gen Y consumers (aged 22-34 today) view a personal car as their preferred option. The share of 16-24 year olds holding a driver's license has dropped from 76% in 2000 to 71% in 2013. Between 23% and 39% (depending on the geography) of Millennials responding to a recent APTA (American Public Transportation Association) study indicated that they wanted their primary mode of transportation to be something other than a personal car. These trends exist in other markets as well (in Germany only 65% of <25 year olds have a drivers license, down from 69% 5 years ago. Only 16% within the same age group own a car versus 31% in 2000).

- **Technology will provide consumers with options.** Mobility Service Providers are emerging to take advantage of new technologies and diseconomies of individual vehicle ownership - vehicles are expensive purchases that depreciate rapidly, yet they are only utilized 5% of the time.
- **Based on our analysis of the largest 20 U.S. Metropolitan Statistical Areas** (MSA's which account for 37% of U.S. households and 101MM (39%) out of 257MM vehicles), **we estimate that up to 4.2% of U.S. households (within these 20 MSAs) would already experience cost savings through the use of On Demand Mobility Services** such as Uber or Lyft (the average cost of operating an individually owned vehicle in the top 20 U.S. MSA's is $0.90/mile, while the average cost of uberX is ~$1.54 per mile). We expect this percentage to increase as efficiencies are gained through the application of technology (i.e. dynamic ride sharing models reduce the cost of on demand mobility services by 20%-50%).
- **The cost of On-Demand Mobility Services should decline dramatically as autonomously driving vehicles come to market.** For example we've estimated that the cost of operating an Autonomous Taxi could be around $0.52 per mile. We estimate that a fleet of these vehicles could potentially operate at a 20% ROIC for ~$0.89 per mile (vs. $0.90 per mile average cost of operating a vehicle within the top 20 MSAs, and a $0.70 average cost per mile for private vehicle ownership across the U.S.).
- **But On-Demand Mobility may not work everywhere.** Automakers, consultants, and academics studying Mobility Services all agree that population density and commuting patterns will play a key role in determining where on-demand mobility may replace private ownership and where this may not be practical. The aforementioned 20 large MSAs themselves incorporate a wide variety of urban/suburban/rural markets (e.g. the NY MSA includes Westchester; the Detroit MSA includes Flint). Based on our interviews with industry experts and our detailed analysis of the MSAs' we believe that on demand mobility is likely to be practical and financially attractive in the densest sub-sections which account for ~31% (on average) of total households in the MSAs we studied (13.2MM households, owning 15.5MM vehicles out of the total). Within these sub-segments, up to 61% of households (owning 8MM out of 15MM vehicles) may find it financially attractive to switch to on-demand autonomous vehicle mobility services (that equates to 19% of the households in the studied MSAs; these households collectively account for up to 3.2% of vehicles within the total U.S. Vehicle Parc). We would note that the financial attractiveness of this model is likely to vary significantly from city to city. Within New York City, 99% of households may find on-demand services to be more financially compelling than private vehicle ownership (Mega-cities such as NY have relatively high ownership costs due to costs for parking and relatively low utilization; the cost of ownership in NYC averages $3.10 per mile).

- **We believe that network owned autonomous vehicles (e.g. operated by Uber, Lyft, Maven, Google) may ultimately reduce the U.S. Parc by 7MM vehicles. And Autonomous Privately Owned Vehicles could further reduce the U.S. Parc by an additional 18.5MM.** A joint University of Utah and University of Texas study concluded that in an urban environment such as Austin (12x24 mile area), each shared autonomous vehicle (SAV) could replace 9 conventional vehicles while maintaining a <5 minute wait (and an average wait of 1 minute). Automakers we've spoken to estimate that the ratio may be closer to 1:6. The ratios of 1:6 and 1:9 imply that the U.S. vehicle parc may decline by 6.8-7.3MM vehicles (out of a total parc of 257MM). Separately, we believe that the impact from privately owned autonomous vehicles may be even greater, as households improve the utilization of vehicles which currently sit idle at home or at work 95% of the time. For example, a single vehicle may bring one household member to an office, train station, or school, return home for use by another household member, and then collect the first household member later in the day. If we assume that 15% of households go from 2 vehicles to 1, this could reduce the vehicle parc by an additional 18.5MM vehicles.
- **The consensus view amongst investors is that a decline in the total population of vehicles will lead to a decline in annual vehicle sales. We believe that this is wrong. Annual sales will likely increase and the Auto Industry may also become somewhat less cyclical.** Our view on the outlook is based on: 1) The average engineered life expectancy of a vehicle is primarily based on miles driven, and not calendar age (average life expectancy in the U.S. is 210,000 miles); and 2) Without any doubt, each shared vehicle will travel more miles than the cumulative sum of miles driven by the vehicles they replace, since on-demand vehicles will almost always travel without any passengers between pickups, which are called Empty Legs (Average NYC taxi travels 70,000 miles and is unoccupied 51% of those miles; 47% of the average uberX vehicle miles traveled in NYC are unoccupied; the average autonomous mobility service or privately owned vehicle will likely travel unoccupied 10%-20% of the time). If we assume 1% of vehicles in the U.S. are in on-demand mobility networks and they drive unoccupied 10%-20% of the time, this would add 10-20bps to annual scrappage and sales. If we assume 15% of U.S. vehicles are privately owned autonomous and they travel unoccupied 10%-20% of the time (thereby increasing miles traveled by 10%-20%), this would add 1.5%-3% to annual sales. Moreover, many studies suggest that miles traveled will be further augmented through increased mobility for the young and elderly (a KPMG study suggests that this will add 13% to miles traveled, with a corresponding impact on scrappage and annual auto sales).
- **We are aware of one significant factor that could conceivably help increase efficiency, and reduce aggregate miles driven: Dynamic Ride Sharing (DRS).** Lyft and Uber have indicated that 40-50% of their San Francisco business has shifted to UberPOOL and Lyft Line since they began offering this option in 2015. That said, we believe that this service is disproportionately capturing market share from livery and transportation services, rather than private vehicles. Experiences from BMW's DriveNow program also point to this. Interestingly, industry participants currently believe that DRS may decline as on-demand

transportation vehicles become Autonomous. This view is based on consumer concerns about safety/security of sharing a ride with a stranger in the absence of a driver (i.e. the human driver adds to the perception of safety).

- **The consensus view is that shared mobility will be negative for U.S. Automakers. We believe that this is incorrect.** The use of On-Demand Mobility service companies such as Uber, Lyft, or Google/Alphabet clearly has the potential to disintermediate Automakers' brands. Said another way, consumers do not care about the brand of vehicle that arrives after requesting a ride via the Uber or Lyft App. For Automakers, this significantly increases the likelihood of commoditization and low returns as they increasingly sell their products to fleet operators, which may account for 3% of annual U.S. sales by the late 2020's (McKinsey recently estimated that sales to these operators may account for up to 10% of annual sales globally). That said, we believe that this risk is mitigated by the fact that mass market OEM's such as GM, Ford, and Chrysler currently are not profitable in the segments that are most likely to be disrupted (e.g. we estimate that GM loses $4,700 per vehicle for every passenger car that they sell in North America). At the same time, the segments least likely to be disrupted (i.e. large SUV's, pickup trucks) account for more than 100% of GM's and Ford's earnings and free cash flow. The implication is that U.S. Automakers likely have more upside vs. downside as they enter shared mobility services themselves. This may become a means to fix one of the most challenged parts of their businesses, improving overall returns. More specifically, we estimate that each passenger car unit placed into an on-demand mobility network may add $53,000 to annual recurring revenue, $15,400 to annual recurring EBIT, and have a 20% ROIC. GM and Ford could conceivably improve their recurring NA profits by $1.7bn and $1.4bn, respectively, if they build up networks by directing just 1% of their output to their own mobility service units. We see this phenomenon as a positive even if the autonomous passenger vehicles wind up being sold to third parties (such as Uber or Lyft), as they will likely be accompanied with significant service and parts revenue streams (OEMs may capture an entire lifetime's worth of aftermarket parts over the course of 3 years; as of today, aftermarket parts revenue diminishes dramatically after 4 years). We also believe that the proliferation of on-demand mobility vehicles should reduce cyclicality.

- **We see the advent of Automation and On-Demand Mobility as a boon to Suppliers.** In a recent study McKinsey estimated that by 2030, approximately 50% of all vehicles sold globally will have semi-autonomous driving capability and 15% will be fully autonomous. We believe that most of the remaining 35% will have significant active safety technology (i.e. autonomous braking). Based on these forecasts, we believe that the market for Automation alone (i.e. hardware and software) could climb to $120 bn sometime between 2025 and 2030. And increased utilization of vehicles should have other knock on effects, such as improving the economics of electrification, by accelerating the payback on a technology that adds cost up front, but which accrues significant operating cost benefits. Amongst the Global Auto Parts Suppliers, we believe Mobileye, Delphi, Autoliv, and Continental are significantly exposed to this growth opportunity.

- **Semiconductors poised to benefit from autonomous driving.** The advent of autonomous driving and ADAS underscores the ongoing secular increase in automotive semiconductor content. Semi-autonomous cars could hold up to $1k of additional electronic content on top of the current avg of $350 per car (~$400 from semi-autonomous ADAS alone and more from fully autonomous) and yield an additional $50b to the current $32b Automotive semiconductor TAM (according to SIA), implying a +6% y/y 2015-30E CAGR (roughly half from semi-autonomous ADAS alone). Sensors for radar and video systems, high-end Automotive-grade microcontrollers, and graphics- & application processors are set to benefit most in this transition over the coming years, in our view. Top picks in global semiconductors to play this theme include Buy-rated Infineon, Maxim Integrated, and NXP.

The Cost of Vehicle Ownership

The cost of vehicle ownership in the largest 20 U.S. metropolitan areas averages $0.90 per mile; but costs vary significantly from city to city. In this section, we compare these costs against On Demand Mobility services today, and the cost of Autonomous On-Demand Mobility in the not too distant future. This analysis leads us to interesting conclusions regarding the implications for U.S. Auto Demand.

A number of variables are likely to impact how consumers will behave when presented with options for personal mobility. These include safety, convenience (the car is an extension of the home and it contains many personal items), flexibility, and cost. We've focused our analysis on the cost side of the equation with most of our efforts centered on the most densely populated metropolitan markets (i.e. dense urban centers), as we believe that population density will play a key role in driving the economics and practicality of shared mobility models. Interestingly, based on variables that we've collected from census data, taxes, parking costs, insurance costs, and other factors, the cost of individual vehicle ownership varies greatly by metro area. For example, while we assumed that variable cost (i.e. fuel, maintenance, tire replacement costs, and depreciation) was relatively stable at ~$0.45 per mile in most regions, fixed costs (i.e. insurance, registration, taxes, parking, and traffic tickets) could range from $2,300 to $6,200 (20 MSA average is $3,700). On average, across 20 metropolitan areas, the cost of operating an individually owned vehicle is $0.90 per mile. However, it ranges from $0.67-$0.70 in St. Louis and Atlanta to $3.10 in Manhattan. In addition, we found it interesting that vehicles were typically driven with only 1 occupant (70%-80% of the time), which makes these data points a good proxy for individual mobility costs.

Figure 1: Cost of private vehicle ownership

	Top 20 MSAs	Nationwide
variable cost ($/mile)		
fuel cost	0.09	0.09
maintenance	0.11	0.11
depreciation	0.24	0.24
tires	0.01	0.01
variable cost per mile	**0.45**	**0.45**
fixed cost ($/year)		
insurance	923	841
license, registration, taxes	665	665
parking	1,717	1,030
traffic tickets	75	75
finance cost	366	366
	3,746	**2,977**
miles traveled	**8,324**	**12,000**
fixed cost per mile	**0.45**	**0.25**
cost of ownership per mile	**0.90**	**0.70**

Source: Deutsche Bank, AAA, Census, NAIC, Colliers, Industry Experts

Figure 2: Demographics and Transportation Characteristics of Top 20 MSAs, continued in Figures 3-5

metro area	NYC - Tri State	LA	Chicago	Dallas-Fort Worth	Houston
Populaton (mm)	20.1	13.3	9.6	7.0	6.5
Total households in metro area	7,152,760	4,287,974	3,442,174	2,445,239	2,226,123
Urban Density Center households	3,261,579	1,389,558	1,081,907	753,219	834,204
Avg. Vehicles Per Household in MSA	1.9	2.6	2.4	2.5	2.6
Avg. Vehicles Per Household - high density	0.6	1.5	1.1	1.6	1.5
Urban Density Center household % of total MSA	46%	32%	31%	31%	37%
Total vehicles in MSA	13,590,244	11,354,399	8,113,325	6,016,039	5,710,845
Total vehicles in Urban Density Center	1,988,568	2,079,690	1,197,287	1,183,605	1,251,306
% commuting by car	57.8%	84.7%	80.0%	91.6%	91.2%
Average Commute in Miles One Way	7.7	8.8	10.0	12.2	12.2
mean travel time to work	35.8	29.3	31.5	27.5	29.2
drove alone	50%	75%	71%	81%	80%
carpooled	6%	10%	8%	10%	11%
cost of vehicle ownership					
fixed cost	6,154	3,397	3,931	2,613	3,103
variable cost	2,552	3,648	3,284	4,008	3,567
total cost	8,706	7,045	7,216	6,621	6,670
cost per mile	**1.53**	**0.87**	**0.99**	**0.74**	**0.84**

Source: Deutsche Bank, DOT, Census, Uber, Lyft, AAA, Industry Experts

Figure 3: Demographics and Transportation Characteristics of Top 20 MSAs, cont.

metro area	Philadelphia	Washington, DC	Miami	Atlanta	Boston
Populaton (mm)	6.1	6.0	5.9	5.6	4.7
Total households in metro area	2,230,807	2,154,147	2,047,325	1,981,447	1,777,817
Urban Density Center households	604,258	478,280	350,206	255,406	353,781
Avg. Vehicles Per Household in MSA	2.1	2.4	2.4	2.2	2.5
Avg. Vehicles Per Household - high density	1.0	1.1	1.3	1.3	0.9
Urban Density Center household % of total MSA	27%	22%	17%	13%	20%
Total vehicles in MSA	4,644,739	5,073,739	4,902,869	4,274,331	4,429,256
Total vehicles in Urban Density Center	601,618	527,766	449,397	343,108	329,798
% commuting by car	81.9%	76.8%	88.4%	88.6%	76.9%
Average Commute in Miles One Way	7.8	9.1	8.6	12.8	8.1
mean travel time to work	29.1	34.5	28.1	31.0	30.8
drove alone	73%	66%	79%	78%	68%
carpooled	8%	10%	9%	10%	7%
cost of vehicle ownership					
fixed cost	4,133	4,165	3,150	2,590	5,267
variable cost	2,984	3,488	3,746	4,700	3,669
total cost	7,117	7,654	6,895	7,290	8,937
cost per mile	**1.07**	**0.98**	**0.83**	**0.70**	**1.09**

Source: Deutsche Bank, DOT, Census, Uber, Lyft, AAA, Industry Experts

Figure 4: Demographics and Transportation Characteristics of Top 20 MSAs, cont.

metro area	San Francisco-Oakland	Phoenix-Mesa	Riverside-San Bernardino	Detroit	Seattle
Populaton (mm)	4.6	4.5	4.4	4.3	3.7
Total households in metro area	1,665,925	1,590,240	1,317,650	1,654,584	1,406,259
Urban Density Center households	553,452	779,827	174,815	310,588	437,226
Avg. Vehicles Per Household in MSA	2.6	2.5	2.8	2.4	2.5
Avg. Vehicles Per Household - high density	1.2	1.6	1.9	1.2	1.5
Urban Density Center household % of total MSA	33%	49%	13%	19%	31%
Total vehicles in MSA	4,330,263	4,002,657	3,644,961	3,971,002	3,463,284
Total vehicles in Urban Density Center	664,479	1,255,466	330,269	359,838	651,915
% commuting by car	72.4%	88.8%	91.0%	93.0%	81.2%
Average Commute in Miles One Way	8.0	11.4	9.1	10.4	9.0
mean travel time to work	31.9	25.4	31.4	27.0	29.6
drove alone	59%	77%	77%	84%	69%
carpooled	9%	11%	13%	9%	10%
cost of vehicle ownership					
fixed cost	4,588	2,277	2,788	3,245	4,061
variable cost	3,339	3,497	3,774	3,963	3,787
total cost	7,928	5,775	6,563	7,209	7,848
cost per mile	**1.06**	**0.74**	**0.78**	**0.82**	**0.93**

Source: Deutsche Bank, DOT, Census, Uber, Lyft, AAA, Industry Experts

Figure 5: Demographics and Transportation Characteristics of Top 20 MSAs, cont.

metro area	Minneapolis-St. Paul	San Diego	Tampa-St. Petersburg	St. Louis	Baltimore
Populaton (mm)	3.5	3.3	2.9	2.8	2.8
Total households in metro area	1,337,263	1,100,858	1,149,735	1,096,200	1,032,604
Urban Density Center households	280,284	532,177	326,180	159,089	262,683
Avg. Vehicles Per Household in MSA	2.5	2.7	2.2	2.0	2.2
Avg. Vehicles Per Household - high density	1.4	1.7	1.4	1.3	1.1
Urban Density Center household % of total MSA	21%	48%	28%	15%	25%
Total vehicles in MSA	3,308,448	2,931,329	2,575,960	2,233,181	2,223,860
Total vehicles in Urban Density Center	386,565	909,358	453,034	201,559	298,466
% commuting by car	86.9%	86.6%	90.2%	91.2%	86.3%
Average Commute in Miles One Way	9.5	8.5	8.5	10.0	8.6
mean travel time to work	25.4	25.0	26.7	25.4	30.3
drove alone	77%	76%	81%	83%	77%
carpooled	9%	9%	7%	7%	8%
cost of vehicle ownership					
fixed cost	4,036	3,112	3,150	2,522	3,093
variable cost	4,002	3,645	4,081	5,011	3,918
total cost	8,039	6,758	7,231	7,533	7,011
cost per mile	**0.90**	**0.83**	**0.79**	**0.67**	**0.80**

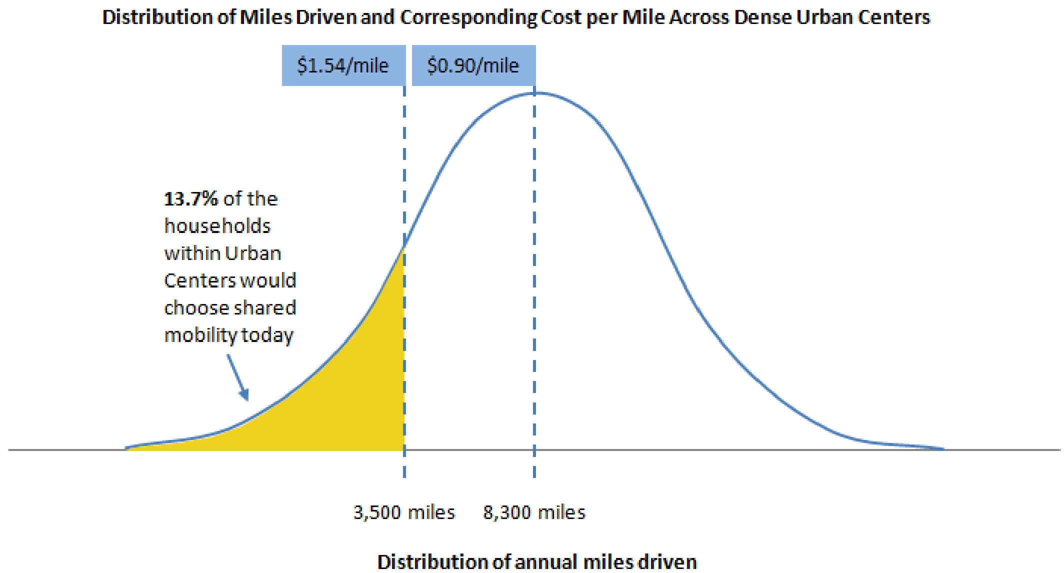
Source: Deutsche Bank, DOT, Census, Uber, Lyft, AAA, Industry Experts

The Cost of On-Demand Mobility Today

The cost of Uber or Lyft's base non-shared offering average $1.54 per mile today, but also varies significantly from city to city. Based on discussions with industry experts, and our own independent analysis of the data, we believe that On-Demand transportation should gain the most traction (i.e. minimal wait times) in the densest 1/3 of the 20 largest U.S. MSAs. We've concluded that it would be attractive (based on financial metrics only) for approximately 4.2% of households, collectively owning 2.1% of the vehicles in these MSAs.

Pricing for On-Demand Mobility Services also varies from city to city. We used publicly available pricing from uberX and census data on driving patterns (i.e. commute time, commute distance) to assess these costs and compare them against our regional operating cost estimates for privately owned vehicles. Based on normal distributions around the census averages in the metro areas we studied, we concluded that using uberX may already be cheaper than using a personally owned vehicle for ~14% of households in high density urban sub-sections (these urban households account for 4.2% of total households in the broader MSAs, and they collectively own 2.1% of the vehicles in these MSAs). There was also significant variability between percentage of households between cities. For example, uberX appears cheaper than individual vehicle ownership for 10% of households in the urban center of San Francisco, 16% in NYC, and 21% in the San Bernardino-Riverside area. The attractiveness of on-demand mobility in a city such as New York appears to correlate well with other data points. For example, NYC had the highest cost per mile for operating an individually owned vehicle ($3.10 per mile in Manhattan and $1.53 across the rest of the New York MSA). NYC also has the lowest vehicle ownership density of any of the major metro areas that we studied (0.6 vehicles per household, compared with a national average of 2.1 vehicles per household).

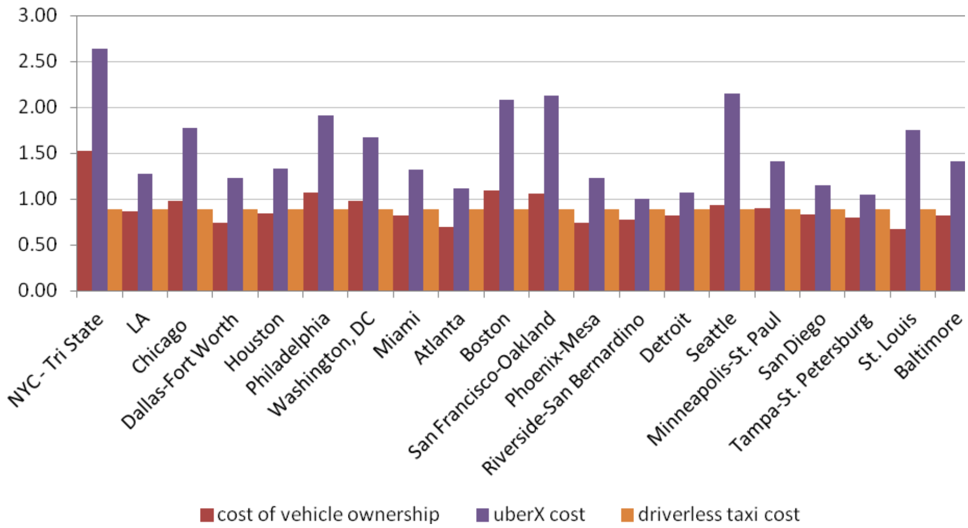
Figure 6: 13.7% of households in dense urban centers would see economic benefit from giving up vehicle ownership in favor of on-demand shared mobility today



Source: Deutsche Bank, Uber, Lyft, Census, DOT

Importantly, we take these calculations as a reference point, and not an indication of what consumers will necessarily do. Even if on-demand mobility is cheaper for 14% of households, it is also clear that 14% of households have not, and likely will not abandon their privately owned cars (these regions still average 1.2 vehicles per household). There are many reasons for this, including the aforementioned convenience factors. In addition, consumers unquestionably also value the freedom, flexibility, and personalization that their vehicles provide. Families want their cars to be capable of the occasional longer distance trips (e.g. to visit relatives on holidays, or summer road trips), even if these situations are relatively infrequent. Nonetheless, the underlying trends are likely to drive growth for on-demand mobility as: 1) Consumer awareness of alternatives to individual vehicle ownership continues to rise (we'd note that Uber itself is only 7 years old); 2) Alternative modes of transportation proliferate (including car sharing services such as Zipcar, Getaround, Turo, Car2go); and 3) The cost of all alternatives continues to decline.

Figure 7: Cost per mile of various personal transportation options in Top 20 MSAs



Source: Deutsche Bank, DOT, Census, Uber, Lyft, Industry Experts, AAA

The Cost of Autonomous On-Demand Mobility

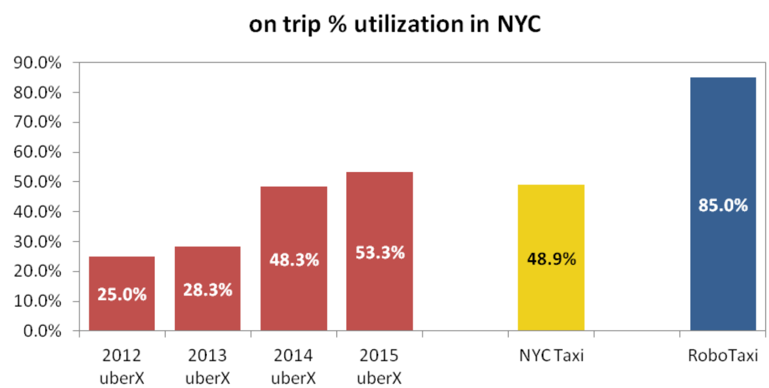
The cost of on-demand mobility should come down dramatically with Dynamic Ride Sharing (such as uberPOOL and Lyft Line), and to an even greater extent as Autonomous Driving eliminates the cost of a human driver and utilization increases.

The aforementioned cost discussion does not work in the fact that the cost of on-demand mobility services continues to decline rapidly. Costs should continue to decline as efficiencies are gained and as providers use information technology to create new offerings. One example happening today is the application of dynamic ride sharing models—i.e. pooling of individuals with similar points of origin and destinations through services such as uberPOOL and Lyft Line. uberPOOL could reduce the cost of a ride by 20%-50% (an uberPOOL user pays as little as ½ price for the fraction of the ride that is shared with another uberPOOL customer). In San Francisco the cost per mile could decline from $2.13 to $1.06-$1.70 per mile. This compares with an estimated $1.06 per mile average cost of using a privately owned car in San Francisco. The option of ride sharing unquestionably increases the percentage of households that could see benefits from on-demand mobility services. The appeal of this service is also apparent through the impressive penetration levels that have been reported so far. For example, Lyft recently noted that 40% of their rides in San Francisco are now Lyft Line. The equivalent number for the uberPOOL service in San Francisco is close to 50%.

And the costs will decline further still as vehicles become Autonomous (driverless): Without human drivers we estimate that on-demand mobility companies, without DRS noted above, will be able to generate a 20% ROIC at $0.89 per mile; close to the $0.90 per mile average cost of operating a car in the top 20 U.S. MSAs. Based on a normal distribution of miles driven, it is conceivable that 1/2 of consumers in these areas would derive financial benefit from on-demand mobility, if the use case is practical (determined by network density and other factors).

To determine the cost of operation for an Autonomous "RoboTaxi" we assumed that such a vehicle is on the road ~17 hours a day (similar to an NYC taxi), and generates revenue 85% of that time (compared with revenue generation of ~53% for uberX and ~49% for taxis in NYC today). We acknowledge that robo-taxis could conceivably have availability that is significantly higher. However, based on academic studies, utilization declines dramatically overnight (with a few notable exceptions such as New York City-being the city that never sleeps). This implies that these vehicles would generate 59,500 revenue miles per year out of 70,000 annual miles driven (analysis is based on an average of 11.5 MPH traveled for a typical NYC taxi; typical taxi drives 70,000 miles per year over 2 driver shifts and generates 34,230 revenue miles).

Figure 8: On Trip Utilization of various on-demand mobility options



Source: Deutsche Bank, NYC TLC, Uber, Lyft

To estimate the actual cost of operation, we adjust the depreciation of the vehicle to reflect a 3-year life expectancy. This implies that these vehicles will last 210,000 miles (compared with a 202,000-223,000 lifetime vehicle miles traveled for passenger cars and light trucks). Even after adjusting the price of an Autonomous vehicle upwards by $20,000 (We used a $50,000 total vehicle price; companies such as Delphi believe that the cost premium to produce will ultimately decline to $4,000), the improved amortization of fixed costs implies that the total cost per mile will decline to ~$0.52/mile ($0.46 per mile variable cost plus $0.06/ mile for fixed costs, which is $4,300 in fixed cost per year spread over 70,000 miles).

Importantly, this $0.52 reflects operating costs for the network operator (e.g. Uber, Lyft, Google, or GM's Maven). To determine pricing for this service, we assumed that the service provider would require a 20% return on invested capital (i.e. NOPAT should be $10,000 on a $50,000 vehicle investment), which corresponds to $0.17 per mile for a vehicle generating 59,500 revenue miles per year. We then backed up through the income statement based on a 35% tax rate, $0.12 per mile for SG&A and R&D (13% of revenue), $0.52 per mile for cost of goods sold, to derive a $0.89 per mile retail rate for the customer—very close to the $0.90 average cost of driving a privately owned vehicle in the top 20 U.S. MSAs, and significantly lower than the average for the dense urban centers within these MSAs (average cost in NYC is $3.10).

Figure 9: Miles Driven and Utilization of On-Demand Autonomous Vehicles

	nationwide
driverless vehicle price	**$ 50,000**
miles driven	
average driverless miles driven per hour	11.5
miles traveled annually	**70,000**
utilization on trip	*85%*
revenue miles	**59,500**

Source: Deutsche Bank, Industry Experts, NYC TLC

Figure 10: Variable Cost per Mile of On-Demand Autonomous Vehicles

	nationwide
variable cost (per mile)	
mapping and data services	0.01
fuel cost	0.09
maintenance	0.11
depreciation (straight line, no residual)	0.24
tires	0.01
operating cost per mile	**0.46**
fixed cost (per year)	
insurance	3,000
license, registration, taxes	665
taxi comission inspection	105
finance cost	552
	4,322
annual cost of operation	**36,284**
annual cost of operation per mile	**0.52**

Source: Deutsche Bank, Industry Experts, AAA, Census, NAIC

Figure 11: Based on our estimates of costs involved, we estimated that a mobility service provider should be able to generate a 20% ROIC by charging $0.89 per mile

per mile	**nationwide**	*% of Revenue*
revenue	0.89	
COGS	0.52	*58%*
gross margin	0.37	*42%*
SG&A/R&D @13% of revenue	0.12	*13%*
EBIT	0.26	*29%*
taxes, @35%	0.09	
NOPAT	0.17	*19%*
implied cost per mile to consumer	**0.89**	

Source: Deutsche Bank, Industry Experts, AAA, Census, NAIC

Figure 12: Summary of Academic Research on the Subject of On-Demand Mobility

Summary of Academic Research on the Subject of On-Demand Mobility

- A study by the University of Utah in Austin modeled a fleet of autonomous on demand vehicles and found that a single RoboTaxi could replace 12 conventional vehicles.
- A group at SENSEable Lab at MIT concluded that the 13,400 vehicle taxi fleet in NYC could be reduced by 40% with on-demand vehicles.
- An OECD/International Transport Forum study of driverless cars in Lisbon concluded that RoboTaxis, in combination with effective public transport, could reduce the number of cars in operation by 80-90%.
- A Singapore case study by Speiser concluded that the entire population of Singapore can be served with 1/3 of the vehicles if they were autonomous mobility on demand vehicles.
- A study by Columbia University found that 9,000 RoboTaxis could replace all 13,500 taxis in NYC and achieve an average pickup time of less than 1 minute at a cost of $0.50 per mile.
- Columbia also estimated that a RoboTaxi fleet that is 15% of the current vehicle fleet could serve all of the 120,000 residents of Ann Arbor. This study also estimated that costs per mile would decline from $1.60 to $0.41 per mile.
- A study by Rigole using Stockholm as a model concluded that personal trips could be completed by 10% of the current vehicles in operation if they were Autonomous and as long as consumers were willing to spend 15% more time per trip.

Source: Deutsche Bank, Academic Studies

Estimating the Impact on the U.S. Auto Market, and Annual U.S. Auto Demand

We've interviewed a number of industry participants (i.e. Automakers, Suppliers, Consultants, Academics, and Mobility Service Providers) to gain insight into the potential impact of on-demand and privately owned autonomous vehicles. From these discussions and our own analysis of city and town data for each of the top 20 MSAs, we've concluded that there is a minimum population density required for on-demand mobility services to replace private vehicle ownership (even today, Uber drivers from Akron Ohio will commute to Cleveland to work in a more dense market). We estimate that on average, the densest 1/3 of the largest 20 MSAs (approximately 15.4MM vehicles) appear to represent viable markets. For example, within the NY MSA, on-demand mobility will likely continue to work well in the 5 boroughs of NYC, Hoboken, and Newark, but not in Westchester. The model may work well in Detroit but not in Flint. We've incorporated these assumptions into our Model, as illustrated in figure 13.

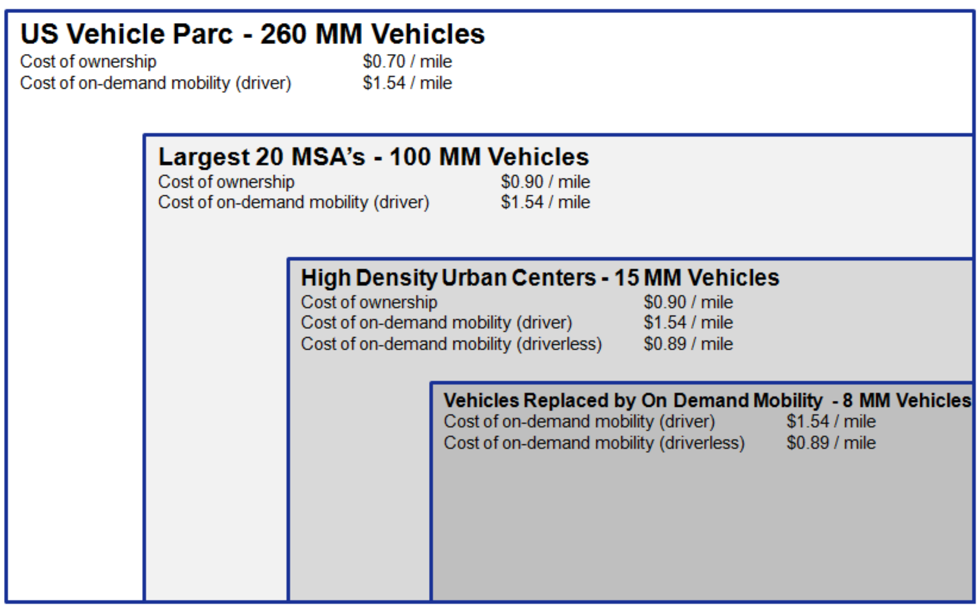
Figure 13: Dense Urban Center Characteristics

dense urban centers within MSAs

	Top 20 MSAs	Dense Urban Centers
total population	121,600,000	35,292,658
total households	43,097,131	13,178,719
average vehicles per household	2.3	1.2
total area (square miles)	33,087	5,165
average density (people per square mile)	3,675	6,833
households as % of total in top 20 MSAs		**30.6%**
number of vehicles	**100,794,729**	**15,463,090**
number of vehicles as % of total vehicles in MSA		**15.3%**

Source: Deutsche Bank, Census, DOT

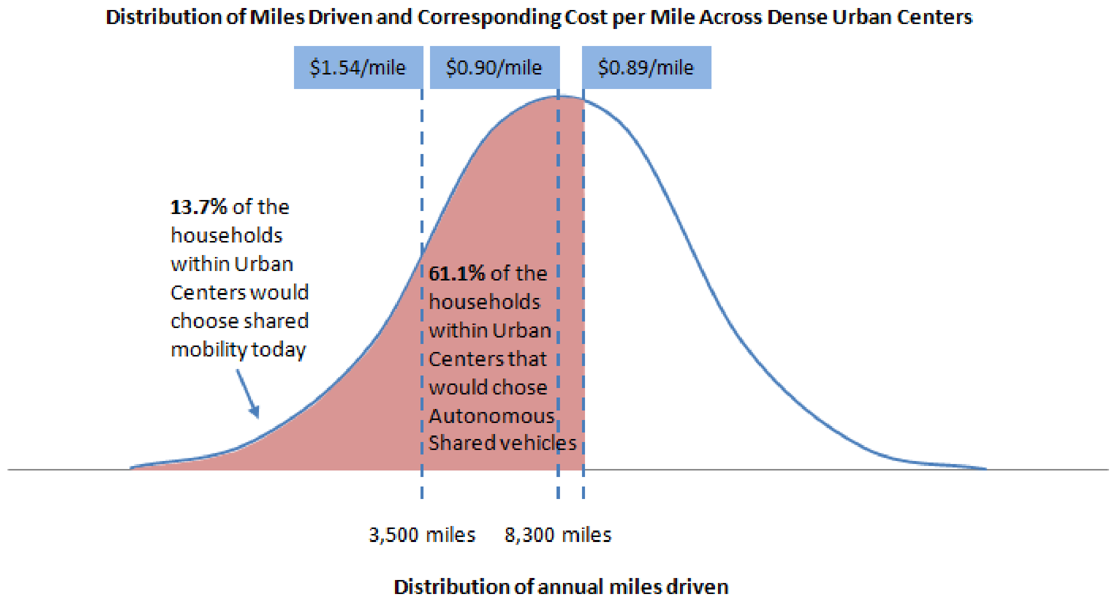
Figure 14: Vehicles impacted by on demand mobility



Source: Deutsche Bank, Census, DOT, AAA, Uber, Lyft, Industry Experts

Based on our analysis, assuming a normal distribution for miles driven, and additional feedback from Industry participants (who have been conducting consumer research), we've estimated that approximately 30% to 60% of households in the densest urban sub-sections within the MSAs we studied will find it financially compelling to shift from individual vehicle ownership to on demand autonomous vehicles (8MM out of 15MM vehicles in these sub-sections could theoretically get replaced by on-demand mobility services).

Figure 15: 61.1% of households in dense urban centers would see economic benefit from giving up vehicle ownership in favor of autonomous on-demand mobility in the future



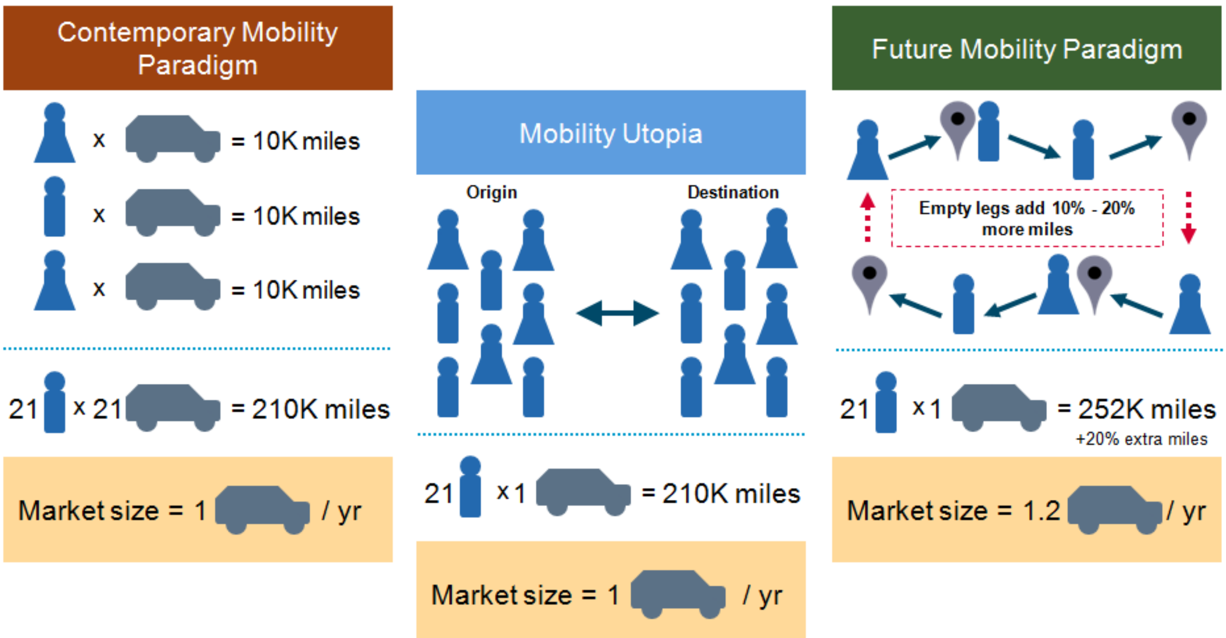
Source: Deutsche Bank, Uber, Lyft, Census, DOT

Once this has taken hold, the vehicle parc within dense urban sub-segments could decline from 15MM to 8.4MM vehicles (8.0MM vehicles would be replaced by 1.4MM on demand vehicles; we assume that the remaining 7MM privately owned vehicles are unaffected). At the same time, however, given increased utilization and increased mileage (due to empty legs) compared with the vehicles they replace, annual sales would increase within this region. Within these markets, sales to on-demand mobility service entities may account for 67% of these annual sales.

We believe that shared mobility will lead to fewer vehicles, but higher annual demand

There are many scenarios that we've considered when looking at Autonomous vehicles. In all of these scenarios, the total population of vehicles in the U.S. (also referred to as "the Vehicle Parc") declines. After all, the concept of on-demand and shared mobility is based on the premise that vehicles are underutilized (they are utilized only 5% of the time). And by definition, addressing this implies that fewer vehicles will be needed. In fact, a University of Utah and University of Texas study concluded that in an urban environment such as Austin (12x24 mile area), each shared autonomous vehicle (SAV) could replace 9 conventional vehicles while maintaining a <5 minute wait, and an average wait time of 1 minute. Automakers we've spoken to estimate that the ratio may be closer to 1:6, but they still acknowledge the potential for significant declines for the U.S. vehicle parc.

Figure 16: In the contemporary scenario we have 21 people & 21 vehicles. Each vehicle drives 10,000 miles. Since the life expectancy of a car is around 210,000 miles this market would likely scrap/replace 1 car per year. In the Utopian model 21 people share 1 car. And this car replaced once a year. In the Real World model (Future Mobility), empty legs between rides add 10%-20% to miles driven. This market would require up to 1.2 cars per year (i.e. one new car sold every 10 months).



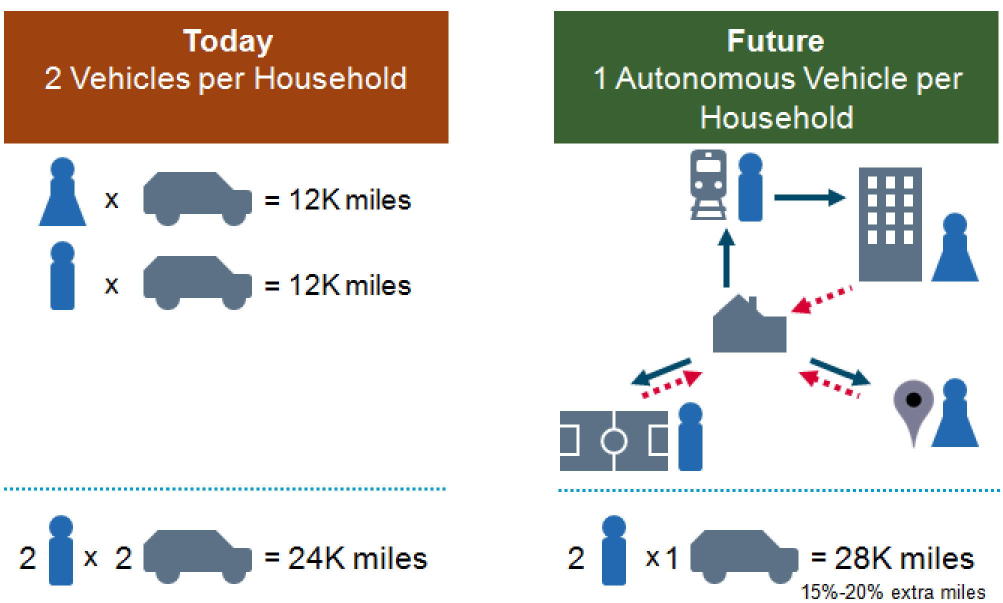
Source: Deutsche Bank, Industry Experts, University of Texas in Austin, Univeristy of Utah, McKinsey

U.S. Sales nonetheless increase under every scenario we've examined because vehicle scrappage is determined by miles driven. Aggregate miles driven will inevitably go up. And the Auto Industry also will likely become somewhat less cyclical. Based on incoming questions we've received, a framework in which annual sales increase while the total population of vehicles declines appears to be quite difficult for investors to grasp. But consider that the average engineered vehicle life expectancy of a vehicle is primarily determined by miles driven (average engineered life expectancy is 210,000 miles), and not calendar age. The practical real world application of any "shared" vehicle is also an important consideration (shared through an on-demand service such as Uber, or shared within a household). A New York City taxi represents an excellent sample use case. Based on NYC TLC data, the average NYC taxi drives approximately 70,000 miles per year. But it only transports passengers 49% of those miles. The rest of the driving is primarily accounted for by empty legs between customers. Uber vehicles transport passengers approximately 53% of the time, and the remaining miles are empty legs. In every model for the future in which autonomous on-demand or household vehicles are shared, there will always be empty legs. As a result, each on-demand vehicle will travel more miles (10%-20% more) than the cumulative 6-9 privately owned vehicles that it replaces. In addition, many studies suggest that miles traveled may be further augmented through increased mobility for people who cannot travel with their own private vehicles, such as the very young or elderly—a KPMG study projected a 13% increase in miles traveled as a result of this factor alone.

Proliferation of privately owned autonomous vehicles may have an even greater impact in shrinking the U.S. Vehicle Parc while increasing annual U.S. Auto Sales.

The second phenomenon that we studied was the effect of autonomous vehicles within a household. Here again, empty legs will play a role in the market, as this vehicle will provide service to multiple family members (e.g. a single vehicle may bring one household member to an office, train station, or school, return home for use by another household member, and then collect the first household member later in the day). One Automaker that has been analyzing the impact of Autonomous shared family vehicles suggested that the average Autonomous family vehicle may drive 28,000 miles per year; well above the sum of each individual vehicle within the household (typically 2 vehicles driving 12,000 miles each). If 15% of the 245MM privately owned vehicles in the U.S. (excludes 15 million commercial, vocational, and private company vehicles) are shared within households, and these households go from 2 to 1 vehicles, this could reduce the total vehicle parc by 18.5MM. But here again, aggregate annual auto sales would likely increase. Additionally, the Auto Industry may become less cyclical as vehicle demand becomes somewhat more correlated with miles driven (which are somewhat less volatile than the cycle).

Figure 17: Illustrating the impact on vehicle sales from Autonomous privately owned vehicles



Source: Deutsche Bank, Industry Experts, University of Texas in Austin, Univeristy of Utah, McKinsey

So how will Automakers be affected?

Our analysis, described above, suggests that in the U.S. alone, up to 8.2% of households (up to 61% of those living in dense urban cities) will find on-demand autonomous vehicles to be cheaper and potentially more convenient than privately owned cars. High level census data from markets such as China suggest that the penetration may be even higher, due to concentration in urban centers. A McKinsey/Stanford study published in January 2016 concluded that by 2030 one in ten vehicles sold globally will be a shared vehicle. Clearly, this has the potential to change the Auto Industry's landscape. Our prior analysis established that annual vehicle sales should actually rise due to the increase in annual miles driven after accounting for empty legs. That said, we believe that investors have legitimate concerns:

- A consumer of on-demand mobility services such as Uber or Lyft currently does not care about the brand of vehicle that arrives after he or she requests a vehicle. The primary focus is on the service experience: wait time, safety, efficiency, comfort, cleanliness. The vehicle itself may become a commodity (i.e. Automakers may be relegated to the position of handset maker to Google's or Uber's network).

- To the extent that these vehicles are purchased by fleets, there is potential for additional leverage from buyers—just as rental fleet sales are heavily discounted today. Moreover, larger fleet purchasers are less likely to utilize some of Automaker's highest return services, including financial services (e.g. Ford Credit or GM Financial).

- Digital players (e.g. Google, Apple) may have a number of competitive advantages vs. physical players (e.g. GM, Ford) in the development of Autonomously Driving Vehicles and Mobility Services. They have intimate familiarity with the most applicable development tools (such as machine learning), and they are particularly skilled in the design and development of elegant human machine interfaces. Moreover, companies such as Google and Apple are increasingly entrenching themselves into consumers' daily lives—We manage our calendars through them, consume media through them, learn through them, receive advertising through them, shop through them, etc. These players may be able to use mobility services as the link between consumers' digital and physical worlds, and they should have certain advantages in leveraging both. For example, directing a consumer to a web site may be worth a few pennies per click; driving a consumer to a store or restaurant may be worth a few dollars per ride.

- Companies such as Uber, Lyft, and Didi already have first mover advantage in terms of establishing transportation networks, building efficiencies into network operations, and building brand equity amongst consumers.

On the other hand, we believe that traditional OEMs (particularly U.S. Mass Market and Luxury OEMs) are advantaged in other respects.

- They have an established manufacturing base that is capable of producing vehicles at high volume, high quality, long life, and low cost given economies of scale and efficiencies gained over decades. And they are experienced in engineering products (including electronics/software) to performance specifications that are unheard of in the consumer electronics world (vehicle systems are designed for 100% reliability and availability).
- Automakers have large vehicle distribution and maintenance networks through their dealers (including thousands of trained technicians around the world), and they are therefore capable of servicing millions of vehicles in operation (and storing these vehicles when they are off-line). We'd emphasize that the service/parts revenue angle could be a significant positive for Automakers. Most of the aftermarket revenue today is achieved over the first 4-years of a vehicle's life. The accelerated use of vehicles deployed in on-demand models suggests that OEMs may generate an entire lifetime's worth of aftermarket parts sales over just 3 years in operation.
- Automakers may be able to take advantage of certain network/scale benefits to produce offerings that mobility startups and tech companies are unable to provide. An excellent example, which we describe in more detail in the Supplier section below, is GM's, VW's, and Renault-Nissan's strategy for collecting map data. Nearly all of the industry's participants recognize that accurate digital map data is required in order to implement Autonomous Driving. Companies such as Google are starting to collect 3D map data through vehicles equipped with laser scanning technology. This approach is expected to provide Google vehicles, or other vehicles that use Google's data, with the ability to conduct Autonomous driving within specific geo-fenced areas that have been mapped. The challenge with 3D mapping is scaling the collection process. 3D map data for 4MM miles of U.S. roads does not currently exist (note that ~30% of these roads are unpaved). Moreover, there is no mechanism currently available to regularly update these maps in real time. GM, VW, and Renault-Nissan are looking to circumvent this requirement by equipping millions of vehicles with systems that collect visual landmark data in real time (GM will begin crowd sourcing map data with this approach later this year). Google and other tech startups may not be able to compete with traditional OEMs collecting map data from millions of drivers. If these Automakers are successful in achieving their targets, they will be first to market with Autonomous vehicles that are capable of driving almost everywhere (even outside of specific geo-fenced locations).

Importantly, we'd also note that U.S. Automakers are under-indexed to the segments that are most likely to be disrupted by On Demand Mobility. Any assessment of the extent of risks to U.S. OEMs requires understanding of where Automakers make their money. As noted in figure 18, we believe that U.S. OEM's generate more than 100% of their North American profit and more than 100% of global profitability/free cash flow from the light truck market (disproportionately from pickup trucks, which we view as less likely to be replaced by on-demand mobility services given their specialized work/lifestyle application). At the same time, the U.S. Automakers are under-indexed and unprofitable in the segments most likely to be disrupted by mobility on-demand: Passenger Cars (Based on contribution margin disclosures in GM's 10K, and our analysis of GM's fixed costs, we estimate that GM may be losing up to $4,700 per passenger car in North America). We believe that U.S. mass market passenger cars have not earned their cost of capital for decades. They have already been commoditized, and returns in these segments have been ravaged by overcapacity.

Figure 18: General Motors and Ford's North American fixed cost per unit, contribution margin per unit, and contribution margin by segment

	Ford		GM	
Contribution Margin per Vehicle	$8,603		$8,542	
Truck/SUV	$11,614	*135%*	$14,521	*170%*
Crossover	$8,603	*100%*	$6,833	*80%*
Car	$4,302	*50%*	$2,563	*30%*
Fixed Cost per Vehicle	$6,953		$7,228	

Source: Deutsche Bank, Ford, General Motors

Based on our assessment of the (favorable) volume implications of on-demand mobility, as well as the current sources of profit and losses for U.S. OEMs, we believe that on demand mobility services may represent more of an opportunity than a threat for Automakers.

If executed properly we believe that the advent of mobility services could present opportunities to fix large parts of the Auto Industry that are broken: As illustrated in figure 18, North American passenger cars have not, and likely will not earn their cost of capital for the foreseeable future (we would be surprised if this segment has earned its cost of capital for decades). The European mass market is similarly challenged, as capacity has been insufficiently consolidated. We believe that the largest, most technically capable Automakers will be seeking to pursue Autonomous driving and Mobility Services as a means to change the business model in these areas.

To illustrate the opportunity in simple terms, we assume that each passenger car unit sold by GM in NA achieves a $2,500 contribution margin (before fixed costs are allocated). In comparison, each passenger car unit placed into an on-demand mobility service may add $53,000 annual recurring revenue (59,500 revenue miles per year x $0.89 per mile), ~$15,400 of EBIT (see figure 19), and have a 20% ROIC. If, hypothetically, we were to pro-forma GM's 2015 North American earnings to reflect 1% volume into on-demand mobility, GM's North American Pro Forma profitability would have come in ~$570MM higher. If they deployed 1% of their volume to ride sharing per year, and those vehicles remained in operation (vehicle life expectancy assumed to be 3 years), GM's earnings would rise by $1.7bn. Doing the same for Ford would imply a

~$470MM improvement to their NA profits (climbing to $1.4bn as these vehicles remained in operation). We believe that the shift toward recurring revenue through on-demand mobility services would also significantly reduce OEM's cyclicality.

Figure 19: Pro-forma Profit Improvement from On Demand Autonomous Fleet

	Ford	GM
NA Wholesale Volume (thousands)	3,073	3,558
Share of Volume Directed to On-Demand Autonomous	1%	1%
On-Demand Autonomous Volume (thousands)	31,000	36,000
Revenue per vehicle ($)	53,068	53,068
EBIT per vehicle ($)	15,385	15,385
On Demand Vehicles in Service After 3 years of Allocating 1%/year	93,000	108,000
Steady State* NA Profit Improvement ($MM)	**1,400**	**1,700**

* assuming 3 year lifecycle for autonomous shared vehicles

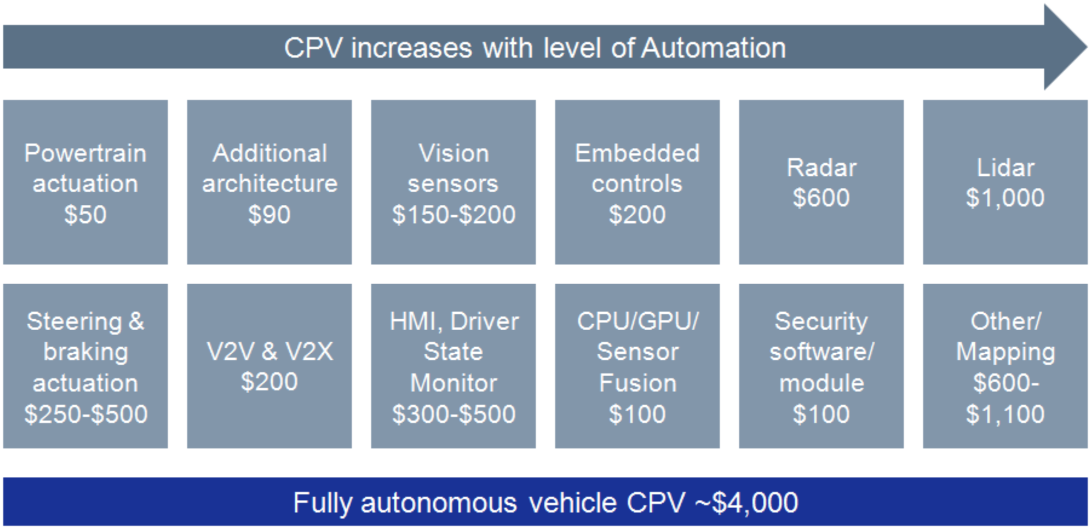
Source: Deutsche Bank, Ford, General Motors

How will Suppliers be affected?

We believe that Automation will represent a $120bn+ opportunity for suppliers of vehicle software and electronics by 2030. Increased utilization (i.e. up to 70,000 miles per year for an Autonomous On-Demand Vehicle and up to 28,000 miles per year for a Privately Owned Autonomous Vehicle) should have other knock on effects, such as improving to the economics of advanced powertrain technologies (i.e. electrification).

The first semi-autonomous vehicles, capable of simultaneous control of the vehicle's speed (throttle and braking) and steering (to stay within a lane on a highway) are starting to appear in the market today. The first fully autonomous vehicles, capable of point to point navigation and driving, are likely 4-years away (~2020). We see these developments as offering a very compelling growth opportunity for select suppliers. A recent McKinsey study estimated that by 2030, up to 50% of vehicles sold globally will be semi-autonomous and 15% of new vehicles sold could be fully autonomous. To illustrate the potential market opportunity, we make a simplifying assumption that the Global Auto Market peaks at approximately 100MM vehicles per year (We actually believe that this will be reached by 2018). Based on discussions with suppliers, we estimate that the average Semi-Autonomous Driving Vehicles will have ~$1,000 of additional content (sensor and electronic content will likely be higher initially). If McKinsey's estimate is correct, and 50MM vehicles will be equipped with this level of content, this would imply a $50bn market (50MM x $1,000 per vehicle). Based on discussions with suppliers, we estimate that Fully Autonomous Vehicles will average ~$4,000 of additional content related to this level of automation (again, we acknowledge that the content will initially be significantly higher). Assuming 15%, or 15MM vehicles per year are equipped with this level of Automation, we believe that suppliers could benefit from $60bn of additional content. In addition, we believe that the majority of the remaining 35MM vehicles will be equipped with Active Safety technologies such as Autonomous Emergency Braking (AEB). At $300 per vehicle this would create a $10bn market opportunity. Taken together, we estimate a $120bn+ global market opportunity for vehicle sensors (cameras, radars, lidars, sonars), semiconductors, artificial intelligence software, vehicle communication/data connectivity, mapping, and other services being developed by companies such as Delphi, Continental, Bosch, Mobileye, and Autoliv.

Figure 20: Cost per Vehicle of Autonomous System



Source: Deutsche Bank, Delphi

What's the Path to Autonomous Driving and What's the Supplier Opportunity

We believe that the Industry's trajectory towards advanced levels of automation may happen more quickly than is widely anticipated. Automakers including Daimler, BMW, Nissan, Volvo, and Tesla have begun to introduce semi-autonomous driving capabilities (also known as Level 2 Automation) into their flagship vehicles. This level of automation combines Adaptive Cruise Control and Lane Keeping Assistance to relieve drivers of tedious work such as driving in traffic or long distances on the highway. Automakers will continue to push the envelope of automation. Companies such as Google, Ford, General Motors, Daimler, Nissan, Volvo, and others are currently testing vehicles that are capable of completely automated driving in highway and city driving. The first such completely automated vehicles-with Level 3 (Autonomous Driving under certain conditions, but with a driver that can regain full control) and even Level 4 (Full Automation under all conditions, including vehicles that are unoccupied) are likely just 4-years away.

Figure 21: NHTSA's Levels of Autonomous Functionality

In the U.S., NHTSA defines 4 levels of autonomous functionality:

Level 0 – no automation

Level 1 (Function-specific Automation) – some vehicle control functions such as ABS and ESC systems are automated

Level 2 (Combined Function Automation) – automation and cooperative working of at least 2 vehicle control functions, includes Adaptive Cruise Control and Lane Keep Assist working together

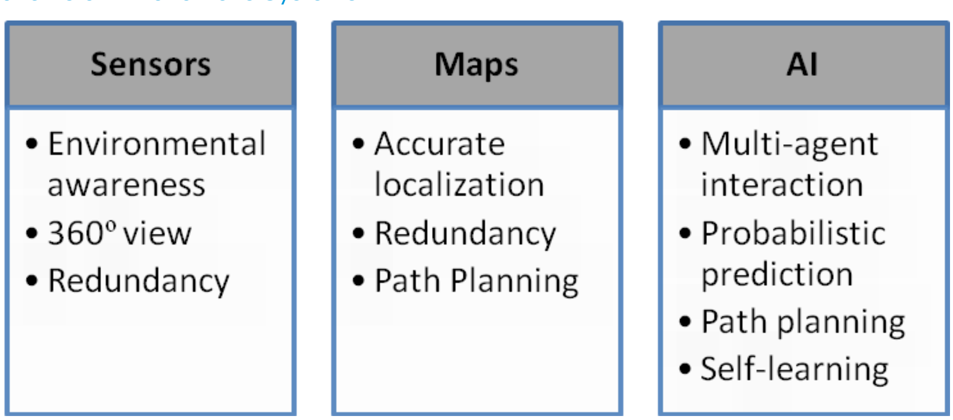
Level 3 (Limited Self-Driving Automation) – automation of all control functions under certain environments and scenarios, with the driver available to regain control with enough warning time (eg. Google cars)

Level 4 (Full Self-Driving Automation) – automation of all control and safety functions under all conditions and scenarios, including occupied or unoccupied by passengers

Source: Deutsche Bank, NHTSA

To achieve advanced levels of automated driving it has been widely believed that vehicles will require 3 tools: 1) Sensors (i.e. cameras, radars, lidars, sonars); 2) Advanced artificial intelligence that is capable of operating in highly complex and dynamic multi-agent environments; and 3) Detailed digital 3D map data for accurate localization, path planning, and redundancy (confirming data from sensors). Until now most of the industry's discussion has been focused on artificial intelligence. In reality, we believe that there is still significant development taking place in each of these areas.

Figure 22: Components of Autonomous Systems



Source: Deutsche Bank, Mobileye, Industry Experts

Artificial Intelligence and the Systems That Run Them

There is a significant amount of ongoing work in developing artificial intelligence for autonomous driving. Artificial intelligence has advanced to the point that computers are attaining high degrees of accuracy in identifying features that can be seen visually through a camera (i.e. vehicles, pedestrians, cyclists, lane markings, traffic signs, traffic signals, and other landmarks). The industry's state of the art is advancing to a level in which a computer is able to project the correct drivable path even when common visual cues (i.e. lane markings, curbs) are partially obscured, such as on snow covered roads. This level of cognition, known as "Holistic Path Planning" or "Semantic Path Planning," is aimed at replicating the way that humans interpret the appropriate course of action even with imperfect visual cues. Within the next 3-4 years, it is expected that on board automation capability will achieve "super-human" capability, as data is interpreted at speeds that exceed human capabilities, with no distraction and no change in performance due to fatigue, and augmented via sensor fusion (radars, lasers, or sonars can augment data on the scene even when vision is impaired).

Today's AI work is also advancing in the field of "Driving Policy." While this subject is typically described as developing the "driving rules" for vehicles to follow, the subject matter is much more complex. Robo-cars need to be integrated into real world conditions with drivers and pedestrians that do not necessarily follow consistent rules and laws, and where the cues that determine proper courses of action may have billions of permutations (e.g. construction zones, turns at intersections, dense urban areas with numerous unpredictable agents, roads that have poor or undetectable lane markings, merging into traffic). The computer systems also need to understand how the driver should behave based on millions of indirect cues. For example, when two vehicles reach a 4 way intersection at the same time and both want to turn left, which one goes first? There are literally hundreds of subtle signs that humans interpret to determine the outcome. When a human driver sees a ball roll into the middle of the road, a human driver will likely prepare for the possibility of a child entering the roadway. Computers need to achieve very high levels of cognition in order to function well in these, and other scenarios. One of the factors that has recently accelerated progress in this area is derived from the application of Supervised Machine Learning.

Broadly speaking, Machine Learning involves the construction of statistical tools for machines to learn from vast amounts of data and ultimately make determinations and/or predictions based on this learning. In the development of Autonomous Driving Software, vehicles are driven to collect vast amounts of data from real world driving conditions, this data is annotated by engineers, and computers analyze the data to create rules that allow them to accurately identify the annotated data, and draw conclusions (There are proprietary automotive as well as generic machine learning software platforms being used to do this). The machine can generate rules based on observed driving behavior and reactions to numerous inputs. While this is a somewhat simplistic description (there is both science and art behind the machine learning techniques), a computer program can effectively be developed to direct driving in the real world based on the analysis (learning) of vast amounts of driving data.

Based on misconceptions that we've heard amongst investors, we believe it's important to note several points:

- The machine learning process is a tool used by software developers (i.e. Continental, Delphi, Bosch, Mobileye, Nvidia). It will not happen within the vehicle.
- It is a misconception to believe that computers can learn to drive based on unsupervised observation of driving. This level of AI technology does not yet exist.
- While machine learning is a phenomenal tool for analyzing vast amounts of data, it is not devoid of challenges. For example, while there is specific statistical confidence in the model, the measurement of this is complicated by the approach taken in development of the model (the programmers often do not know why or how certain aspects of the model work). Based on this complexity, it is often difficult to identify and correct errors that are found when the model is tested.

Where will the AI reside and why does it matter?

OEMs and Suppliers have several architectures at their disposal when it comes to integrating ADAS into vehicle electronics. The architecture is an important point for investors, as it determines the market opportunities for companies (i.e. Nvidia, Freescale, Hitachi, Delphi, Mobileye) that are competing for content in this arena. The most common architecture that we are seeing today involves a linear format. Vision, Radar, and Lidar sensors are paired with ASICs (Application Specific Integrated Circuits). Each ASIC (i.e. computer chip) interprets the sensor data, and passes information along to the primary ASIC, typically the vision ASIC. Vision is viewed as the best "General Sensor", and the vision ASIC is also typically the most powerful processor in this system (In many cases, this vision chip is also capable of performing the "sensor fusion"; and in a few cases, this chip may also be powerful enough to run driving policy algorithms). This architecture is viewed as an efficient means of processing sensor data—There is minimal wasted processing power, and each chip is optimized for the task.

The Alternative architecture being promoted by a number of semiconductor companies, and a number of Automakers, still involves the use of individual ASICs for processing raw data from the sensors (Vision, Radar, Lidar, Digital Maps/GPS). But these multiple channels of data then flow to a CPU or a GPU, where decisions are made about the data (i.e. in instances that suggest conflicting information between sensors, the GPU contains programming to make sense of it), and then appropriate courses of action are determined. The advantage of using GPUs is derived from the parallel processing of information. This design is well suited to algorithms developed through deep neural networks (A subset of Machine Learning structured in layers that draw conclusions based on the weighted sum of inputs. Each successive layer of data processing relies on the prior layer's work for more complex analysis). This "Multi Channel Architecture" provides an added advantage of flexibility and redundancy. But the costs may be a bit higher. That said, it is believed that the multi-channel GPU based architecture may become more financially attractive as processing power is better utilized… For example, if the GPU is utilized for control of multiple vehicle functions and/or the Human Machine Interfaces (also called a "Multi-Domain Controller")

Maps

Most engineers developing autonomous driving believe that detailed 3D maps will be key as they will provide 3 important functions: 1) Accurate localization (for the on-board computer to know exactly where the vehicle is), 2) Path planning; and 3) Redundancy for vehicle sensors (can compare what the sensors see vs. what was expected). Overall, it's not that the car can't drive on unknown roads. It's about adding robustness to the system. The maps allow for prediction and forecasting, foresight into scenes that are obstructed, and they can be used to reduce false positives and negatives (maps can embed info such as location of a guard rail that sets off the radar, or the location of an exit ramp that has previously confused the vision systems). The map also provides vehicles with key baseline data points on the environment, with details on lane width, road curvature, locations of cross walks and traffic lights. This data works in conjunction with onboard AI to interpret the real world situation. The importance of mapping data was in some ways underscored by the $4bn spent by Daimler, Volkswagen, and BMW to acquire Nokia's HERE business in 2015.

The challenge with mapping is scaling the collection process. 3D map data for 4 million miles of U.S. roads does not currently exist (and we'd further note that ~30% of these roads are unpaved). Moreover, there is no mechanism currently available to regularly update these maps real time. A technique known as SLAM (Simultaneous Localization and Mapping), in which millions of vehicles send real time updated sensor data back to a central database, is generally viewed as impractical today given the immense amount of bandwidth that would be required (Ford recently put out a press release indicating that their LIDAR scanning system collects 2.8 million laser points per second. The resulting data stream is 600 gigabytes per hour. 1 hour's data from the vehicle is the equivalent of almost 28 years worth of data usage for the average smartphone user). Given the scaling challenge, industry participants have envisioned gradual rollouts for autonomous driving in defined and specific "geofenced" areas that are covered by scanning vehicles on a regular basis (Google is doing this in Mountain View, CA and Austin, TX). Mobileye has announced an innovative approach that involves a combination of sparse 3D data collection (their vision system has over 99.9% accuracy at identifying visual landmarks) combined with detailed 2D maps, which could effectively circumvent the need for detailed 3D, while still providing localization within 10cm. And they believe that their data gathering approach has the benefit of scalability (less than 10 kb/km will be required), which will allow for crowd-sourcing of map data. If Mobileye is correct, their approach lead to Autonomous Driving without significant geographic limitations.

The Sensors

Vision

Benefits – For much of the past decade, most Automakers and Suppliers believed that radar would serve as the core sensor for active safety. Only recently has machine vision advanced to the point that computer algorithms are viewed as highly reliable for interpreting the visual world (i.e. object recognition, distance measurement, trajectory estimation, identifying road boundaries, etc.). With these advances, a consensus has grown around vision serving as the best "general sensor" to serve as the basis for a variety of safety functions (i.e. Autonomous Emergency Braking, Pedestrian Recognition, Traffic Sign Detection, Lane Departure Warning, Adaptive Cruise Control, Lane Keeping Assist, Intelligent High Beam Control, etc). Vision continues to advance. And it is expected to serve at the core of future Autonomous Driving systems.

Challenges – The key deficiency for vision is that it suffers at the same time that human vision is also impaired. Examples include inclement weather, direct sunlight, and extreme darkness. Automakers often include other sensor modalities (i.e. typically radar) to offset these deficiencies, provide redundancy, as well as increased accuracy

Radar

Benefits – Radar calculates distance by comparing microwaves of emitted and reflected signals. As a secondary sensor, radar appears to be the most affordable option ($100 per vehicle). Radar is unaffected by poor visibility, which would appear to be very complimentary to vision.

Challenges – Radar can't see lanes signs or traffic lights. And radar has difficulty with non-metallic, stationary, or laterally approaching objects.

Lidar

Benefits – Lidar measures distance accurately by illuminating an object with laser and analyzing the reflected light. It creates a depth map over large field of view.

Challenges – The breadth and resolution of data from lidar is less than vision, so it is typically used as a secondary sensor. In the application as a secondary sensor, Lidar is currently more expensive than radar. It also faces many of the same challenges as vision, so it cannot always offer optimal redundancy. Packaging is also a concern.

Among others, radar market leader Infineon, NXP Semiconductor, and STMicro are strongly positioned here.

Vehicle to Vehicle, Vehicle to Infrastructure

Benefits – V2V involves the installation of DSRC (dedicated short range communications) radio transponders which will send basic vehicle telemetry information including location, direction of travel, speed, turning/yaw, and application of brakes. This data will be sent to surrounding vehicles that are within 1000 feet of one another. Once deployed, this technology will be used to prevent crashes in many instances that may not necessarily be prevented by onboard vehicle sensors. For example, it can warn drivers not to turn left in front of opposing vehicle traffic or not enter intersections due to a high probability of colliding with another vehicle. Unlike onboard sensor based ADAS technology, V2V should work even when the threat is not visible (because opposing traffic is blocked by buildings, blind curves, etc.).

NHTSA estimates that two features alone—Intersection Movement Assist and Left Turn Assist—could prevent up to 592,000 crashes and save 1,083 lives per year. It is also believed that this technology will be fused with onboard Autonomous Emergency Braking Dynamic Braking Support systems, and these will serve as important building blocks for Autonomous Driving.

NHTSA views V2V technology as an area that will require rule-making and changes to the FMVSS. The system will cost roughly $220 to the OEM ($130 for DSRC transmitters, $10 for the antenna, $20 for onboard GPS, and $50-$60 for wiring, changes to the vehicle HMI, and control units). NHTSA issued an Advanced Notice of Proposed Rulemaking (NPRM) in 2015, and they are currently soliciting feedback from affected stakeholders. They intend to promulgate rules requiring a phase-in of V2V in 2016, and are targeting full implementation in all new vehicles produced starting in 2020.

Challenges – The largest challenge for vehicle to vehicle communication is the fact that most vehicles do not have V2V capability (very few vehicles to "talk to" during the initial years of implementation). The cost of implementation (more specifically who will bare this cost) of vehicle to infrastructure is another significant challenge. Many researchers are working to achieve full automation without the use of V2X.

On the whole, more electronics and more data necessitate additional, faster networking to ensure coordinated operation of automobiles. A multitude of standards exists to accomplish this, but cost-effectiveness and rapidity in execution are paramount considerations. Intersil, Maxim Integrated, and NXP Semiconductor among others stand as semiconductor firms with networking exposure.

Processors and microcontrollers

Autos' increase in computing intensity by definition necessitates processors of some sort, be them centralized processing units (CPU/GPU), application processors (AP) with a graphics-heavy focuses for a central sensor fusion box or the infotainment system, or multiple microcontrollers (MCUs). The latter is no longer used solely for control over an automobile's engine, anti-lock brakes, cruise control, and other relatively simple functions: high-end fully Auto-qualified MCUs also play a central role as ADAS fallback options, ensuring fail-proof systems even if other components (temporarily) stop working. Thus far, automotive processors have served mainly for infotainment (e.g., graphics interfaces, 3D navigation); however, the technology appears poised to advance to autonomous controls, allowing for automobiles to detect, analyze, and accommodate their surroundings. Such situational awareness requires processors to integrate various data (from cameras, navigation sources, etc) and calculate optimal driving paths. Infineon (on high-end MCUs), Intel, NVIDIA, NXP Semiconductor, Qualcomm, STMicro, and Texas Instruments stand as the primary semiconductor companies exposed here.

Power management

Greater electronic content implies greater battery power consumption, increasing the importance of power management analog content. IGBTs and MOSFETs for energy conversion and inversion as well as highly integrated (to reduce technical parts numbers and system complexity) power management integrated circuits (PMICs) serve to maintain the reliability of autonomous cars' functions, powering cars' processing, sensing, actuation, memory, and digital networking functions. A long list of companies focus on this area, including (but not limited to) Infineon, Intersil, Maxim Integrated, STMicro, and Texas Instruments.

Mobileye

Mobileye has emerged as the market leader in the development of complex algorithms and proprietary chip designs used to interpret the visual world; a capability that is playing a critical role in the burgeoning market for "Active Safety" features such as Autonomous Emergency Braking and Lane Departure Warning. And we believe that the company's vision software will ultimately play a key role in enabling autonomous driving capability.

The "Active Safety" theme started gaining prominence in the late 1990's. Bosch, Continental, Autoliv, TRW, Delphi, Denso, and others developed or acquired radar technologies that they adapted for automotive applications (i.e. the goal was to identify dangerous convergence with other vehicles, pedestrians, etc. in blind spots or directly ahead). The first vehicles to feature Forward Collision Warning and Autonomous Emergency Braking primarily utilized radar to identify potential threats. And until relatively recently, the global auto supplier/automaker market was somewhat skeptical that a vision based system would be able to identify hazards as accurately as conventional technologies such as radars and lidars. However, vision tech has clearly advanced to the point that vision is now expected to be the primary sensor, given its cost and wealth of information these sensors provide. The majority of Automakers have either begun to or will soon begin to migrate to more sophisticated vision based systems for their ADAS systems.

We believe that Mobileye is positioned as an industry leader in vision technology. Through partnerships with Delphi, ZF TRW, Magna, Mando, and others, Mobileye's software and computing hardware is being deployed in the majority of vision based active safety systems on the market today (they will be on 273 different models from 25 OEMs this year). And based on contract awards, we expect the company to maintain its leadership for years to come. Mobileye recently estimated that they will reach $1.1 bn revenue by 2019 (implies a 46% revenue CAGR). Based on an ASP of ~$50, this would imply installations on ~20 million vehicles in that year. If our penetration assumptions are correct (we assume active safety will achieve a 34% global penetration rate in this timeframe), we estimate that Mobileye's market share will be approaching 60% in this timeframe. And we believe that Mobileye will have significant runway ahead of them as Automakers adopt this technology for the majority of their new models.

Figure 23: Deutsche Bank's Global FCAM Penetration Assumptions. We'd note that these assumptions are likely conservative. 20 Automakers recently announced that they will add AEB as a standard feature in their vehicles by 2021.

	2015	2016E	2017E	2018E	2019E	2020E	2025E
European Production (Source IHS, in 000s)	20,424	20,989	21,749	22,510	22,888	23,018	24,256
Penetration %	26.0%	37.0%	49.0%	58.0%	69.0%	79.0%	100.0%
North American Production (Source IHS, in 000s)	17,185	17,484	18,156	18,290	18,407	18,427	19,201
Penetration %	7.0%	10.0%	18.0%	29.0%	42.0%	54.0%	100.0%
Japan Sales (Source DB, in 000s)	5,200	5,252	5,305	5,358	5,411	5,465	5,744
Penetration %	16.0%	18.0%	26.0%	38.0%	50.0%	62.0%	100.0%
ROW Production (Source IHS, in 000s)	47,912	50,116	52,598	54,316	55,976	57,420	65,752
Penetration %	2%	3%	4%	9%	16%	21%	46%
Global Automotive Production (Source IHS, in 000s)	90,721	93,840	97,807	100,473	102,682	104,329	114,954
Global Forward Crash Avoidance and Mitigation Systems (I	9.1%	12.6%	18.0%	25.0%	34.1%	42.0%	69.4%
FCAM Volume	8,220	11,837	17,562	25,074	34,963	43,778	79,725

Source: Deutsche Bank, IHS, DB, Industry Experts

At a high level, the growth in Active Safety is being promoted through changes to New Car Assessment Programs (NCAPs), in which Regulators test vehicles for safety performance, and then publicize their findings through "Star Ratings". Regulators are well aware that Consumers and Automakers both place a high priority on Safety—97% of the U.S. vehicles achieve 4 or 5 stars and 90% of European vehicles are assessed at this level. Consequently, regulators have found that they can push high levels of adoption for advanced safety technologies simply through adjustments to these ratings. Globally, we estimate that AEB was ~9% penetrated across the Auto Industry in 2015. Based on our assumptions for global adoption, we project that global penetration of AEB will be over 40% by 2020 and just under 70% by 2025.

Figure 24: Global Vision ADAS Awards

Global Vision ADAS Awards											
US OEMs	LTM Vol	Market Share	Inknown Timin	2008	2009	2010	2011	2012	2013	2014	2015
FCA	4,560,886	5.16%		Bosch			MBLY	MBLY	MBLY		MBLY
Ford	6,023,379	6.82%		Conti	MBLY				MBLY		
					MBLY						
GM	9,448,611	10.70%	Conti	MBLY		MBLY		MBLY	MBLY	MBLY	MBLY
Cadillac	263,793					MBLY					
						MBLY					
Tesla	42,999	0.05%							MBLY		
EU OEMs											
BMW	2,156,391	2.44%		MBLY	MBLY	MBLY	Conti				MBLY
Daimler	2,165,799	2.45%				Kostal		Conti			Conti/ALV
						Conti					
PSA	3,207,323	3.63%		MBLY				MLBY		MBLY	
Renault	2,840,071	3.21%			Valeo			MBLY			MBLY
VW	9,596,188	10.86%	Conti		Bosch	MBLY (Audi)					MBLY
Audi	1,738,406		Conti								MBLY
Geely	1,013,749	1.15%		MBLY	MBLY	MBLY					ALV/MBLY
Volvo	489,543										
Tata	766,000	0.87%									
Jag/LR	455,313						MBLY		Bosch		
Japanese OEMs											
Honda	4,488,121	5.08%					MBLY		Bosch		
Nissan	4,894,894	5.54%			Valeo			MBLY			MBLY
Toyota	8,897,903	10.07%							Conti		
Mazda	1,376,178	1.56%	Conti							MBLY	
Mitsubishi	920,758	1.04%						MBLY			
Subaru	933,299	1.06%									
Suzuki	2,679,219	3.03%									
Korean OEMs											
Hyundai/Kia	6,876,795	7.78%			MBLY	MBLY	MBLY	MBLY	MBLY		MBLY
					Conti/Mob	Conti/Mob		Mobis	MBLY		

Source: Deutsche Bank, Industry Experts

We believe that Mobileye's success is primarily driven by the strength of their technology. The first suppliers that focused on developing their own competing vision technology directed their R&D towards an approach known as "Stereo Vision"; a system that utilizes the "parallax effect" of two individual cameras to produce a "depth map" with estimated distances to various objects. However, a key disadvantage of stereo is that the parallax effect decreases as objects move further away (with greater distance, the angle from each camera to the target becomes less acute). Consequently, the accuracy of stereo vision systems decline significantly with distance (increasing distance by 2x results in 4x the error). At the same time, Mobileye's scientists and engineers took a different track, pursuing algorithms that can be applied to the video image produced by a single camera, to achieve even greater accuracy, functionality, and lower cost. Mobileye is currently in the lead with mono-vision technology. And based on discussions with OEM's, Tier 1 Suppliers, Mobileye's Competitors, and Consultants, we've come to the conclusion that investors generally underestimate the challenges involved in achieving Mobileye's performance levels.

There is no question that Mobileye's competitors are expending massive resources to "catch up" to Mobileye. Consequently, it is critically important for Mobileye to remain at the leading edge of capability and performance.

Particularly as Automakers are aggressively moving to develop their ADAS platforms into fully autonomous driving capability. Examples in which Mobileye is pushing the leading edge of technology include the development of vision based algorithms for adaptive cruise control (no other supplier has achieved this), and the introduction of semantic path planning (used in Tesla's Autopilot system). More recently, Mobileye announced a proprietary road mapping technology that many automakers believe will serve as a key enabler for autonomous driving.

Mobileye's road mapping system, called REM (Road Experience Management), represents one of the most impressive examples in which this company is creatively leveraging their capabilities (including 99.99% accuracy in object recognition) into a critical offering that should allow them to sustain high market share (with high barriers to switching for customers) and increasing value over time. Mobileye's innovation involves a novel approach to mapping that utilizes the company's proprietary algorithms and 99.99% accuracy in object recognition to accurately identify specific landmarks, and record them in a master "Road Book" database.

As noted earlier in this report, Mapping is considered one of the 3 critical enablers (along with sensors and artificial intelligence) for fully autonomous vehicles. Most engineers developing autonomous driving believe that detailed 3D maps will be key, as the 3D maps will provide 3 important functions: 1) Accurate localization (for the on-board computer to know exactly where the vehicle is), 2) Path planning, and; 3) Redundancy for vehicle sensors (can compare what the sensors see vs. what was expected). The importance of mapping data was in some ways underscored by the $4bn spent by Daimler, Volkswagen, and BMW to acquire Nokia's HERE business in 2015. The challenge with mapping is scaling the collection process. 3D map data for 4 million miles of U.S. roads does not currently exist (and we'd further note that ~30% of these roads are unpaved). Moreover, there is no mechanism currently available to regularly update these maps real time. Ford recently put out a press release indicating that they have developed a LIDAR based mapping system that collects 2.8 million laser points per second. The resulting data stream is 600 gigabytes per hour. 1 hour's data from the vehicle is the equivalent of almost 28 years worth of data usage for the average smart phone user. Given the scaling challenge, industry participants have envisioned gradual rollouts for autonomous driving in defined and specific "geofenced" areas that are covered by scanning vehicles on a regular basis (Google is doing this in Mountain View, CA and Austin, TX).

Mobileye's approach involves a combination of sparse 3D data collection (their vision system has over 99.9% accuracy at identifying visual landmarks) combined with detailed 2D maps, which could effectively circumvent the need for detailed 3D, while still providing localization within 10cm. And they believe that their data gathering approach has the benefit of scalability (less than 10 kb/km will be required), which will allow for crowd-sourcing of map data. If Mobileye is correct, their approach will lead to Autonomous Driving without significant geographic limitations. Moreover, this sparse data can be easily collected and transmitted with minimal bandwidth (10kb/km). The relatively simplicity and scalability of MBLY's approach is underscored by the fact that GM expects to begin crowd sourcing map data from MBLY/On Star connected vehicles later this year, and they believe that useable localization/planning maps will be ready for use within 12-months. This could circumvent the challenges involved in assembling and updating detailed 3D maps.

There are several aspects of this development that we find compelling: 1) This approach appears to be interesting from an OEM's perspective because it could allow them to take advantage of their scale (i.e. incumbent OEMs appears to have an advantage vs. tech companies). Even with hundreds of vehicles creating detailed 3D maps, the likes of Google, Here, or TomTom may not be able to compete with crowd-sourced maps generated via millions of roaming GM vehicles; 2) This approach can be used to accelerate the deployment of Autonomous driving very broadly (i.e. outside of specific geofenced areas), and; 3) From the perspective of a Mobileye investor we believe that this approach could help perpetuate a competitive moat and significant barriers to switching. Mobileye's partners would likely need to incorporate Mobileye's algorithms into their vehicles to take maximum advantage of the sparse 3D data. Even if Mobileye's competitors were to circumvent patents on the company's 2D/sparse 3D approach, we believe that it would be challenging for other systems to make use of the data. Moreover, the "Road Book" data is expected to be co-owned (i.e. the GM-MBLY data will be co-owned by GM and MBLY). Sharing of this data with a third party (i.e. another auto supplier) would be viewed as a commercial transaction in which case Mobileye would be compensated.

Mobileye recently estimated that they should reach $1.1 bn revenue by 2019. We believe that this corresponds with EPS in the $2.30 range. At 20-30x this estimate, Mobileye's shares should reach $46-$69 by late 2018. Our $72 target for Mobileye reflects 30x our 2020 estimate ($3.20), discounted to YE2016. Downside considerations are related to potential for others to develop more competitive systems, which could affect share and/or pricing.

Delphi

Delphi's Active Safety business accounted for ~$245 MM of the company's $2.7 bn Electronics and Safety division (~20% of Delphi's revenue) in 2015. Within this business, the company provides technology and expertise in radar, lidar, vision (through a partnership with Mobileye), sensor fusion, and system integration. Major Automakers that appear to have preference for Delphi's Active Safety technologies include Ford, Renault, Audi, and Volvo. Based on contract awards, Delphi believes that they will be the second largest player, with ~15% market share in the Active Safety market by 2017.

While the active safety business itself is still relatively small, it is growing at 50% per year, which makes this business material to the company's overall organic growth rate (We estimate that Active Safety will accrue 450 bps to Delphi's Electronics and Safety division growth rate and 80bps to Delphi's overall 8-10% organic growth rate in 2016), and the growth contribution will increase as this business accounts for a growing proportion of the company's overall sales. Ultimately, we see active safety as developing into a very significant contributor to Delphi's revenue. The average AEB equipped vehicle may contain $300 of Delphi content; the average semi-autonomous vehicle may contain $1000 of Delphi content; the average fully autonomous vehicle may contain $2000-$2500 of Delphi content. Moreover, we believe that that growth in Active Safety will contribute to accelerated growth for other parts of Delphi's business, including increased connectivity (Delphi believes basic embedded connectivity is going to be on more than 50% of vehicles produced by 2020), more advanced human-machine interfaces, multi-domain controllers (a single computer that controls multiple functions within the vehicle), more sophisticated electronic architectures (Delphi's Electrical Architecture division, which accounts for 54% of the company's sales, is involved in networking the computers and sensors that are proliferating within the vehicle), and more advanced powertrain technologies such as electrification (increasing miles driven by each vehicle will result in faster paybacks for powertrain technologies that involve upfront costs, but provide significant paybacks through increased efficiency over time). Micro hybrids contain 4x the average content per vehicle for Delphi's Electrical Architecture division (which accounts for 50% of Delphi's revenue). Fully electric vehicles contain 8x the average Electrical Architecture content.

Delphi's advantages in the burgeoning market for Active Safety include:

- Delphi is one of only a few companies that has engineering depth through the entire vehicle—Powertrains, Electrical/Electronic Architectures, Advanced Safety Electronics/Sensors, Connectivity, and Software. Delphi has predicted that given increasingly complex electronic architectures (50-80 computers are typical in luxury cars), and increased interest in over-the-air upgradeability, automakers will require complete system knowhow. Over time, increased complexity is also likely to drive increased interest in multi-domain control. The significance for Delphi is that there are fewer suppliers which have capability to offer this (i.e. companies specializing in infotainment may not be able to compete in this arena).
- A number of the Delphi's sensor technologies are viewed as state of the art. These include the company's 77 GHz radars, and their RaCam system that integrates radars and cameras into a relatively small and cost effective module.
- Delphi has a long-standing relationship with Mobileye, which provides them with industry leading vision technology.
- The company has also invested in development of their own autonomous driving algorithms (expanded through their recent acquisition of Ottomatika).

We continue to view DLPH's valuation as compelling at 16.8x our 2016 and 14.5x our 2017 estimates. Based on Delphi's exposure to secular growth opportunities, we project 8-10% annual top line growth and 13-15% EBIT growth. Combined with deployment of free cash flow towards dividends and share repurchases (6% free cash flow yield), Delphi shareholders may be able to achieve 19%+ returns even before multiple expansion. Our DCF derived target is $103. This target also calibrates to a 14.5x 2017 PE multiple. Downside risks are predicated on the achievement of Delphi's growth forecasts, which are partly dependent on macro developments.

Autoliv

Autoliv has built a sizeable business in vehicle safety technologies. They currently have ~40% market share in the global airbag market, and 41% of the global market for seatbelts. In recent years Autoliv has also increased their focus on the burgeoning market for Active Safety technologies, as they believe that this business will sustain very strong growth even as the passive safety business begins to mature. Much of Autoliv's Active Safety business has been built through acquisition. They acquired night vision technology from FLIR's

Indigo division in 2002. Autoliv acquired a very strong portfolio of radar technologies from Tyco in 2008. They acquired other capabilities in vision algorithms through the acquisition Hella's vision assets in 2011. They acquired brake control systems from Nissin Kogyo in 2015. And they acquired the Automotive Solutions business of Macom (includes a number of Automotive ADAS technologies, GPS modules, Electronic Horizon) in 2015.

As of 2015 Autoliv's Active Safety business accounted for approximately $500 MM revenue—largely derived from radar (radar accounts for the majority of the $500 MM revenue), augmented night vision, brake control systems, and a vision AEB contract with BMW (these contracts were awarded to Autoliv using Mobileye technology in 2008, 2009 and 2010). ALV's management views vision is a core technology for future active safety and autonomous driving, and they acknowledged that their own proprietary vision algorithms required significant development to become competitive with industry leaders, including Mobileye, Continental, and Bosch (Rising R&D has resulted in notable pressure on margins since 2010). Autoliv and Mobileye parted ways as it became clear that Autoliv intended to develop their own proprietary vision algorithms, and the company's market position in Active Safety/Autonomous Driving has not been entirely clear. But Autoliv believes that they are catching up. Later this year (2016) they will launch their own proprietary Mono and Stereo based vision systems on the new Mercedes E Class. Autoliv hopes that by showcasing their technology with Mercedes, opportunities with other OEMs will materialize. At a high level, this appears to be happening. Autoliv expect to achieve 20-25% annual growth in their Active Safety business going forward. And they believe that this business will double (to $1 bn annual revenue) by 2019. Growth drivers Include:

- Radar: ALV's competitive positioning appears to be strongest in radar (ALV's radar products are on >80 vehicles). Applications for ALV's systems include blind spot detection and radar fusion with vision for Autonomous Emergency Braking. The company's wide band radar (77 GHz) is significantly more advanced than traditional radar, and it is capable of localizing targets to within 18mm.
- Vision: Autoliv remains confident in the increasing competitiveness of their own stereo and mono vision offerings. Their first proprietary Stereo and Mono systems will launch with Mercedes on the E Class in 2016. The mono system will be relatively simple (used for lane departure warning and not autonomous emergency braking). But Autoliv expects to launch a more sophisticated mono system (offering AEB and pedestrian detection) in 2017.
- Autonomous Driving: Autoliv disclosed that they are working with two OEMs (one of them appears to be Volvo) in applying their stereo vision technologies for Autonomous Driving.
- The company also believes that they participated in 80% of the FCAM (Forward Crash Avoidance and Mitigation) contracts in 2015 (with around 10 OEMs) and that they have won 30% of these contracts over the last 12 months. Autoliv did not disclose details on the nature of these contract awards (i.e. whether they were for radar, vision, or other controls).

While Active safety represented less than 5.5% of Autoliv's revenue in 2015, the company's strong growth in this area nonetheless produces measurable organic growth (Active Safety will likely contribute to 110-140 bps of ALV's 5%

organic growth this year; total company organic growth is projected in the 7% range over the mid-term). Our DCF derived price target ($102) corresponds with a 14x 2017 PE multiple. Upside/downside risk to this target is highly dependent on Autoliv's ability to gain additional traction with their active safety technologies. The company has expended significant resources in building capabilities in this area (EBIT has been relatively flat between 2010 and 2016 despite a $2.7 bn increase in revenue, in part due to significantly higher R&D and footprint costs). We are seeking additional evidence of returns on this investment.

Continental

Continental is well positioned to benefit from growth of ADAS products on multiple fronts. The company not only acts as a Tier 1 system supplier but also recently expanded its own algorithm know-how via the acquisition of Elektrobit. On the hardware side, Continental supplies vision systems with mono as well as stereo and surround view cameras, short and long range radar, flash lidar (3D flash lidar from 2019 onwards) and sensors. With the e-horizon system the company also aims to participate in mapping/ connectivity. Continental supplies almost all OEMs globally with ADAS components as displayed below (Gen 1 is running out this year):

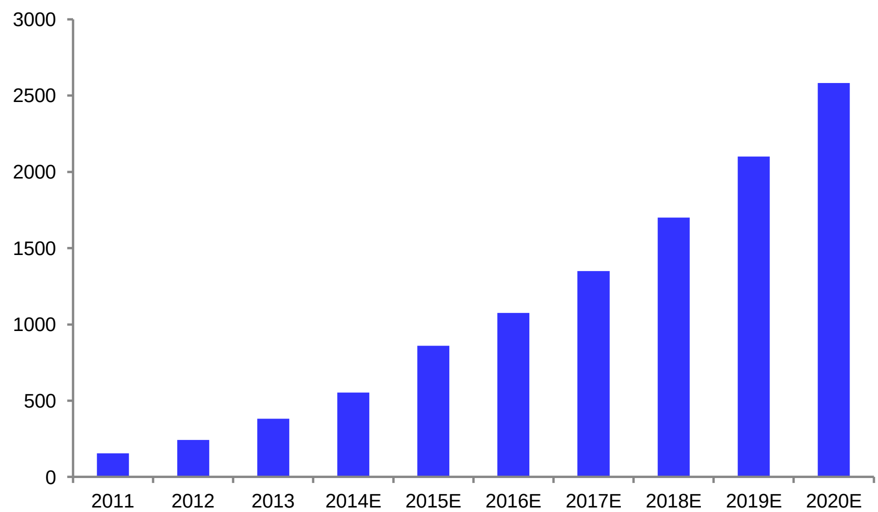
Figure 25: ADAS by Customer and Supplier

OEM	Radar	Camera	Lidar	ECU[1]
Audi		Mono (Gen 1)		
BMW	LRR	Stereo		
Chrysler	SRR			
Daimler	LRR	Mono / Stereo		X
Daimler Truck	LRR	Mono		X
Fiat	SRR		SRL	
Ford	SRR	Mono	SRL	
Geely/ Volvo			SRL	
GM	LRR	Mono		X
Honda			SRL	
Hyundai		Mono		
Mazda	SRR	Mono	SRL	
Mitsubishi	LRR		SRL	
PSA			SRL	
Renault/ Nissan	LRR / SRR			
Subaru	SRR			
Suzuki			SRL	
Toyota	SRR	Mono (MFL = SRLCam)	SRL (MFL = SRLCam)	
Volkswagen		Mono (Gen 1)	SRL	
Volvo Truck	LRR / SRR	Mono		X

Source: Deutsche Bank, Company Data, Industry Experts

During 2015, Continental generated €850m revenues from ADAS products and they aim for >€1.5bn by 2018. By 2020, technologies related to autonomous driving (incl. V2x, road databases, etc) should account for €3bn. By our calculations, this would add 1-2% to automotive revenue or close to 1/4 of the total automotive revenue growth through 2020 (assuming content reaches €30bn by then). By 2020, ADAS could contribute close to 10% of automotive revenues, up from 4% this year. In terms of profit, ADAS was break-even last year, and it is predicted to achieve a 10% margin by 2018. The revenue split is expected to remain broadly unchanged from last year with about 1/3 each coming from Europe, North America and Japan while China is only expected to contribute 9% by 2018 from 7% last year. Continental believes that ultimately every vehicle will require a system of 1 SRR, 1 LRR, 4 flash lidar, one camera and a surround view system.

Figure 26: Revenues with ADAS products



Source: Deutsche Bank, Continental

Summary of our Continental thesis:

Our Buy case on Continental is based on our view that Continental should benefit from ongoing growth in both of its divisions. The Automotive group should benefit from leverage to key industry trends such as emission reduction, safety, infotainment and ADAS, as discussed above. This should result in an increased content per vehicle in the coming years. At the same time, the Rubber group is expected to remain a significant cash flow and earnings pillar with structural competitive advantages. We forecast that the tire business to still be supported by a small raw material tailwind and market growth this year, while Contitech should improve from low levels. Key risks: worsening volume environment, especially in Europe given Continental's regional exposure, and higher operational gearing. Additionally, a weaker tire demand and pricing also present risks.

Bosch

Bosch is a €71bn revenue company, of which about €42bn was generated from Automotive in 2015. The company is geared to almost every trend in automotive and thus also offers a broad range of technologies for assisted and automated driving.

Products include radars (long and mid range), cameras (multipurpose, stereo, near range) and several sensors that support advanced driver assistance functions. Bosch currently employs about 2500 engineers that are working to further develop assistance systems and automated driving functions (up from 700 in 2013). The company has been running a trial for autonomous driving cars in Germany for several years, and is involved with several OEMs as well (Honda for example).

Bosch's Automotive divisions outpaced global car production with revenue growth of 12% in 2015, helped by FX. Revenues from ADAS products were the fastest growing sub-portfolio with driver assistance products including sensors (50m sensors delivered in 2014) growing 30%+ per year. Traditionally, Bosch was primarily focused on radar. But they now also have vision technologies in their portfolio (customers include Jaguar/Land Rover and Honda). In fact, in ADAS their radar and vision systems grew 100% for the second year in a row. In particular on the radar and sensor side Bosch has competitive advantages over its peers. For example Bosch describes itself as the global market leader for radar systems used in adaptive cruise control (ACC). In total, the company targets about €1bn for 2016 and long-term customers include Audi (e.g. radar system for A4) as well as VW (e.g. video and radar system for Tiguan). Audi also developed a stereo camera for the Land Rover that does not require a radar system for autonomous braking.

Denso

Sales in the information & safety systems field currently account for about 15% of Denso's sales. In December 2015 the company announced that sales in the segment will increase from ¥626.6bn in FY14 to ¥1trn (+60%) in 2020. It assumes CAGR of 8.1% in information & sales systems through 2020 within a corporate target of 3%. We think a higher rate is achievable, thanks partially to growth in the advanced safety systems field. Over this timeframe it will maintain an around 9% ratio of R&D expenses to sales in response to developments such as driverless cars and we assume capex and continued investment is required. Our current earnings forecasts are premised on FY3/16-FY3/18 capex of ¥995bn.

For its driver assist business, volume production of Toyota Safety Sense P has started. Using a combination of millimeter-wave radar and mono-camera, Toyota is using this system on mid-size and larger vehicles, including an enhanced version for the Lexus brand. Combined with the Safety Sense C (from Continental) Toyota aims for full availability of collision avoidance and mitigation across its line-up ranging from $300-$650. Supplying the P-package, which includes pedestrian and vehicle avoidance as well as full-speed radar range cruise control, Denso looks to benefit from this volume push. Outside of Toyota, Denso says it will promote sales in 2016 at the earliest. It expects to shift from an upfront investment phase that has weighed down earnings to an investment recoupment phase triggered by volume production going forward with a soft target of 2m systems by FY3/18.

In Japan, development of advanced safety systems has been helped by regulatory changes. In 2016, restrictions are expected to be lifted on the use of automated steering at speeds over 10km/hour (prohibited under the Convention on Road Traffic). Also, Japan is pursuing a framework aimed at commercialization of fully automated driving starting in the second half of the 2020s. Denso is leading the development of V2I and V2V communication technologies in the "Automated Driving System" program being promoted under a directive by Japan's Cabinet Office.

To advance its capabilities, Denso has been investing in software companies and overseas auto parts makers, as well as gradually strengthening its competitiveness through joint industry-university research and other initiatives in the sensor field:

- In February 2016, Denso announced a tie-up with NTT Docomo – Japan's top mobile phone service provider - aimed at developing self-driving technologies and ADAS. Denso's focus in ITS development thus far has been on road-to-vehicle and vehicle-to-vehicle communication technologies using the dedicated 760MHz band. Its ITS Connect system is installed on Toyota vehicles. However, systems that use 5G and LTE infrastructure are better suited for existing wide-area networks, with communication delays under one millisecond versus 4G systems with a 20 millisecond delay. Denso aims to construct LTE/5G-based vehicle control systems in FY16. NTT Docomo has been researching and developing vehicle communication technologies that use 5G and LTE mobile telecom systems to enable automobiles to interact with various objects. Combining their respective vehicular communications expertise will enable speedier vehicular communication. Specific uses of the technology include helping vehicles merge onto expressways and better transverse urban intersections with poor visibility.
- In December 2015, Denso announced that it would jointly develop technology with Morpho (3653.T, unrated), a company that supplies image-processing software for installation mainly in smartphones and other cameras. The acquisition is valued at about ¥1.2bn and will give Denso a 5% stake in Morpho. Research will focus on on-board applications of image-recognition technologies capable of recognizing people and objects and image-processing technologies including optical image stabilization for photos and videos. The partners will develop electronic mirrors and other products capable of replacing car door mirrors and rear-view mirrors with vehicle-mounted cameras. Denso already invested in Adasens Automotive, a German developer of image-recognition technology, in 2013. Adasens is accumulating expertise in camera-based obstacle detection.
- In March 2015, Denso began working with Tokyo University to develop new principles for sensor technologies that are aimed at applications for fully automated driverless cars. These include 1) high-precision sensors enabling specific vehicle positioning that use inertial-navigation methods without counting on global positioning systems (GPS), 2) multi-wavelength sensors that greatly enhance accuracy in peripheral recognition, and 3) image-processing methods based on

multi-wavelength imaging data. The aforementioned high-precision sensors are being developed with the aim of installing inertial-navigation systems featured on aircraft in passenger vehicles at reasonable prices. Currently, vehicles receive multiple radio waves from GPS and identify vehicle positions using principles of triangulation, but they cannot identify positions inside tunnels and in building parking lots, where radio waves cannot be received. The company has therefore pushed forward with the development of sensors based on unconventional detection principles.

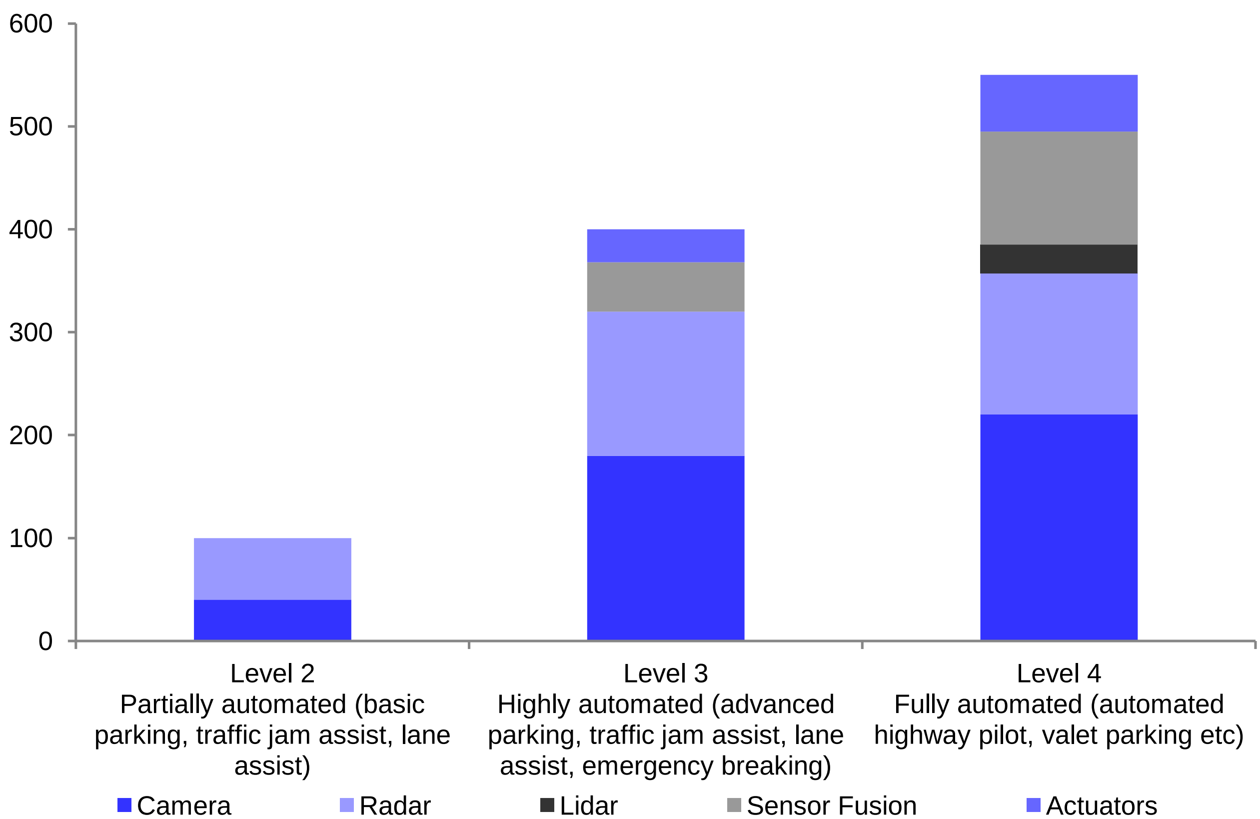
Downside risks include 1) greater exposure than peers to rapidly declining demand because of Denso's higher marginal profit rate, 2) higher recall risk due to expansion in scale and scope of business, and 3) stronger demands for cost reductions from automakers.

ADAS to drive rapid semi-conductor content growth

$600 incremental semi content per car from $350 today

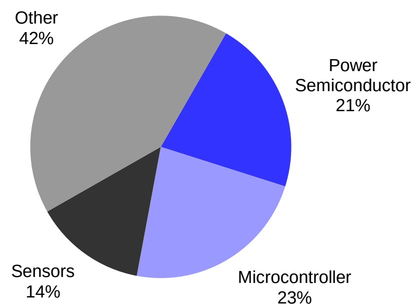
The moves to ADAS and long-term autonomous driving will substantially increase the amount of semiconductor content per car over the coming years. Current average semiconductor content per car is ~$350 according to industry sources and Deutsche Bank estimates, and we see an expansion by up to $600 ($400 from semi-autonomous or Level 3 automation, as shown in Figure 1 below) as the auto industry adopts high-end ADAS and increasingly autonomous features over time. Fully autonomous driving requires an even higher content of up to $1000 in the long-term, in our view. We note that main drivers initially should be radar sensors and video camera based systems with LIDAR sensors as well as sensor fusion box implementations and actuators coming over the next few years on the way from ADAS to fully autonomous driving.

Figure 27: Up to $600 incremental semiconductor content per car with high-end ADAS alone



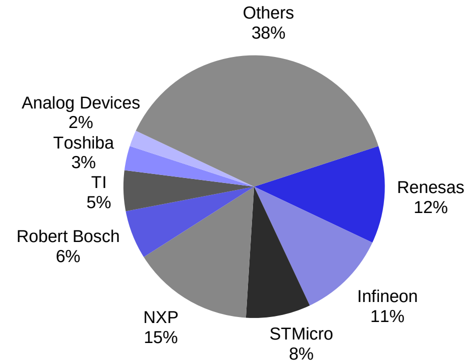
Source: Deutsche Bank, Strategy Analytics, Infineon

Figure 28: Auto semi content split of average $350 BOM



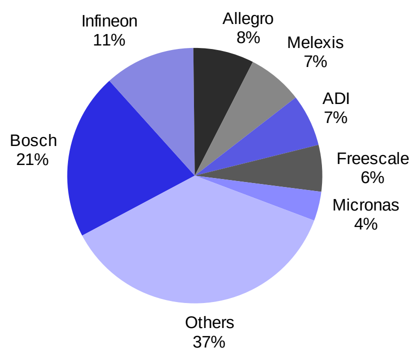
Source: Deutsche Bank, Company Data

Figure 29: Automotive semi market share globally



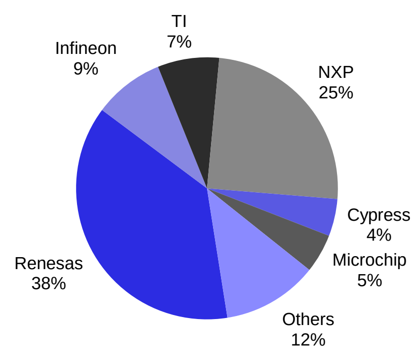
Source: Deutsche Bank, Infineon, Company data, Strategy Analytics April 2015

Figure 30: Auto sensor market share (radar, hall etc)



Source: Deutsche Bank

Figure 31: Auto microcontroller market share

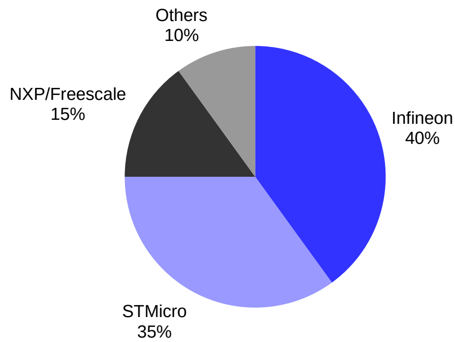


Source: Deutsche Bank

Radar Rapidly Growing Already in 2016, Video Accelerating

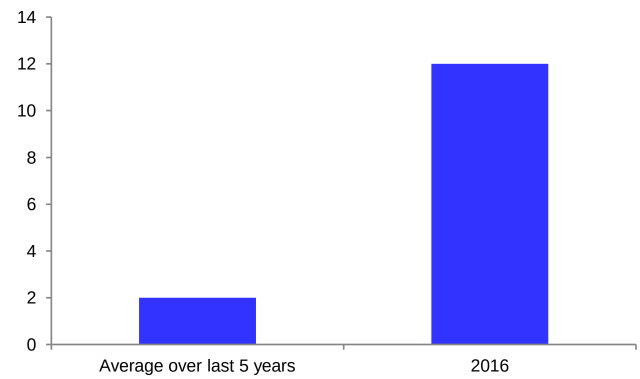
Radar is already seeing rapid growth this year with market leader Infineon (~40% share) indicating a strong acceleration in demand. The company has shipped 10m radar sensors over the last 5 years in aggregate and is now targeting 12m+ just in 2016 (revised upwards from initially planned 10m). STMicro is also strongly positioned here behind Infineon and NXP/Freescale is the number 3 in the market, all indicating increasing radar demand for ADAS applications such as automated emergency breaking, lane assist and automated parking. All three companies have offerings in the lower-end short range 24Ghz range as well as the 77Ghz range for more flexible (long and short distance) higher-end systems. However, STM is highly focused on the lower-end 24Ghz radar sensor with little share at 77Ghz where we expect more growth given applications become more sophisticated. NXP exhibited its progress in 77Ghz technology at 2016's Consumer Electronics Show, where it announced the market's smallest single-chip radar transceiver for use in ADAS-enabled cars (capable of enabling collision warning & mitigation, pedestrian/cyclist detection, blind-spot monitoring, and lane-change assistance), a technology currently being field tested by Google for its self-driving car project.

Figure 32: Infineon is the market leader in radar semis…



Source: Deutsche Bank, Infineon, IHS

Figure 33: …and seeing a rapid acceleration in demand



Source: Deutsche Bank, Infineon Shipments in million

Video Opportunity for Processors and Microcontrollers

On the video camera side, we see STMicro and Infineon well positioned. STM is doing the ASIC for Mobileye's camera system (the EyeQ4) based on its in-house FD-SOI manufacturing process. While this is good exposure with a leading player in the market, we deem ST's exposure as too small to view this as a positive given large parts of ST's Auto business (e.g. infotainment) are facing structural pressure. Infineon focuses on high-end Automotive microcontrollers. These go into camera systems by tier 1 suppliers such as Bosch, Continental and Delphi and are used in combination with a Mobileye or competing systems. Infineon's Aurix microcontroller secures fail-proof operations of the video system and is qualified to the highest Automotive security standard (automotive safety integrity level – ASIL D). These strict certifications justify prices meaningfully above 'normal' microcontrollers for less critical applications and we expect increasing video camera adoption to become a meaningful growth driver for the company's Auto business, especially as several contracts ramp here from 2017 onwards.

Beyond stand-alone MCUs, rising ADAS-related video usage in vehicles is creating opportunities for a multitude of semiconductor applications such as Intersil's video signal processing for rear-view cameras and Texas Instruments' processors with digital signal processing (DSP) capability for use in vision/radar systems for lane-departure warning, rearview and surround-view camera systems, collision warning/avoidance, and blind spot detection.

Sensor Fusion Box an Opportunity for GPU, MCU, Power

Another opportunity with the move to Level 3 ADAS/autonomous is the sensor fusion box, a central platform in the car that aggregates and processes all data from various sensors. This sensor fusion box is ultimately driving the decision-making in implementations with various different sensors such as camera, radar, LIDAR which may at times provide conflicting input. We see this as especially important for highly automated and autonomous driving. A big beneficiary here is potentially NVIDIA with its Tegra-/GPU-based solutions, along with NXP's i.MX processors and Texas Instruments' DSP-enabled processors. We also see Infineon well positioned with its high-end fail-proof

Auto microcontroller (Aurix) as well as some power semiconductor content for highly reliable energy supply of the sensor fusion box system. In addition, these systems tend to have several ASICs in addition to the main GPU which leaves potential for the likes of STM to win designs here as well.

Figure 34: Sensor fusion box an opportunity for GPU, microcontrollers, power semis

Source: Deutsche Bank, Infineon, Audi

Other Opportunities

In addition to the ones mentioned above, we see several other opportunities for ADAS content increases on the semi side. Examples include LIDAR as a third sensor (in addition to camera and radar) or actuators, a combination of sensor, microcontroller and power semi. These are for example used for automated steering correction, i.e. semi-autonomous driving. We see Infineon and Melexis as well positioned here. Internal driver monitoring cameras are also likely going to see more adoption to improve safety, an area where Infineon is gaining some momentum.

Who Does What?

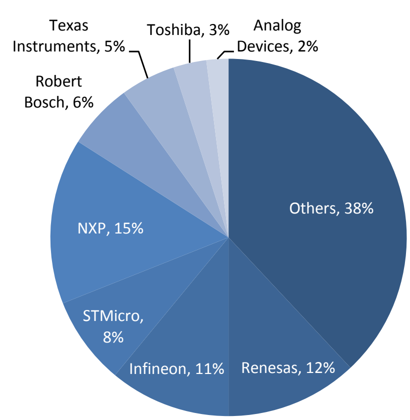
Below, we outline the main Auto semiconductor offerings of key players and highlight ADAS and autonomous driving relevant product categories.

Figure 35: End market exposure of the automotive semiconductor suppliers

Company	Major automotive semiconductor products/End market area
Infineon	Number 1 in Power semis (incl. **actuators**), also strong in **Microcontrollers** and **Sensors (e.g. radar, hall)**
STMicroelectronics	Infotainment & Connectivity, Power semis, Body, Chassis & Safety, **radar**, **ASIC for Mobileye**
NXP	Auto infotainment, In-vehicle networking, Auto access/security, **Sensors (radar, magnetic) and Microcontrollers**
Analog Devices	**ADAS**, Infotainment, Powertrain, Body and Chassis & Safety
Elmos	**Sensors** (e.g. **hall**), Motor control, Embedded systems
Melexis	**Actuators**, Analog and digital semiconductors, **Sensors** (e.g. **hall**), Smart motor drivers
Renesas	Number 1 in **Microcontrollers**, also present in powertrain, chassis & **safety**
Linear Technology	Entertainment, Hybrid/EV battery, navigation and **safety**, emission controls, parking assistance, LED lighting
Maxim	Serial Link, LED Lighting, Smart Key, Infotainment, **Sensors**, High-Integration Power, EV battery
Intersil	**Camera Video signal processing**, Power systems
Xilinx	Auto-grade programmable SoCs, FPGAs
Nvidia	Infotainment and navigation, **ADAS**, Rear seat entertainment, Digital instrument clusters
ON Semi	Powertrain, Infotainment, **ADAS, Park Assist, Image sensors**, LED Lighting
Fairchild	Engine management, Electric power steering, Discrete power products, Gate drivers, Power modules

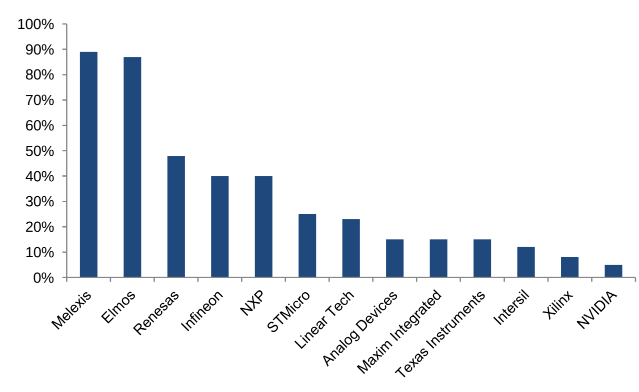
Source: Deutsche Bank, Company Data

Figure 36: Automotive semiconductor supplier share



Source: Deutsche Bank, Infineon, company data, Strategy Analytics (April 2015)

Figure 37: Automotive as % of total sales

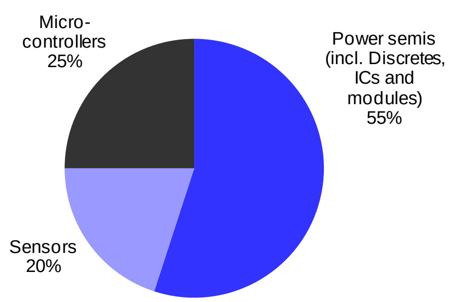


Source: Deutsche Bank, Company Estimates

Infineon (Buy) – Strong ADAS Position, Top Pick in European Semis

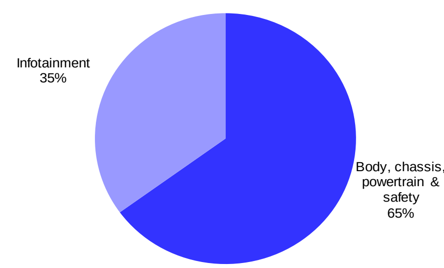
For Infineon, we see the sensor business with hall and radar sensors strongly exposed to ADAS and also view the microcontroller business as a meaningful beneficiary through video camera solutions (Mobileye and others), sensor fusion boxes (TTTech at Audi, and others) and other systems. The other half of Infineon's Auto semis business (power semiconductors) is geared into the growing EV/(P)HEV market which also enjoys strong growth. We like the company's high exposure to ADAS and power semis with no infotainment exposure, a category which should see less growth over the coming years. Infineon currently grows its Auto business 8%+ organically per year and we believe >1/4 of this growth is directly ADAS driven (largely radar for now) in 2016 and likely more going forward as further projects (e.g. camera) start contributing. The stock is our top pick in European Semis.

Figure 38: Infineon ATV revenue split by product group



Source: Deutsche Bank, Company Data

Figure 39: STMicro APG revenue split by product vertical



Source: Deutsche Bank, Company Data

Intel (Buy)

Intel leveraging PC leadership to penetrate Automotive infotainment

Intel has leveraged its leading position in PC microprocessors to provide platform solutions for automotive infotainment computing modules (including its Atom E3800 processor), software packages (for connectivity, multimedia and entertainment), middleware, and development kits), partnering with Hyundai, BMW, Infiniti, and Kia. The company has also emphasized Automotive in its R&D efforts, committing capital to advanced sensing technology, safety and efficiency, and automotive situational awareness, among other areas.

Intersil (Buy)

Intersil specializes in Automotive power mgmt and signal processing

Emphasizing Automotive as an area of strategic focus, Intersil generates ~$60m annually in Automotive revenues (~12% of sales) and provides an array of Automotive power management and mixed signal solutions. Among its product offerings, the company's analog video decoders and LCD controllers comprise one of the market's largest portfolios for automotive infotainment, and its power & analog products include battery regulators, low-voltage power management controllers, and power management integrated circuits (PMICs) & LED backlight drivers for LCD panels.

Linear Technology (Hold)

Linear more exposed to EV/HEV than ADAS

Linear generates ~20% of its ~$1.4b in revenues from Automotive and Transportation, maintaining a keen focus on the end-market through navigation/entertainment, battery management, electronic braking, power conversion, electronic steering, engine management, safety systems, and other areas. Achieving roughly +20% y/y Automotive sales growth for the past three years, the company supplies to Tier 1 Automotive OEMs in Europe, Japan, Asia, and North America. We believe Linear's power management expertise generally makes it more exposed to the electrification of auto powertrains (EV/HEV) than ADAS-enabled/autonomous cars.

Maxim Integrated (Buy)

Maxim exposed to ADAS through a broad array of power management and other solutions

Maxim Integrated focuses on power management, RF, keyless access, and high-speed serial linkage in the Automotive market, a strategy that has yielded +26% y/y growth for Maxim's Automotive business over the past 5 years (to ~$330m (15% of revenues) as of CY15). The company provides power management integrated circuits (PMICs) that execute 14 power functions per circuit and power processors from a number of suppliers (NVIDIA, Freescale/NXP, etc), a solution that reduces Automotive parts count and in turn improves autonomous vehicle reliability. Its high-speed video links (SerDes) connect multiple vehicle camera signals to a central console and allow for automation of lane positioning and collision avoidance, and its switching regulators are used for interior and exterior Automotive LED lighting applications.

NVIDIA (Hold)

NVIDIA parlaying infotainment success to broader processor leadership

NVIDIA's Automotive business has been one the fastest growing in the semiconductor sector, rising more than threefold since 2013 to over $300m (~6% of company revenue). This explosive growth has thus far stemmed from the company targeting its Tegra application processors to infotainment, instrument panel and rear-seat video applications. NVIDIA has partnered with a wide area of automakers to drive this growth, including (but not exclusive to) Audi, BMW, Mercedes-Benz, Tesla, Volvo, and other Tier 1 OEMs.

NVIDIA aims to parlay its infotainment success into enabling autonomous vehicles through January 2016 introduction of Drive PX2. This automotive supercomputing platform carries 4 processors (2 Tegra, 2 GPUs) with 12 CPU cores that can perform 24 million deep learning operations per second to analyze data from automobile cameras & LIDAR, radar, and ultrasonic sensors to calculate optimal driving paths. Volvo is NVIDIA's first customer for the PX2, with plans to have 100 SUVs outfitted with PX2 in 2017.

NXP Semiconductors (Buy)

NXP/Freescale offering turnkey in-car and V2X networking solutions

As one of the largest players in the Automotive semiconductor market, NXP Semiconductor generated $1.3b in Automotive revenues in 2015 (~20% of revenues) and advanced its end-market positioning with the acquisition of Freescale last December (bringing combined auto-related revenue to over $3b). The company offers a broad array of solutions for in-car networking and secure keyless entry, featuring applications in the steering wheel (e.g., cruise control, wiper, turning light, climate control), roof (rain sensor, light sensor, light control), engine (sensors, small motors, control panel), and door & seat (mirror switch, window lift, door lock, occupant sensors, seat control panel), all of which are supported by Freescale microcontrollers (MCUs). The company also will provide V2X ("vehicle-to-x") chipsets to Delphi Automotive beginning later this year, allowing vehicles to communicate wirelessly with each other and with traffic infrastructure, potentially reducing traffic collisions and jams. Most recently at 2016's Consumer Electronics Show, the company announced the market's smallest single-chip radar transceiver for use in ADAS-enabled cars (capable of enabling collision warning & mitigation, pedestrian/cyclist detection, blind-spot monitoring, and lane-change assistance), a technology currently being field tested by Google for its self-driving car project.

STMicro (Sell)

STM's ADAS exposure promising, but the co faces headwinds in infotainment price pressure, share loss

We also like STM's ADAS exposure through the Mobileye ASIC as well as the radar exposure. However, 1/3 of the Auto business still comes from infotainment where STM is facing price pressure and share losses, especially in the Chinese aftermarket as well as difficult momentum in Japan. This and the overall larger exposure to non-Auto compared to Infineon (75% of STM is non-Auto) make us cautious on the company despite some good ADAS-related momentum.

Texas Instruments (Hold)

Texas Instruments also offers a broad ADAS portfolio

Generating roughly $2b in Automotive revenues (~15% of total revenues), Texas Instruments offers several compelling Automotive solutions with a portfolio including ADAS and infotainment processors, safety MCUs, and general analog & connectivity products. The company's processors with digital signal processing (DSP) capability allow for use in vision/radar systems for lane-departure warning, rearview and surroundview camera systems, collision warning/avoidance, and blind spot detection. Its front ends allow for radar and LIDAR data conversion, and its FPD-Link Serializer-Deserializers (SerDes) connect Automotive cameras through thin cost-optimized cables.

Appendix 1

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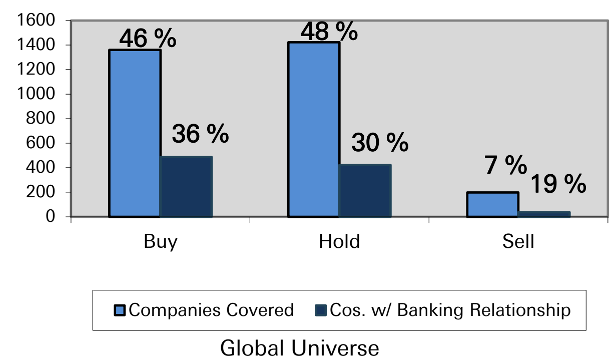

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Deutsche Bank AG
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60272 Frankfurt am Main
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Tel: (49) 69 910 00

Deutsche Bank AG
Filiale Hongkong
International Commerce Centre,
1 Austin Road West,Kowloon,
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Deutsche Securities Inc.
2-11-1 Nagatacho
Sanno Park Tower
Chiyoda-ku, Tokyo 100-6171
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Tel: (81) 3 5156 6770

Deutsche Bank AG London
1 Great Winchester Street
London EC2N 2EQ
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Tel: (44) 20 7545 8000

Deutsche Bank Securities Inc.
60 Wall Street
New York, NY 10005
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