Quantifying an uncertain future

Insurance in the new mobility ecosystem

The writing is on the wall. Technology is being developed to take humans out of the driver's seat. People are opening up to the idea of shared mobility.

What does this all mean for the auto insurance industry?

Contents

Introduction

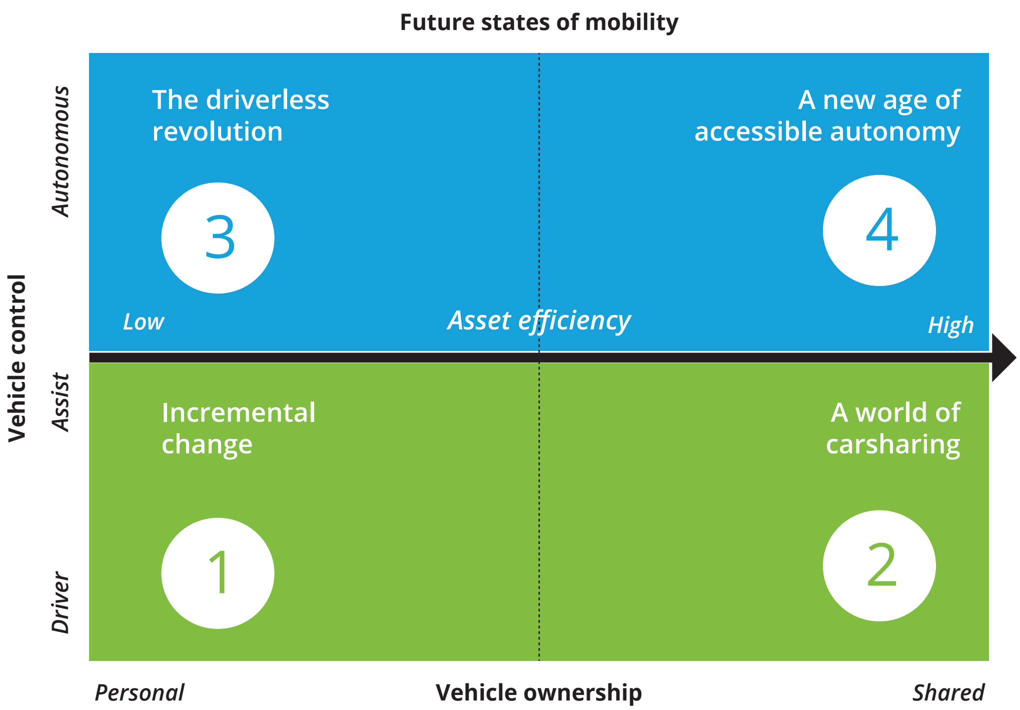
In *Insuring the future of mobility: The insurance industry's role in the evolving transportation ecosystem*, we concluded that the auto insurance industry is poised to undergo significant changes in the not-so-distant future.[1] From the customers who purchase policies to the products being underwritten, what is being insured, the channels through which products are distributed, and the types of claims that will likely emerge, change is more certain than ever. Just a few months ago, the first fatality involving Tesla's "autopilot" feature occurred,[2] which has already raised questions about who (or what) is ultimately liable: the driver, the car, or the software?

In *The future of mobility*, we presented four future states of mobility (see figure 1).[3] In future state 1, "Incremental change," vehicles remain personally owned and driver-driven, much as today. In future state 2, "A world of carsharing," driver-driven vehicles are accessed on demand, via car- and ridesharing. Future state 3, "The driverless revolution" sees the adoption of personally owned autonomous vehicles. Finally, future state 4, "A new age of accessible autonomy," envisions a world of shared self-driving vehicles. The future states will likely arise unevenly and all four are likely to exist simultaneously.

Figure 1: Four futures will coexist

Extent to which autonomous vehicle technologies become pervasive:

- Depends upon several key factors as catalysts or deterrents–e.g., technology, regulation, social acceptance
- Vehicle technologies will increasingly become "smart"; the human-machine interface shifts toward greater machine control



Extent to which vehicles are personally owned or shared:

- Depends upon personal preferences and economics
- Higher degree of shared ownership increases system-wide asset efficiency

Definition: By autonomy and autonomous vehicles (AV), we refer to stage 5 of the National Highway Traffic Safety Association (NHTSA) scale of autonomy—i.e., full self-driving automation in which the passengers are not expected to take control for the entire duration of travel.[4]

Graphic: Deloitte University Press | DUPress.com

In *Insuring the future of mobility: The insurance industry's role in the evolving transportation ecosystem*, our primary focus was future premium revenue streams. We concluded that by the year 2040:

- Total annual auto insurance premiums could decrease by up to 30 percent from current levels as a result of significant improvements in safety from autonomous vehicles;
- Personal auto premiums could see an even more significant decrease, but would likely be offset by growth in commercial auto and product liability premiums;
- And the geographic distribution of auto insurance premiums will likely shift.

These conclusions are rooted in an actuarial model that projects annual auto insurance premiums into the future. Drawing on publicly available insurance industry data, third-party projections, and our own research and informed assumptions, we quantified the changes that we believe will be realized by the auto insurance industry as a result of the four future states of mobility. This paper discusses our methodology, the results of our modeling, and the potential implications for insurers and their actuaries.

Modeling future auto insurance premiums

The goal of our model is to estimate future annual auto insurance premium need[5] of the US Property & Casualty (P&C) industry through 2040 related to the transportation of people using passenger vehicles. This can be either through personal (driving a vehicle you own) or commercial (taxi, ridesharing, carsharing, or rental car) private transportation. Our model does not consider commercial trucking or delivery services, nor does it account for the potential effects of self-insurance or alternative forms of coverage.

Our projections of premium need are rooted in the fundamental insurance equation as defined by actuarial literature.[6] This equation contains the basic building blocks that pricing actuaries across the world use.

Premium = Losses + Loss Adjustment Expenses + Underwriting Expenses + Underwriting Profit

To estimate future premiums we followed the process below:

1. **Baseline assumptions**—Estimate baseline pure premiums (the average loss per exposure unit), loss adjustment expense (LAE) ratios, underwriting expense ratios, and underwriting profit provisions.
2. **Pure premium modifiers**—Identify and quantify what will likely affect future pure premiums as advances in vehicle safety and autonomous driving technology proliferate and customer and product types change as mobility preferences transition through the four future states.
3. **Autonomous vehicle product liability**—Estimate the size of the market for the new class of coverage to insure the software and sensors enabling autonomous vehicles.
4. **Future premium through 2040**—Multiply modified pure premiums by estimated miles driven in each future state; apply LAE, underwriting expense, and underwriting profit percentages; and add the autonomous vehicle product liability load to arrive at future premium by each future state.

Exposure base:
Miles driven vs. number of vehicles

Today, the most common exposure base used in auto insurance ratemaking is number of earned vehicle years. However, our model is built using an underlying exposure base of expected miles driven. This facilitates a direct link to our previously published paper, *Gearing for change: Preparing for transformation in the automotive ecosystem*, in which a key output was expected annual miles driven in each future state. But using miles driven can offer other advantages as well:

- Miles driven is generally a closer proxy to the risk of loss.
- We anticipate significant shifts in the way people will use vehicles as we progress through each future state. Consequently, a vehicle year in 2040 likely will not be equivalent to a vehicle year today, while a mile driven in 2040 should have more equivalency to a mile driven today.
- With advances in vehicle connectivity and the push for usage-based insurance, it is conceivable that the industry could move away from vehicle years toward either miles driven or driver-based exposure.

1. **Baseline assumptions**
   We developed baseline loss, LAE, and underwriting expense assumptions by examining publicly available insurance industry annual statement data. We developed separate assumptions for private passenger auto liability and auto physical damage using NAIC annual statement data. Additionally, we split auto physical damage into collision and comprehensive components. This was an important step because of the specific impact the future of mobility will have on each loss type.

   We decomposed the average losses per exposure (pure premiums) into their corresponding frequency and severity components. We reviewed historical claim count and loss activity as presented in the combined US P&C industry Schedule P[7] and developed baseline frequency and severity assumptions. Our exposure base, miles driven by each future state, was derived through a modeling exercise described in *Gearing for change: Preparing for transformation in the automotive ecosystem.*[8]

   Next, LAE and underwriting expense ratios were developed. LAE ratios were again developed by reviewing historical LAE ratios from the combined US P&C industry Schedule P.[9] Underwriting expense percentages were similarly developed by reviewing historical ratios obtained from the Insurance Expense Exhibit.[10] Each expense category was reviewed separately: general, commissions and brokerage, other acquisition, and taxes/licenses/fees.

   To round out the fundamental insurance equation, we researched publicly available rate filings to establish an underwriting profit provision for liability and physical damage components.

2. **Pure premium modifiers**
   We performed extensive research in an attempt to identify and quantify the forces that might affect insurance premiums in the future. With losses being the most significant component of premium (Schedule P confirms that losses account for more than 60 percent of premiums collected),[11] we focused on understanding the forces that could influence the frequency and severity of losses over time. From this research, we developed multiplicative frequency and severity modifiers unique to each future state that allowed us quantify these changes. Table 1 and Table 2 on the next page discuss these modifiers in detail.

3. **Autonomous vehicle product liability**
   Modeling product liability associated with autonomous vehicles presented a challenge, primarily because there is little historical data to develop modeling assumptions. As a result, we view this coverage in two components.

   First, there is the risk that an autonomous vehicle gets into an accident as a result of an unforeseen or random event, similar to a car accident today. For this risk, we used our previously discussed modified pure premium methodology, with the estimated premium a function of the expected miles driven in future states 3 and 4. Second, there is a new type of risk that autonomous vehicles will potentially face, encompassing catastrophic systems malfunction across many vehicles, malicious hacks of autonomous driving systems resulting in vehicle damage or passenger injuries, and leaks of personal information linked to autonomous vehicles. We believe this type of risk is most closely related to the cyber liability coverage of today. After reviewing industry publications and data from recent major cyber breaches,[17] we estimated an amount to represent the per vehicle cost associated with a major breach. This was an important consideration, because this type of risk is not represented in the historical loss data we reviewed.

4. **Future premium through 2040**
   Aggregating all of these moving parts, we developed modified pure premiums unique to each future state. Multiplying these pure premiums by the miles driven for each future state, applying expense and profit percentages, and adding the autonomous vehicle product liability load yields an estimate of annual premium for each future state. Summing up the annual premium across each future state yields our estimates of total annual premium through the year 2040.

   Like any forward-looking estimate, our findings are subject to significant uncertainty and they are dependent on a number of judgmental assumptions. That said, we believe our approach provides a solid foundation for thinking about the speed and magnitude of the changes coming to the auto insurance industry over the next 25 years.

The NHTSA cites that approximately 94 percent of accidents are caused by human error.

Table 1 – Frequency modifiers

Modifier	Discussion
Fraud reduction	The Insurance Research Council has estimated that 13-17 percent of auto insurance claim payments are excessive or fraudulent.[12] As vehicles become more technologically advanced and connected, more data will be available to claim adjusters. It is expected that this will enable insurers to identify fraud more often and earlier in the claims process. Our modeling considers a gradual reduction in claim frequency over time across all future states, as we expect that a greater number of fraudulent claims will close without payment or that there will be a general reduction in fraudulent claims reported.
Human error reduction	Potential frequency reductions occur in all four future states. First, the Insurance Institute for Highway Safety (IIHS) estimates that if all vehicles were equipped with both automatic braking and collision warning, approximately 13 percent of police-reported crashes could have been averted in 2013.[13] Our model accounts for both the uptake of these technologies and the potential reductions to liability and collision claim frequencies in future states 1 and 2. Second, the NHTSA cites that approximately 94 percent of accidents are caused by human error.[14] Autonomous vehicles will effectively take humans out of the driver seat. As a result, our modeling assumes significantly lower liability and collision claim frequency for future states 3 and 4.

Table 2 – Severity modifiers

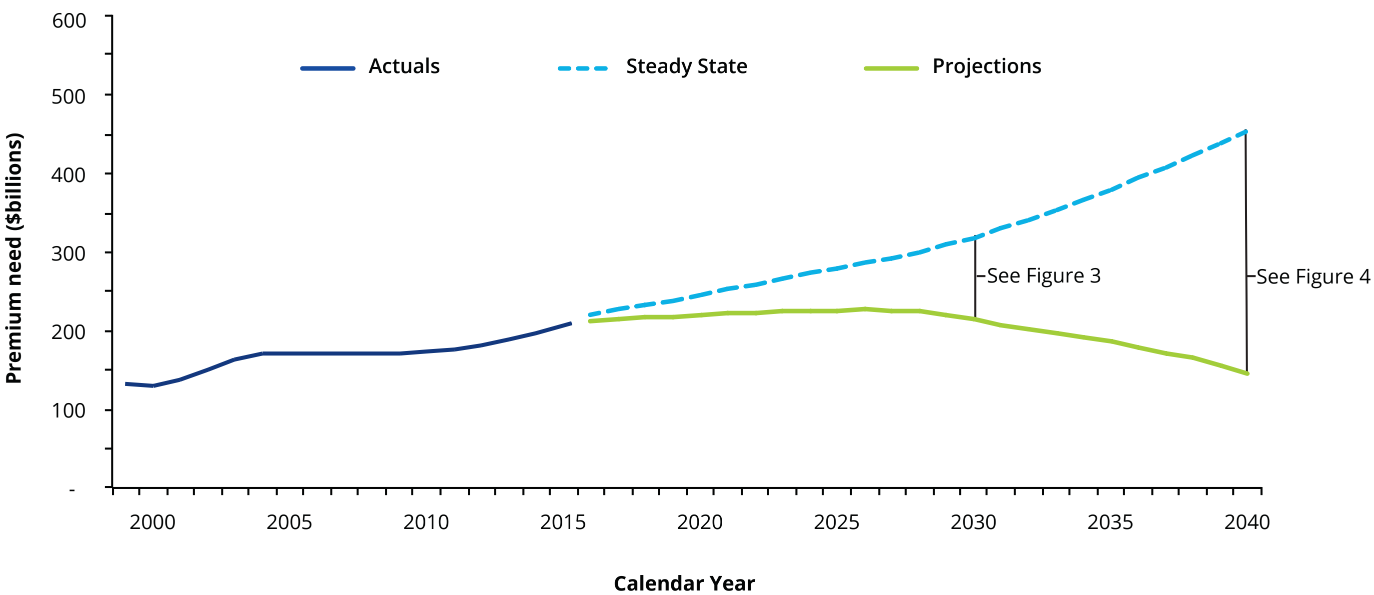
Modifier	Discussion
General inflation	Our model includes a separate liability and auto physical damage severity trend. We derived these amounts by reviewing the severity trends implied by the combined P&C industry Schedule P.
Accident intensity	Our research points to industry consensus that advanced driver-assist technologies can reduce the severity of accidents. For example, if automatic braking is able to apply braking sooner and reduce speed at impact, the bodily injury component would likely be reduced. Our model incorporates varying levels of future liability severity reductions across each future state.
Auto repair costs	While it may reduce accident severity, advanced driver-assist technology also increases vehicle complexity, leading to more expensive repair costs. Research conducted by CCC Information Services indicates that average auto repair costs have increased by about 3 percent annually since 2013, driven largely by growth in the average number of parts replaced per claim as well as more labor hours per claim.[15] Our model incorporates a longer-term average of this expected trend.
Shared autonomous vehicle costs	In future state 4, large fleets of autonomous "pods" could emerge. These pods would benefit from economies of scale, making their production cost significantly less than other vehicles.[16] The current vision is that autonomous "pods" will likely cost between $10,000 and $15,000 per vehicle, more utilitarian than current cars. From an insurance perspective, their replacement cost should be less. Our model accounts for this in the form of a baseline severity reduction for future state 4.

How are premiums affected?

Decomposing estimated premium need into each of its components (bodily injury, collision, etc.) offers insight into how our assumptions impact the total result. To illustrate, we created a "steady state" scenario assuming the current mobility environment persists—there are no further advances in driver-assist technologies, autonomous vehicles do not become part of the national fleet, and ridesharing does not continue to expand—adjusted to account for population growth and inflation. Then, we incrementally reviewed the impact that our assumptions had on total premium.

Figure 2 displays actual personal auto premiums from 1999-2015 and compares our steady state with our projections. From 2015 through 2040, the steady state CAGR is approximately 3 percent. This is consistent with the actual CAGR from 1999-2015[18] of approximately 2.9 percent.

Figure 2: Premiums – steady state vs. projections



Overall, our model estimates premiums of $145 billion in 2040. This represents a nearly 70 percent decrease in premiums the industry would collect.

Figure 3 reconciles the difference between the estimated steady state and our projections in the year 2030, while figure 4 reconciles the difference in the year 2040.

Drilling down into the year 2030:

- Steady state premiums would hit nearly $320 billion.
- The driver-driven sharing economy could boost total premiums by 10 percent, as the commercial auto policies for those drivers would tend to be more expensive.
- Adding autonomous vehicles could reduce premiums by up to 26 percent of the steady state because of the unprecedented potential safety benefits. Some of this is recovered in the form of product liability insurance, adding around 1 percent.
- Other factors, including reduced fraud and additional safety benefits from driver-driven and autonomous vehicles alike could reduce premiums by up to 18 percent of the steady state.
- Overall, our model estimates premiums of $214 billion in 2030. This represents a nearly 33 percent decrease in premiums the industry would collect in 2030 relative to a steady state.

Drilling down into the year 2040:

- Steady state premiums would hit nearly $450 billion.
- The driver-driven sharing economy could boost total premiums by 23 percent of the steady state in the form of commercial auto premiums.
- Autonomous vehicles are likely to have proliferated, providing considerable safety benefits and driving premiums down by 80 percent of the steady state. Some of that is made up by product liability insurance, adding around 6 percent.
- Other factors, including reduced fraud and additional safety benefits from driver-driven and autonomous vehicles alike could reduce premiums by up to 17 percent of the steady state.
- Overall, our model estimates premiums of $145 billion in 2040. This represents a nearly 70 percent decrease in premiums the industry would collect. Of course, if autonomous vehicles are adopted at a slower rate than our underlying assumption, the decline in premiums would be less precipitous.

Figure 3: Premium need breakdown – 2030

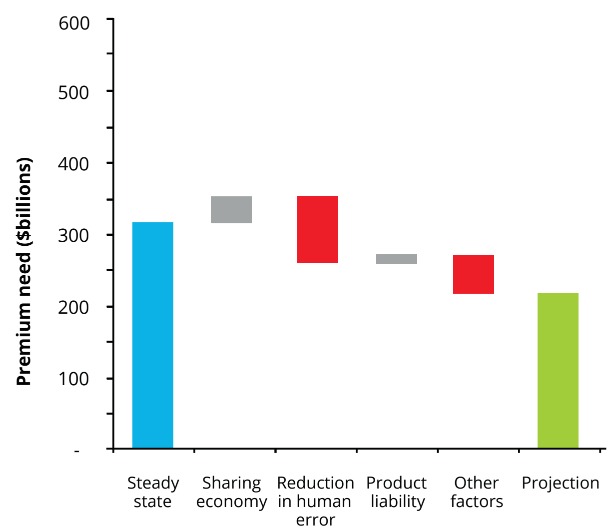
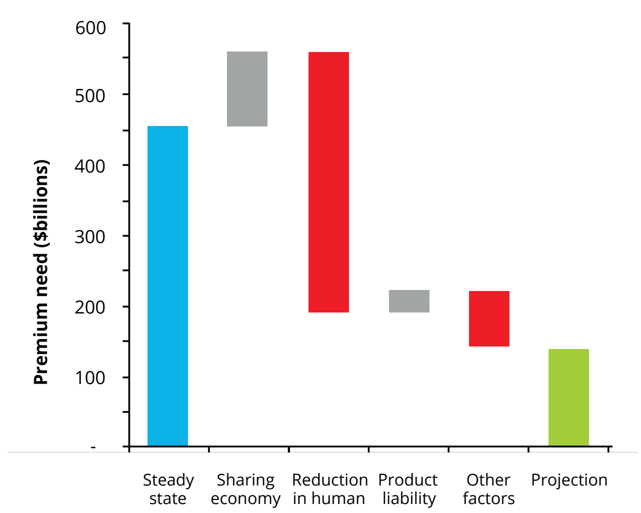


Figure 4: Premium need breakdown – 2040



Other implications to insurers

LAE and underwriting expenses

We believe the industry is poised to see a decrease in premium volume. In order to maintain profits in an environment where revenue is expected to shrink, costs must be reduced. Losses are already expected to shrink, but the impact on LAE and underwriting expenses is less understood. Insurers could target these expenses to help improve profitability.

The largest components of LAE include the costs to staff the claims department and the legal costs incurred to settle claims.

- The size of the claims department as measured by salaries is a fixed cost. As claim volumes and loss payments decrease, this cost should follow closely in order to maintain profitability. Additionally, specialization may increase as claims handlers will need to better understand the impact that autonomous driving software and advanced electronics have on claims.
- We anticipate that the claims handling process will be streamlined as a result of the increased sensors, cameras, and other equipment core to the autonomous vehicle. As a result, determining fault in accidents can be more fact-based with both structured and unstructured data. This will help reduce claims handling complexity and litigation in the long term.
- In the early years of autonomous vehicle adoption there could be additional uncertainty of liability in an accident, which could drive legal costs higher. Product liability claims tend to have much higher LAE costs.

Underwriting expenses are highly dependent on the distribution channels used by insurers. Agency or broker channels tend to have higher expenses because of commissions, while the direct-to-consumer channels (such as websites) tend to have lower expenses, depending on marketing spend. The agency channel is particularly vulnerable to disruption by the future of mobility. Shrinking premiums would lead to lower total commissions, which will reduce agents' compensation.

There are several scenarios that could play out:

- There could be consolidation among agents. For an agency to maintain its current revenue stream with lower total commissions, it's conceivable that larger agencies would look to absorb smaller agencies.
- Agencies may look to expand their footprint with their existing customer bases. They may look to offer new products outside of traditional auto insurance.
- Insurers could look to revise agent compensation structures. Traditionally, commissions vary according to the amount of premium bound by each agent. Insurers could look to incentivize agents using alternative metrics.
- Insurers could opt to reduce or altogether eliminate their reliance on agents in favor of the direct-to-consumer channel.

The agency channel is particularly vulnerable to disruption by the future of mobility.

Pricing and ratemaking

Insurers and their actuaries should alter or overhaul existing rating algorithms as shared mobility and autonomous vehicles proliferate. Rating algorithms should reflect the new and changing risk profiles of their policyholders, the use of car-year as the base exposure may need to change, and new rating variables may need to be incorporated to accurately segregate risks (e.g. between autonomous and non-autonomous vehicles).

Reserving

While pricing actuaries may feel a more significant impact, there will be some impacts to consider for reserving. One of the most important concepts reserving actuaries should implement is to organize data into homogenous groups to promote data stability. As autonomous vehicles enter a book of business over time, it may become necessary to group those risks separately. Actuaries rely on past history to project future loss emergence, but when that history is no longer indicative of expected future experience, greater judgment will be needed.

Change is coming

Our research and modeling work points to significant changes coming to the auto insurance industry over the next 25 years. Whether our modeling holds true to actual future experience remains to be seen. Regardless, the automotive industry is undoubtedly undergoing changes that will help improve vehicle safety, change vehicle ownership models, and increase asset utilization, all of which impact the auto insurance industry.

Today there are nearly 300 insurers that write personal auto insurance.[19] In an environment where premiums will likely decline and coverages will shift, those insurers that recognize this early and take appropriate actions now will be better prepared to effectively navigate the disruption that lies ahead. They will be able to maintain or grow market share, have greater customer retention, and perhaps most importantly, have the data and expertise necessary to make informed decisions.

This change will not only impact auto premiums but all lines of business. How we live, where we live, and what we own will change dramatically. For example, the design, use, and underlying risks of the roughly 115,000 gas refueling stations in the United States[20] will change dramatically over the next 25 years. This will impact all P&C lines, not just automobile insurance. Stay tuned for future perspectives from Deloitte on the everyday impacts to the world we live in as the future of mobility emerges.

Endnotes

1. John Matley, et al., Insuring the future of mobility, Deloitte University Press, May 13, 2016, http://dupress.com/articles/mobility-ecosystem-future-of-auto-insurance/.
2. Mike Spector and Ianthe Jeanne Dugan, Tesla Draws Scrutiny After Autopilot Feature Linked to a Death, The Wall Street Journal, http://www.wsj.com/articles/tesla-draws-scrutiny-from-regulators-after-autopilot-feature-is-linked-to-a-death-1467319355
3. Scott Corwin, Joe Vitale, Eamonn Kelly, and Elizabeth Cathles, The future of mobility, Deloitte University Press, September 24, 2015, http://dupress.com/articles/future-of-mobility-transportation-technology//?coll=16426.
4. NHTSA, Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety, September 2016. As of the date of this publication, the NHTSA adopted the SAE International definitions for levels of autonomy. These can be summarized as follows:
   - SAE Level 0 – the human driver does everything
   - SAE Level 1 – an automated system can sometimes assist the human driver conduct some parts of the driving task
   - SAE Level 2 – an automated system on the vehicle can conduct some parts of the driving task, but the human continues to monitor the driving environment and performs the rest of the driving task
   - SAE Level 3 – an automated system can both conduct parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests
   - SAE Level 4 – an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions
   - SAE Level 5 – the automated system can perform all driving tasks, under all conditions that a human driver could perform them
5. ***Premium need*** is defined as the amount of premium that is implied if the fundamental insurance equation is in balance.
6. Geoff Werner and Claudine Modlin, Basic Ratemaking, 4th edition (Casualty Actuarial Society, 2010), p. 5.
7. SNL Financial. We reviewed Annual Statement Lines of Business *Private Passenger Auto Liability, Commercial Auto Liability*, and *Auto Physical Damage*.
8. ***See Gearing for change: Preparing for transformation in the automotive ecosystem*** for a more complete description of the methodology and findings of this effort. Importantly, note that rather than attempt to determine adoption rates from "the ground up" using, for example, consumer attitudes, that effort simply assumed that the adoption of shared and self-driven vehicles would follow a similar pattern as other recent technologies. In our analysis, we posited three possible trajectories of adoption—fast, medium, and slow—which we proxied with actual adoption rates for smartphones in the United States, conventional cell phones in the United States, and the Internet globally. Applying different assumptions about the speed of adoption could significantly alter the model results.
9. SNL Financial
10. SNL Financial
11. SNL Financial
12. Insurance Research Council, February 3, 2015, "Insurance Research Council Finds That Fraud and Buildup Add Up to $7.7 Billion in Excess Payments for Auto Injury Claims"
13. Susanna Gotsch, "2016 CCC Crash Course", CCC Information Services
14. NHTSA, "Traffic Safety Facts", February 2015
15. Susanna Gotsch, "2016 CCC Crash Course", CCC Information Services
16. Deloitte analysis
17. Several internet sources were reviewed. The primary publication is as follows: Ponemon Institute LLC, "2015 Cost of Data Breach Study: Global Analysis", May 2015
18. Insurance Information Institute, http://www.iii.org/table-archive/20967
19. SNL Financial. Based on 2015 direct premiums written for private passenger auto liability and auto physical damage as reported in the Insurance Expense Exhibit. Based on groups and unaffiliated singles.
20. US Census Bureau, 2012 Economic Census. For NAICS code 447 (Gasoline Stations) the actual number of establishments per the last economic census conducted in 2012 was 114,474. http://thedataweb.rm.census.gov/TheDataWeb_HotReport2/econsnapshot/2012/snapshot.hrml?NAICS=447

Authors

John Matley
Principal | Insurance Technology
Deloitte Consulting LLP
+1 203 918 0358
jmatley@deloitte.com

Matt Carrier, ACAS, MAAA
Principal | Actuarial, Rewards & Analytics
Deloitte Consulting LLP
+1 312 486 3904
macarrier@deloitte.com

Malika Gandhi
Principal | Financial Services | Strategy
Deloitte Consulting LLP
+1 215 796 0921
malgandhi@deloitte.com

Peter Tomopoulos, ACAS, MAAA, MBA
Senior Manager | Actuarial, Rewards & Analytics
Deloitte Consulting LLP
+1 212 618 4656
ptomopoulos@deloitte.com

Stefan Peterson
Manager | Actuarial, Rewards & Analytics
Deloitte Consulting LLP
+1 312 486 1463
speterson@deloitte.com

Appendix

Data used to calculate the impact of the four future states on miles travelled and unit sales came from the following sources.

- For miles traveled in rural and urban areas: "Highway statistics," US Department of Transportation
- Federal Highway Administration, www.fhwa.dot.gov/policyinformation/statistics.cfm.
- Since data on urban areas includes suburban areas, we follow economist Jed Kolko's methodology to back out the suburban share: Kolko, "How suburban are big American cities?" FiveThirtyEight, May 21, 2015, http://fivethirtyeight.com/features/how-suburban-are-big-american-cities/.
- For shared vehicle data, we use a combination of data on the size of the rental car fleet and vehicle usage in miles used to calculate annual miles driven by rental cars: Auto Rental News, "2015 U.S. car rental market," *Fact Book 2016*, page 8, www.autorentalnews.com/fileviewer/2229.aspx; Scott McCartney, "Rental cars with higher mileage populate lots," Wall Street Journal, August 28, 2013, www.wsj.com/articles/SB10001424127887324463604579040870991145200.
- We include data on annual taxi mileage: Transportation Research Board, *Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services*, National Academies of Sciences, Engineering, and Medicine, May 13, 2016, www.trb.org/Main/Blurbs/173511.aspx.
- We incorporate annual miles driven by Uber and Lyft: Pavithra Mohan, "Uber is even bigger than you realize," *Fast Company*, September 8, 2015, www.fastcompany.com/3050784/elasticity/uber-is-even-bigger-than-you-realize; Anne Freier, "Uber usage statistics and revenue," Business of Apps, September 14, 2015, www.businessofapps.com/uber-usage-statistics-and-revenue/; SherpaShare, "Uber trips are becoming longer and faster, but are they more profitable?" SherpaShare Blog, February 2, 2016, http://sherpashareblog.com/2016/02/02/uber-trips-are-becoming-longer-and-faster-but-are-they-more-profitable; Matt Rosoff, "Uber is now more valuable than Ford, GM, and a bunch of huge public companies," *Business Insider*, December 4, 2015, www.businessinsider.com/uber-valuation-vs-market-cap-of-publicly-traded-stocks-2015-12; Alison Griswold, "Why General Motors is making a $500 million bet on Lyft," *Quartz,* January 4, 2016, http://qz.com/585520/why-general-motors-just-made-a-500-million-bet-on-lyft.
- For projected population growth, we tap World Bank projections: "Health nutrition and population: Population estimates and projections," World Bank, http://databank.worldbank.org/data/reports.aspx?source=Health Nutrition and Population Statistics: Population estimates and projections.
- We estimate when autonomous vehicles will be launched using a thorough scan of OEM, technology companies, and subject-matter expert statements, and use data on the diffusion of other recent innovations to proxy adoption rates.
- Looking at generational data from the World Bank as well as poverty data from the US Census Bureau allows us to estimate what additional population segments might become mobile in the future: "Health nutrition and population: Population estimates and projections," World Bank; Carmen DeNavas-Walt and Bernadette D. Proctor, "Income and poverty in the United States: 2014," US Census Bureau, September 2015, www.census.gov/library/publications/2015/demo/p60-252.html.
- We use several sources for information on the average number of passengers per vehicle: Transportation Research Board, Between Public and Private Mobility; Office of Highway Policy Information, "Annual vehicle distance traveled in miles and related data—2014," US Department of Transportation Federal Highway Administration, December 2015, www.fhwa.dot.gov/policyinformation/statistics/2014/vm1.cfm; and Taylor Soper, "Lyft's carpooling service now makes up 50% of rides in San Francisco; 30% in NYC," GeekWire, April 22, 2015, www.geekwire.com/2015/lyfts-carpooling-service-now-makes-up-50-of-rides-in-san-francisco-30-in-nyc/.
- To project vehicle lifetime, we take US government data and apply the historic rate of lifetime improvement going forward: National Center for Statistics and Analysis, *Vehicle Survivability and Travel Mileage Schedules,* National Highway Traffic Safety Administration, January 2006, www-nrd.nhtsa.dot.gov/Pubs/809952.pdf.
- Finally, rather than attempt to determine adoption rates from "the ground up" using, for example, consumer attitudes, we simply assumed that the adoption of shared and self-driven vehicles would follow a pattern similar to other recent technologies. In our analysis, we posited three possible trajectories of adoption—fast, medium, and slow—which we proxied with actual adoption rates for smartphones in the United States, conventional cell phones in the United States, and the Internet globally. These technologies had sufficient historical data and important similarities to the mobility innovations in which we were interested: They were expensive when first introduced, required significant infrastructure investment, and exhibited strong network effects. That said, there are important differences: The automobile is a fixed capital asset that most households turn over relatively slowly, for instance. Accordingly, applying different assumptions about the speed of adoption could significantly alter the model results.

Deloitte.