What will drive the future of self-driving cars?

By J.C. Sullivan

May 2015

KEY POINTS

- Companies such as Google are pursuing projects to produce and bring to market driverless (autonomous) cars. While the future success of this technology is fragile and uncertain, it is useful to assess the producer deployment and consumer adoption dynamics that could impact the diffusion of such an innovation.

- Key factors that would impact producer deployment of autonomous vehicles include technological feasibility, digital infrastructure, producer liability, regulation, diverging business models, and profitability.

- Determinants of consumer adoption, which often have the effect of neutralizing or exacerbating each other, include consumer trust of vehicle safety and privacy, pricing, and network effects.

If you are like 86 percent of working Americans, you drive to work. Most likely, you do not enjoy this daily undertaking. In fact, most Americans consider it to be the worst part of their day. For the purposes of emotional recall, consider this hypothetical morning. You wake up early in an effort to beat rush hour, but despite your efforts, you inch along your route for an excruciatingly long period of time. Everyone around you drives either too slowly or too fast. You are tired, stressed that you might be late for your morning meeting, and furious when you learn the undoubtedly ridiculous source of that particular morning’s traffic jam. While those who do not suffer through morning rush hour probably consider this a dramatic retelling, I imagine 86 percent of readers think it does not go far enough or include a sufficient number of expletives.

Research shows that long commutes have negative effects on physical and mental health, as they are correlated with poor cardiovascular and metabolic health and fewer social engagements and less time spent with friends and family. Conservative estimates show that human error accounts for about 95 percent of automobile accidents.
accidents. Moreover, approximately 30,000 people die each year from automobile accidents.

For these reasons, when Google announced its self-driving (autonomous) car project in 2010, journalists, analysts, and pundits began to feverishly write about the benefits of such technology. While a primitive form of the technology had been around since at least the 1980s, the Google brand elevated the idea of a robotic chauffeur from science fiction to imminent reality, spawning conversation and buzz.

These analysts projected that a full roll-out of autonomous vehicle technology in the United States would lead to a minimum 90 percent reduction in automobile accidents and deaths, commuter time and energy, and cars on the road. Further, predictions asserted reductions in environmental impact and up to $300 billion in savings for the American people. While some analysts expressed data privacy and security concerns and general uneasiness about letting go of the wheel, a casual follower of this discussion could easily believe that we are headed toward a driver’s utopia.

The excitement is to be expected, considering what life could be like if autonomous vehicles were a reality. However, there has been little thoughtful analysis of whether this technology would even become mainstream. It seems that a focus on long-term social and economic benefits has overshadowed any discussion of what factors might motivate suppliers to bring driverless cars to market, and why consumers might choose to adopt this technology. Predictions overwhelmingly assume imminent deployment and adoption.

This is not an inherently incorrect and unhelpful exercise, but treating the arrival of this innovative technology as a foregone conclusion could lead one to incorrectly understand the future, spurring mistaken conclusions and actions aimed at fulfilling such outcomes. As Randal O’Toole of the Cato Institute writes on the topic of regulatory action related to autonomous vehicles, “Not all of the changes that will result from autonomous vehicles are predictable, but what is predictable is that the changes will be profound. Legislators and policymakers need to be aware of the implications of these changes before they make long-range decisions relating to transportation and land use.”

Overcoming the optimistic assumption that producer deployment and consumer adoption of driverless cars are both guaranteed and imminent raises a new line of questioning regarding this technology. Can we expect autonomous car adoption to be similar to that of the fax machine, which experienced near-universal adoption over a short period of time in the 1980s? Or will it be closer to that of videophones, which never achieved significant adoption until the concept was bundled with smartphones?

The paragraphs that follow assesses the dynamics of producer deployment and consumer adoption of autonomous vehicle technology, outlining the factors that are likely to impact deployment and adoption. The objective is to clarify how such factors could impact the shape and steepness of the autonomous car adoption curve.

The Adoption Curve in Theory and Reality

This paper makes one fundamental assumption regarding consumer adoption: that the adoption of innovative technology follows Everett Rogers’s theory of innovation diffusion (figure 1). Rogers’s theory holds that consumer adoption grows exponentially and then tapers off as a critical mass of consumers adopt the technology. While the time period over which this curve
substantiates varies, the shape remains somewhat constant and reflects a small population of innovators with high social status and financial means, among other identifying characteristics, who first adopt this technology. Then, the technology is adopted at an exponential rate among the masses, eventually slowing as adoption reaches critical mass.10 (A critical mass does not mean 100 percent consumer adoption, as there is the “laggard” population who will resist innovation.)

In examining historical patterns of innovation adoption, the past century shows that the time it takes for a technological innovation to reach a critical mass of adoption has decreased.11 This trend is most clearly observed when examining the adoption of major, far-reaching innovations such as the automobile, microwave, and cellphone. It took nearly 65 years for automobiles to reach 80 percent adoption, whereas it took less than 20 years for microwaves and cellphones to reach this same level.12

These examples could lead one to believe that autonomous vehicles, following the logical progression of technology adoption rates, could reach an 80 percent adoption rate less than 20 years after deployment. At the very least, logical progression would hold that driverless cars would be adopted more quickly than the first automobiles were.

However, this process might not be so straightforward. Autonomous vehicles represent a drastic disruption to transportation. They present questions of safety, technological plausibility, and trust that did not apply to consumer adoption of the microwave or cellphone, meaning the autonomous vehicle adoption curve might more closely resemble that of its automobile forefathers. Moreover, the introduction of an innovative technology does not guarantee adoption.

Even more importantly, the fact that a technology is “innovative” does not guarantee producer deployment. Consider Google Glass. Despite the

**Figure 1. Everett Rogers’s Diffusion of Innovation Curve**

<table>
<thead>
<tr>
<th>Innovators</th>
<th>Early Adopters</th>
<th>Early Majority</th>
<th>Late Majority</th>
<th>Laggards</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 %</td>
<td>13.5 %</td>
<td>34 %</td>
<td>34 %</td>
<td>16 %</td>
</tr>
</tbody>
</table>


**Notes:** According to Rogers’s theory, there are five categories of innovation adopters. Innovators have a high level of risk tolerance, high social status, and financial liquidity. Early adopters have the highest level of opinion leadership among all groups and have high social status and financial liquidity. Early adopters are more particular in their adoption decision than innovators, whereas the early majority have average social status and usually rely on early adopters to help make their adoption decision. The late majority have below-average social status, little financial liquidity, and are typically skeptical of innovative technology. Finally, the laggards, the last group to adopt, have the lowest social status, lowest financial liquidity, and are usually the oldest category of adopters.
innovative nature and proposed benefits of such a technology, Google has recently announced its intention to indefinitely pause its production and sales of the product. The factors that ultimately led Google to cancel its sales demonstrate that the proposed benefits of a technology often do not guarantee a smooth or profitable introduction into the marketplace.

It is difficult to determine exactly why certain technologies are adopted and others are not, and assuming that technology will definitively be adopted is unwise. Examining the theoretical adoption curve provides a valuable guide for the shape and timeline of a potential adoption curve for driverless cars. However, the factors that ultimately drive adoption are variable and technology specific. I therefore dedicate the remainder of this paper to analyzing what could ultimately determine the shape and timeframe of the autonomous vehicle adoption curve.

Producer Deployment Factors

Producer factors influence if and when companies will go to market with an autonomous vehicle. The starting point of the consumer adoption curve can be approximated by examining which of these factors will most impact the actions of firms hoping to enter this market.

**Technological Feasibility.** There is little debate as to the feasibility of autonomous vehicle technology in general. In fact, a number of vehicles on the road already incorporate autonomous functions, including speed-adaptive cruise control, self-parking technology, and threat recognition and reaction.

However, there is no clear consensus regarding the technological feasibility of truly autonomous vehicle technology that requires no human intervention while driving in any scenario. Elon Musk expressed this concern, stating, “My opinion is it’s a bridge too far to go to fully autonomous cars. It’s incredibly hard to get the last few percent.” Some, however, including a number of auto manufacturers, maintain that completely driverless cars are both possible and imminent. Google, for instance, recently revealed an autonomous prototype without a steering wheel or brake pedal. However, this model requires near-perfect weather and data-rich maps for the roads it drives on.

The question that seems particularly relevant in this debate is the autonomous vehicle’s ability to interpret and correctly react to the innumerable complexities of driving at the level of a human, who can appropriately respond to the limitless subtleties even an average driving experience can bring about. As the RAND Corporation reports, “Human eyes are sophisticated and provide nearly all of the sensory data we use to drive. We are also adept at interpreting what we see. Although our eyes are passive sensors, only receiving information from reflected light, we can judge distances; recognize shapes and classify objects such as cars, cycles, and pedestrians; and see in a tremendous range of conditions.”

Consider this example: If you are driving in a residential area and you see a baseball roll across the street 50 yards ahead, you will likely slow down in anticipation of a child blindly chasing the ball. Will an autonomous vehicle be able to recognize the ball, pair that recognition with its geolocation in a residential neighborhood, and then slow down and actively search for a child to appear in its sensors?

The more difficult it becomes to achieve a certain level of technological capability, the more expensive research, development, and testing become. If achieving this level of technological sophistication becomes cost inefficient, producers could decide to cease research and development of such technology.

The ability to synthesize sensors, cameras, algorithms, and software into an automated driver that is equally or more effective than a human represents a key determinant in the technological feasibility of autonomous vehicles. A given technology may be possible in promotional prototypes and consumers’ imaginations, but this does not guarantee that such a technology is possible or, more importantly, profitable in practice. The technological feasibility of driverless cars and the
associated cost of developing such a technology will largely influence a producer’s decision to deploy this technology.

**Digital Infrastructure.** Beyond the feasibility question, driving autonomous vehicles requires an optimal technological environment, or digital infrastructure, beyond just a smoothly paved road. Producer deployment will be impacted by the presence of this infrastructure and who is responsible for creating and maintaining it.

Two important infrastructure components are Internet access and mapping technology. As described earlier, the crucial technological component of autonomous vehicles is their ability to interpret their surroundings, which relies on detailed mapping technology. As Greg Miller of *Wired* writes, "Autonomous cars will require maps that differ in several important ways from the maps we use today for turn-by-turn directions. . . . Autonomous cars will need maps that can tell them where the curb is within a few centimeters. They also need to be live, updated second by second with information about accidents, traffic backups and lane closures."16 While companies such as Google and Apple have invested in this technology, the cost of building and sustaining it is another matter that a producer would have to consider before deploying the autonomous model.

Part of the reason the mapping technology is possible is that cars can transmit data about their surroundings to other cars surrounding cars and to a central map database, all in real time. This interconnectedness is beneficial (discussed further in the next section), but it does rely on a fast Internet connection. In fact, a significant portion of the increased features evident in today’s cars rely on Internet technology. But Internet access and speed play a crucial role in the efficacy and safety of driverless cars in particular—to a far greater degree than their nonautonomous counterparts.

As a result, the existence and maintenance of Internet access spanning the entirety of US roads is critical to autonomous vehicle deployment. If certain roads do not have reliable access, their value and safety significantly decreases.

**Liability and Regulatory Hurdles.** Some of the most challenging questions facing producers of autonomous vehicles are legal rather than technological. Regulatory and legal action can negatively impact producer deployment in two ways: by making it costlier and more resource intensive for producers to deploy the technology and by limiting certain functionalities of autonomous vehicle technology and thus reducing the value to consumers.

The presiding conclusion to be drawn from research on the topic is that driverless cars are “probably legal” under existing law.17 Certain states have even begun to work proactively with auto manufacturers and technology companies to determine rules for autonomous vehicle testing: California, Nevada, Florida, and Michigan have all enacted laws that explicitly allow their development and testing.18

**Internet access and speed play a crucial role in the efficacy and safety of driverless cars in particular—to a far greater degree than their nonautonomous counterparts.**

Still, major questions remain. At the forefront is the issue of liability. The question of responsibility when autonomous vehicle technology is involved in an accident has generated debate and concern. Product liability regarding driverless cars incorporates questions of tort and contract law and is complicated by a complex web of insurers, operators, plaintiffs, and manufacturers.19 The legal answers to the liability questions have the potential to impact a producer’s willingness to deploy autonomous vehicles.

Consider a law recently passed in Nevada in which the state Department of Motor Vehicles must adopt rules for license endorsement and
operation of autonomous vehicles, including insurance, safety standards, and testing. This legislation increases costs associated with deploying autonomous vehicles in that firms are now required to take the necessary measures to meet an adequate standard of compliance, therefore potentially decreasing firms’ propensity and ability to deploy the technology.

Laws and regulations can also diminish the capabilities or features allowed in autonomous vehicles. One interesting example is whether operators of autonomous vehicles will be exempt from texting-while-driving laws. Nevada and Florida have granted exemptions to autonomous vehicle operators, but this does not necessarily indicate that all states will be willing to grant such exceptions. If drivers are not allowed to use a wireless device or are otherwise required to be ready to take control of the vehicle at a moment’s notice, this could significantly decrease the added value driverless cars offer consumers.

Another possible development on this topic is privacy measures that limit autonomous vehicles’ capabilities. Car-to-car communication is one of the most impactful technological developments for autonomous vehicles, but it also creates data that track a vehicle’s every move and its driving patterns over time. If legislators or regulators limit the collection and analysis of these data—especially the way they interact with other cars’ data—this could vastly decrease the benefits of autonomous vehicles. This inherently decreases the value producers could provide consumers.

Considering that these legislative and regulatory questions are still in their infancy, it is difficult to predict how they will determine a producer’s decision to deploy autonomous vehicle technology. However, it is clear that the way such rulings either impact a firm’s costs of deploying this technology or the value such technology will provide consumers will impact when and if a producer continues to invest in this space.

**Differing Business Models.** An analysis of the future of the automobile industry would be incomplete without discussing the new shared-service business models of companies like Uber and Lyft. In fact, Google has indicated plans to use some iteration of these models for the deployment of its autonomous vehicle technology.

Companies like Zipcar, Uber, and Lyft have brought the “sharing economy” mentality to transportation. The sharing economy can be summarized as a consumer tendency to prefer on-demand access to a good or service over ownership. This tendency, which companies are racing to take advantage of, applies to automobile ownership.

Buying a car represents one of the largest purchases a consumer will make in his or her lifetime, yet privately owned cars are left idle 95 percent of the time. Business models like those of Zipcar and Uber provide consumers access to a vehicle when they need one, but without the exuberant price tag of individual ownership. Implemented on a larger scale, some believe this shared model of transportation could reduce the number of vehicles owned by up to 90 percent.

Millennials have largely demonstrated this preference for access over ownership. In 2010, consumers ages 21–34 purchased only 27 percent of new vehicles, down from 38 percent in 1985. This trend in consumer preference away from automobile ownership, especially in light of consumers’ high price sensitivity (considered in the next section), may reveal a grim future for privately owned driverless car adoption. One could argue that a growth in on-demand, access-based transportation models would slow the growth of autonomous vehicle technology ownership.

On the other hand, the shared-transportation model also has the potential to accelerate adoption of autonomous vehicle technology through a rapid rollout by ridesharing companies. If companies like Uber and Lyft shifted their fleet to one of autonomous vehicles, consumers could adopt this technology without the full cost of ownership. This could hasten adoption rates in two ways.

First, a simultaneous rollout of a 1,000-car fleet would span a shorter period of time than 1,000 individual purchases. Second, such a business model could allow wide-scale consumer adoption without requiring the purchase of a given vehicle.
as such a model does require a one-for-one adoption rate. A level of 100 percent consumer adoption could hypothetically only require the deployment of 1 autonomous vehicle per 10 consumers. Consider the number of people that drive in a given Uber car on a given day. If this particular Uber car were autonomous, each consumer that used the car could “adopt” the technology with the deployment of just one vehicle.

That being said, such a development would represent a vastly reduced demand for driverless car technology, limiting profit opportunities and, thus, a firm’s willingness to invest in the development of such technology. The development and integration of these business models will undoubtedly play a substantial, even if uncertain, role in producer deployment of this technology.

It is important to note that this introduces a question of what constitutes consumer adoption. Continuing the Uber example, if an individual rides in a driverless Uber taxi one time, does this mean he or she has “adopted” autonomous vehicle technology? What if an individual uses an autonomous Uber twice a week but drives a nonautonomous vehicle otherwise? While the exact definition of consumer adoption is beyond the scope of this paper, this exercise exemplifies the earlier point that a thoughtful analysis of producer deployment and consumer adoption is warranted.

**Profitability.** The degree of confidence a producer has in the profitability of autonomous vehicles is probably the best judge of that producer’s willingness to deploy such technology. One of the most important gauges of profitability is the cost of deployment. If deployment requires a significant cost, firms will be less likely to be able to sell enough autonomous vehicles to not only cover initial costs but also turn a profit. This discussion is further complicated by the uncertainty regarding the technological feasibility of the innovation.

Returning to the earlier example of a car’s ability to recognize the implications of a baseball rolling in the street, one might conclude that it is possible to develop technology that can interpret the baseball and its associated implications. One can even reasonably conclude that it is technically possible to create a vehicle that correctly assesses a vast array of driving experiences similar to the baseball example. However, the technological feasibility is likewise contingent on the profitability of achieving this level of sophistication.

A final consideration, relating to both the market size and price flexibility of consumers, is the degree and nature of competition among firms that are developing autonomous vehicle technology. In addition to nearly every auto manufacturer, Google and Apple have revealed their plans to compete in this space. While this level of competition among prestigious companies would likely be great for consumers, the potential impact on individual firms is less clear.

One particularly interesting consideration is the degree to which producers will be able to differentiate their products from competitors. If producers are not able to create a competitive advantage, firms will begin to compete on price, significantly reducing a firm’s ability to charge a profitable price point. While this would occur after deployment, a firm’s projection of this scenario could very well prevent its propensity to develop such a technology.

One way by which producers might attempt to create a competitive advantage is through vehicle-specific content offerings and connectivity. Consider, for example, if a Google driverless car were only able to sync with an Android-operated smartphone and came with a Spotify membership. Or imagine a partnership in which Microsoft agreed to equip all Google vehicles with a tablet and Xbox. This attempt at differentiation has become common in high-tech Internet markets and is often referred to as “platform competition.” This idea is described by a Morgan Stanley report on the topic:

> The real value here comes from selling content to the occupants of the car. The emergence of the autonomous vehicle opens up a new avenue of revenue generation for all entities involved...We collectively spend over 75 billion hours per year in our cars. With the
ability of the car to drive itself, that time can now be redirected to other pursuits, potentially creating a new revenue stream if the content can be monetized. In a way, this is a content provider’s dream. Short of air travel, there are few other opportunities to have a captive audience for several hours at a time.²⁷

This insight demonstrates that competition, especially following an initial deployment, might have little to do with the actual vehicle and more to do with the experience a firm can provide a passenger. A consumer focus on driving experience versus vehicle functionality will certainly impact a firm’s understanding of the best avenue to profitability and steer the way by which it chooses to deploy a fleet of autonomous vehicles.

Consumer Adoption Determinants

Which factors determine consumers’ adoption of autonomous car technology? This section discusses those factors that could speed up or delay consumer decisions.

Degree of Improvement in Driving Experience. The degree to which autonomous vehicles will improve the driving experience—largely determined by which features and functionalities will be offered to consumers—will be a primary determinant of consumer adoption. Take, for instance, the issue of the fully autonomous car, meaning a vehicle that allows the operator to remove all attention from the road and for the complete redesign of the vehicle’s interior. Dashboards, steering wheels, brake pads, and driver’s seats become entirely unnecessary. A fully autonomous vehicle transforms the interior of a vehicle into a space that can be used to maximize a passenger’s comfort, entertainment, or productivity.

For example, firms could offer customers an entertainment vehicle that comes with high-definition television, gaming and streaming capabilities, a large comfortable couch, and a refrigerator for refreshments. Alternatively, a work vehicle could be equipped with office furniture and enough room to host a client in a mobile meeting space. However, if drivers are required to maintain a focus on the road (either by imperfect technology or by regulation), the potential value added by autonomous technology is much more limited.

Moreover, one must consider the degree to which driverless cars can negatively impact certain individuals’ driving experience. While this might not apply to a large portion of the population, it is important to consider the social and cultural benefits associated with driving. A number of parents likely cherish the time they get to spend with their children while driving, while others enjoy the act of driving, especially in the context of a road trip or vacation.

Automobiles and driving represent a cultural institution, particularly in the US. While the social and cultural implications of driving are outside the scope of this paper, it would be negligent to ignore the role of such factors in a consumer’s willingness to adopt this technology.

Safety. Of the daily tasks of the average American, driving is far and away one of the most dangerous. (Recall the statistics cited in the introduction of this paper.) As a result, vehicle safety is among consumers’ top reasons for purchasing a specific vehicle.²⁸ One of the major benefits that driverless cars might offer is a reduction in traffic accidents. Google claims that its autonomous cars drive more safely than professional drivers, supporting this claim with the nearly 700,000 miles that its test vehicles have driven.²⁹

Ironically, the only incident one of its test vehicles has had on the road occurred when a tester took control of the vehicle. Despite these potential savings, consumers are uneasy with the prospect of turning the wheel over to a robot. Early research shows that only 49 percent of US and UK consumers surveyed said they would be comfortable using a driverless car.³⁰ Another UK poll from this January found that 43 percent of consumers would not trust a driverless car to drive safely, and 16 percent of consumers are “horrified” at the prospect using an autonomous vehicle.³¹ Despite this skepticism, the safety
benefits that have been attributed to autonomous vehicle technology could certainly increase a consumer’s willingness to adopt the technology, therefore speeding up consumer adoption.

Privacy and Security. While driverless vehicles may sharply reduce accidents brought about by human error, they introduce a new set of risks. Autonomous vehicles need to answer consumer privacy and digital security concerns in addition to traditional vehicle safety concerns.

Cybersecurity has emerged as a consumer concern and—considering the potentially dangerous consequences of an attack on a vehicle or even a fleet of vehicles—could prevent consumers from adopting this technology. According to a 2014 survey, 52 percent of Americans fear that a hacker could breach the driverless car’s system and gain control of the wheel. A 60 Minutes report confirmed this fear when it showed an individual on his computer take full control of a car driving nearby. While these concerns are present for any digital product, the potentially deadly consequences of an automobile hack could reduce a consumer’s willingness to adopt this technology.

According to a 2014 survey, 52 percent of Americans fear that a hacker could breach the driverless car’s system and gain control of the wheel.

Another 37 percent of Americans worry about the collection and use of their personal driving data. Again, this concern is not unique to autonomous vehicle technology, as smartphones present an even more specific and accurate recording of one’s movements and tendencies, but it represents a legitimate consumer apprehension that could impact one’s willingness to use the technology.

It is relevant to note that these concerns are remarkably consistent across all age groups; these metrics of fear and uncertainty are not biased by higher rates among the older population but instead reflect a consistent consumer sentiment. These concerns could certainly slow the speed of consumer adoption.

Price. While an increase in the quality and safety of an individual’s driving experience will serve to increase consumer adoption, consumers are only willing to pay a certain premium for this benefit. While Rogers’s theory of technological adoption demonstrates that innovators and early adopters have an above-average willingness to pay a price premium for new technology, this does not guarantee that such technology will reach a critical mass.

This is particularly true in the case of automobiles. Transportation is the second-largest part of an average American’s annual budget, with auto parts and services alone making up about 14 percent of discretionary spending. Further, the current price of the average new car—$31,252, which is a record high—has proven to be too expensive for most Americans (the average American can only afford to spend $20,806 on a car).

Several studies have tried to gauge consumers’ willingness to pay for an autonomous vehicle. A 2012 survey found that 37 percent of Americans would be interested in purchasing one. However, only 20 percent of Americans would be interested if the technology cost $3,000 more than a regular car. Proponents of driverless cars would be disappointed to learn that research indicates autonomous vehicles will initially demand a $7,000–10,000 premium, with this figure falling to $3,000 by 2035.

This analysis demonstrates a low consumer willingness to pay a premium for autonomous vehicles. If these conclusions prove to be true, one can expect an elongated period of consumer adoption. However, it is also important to recall the earlier analysis of shared-service business models, which could provide an affordable alternative to individuals who would otherwise be priced out of the market.
Network Effects. The consumer adoption determinants discussed previously will also be amplified by what economists call “network effects,” which “are present in markets where the value of a product or service to each customer is affected by the number of other customers who use it.” While certain aspects of autonomous vehicle technology are not dependent on the number of people that adopt the technology, autonomous vehicles do become more valuable as more consumers adopt them.

Network effects will increase the value of car-to-car communication, which will increase a number of the benefits associated with such technology. Autonomous vehicles have the ability to interact and exchange data with other such vehicles on the road. In doing so, the vehicles can share relevant data regarding road conditions, upcoming debris or temporary signs, traffic patterns, and more. The more information an autonomous vehicle can incorporate into its driving decisions, the safer and smoother the ride.

Consider if one autonomous vehicle were a mile ahead of another and came across a fallen tree. This car could then transmit that information to the car a mile behind and prepare the vehicle to slow down, as opposed to the second vehicle approaching the fallen tree with no prior information.

Further, network effects will serve to decrease congestion and traffic. Autonomous vehicles will likely be able to essentially synchronize with each other. This would allow such vehicles to travel closely together without the constant braking human drivers engage in because they are uncertain what the driver in front of them will do next. The more cars that are able to drive in synchronization, the less braking and space between vehicles is required. This decreases traffic and congestion and provides for a smoother and safer ride.

Network effects are not only restricted to the adoption of fully autonomous vehicles, but they can also be extended to connected smart cars. As long as a vehicle has the ability to communicate with other vehicles, such a vehicle will be able to benefit, to some degree, from traffic data and decreased congestion.

While network effects are incorporated into Rogers’s theory of consumer adoption and are partly responsible for the exponential rise in adoption rates seen on the curve, it is important to consider what aspects of driverless car technology will drive such network effects. Network effects in this instance increase the technological capacity of cars to make better decisions and better understand their surrounding environment (including other vehicles), providing for a safer and smoother driving experience.

Conclusion

As I have detailed in the preceding paragraphs, there are a number of determinants that will influence producer deployment and consumer adoption of autonomous vehicle technology. Rather than focusing on the magnitude of long-term benefits and costs in autonomous vehicle technology, I strive to promote a realistic understanding of the complexities surrounding when and if these benefits may materialize. Such a shift in focus provides a more robust and comprehensive understanding of the future of autonomous vehicles.

A theoretical examination of Rogers’s theory of consumer adoption provides a model for the basic patterns of consumer adoption. Furthermore, a historical and contemporary analysis of innovation adoption reveals that while innovative technologies are adopted at an increasingly faster rate, adoption patterns are ultimately specific to a given technology. And proposed long-term benefits of a product do not guarantee that it will be deployed or adopted.

Factors that will impact producer deployment of autonomous vehicles include technological feasibility, digital infrastructure, producer liability, regulation, diverging business models, and profitability. Determinants of consumer adoption of autonomous vehicle technology include the driving experience, consumer trust of vehicle safety and privacy, pricing, and network effects.
While an isolated analysis of these determinants provides a foundational understanding of producer deployment, the way these determinants interact with each other will greatly influence producer deployment. For example, consider a regulation that bars a company from recording and analyzing data from an individual vehicle without the express permission of the owner. On the producer side, this decreases the technological capabilities of the vehicle and increases the cost of maintaining adequate mapping technology, therefore decreasing the overall profitability of deploying this technology.

On the consumer side, the regulation alleviates consumer concerns regarding privacy, as those who consider the recording and analyzing a breach of privacy are able to disable this capability. However, the regulation decreases the network effects that could have resulted from the ability to use this data, slightly decreasing one’s driving experience and the safety of the technology. Further, the increased cost a firm must incur to maintain its mapping technology without data provided from the vehicles raises the cost of the car.

This example helps demonstrate the feedback loops that exist among determinants of consumer adoption. One event or regulation exacerbates the effects of certain determinants and neutralizes the impact of others. In certain scenarios, some determinants support each other while in other scenarios, one determinant might contradict another. Although the adoption curve of driverless cars cannot be predicted with certainty, it is helpful to understand the complex set of interdependent factors that will determine the future of autonomous vehicles.

About the Author

J.C. Sullivan (john.c.sullivan.344@nd.edu) is an undergraduate at the University of Notre Dame, pursuing a dual degree in IT management and political science.

Notes

9. See David E. Borth, “Video Phone,” Encyclopedia Britannica,


32. Seapine Software, “Study Finds 88 Percent of Adults Would Be Worried about Riding in a Driverless Car.”


