The future car

Driving a lifestyle revolution

The automotive industry is undergoing a revolution unlike anything we have seen since horses replaced cars. This revolution will reveal the future car, which will change how we live our lives. Certainly this car will be autonomous. It will make travel and commuting more affordable. Most importantly, it will deliver a customizable experience that will make travel both enjoyable and efficient. But when will the future car move from being a novelty on our streets to becoming an integral part of our daily lives? This white paper covers that and more.

Acknowledgement
This white paper was authored by Edward Bernardon,
Siemens PLM Software Future Car Thought Leader
edward.bernardon@siemens.com

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Executive summary

Over the past two to three years, we have seen the topic of autonomous cars go from a novelty to a popular topic at parties to a consistent part of our daily conversation and news feeds. During this time, we've had the opportunity to interview experts working on 3D printed autonomous shuttles, electro-mobility, mobility as a service, flying cars, the technology impact on distracted driving, intelligent traffic systems and autonomous driving platforms and simulations. The result is a multifaceted perspective on issues faced by the transportation industry as it prepares for the future. The insights gained in these conversations are used in this white paper to explore what must be overcome for the vision of the future car to become a day-to-day reality, and the subsequent changes to our lives.

Barriers to realizing the vision of a future car

Later we will discuss the dramatic changes the future car will deliver, a world in which travel is affordable or even free. Traveling to a desired destination could be an experience we look forward to as it will be a seamless continuation of what we are doing in our stationary lives, be it work or play. But in order to transition from our current state of transport to the one afforded by the future car, there are technical, societal and governmental hurdles that must be overcome. Let's begin by looking at the challenges to be faced as the revolution of the future car unfolds.

Siemens Intelligent Traffic Systems (ITS) played a key role in the Oasis project in which the Rinspeed autonomous concept car provided a vision of future mobility. In this project, Siemens ITS solutions were used to optimize traffic flow and provide an app for booking and billing multi-mode transportation, including autonomous ride sharing and rail. Although the autonomous OASIS car is a concept, Siemens connected vehicle solutions are off-the-shelf technologies currently being demonstrated in projects like the United States Department of Transportation (USDOT) Connected Vehicle Pilot in Tampa, Florida. Unfortunately, apps for billing and scheduling of multi-mode transportation are not readily available for trip planning today, but when will they be available?

According to the Insurance Institute for Highway Safety[1], it took approximately three decades from initial introduction for anti-lock brakes and airbags to become standard or optional on 95 percent of registered vehicles. In part this is due to the interaction of humans with new automotive technology that had unforeseen consequences for many years. When anti-lock braking systems (ABS) were introduced, there was a 28 percent increase in fatal run-off-the-road crashes[2] as many drivers did not know how to use ABS or understand its limitations. ABS pulsing terrified drivers and convinced many that brakes were either failing or about to fall off the vehicle. A lack of education and trust also resulted in lost sales and greatly slowed deployment of a technology that could save lives. Since car dealers are trained to sell and service cars and not to be educators, the negative impact of combining untrained drivers and new technology slows the adoption of new technology.

In 1997, the first hybrid electric, the Toyota Prius, became available in Japan. Despite the forecast in the 2008 executive brief "Clarity Beyond the Chaos"[3] by the IBM Institute for Business Value stating that by 2020 all new cars would have some degree of hybridization, hybrid and electric cars haven't managed to get to 5 percent market penetration[4] almost 20 years after introduction of the Prius. Technology adaptation estimates are impacted at times by technology hurdles, regulations or market forces. In this case, demand for fuel efficient hybrids dropped when gas prices in the United States plummeted nearly 40 percent from over $4 in 2008 to less than $2.50 in 2017. In fact, stringent government mandates for emission reduction and fuel economy scheduled after 2020 may have the opposite effect on electric vehicle (EV) market penetration.

Car automation levels

LEVEL 0 No automated features, Driver fully in control	**LEVEL 1** Driver assistance, driver fully in control	**LEVEL 2** Partial automation Driver fully engaged or in control
LEVEL 3 Conditional automation Driver safety intervention	**LEVEL 4** Fully autonomous in limited environments	**LEVEL 5** Fully autonomous in all environments

Figure 1: The six levels of automotive automation.

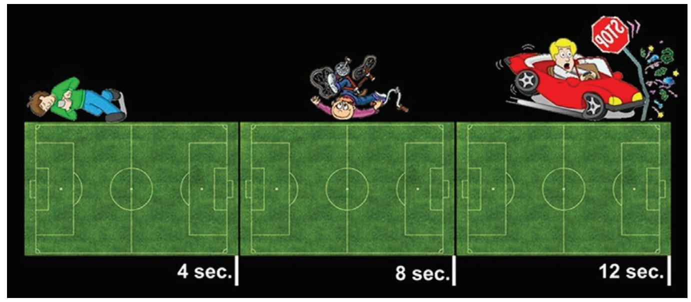


Figure 2: Impact of lack of situational awareness on reaction time.

For many decades, cars had no automation and everything was controlled by mechanical means. This is considered level 0 automation (see figure 1). Level 1 automation has been in vehicles for many years. Cars with anti-lock braking or electronic stability and traction control are an example of level 1 automation. In this case, it's much easier for a controller than a human driver to maintain traction in unfavorable conditions such as ice or snow.

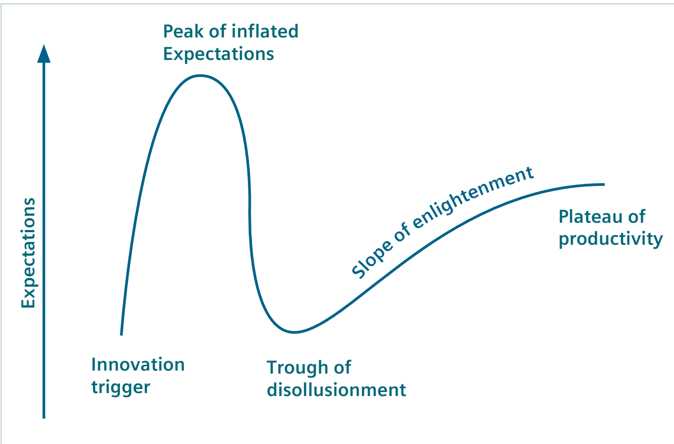
Recently, level 2 or partial automation has become available. You can now buy a car that automatically parallel parks. If you consider the difficulty most people have with parallel parking, it's not hard to imagine how a computer would be better than most humans will ever be. Technology is also available to help cars recognize pedestrians and bicyclists to avoid collisions; similarly, there is technology to help keep a car stay within the white lines. Tesla and others have more recently introduced adaptive cruise control that keeps the car within its lane, maintains distance from the car in front, and provides automatic lane changing triggered by a turn signal.

Through level 2, the human driver must be fully engaged and responsible for all passenger safety. Only level 5, which is full autonomy, physically eliminates brake pedals and steering wheels. Level 4 eliminates the need for them in certain conditions such as highway driving, select city areas, campuses and gated communities.

Note that level 3 autonomy is a unique circumstance since the human driver is handed control when the autonomous system is incapable of handling a situation. Studies show that it can take up to eight seconds for a driver to regain situational awareness[5], plus three to four more seconds of reaction time, during which time the chance of a collision is significantly increased. At 60 miles per hour (mph) (~25m/sec), a car travels over three football fields before a handoff occurs (see figure 2). As a result of the risks involved, many original equipment manufacturers (OEMs) are considering skipping level 3 autonomy.

Level 4 and 5 autonomy, in conjunction with other changes such as mobility as a service, will bring significant societal change. Therefore, only levels 4 and 5 will be considered in this white paper. The rate of market penetration for level 4 or 5 autonomous cars should fall somewhere within the range of other automotive technologies, but will depend on technology challenges, government regulation (or lack thereof) and acceptance by consumers.

Market acceptance of autonomous cars



Source: Gartner, Inc.

Figure 3: Gartner Hype Cycle for emerging technologies; AVs moving towards trough of disillusionment.

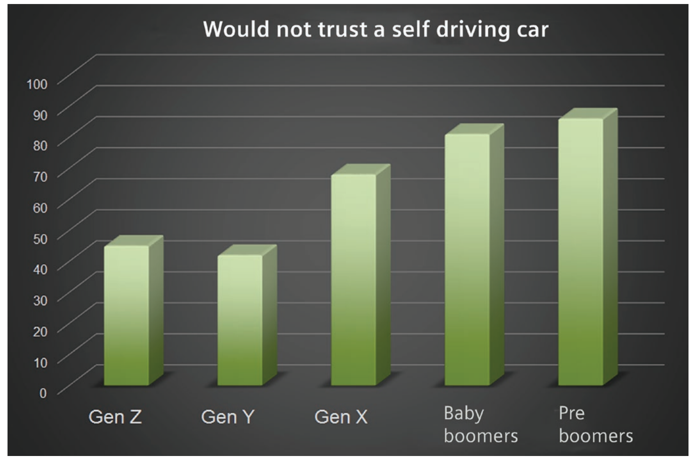


Figure 5: Trust in partial or full automation by age group.

According to Gartner, in 2017[6] autonomous cars just passed the "peak of inflated expectation" and are entering the "trough of disillusionment" in which negative hype will become more evident (see figure 3). As a result, an increase in negative coverage is expected in the coming years that will slow market acceptance. Also, autonomous cars are the only technology past the inflated expectation peak that have more than 10 years until the expected time to the plateau of productivity, and are in the company of other advanced technologies such as the brain computer interface and smart dust. A 2017 prediction by IHS[7] shows a significant increase in percentage of vehicle sales for autonomous cars through the 2030s, but less than a 4 percent penetration by 2030 (see figure 4). As recently as 2015, 2030 levels of over 20 percent were predicted, indicating a downward trend in expectations, which is consistent with entry into the trough of disillusionment.

	L1 and L5 vehicles share of sales
2030	3.80%
2032	7.00%
2034	12.60%
2036	21.90%
2038	35.90%
2040	54.90%

Figure 4: 2017 IHS projection of worldwide autonomous vehicle sales.

Even 4 percent penetration may be a high estimate due to the cost of requisite technologies such as Lidar (light direction and ranging), lack of government regulation and, most importantly, limited consumer trust, especially when you consider electric vehicles have penetrated barely 5 percent after 19 years.

The greatest inhibitor to self-driving car (SDC) market penetration will be lack of consumer trust. An MIT Agelab study found that the consumers don't really want self-driving cars[8] and that comfort with automation is related to age, with younger generations more comfortable with full or partial automation than older generations. Only 40 percent of Gen Y/Z consumers were not comfortable, while approximately 80 percent of baby boomers or pre-boomers were not comfortable. In addition, for those 45 or younger, a 10-to-20 percent decrease in comfort levels occurred between 2016 and 2017, indicating a negative trend in groups that trust SDCs the most (see figure 5). Although consumer trust impacts longer term trends, lack of trust by private consumers may not have a significant impact on initial purchases of SDCs since most initial purchases will be made by owners of fleets for municipal busing, garbage collection, food/package delivery, taxis, police and the military. In addition, the benefits of autonomous cars, which will be discussed later, are not initially obvious as they can only be realized with a fundamental shift in how we live our lives. As a result, as autonomous cars are introduced, there may be an overemphasis on their flaws, but over time these benefits will become evident.

Any missteps or accidents, especially if injury occurs, will also slow acceptance. Recently, a self-driving Las Vegas bus received negative press when it was involved in an accident within two hours of initial launch. Although it was a minor accident and the bus wasn't at fault, it was initially reported as an autonomous bus crash. The accident caused by a delivery truck driving into the stationary bus might have been avoided if the bus had been programmed to sound a horn or avoid a moving object by reversing. Fortunately, lessons learned by a single SDC can be shared fleet wide (unlike human drivers), speeding improvement but not avoiding negative press.

Even a dealer demonstration of driver assistance features created negative press when a Volvo XC60 with autonomous braking abruptly accelerated into two people watching the demonstration, bruising but not critically injuring them.

A big drop into the trough of disillusionment occurred when an accident involving an Uber autonomous car that allegedly struck and killed a pedestrian put autonomous cars back in the headlines in a negative way. The effects of the crash reverberated throughout the auto industry. Within a few days of the incident, Uber, Toyota and the city of Boston halted autonomous car testing, and negative coverage increased, which in turn will slow consumer acceptance of autonomous cars.

Marketing by autonomous technology and vehicle providers can also have a negative impact on consumer trust. In 2016, a man was killed in a crash while using the Tesla Model S Autopilot system when he kept his hands off the wheel for extended periods of time despite automated warnings not to do so. Results of the National Highway Transportation Safety Administration (NHTSA) investigation[9] found no evidence of safety-related defects as the Tesla owners' manual describes the autopilot as a collection of "driver assistance features" and states that motorists are responsible for staying alert and maintaining control of the vehicle. The NHTSA did, however, express concerns about the marketing of automated-driving technologies. The term autopilot brings to mind systems used in aircraft where pilots fly hands-off for extended periods of time. However, aviation is a highly-skilled, highly-trained domain in which reaction times of minutes are needed. Cars, on the other hand, have lower-skilled operators and accidents unfold in fractions of seconds. Overblown marketing messages, even

Figure 6: Adaptive cruise control interface.

if not intentional, may not only be misleading, but they can reduce the market appeal they are trying to build if self-driving capabilities are perceived as greater than they actually are.

Good communication between vehicle and passenger helps drivers and passengers know when to trust or not trust automated systems. Unfortunately, engineers that develop automated technology may be in separate departments from engineers who create human machine interfaces, resulting in suboptimal communication.

Figure 6 shows the traditional adaptive cruise control interface where the majority of real estate is allocated to a speedometer. An on/off light that indicates the status of a safety critical function is allocated much less real estate. Such a warning light will probably go unnoticed in situations when a driver is focusing on the shining brake lights of a vehicle executing an emergency stop in front of his or her vehicle. In order to help maintain driver and passenger trust, instrument panels will need redesign. New communication techniques could be utilized such as a pop-out steering wheel that definitively indicates the driver must take control.

Autonomous cars must overcome the challenge of earning consumers' trust. The greatest benefits of autonomous cars won't initially be obvious because they can only be realized with a fundamental shift in how we live our lives. As autonomous cars enter the trough of disillusionment, their flaws will likely be overemphasized.

Interaction of people and autonomous cars

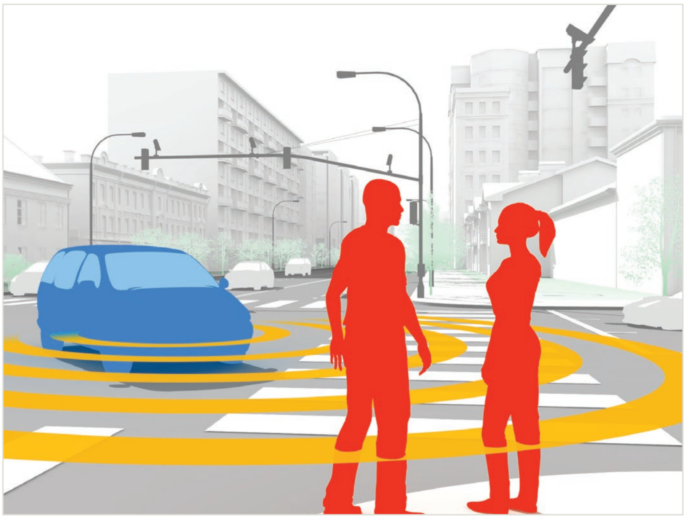


Illustration: Bryan Christie Design

Figure 7: Reading body language.

Rodney Brooks, founder of iRobot, wrote, "The big problem with self-driving cars is people and we'll go out of our way to make the problem worse." Consider his example below illustrating the difficulty of self-driving cars understanding the subtleties of human interaction. Human drivers immediately recognize the couple on the left (see figure 7) is conversing and not about to step off the curb, while on the right the man just stepped onto the curb while the women is about to step into traffic. It is difficult for a self-driving car to distinguish between these situations so a SDC must assume a worst case to ensure safety, as a result slowing traffic. Other subtle interactions that are difficult for a SDC to execute occur between drivers and pedestrians, such as eye-to-eye contact when crossing a street, or driver-to-driver contact when entering a roundabout to determine right of way. These are situations in which SDCs will slow. In addition, people will deliberately try to trick autonomous cars into slowing just for fun.

Autonomous cars will also provide owners anonymity to be a jerk or, as Brooks calls it, "jerk by proxy" (see figure 8). For instance, to secure a position to get home quickly from an event in a crowded city, an owner might send a robotic car to park near the event many hours before it takes place to ensure a parking spot, or even circle the area for hours while the owner is at the event, snarling traffic or reducing available parking. Government regulations that charge for city road usage should help reduce the occurrence of jerk by proxy, but new regulations are likely to lag initial cases of abuse.

Illustration: Bryan Christie Design

Figure 8: Jerk by proxy.

The role of connected vehicles

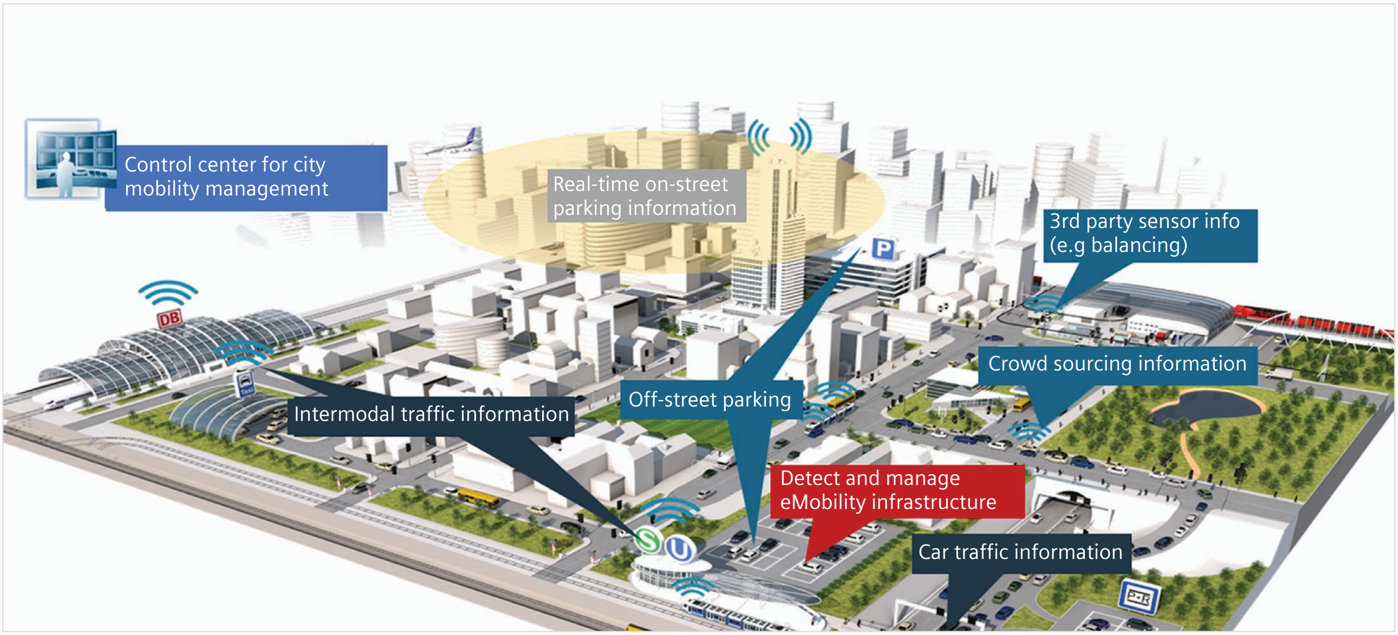


Figure 9: Connected vehicle technology (V2X), vehicle-to- vehicle (V2V), Infrastructure (V2I), network (V2N), pedestrian (V2P).

Mobility as a service is substantially increasing demand for individual mobility. This trend will accelerate even more when mobility services are driven autonomously. As a result, people who previously weren't able to drive, such as the young, old or temporarily unfit, or who previously couldn't afford to drive, will soon be adding to traffic at a time when traffic exceeds the capacity of city streets. Implementing autonomous vehicles within a connected vehicle (V2X) environment that includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2V), vehicle-to-network (V2V) and vehicle-to-pedestrian (V2V) communication will provide benefits that will make autonomous travel more appealing (see figure 9). These benefits include the following:

- Improved use of existing infrastructure for more efficient/ safer throughput
- Better fleet management by cities to help make sure that transportation resources (buses, trains, bikes, police/emergency vehicles) are deployed when and where needed
- The provision for a single location to plan, book and pay for a multi-mode trip

Although these benefits are potentially significant, determining who will pay for the infrastructure required to realize this communication environment has not been defined. Many OEMs and startups are reluctant to design autonomous vehicles that rely on V2X communication if cities are not committed to investing in the required infrastructure. Cities are beginning to understand the benefits of V2X communication, but also assert the transportation industry and their suppliers should be willing to make infrastructure investments as they will be significant beneficiaries. In any case, financial issues such as this must be addressed to speed the introduction of autonomous vehicles.

The future impact of autonomous vehicles on our day-to-day lives

Within the next few years, autonomous vehicles will be introduced onto our streets. As with any new technology, at first it will be a novelty. Conceivably, the utility of the technology will grow at a faster pace than its ability to be a nuisance, especially in the early years of mixing humans and SDCs. If we assume issues, such as lack of trust, low cost LIDAR, government regulation, security and the ability to recognize subtle human gestures, can be solved, autonomous cars will then become part of our daily life. Predicting when autonomous cars will be introduced is much easier than predicting when they will become ingrained in our day-to-day lives. Transitioning society from horses to cars took from 13-to-50 years, depending on if you lived in a highly populated city or a rural area. The transition to autonomous cars could be much faster than the horse-to-car transition due to the benefits autonomous cars bring and the supporting technology infrastructure that will grow around them.

Pillars

Figure 10: Tracks and stadiums is where you will find human-driven cars in 2050

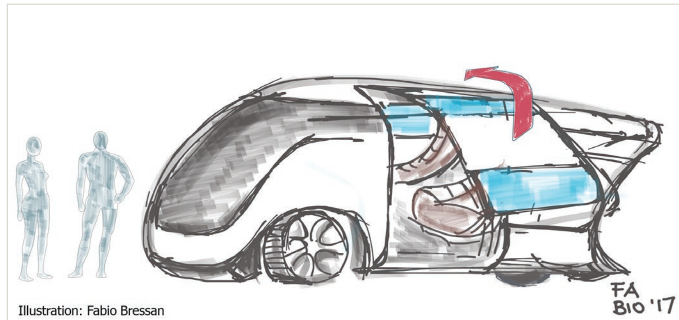


Figure 11: In the future, cars will be standardized pods.

So how will our day-to-day lives be different because of the future car in just over 30 years from now in 2050? One way to build a vison of our transportation future is to consider the impact autonomous cars will have on transportation and, consequently, our lives, based on the following three pillars.

1. **Affordability**: Low-cost short- and long-distance travel
2. **Experience**: Enjoyable, exciting travel experiences, in which the car becomes a living room on wheels
3. **Adaptability**: Easily reconfigured interiors for customizing affordable travel experiences

Pillar 1 – Affordable transportation

In 2050, private ownership of cars will be significantly reduced and even eliminated in certain locations as the alternative, autonomous mobility service, will be more convenient and affordable. As a result, human-driven cars will be relegated to tracks or stadiums for our entertainment, much like horses are today (see figure 10).

Of course, in the interim there will be significant resistance by drivers to give up cars and many will claim the steering wheel will have to be torn from their "cold dead hands." Unfortunately, for those not willing to give up their driving privileges, market forces and other benefits, such as fewer accidents and the freeing up of city parking areas, will gradually erode this resistance. A study by ARK Investment Management[10] indicates that if autonomous cars reduce driver errors consistent with reductions experienced by the airline industry when autopilots were introduced, motor vehicle accident rates will be reduced by 83 percent, from 1.1 to 0.2 deaths per 100 million vehicle miles traveled. As a result, as autonomous vehicles become safer than human-driven cars, one would expect that government regulation will gradually move towards making human driving illegal.

Much like the transition from horses to cars, the human-to-autonomous driving transition will first occur in major cities, then smaller cities, the suburbs and, eventually, rural areas. Transition time should be more rapid than the horse-to-car transition that took approximately 13 years in New York City, and almost 50 years to extend to rural areas according to Canadian online magazine, The Tyee[11]**.** Assuming an introduction date of 2020 for SDCs in larger metropolitan areas, the transition in the largest cities could occur at the latest by the mid 30's; rural areas may not see the transition until after 2050.

In the future, car bodies and drive trains will be part of the standard pods (See figure 11). Car brands will lose importance and consumers will focus on the service cars provide rather than the car itself. This is similar to how we view air travel today, as we are not focused on whether it is a Boeing or Airbus airplane, but more about airline service. Mobility providers, like airlines today, will provide different levels of comfort, such as economy, business or first class, based on consumer willingness to pay.

Today's mobility service providers operate in cities or greater metropolitan areas, but typically do not focus on intercity travel, especially at longer distances. In the future, cost effective autonomous intercity highway driving will become economical in part by electronically linking individual autonomous pods to a high-speed chain that travels at speeds between 150-to-200 miles per hour (mph) (See figure 12). Significant efficiency gains at high speed are achieved as air

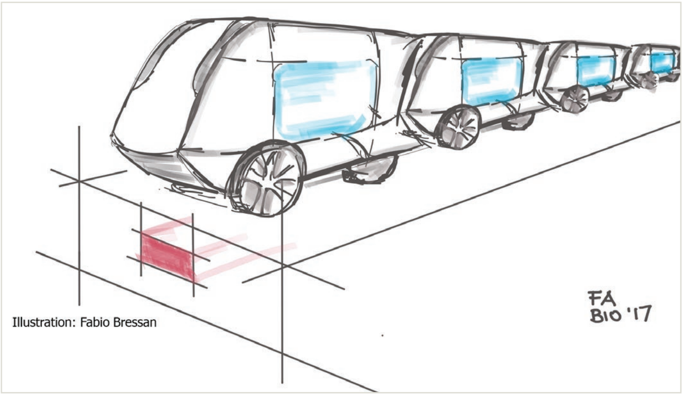


Figure 12: High-speed autonomous car driving chain.

Figure 13: Next Future Transportation's chained modules.

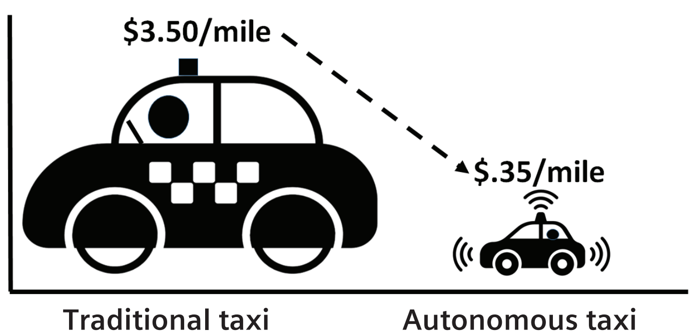
flows smoothly over the entire train while only the lead pod encounters significant power burning aerodynamic resistance. An individual autonomous pod will pick passengers up at home and then move to the highway where the pod chain will part to let a pod in or out. Unlike trains of today, a much greater level of convenience can be achieved as there is no fixed schedule; riders will leave and arrive when it meets their needs, leaving directly from home and arriving at their destination.

This chained herd of pods will not only make highway driving more efficient and convenient, but efficiency gains will extend to city driving. For instance, a string of six or seven cars can simultaneously accelerate after stopping at an intersection. With human drivers, it takes several seconds for each driver to react and start to move when a red light turns green; as a result, cars at the end of the line may not make it through a light, especially if drivers in front of them are distracted by nondriving tasks such as texting. The ability for a line of cars to simultaneously accelerate is just one example of how traffic flow will improve, resulting in fewer vehicles required to move the same number of people, reducing the cost of transportation. Companies like Next Future Transportation are already taking steps to make transportation systems like this a reality (see figure 13).

According to MarketWatch[12] (see figure 14), gaining efficiency and eliminating driver expense will reduce travel cost per mile by an order of magnitude from the current rate for taxis of $3.50 per mile to as little as 35 cents for autonomous mobility service. Since service providers will also have a captive audience, passengers willing to view advertising during a trip may even be able to travel for free, courtesy of the advertiser.

Greater convenience coupled with lower cost may be the strongest motivator to accelerate acceptance of autonomous cars. Autonomous mobility service is like a personal chauffer (see figure 15) at your beck and call for travel or errands like going to the grocery or even transporting children to school (see figure 15). The median hourly pay for a typical chauffeur13 in the United States is $16 an hour. Assuming a human chauffer is on call 12 hours per day, the annual cost is approximately $70,000. Based on annual mileage of 15,000 miles at the $.35/mile cost, the yearly cost of an autonomous chauffer would be about $5,000, and unlike a human chauffer, he or she would be available 24 hours a day. It is easy to see how attractive an autonomous chauffer will be at a fraction of the cost of a human chauffer.

In addition to the above cost efficiencies, low-cost, high-speed intercity travel may also put downward pressure on real estate prices. If you can live 50-to-200 miles outside of a city and still conveniently (by high-speed pod chain) experience the occupational, recreational, educational and cultural aspects of a city, many will be willing to live in areas farther from cities where real estate costs much less. As a result, housing will become much more affordable in cities. Lower housing construction cost will also result from eliminating the need for a personal car garage or by lower land cost in cities



Source: Next Future Transportation

Figure 14: Comparing the per-mile price of traditional and autonomous taxis.

Figure 15: Autonomous mobility service is like a personal chauffer at a bargain price.

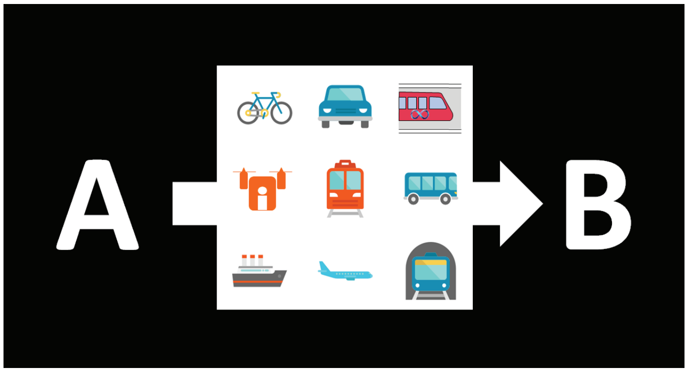


Figure 16: Intermodal mobility services will further reduce cost and increase convenience.

when more land has become available for housing as parking demands lessen.

Many factors mentioned above will also combine to further reduce costs. For instance, fewer accidents will lower insurance costs. Removing autonomous cars from service reduces revenue. As a result, manufacturers will be motivated to increase vehicle reliability as autonomous cars will need to spend 10-to-20 times more time on the road than today's vehicles. As a result, vehicle operating costs per mile will drop due to greater vehicle reliability and fewer accidents.

Further cost improvements occur when multi-mode travel is combined with lower cost travel modes such as subways, trains, buses, rental bikes, etc. (see figure 20). The optimal multi-mode travel combination will vary depending on distance or time requirements. For distances over 500 miles, a combination including the Hyperloop[14] may be appropriate. As distances decrease, combinations with a high-speed pod chain will be more efficient and for even shorter distance, bicycles or even walking may be part of a multi-mode journey.

Although multi-mode transport will be more cost effective, it poses new challenges as resources of multiple mobility providers and public transit services must be managed together. Complexity is further increased as consumer willingness to pay, preferences for reduced travel time, demands for greener routing all add to the number of potential mode combinations.

Multi-mode travel may also include air travel (see figure 17). Solving autonomous navigation on surface streets is complicated by unpredictable scenarios that could involve animals, pedestrians, construction or unexpected debris on roads. These land-based problematic issues are significant, as the time to avoid an accident on city streets or highways can require split second recognition and response. Autonomous aircraft have been flying for many years as air-based navigation allows for greater avoidance response time with no concerns for pedestrians or other land-based obstacles. The advantages of air taxis in congested urban areas is already being demonstrated by Airbus' subsidiary Voom, which offers a helicopter mobility service as an alternative to sitting in Sao Paulo, Brazil's rush hour traffic. Driving 30 kilometers to the airport takes nine minutes and costs $150, in comparison to a traditional taxi on clogged roads that costs only $50 but takes an hour-and-a-half in frustrating stop-and-go traffic

As the benefits above are realized, consumers will become accustomed to the idea of giving up the wheel and, eventually, few will resist the improvements in travel safety, cost and convenience that autonomous cars deliver.

Figure 17: Air travel could be part of a mobility service autonomous travel combination.

Figure 18: Stationary living room.

Source: Bentley Motors, Inc.

Figure 19: Living room on wheels with holographic butler.

Pillar 2 – Enjoyable experience

The perceived value of mobility service will not be driven by the brand name of the pod, but rather by consumer's perception of the transportation experience. The experience will primarily be delivered by the autonomous car interior, which will become the passenger's living room on wheels. Mobility providers will mimic airlines and offer economy, business and first class, but unlike airlines, providers will also try to further differentiate their offerings with unique travel experiences tailored to niche consumer wants. Consumer preference will vary, so the ideal moving living room configuration will also vary much like stationary living rooms in homes vary today (see figures 18 and 19).

The exact nature of the interior experience will not only be driven by personal preference, but also by the willingness to pay, time allotted for travel, current location and the needs of fellow travelers. Interiors may provide environments that facilitate relating to fellow passengers or to learn about what is near the pod's current location. The environment could enhance the ability to coordinate or create with others as we travel. Alternately, we may just want to immerse ourselves in luxury immediately when we get into an autonomous pod, as there is no reason to wait to reach a destination to start a vacation.

For example, consider a pod for a family going on vacation. In its basic configuration, the pod could have a couch and individual seats facing a table for eating (see figure 20a). With a change in lighting and display on table and window surfaces, the pod is now a game room (figure 20b). Finally, when it is movie time, windows and interior surfaces could change to provide a surround-view movie experience (figure 20c).

The surrounding surfaces could immediately be configured to your desired environment based on information in your smart phone or possibly even from your brain waves. At times even in a vacation pod, surfaces could be used for texting, emailing and viewing presentations, just in case you would like to get a little bit of work accomplished.

Augmented reality will become a fixture in autonomous cars as windows are used to display information to educate the passenger about what's outside the pod or near the travel route (see figure 21). Windows could provide information about businesses in proximity based on user demands or time of the day. This could include a nearby shop's current inventory to provide access to a gift for a friend, or if it's mealtime, a menu could be accessible for an establishment just outside the pod's door.

(a) (b) (c)

Illustration: Aimee Roberts

Figure 20: Alternative interiors for the vacation car: a-meal time, b-game time, c-let's watch a movie.

Figure 21: Augmented reality on windows displays information to educate about what's outside on your route.

Augmented reality and holographic technology could be combined on a historical tour. A trip through Boston could provide a holographic Paul Revere in the pod who describes the next tour stop such as the Old North Church. Upon arrival, exiting the pod moves the user from this virtual experience to a physical one walking through the church and tourist areas. Augmented reality information initially provided in the pod could continue to stream on a portable device, like Google Glass, as one walks the church identifying relevant physical items such as the pew that Paul and his family used. In this way, the tourist would easily slip between the physical, augmented and virtual worlds in a way that accentuates the overall experience (See figure 22a, b). Or for special occasions or holidays, such as Halloween, a pod could become a scary experience with ghosts, spiders and an eerie holographic fog (See figure 22c).

Of course, all of this comes with its engineering challenges. For instance, projecting video on all pod windows will have an adverse thermal effect that will tend to heat a pod interior. Additional air conditioning will then be needed to cool the pod, causing a drain on batteries and negatively impacting range. We will also expect the same quality experience in our mobile living rooms as we expect in our stationary ones. If we are watching a movie we will want surround sound even though a typical surround sound amplifier will further increase battery drain. Engineers will be challenged to redesign equipment that delivers experiences in our homes today that consume much less power in order maintain an acceptable range of costs. Techniques such as lightweighting of body and interior components will continue to be a part of the engineering arsenal to achieve the range and energy efficiency expected in our transportation systems.

In addition to power considerations, passenger safety will pose significant engineering challenges as to how to keep passengers safe while they enjoy their travel experience. Currently, driver and passenger willingly accept constraint of movement that comes from seat belt use in order to be safe. Acceptance of constrained movement makes it easier to develop passive safety systems like air bags, which can assume a certain position of the occupant. As transport experience becomes a key feature of the future car, the ability to move within the vehicle will become an important marketable feature. The approach to safety could go in different directions. For instance, in rail travel no seat belts or airbags are utilized. For autonomous pods in a chain, as described above, the rail approach to safety may be an option as long as the pod travel environment is controlled and isolated much like rail travel today. Once the pod leaves the chain then more traditional safety methods such as seat belts would be used. Alternatively, since passenger position may be unknown, numerous airbags might be a path to consider so that the passenger is enveloped in a soft inflatable surface throughout most of the pod interior, or at least all surfaces that could cause harm.

Sharing vehicles that rarely park, except for maintenance and repair, will pose new challenges to engineers and operators. Since operators will attempt to minimize off-road time to optimize revenue, the entire vehicle will need a high level of durability. Material durability requirements will need to be reconsidered. As an example, the seat foam needs to provide support over extended periods of use. Some people will drink and drive since they won't have to worry about safety and, at

(a) (b) (c)

Illustration: Aimee Roberts

Figure 22: Historical tour experience that begins in the pod (a) and seamlessly continues as you enter a historical site (b), (c).The scary ghost car experience.

times, may even leave human substances behind (see figure 26). Materials or sensors will detect any aberrations in the interior and alert the mobility provider so action can be taken to clean a pod or even to penalize a passenger for being inconsiderate. Interiors must be able to be easily cleaned and sanitized, possibly with antimicrobial surfaces that sanitize themselves, or waterproofed for a quick wash before being hurried back on-road. Or possibly a mobile "cleansing pod" will intercept an unoccupied pod suspected of not meeting cleanliness standards while it is still on the road to even further reduce down time.

Pillar 3 – Adapting by easily reconfiguring

Meeting passengers' demands and providing an affordable experience is a critical challenge for automakers and service providers. To provide a range of affordable experiences, pods will be designed for quick reconfiguration, either while in service or with minimal down time. To create reconfigurable environments, a number of components could be employed, such as electronic displays, holograms and retractable tables, chairs and beds. Standardization of mechanical as well as nonmechanical components (see figure 23) will make it easier to substitute components. For instance, requiring components to comply with width, length, height or assembly standards facilitates faster component exchange.

The best choice of where reconfiguration should take place is up for debate. Reconfiguration could be in a factory or by a mobility provider service center. At the lowest level, components could be substituted into a generic pod to change a car from a living room lounger to a sleeper. Alternately, a complete add-on pod that enhances an experience, or provides a product or desired services, such as the ability to cook or sleep, could be hooked up to a basic pod soon after it joins a chain (see figure 24). Since pods will be shared, the cost of manufacture and maintenance will also be shared, helping make the travel experience more affordable.

Source: Luxoft

Figure 23: Holograms could be used to easily reconfigure the travel experience in an individual pod.

Source: Next Transportation

Figure 24: Add-on pods could link to basic pods to provide specialized additional services or products.

The future car – enabling a living internet

Figure 25: Our living rooms on wheels will provide the experience of choice when we want it.

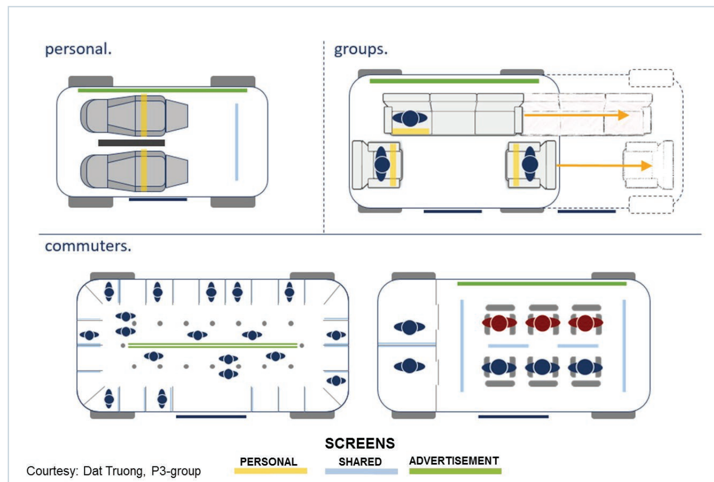


Figure 26: Accepting targeted advertising while traveling may provide free transportation and fuel for experience startups.

The current internet experience comes to us at low-to-no cost (in part because of advertising), is easily customizable to our preferences and has low barriers of entry for those who want to profit by providing content. The future car will create a new version of the internet, or living internet, available where a physical experience seamlessly melds with the familiar virtual experience of the internet today. Let's look at how this may become a reality.

The future car and its surrounding infrastructure will provide a customizable and affordable travel experience (see figure 25). This will significantly impact our day-to-day lives in work and play. Smaller pods will be used for personal transport or expanded for family travel. Larger pods will be used for mass commuting or to host a meeting (See figure 26). Ease of reconfiguration will enable niche providers to create specialized pod experiences. Experience startups will respond to niche demands for unique travel experiences, such as Italian lessons while enjoying wine and cheese, speed dating for the quick 20-minute trip across town, group pods tailored to connect users based on hobbies or political views, or game cars for gambling. The possibilities will be as varied as the users themselves, just as today the internet provides the same profound variety of sites and exploration.

If you choose to allow targeted advertising while traveling, transportation costs could further be reduced from the expected $.35/mile to no cost (see figure 26). Experience providers will fight for advertising dollars much like content providers on the internet today. Advertising will not only reduce travel costs, but will also allow companies to generate revenue by attracting targeted advertising to pods holding captive audiences with a particular product predisposition based on the travel experience selected. Today, with low barriers to entry, content is provided on the internet at minimal-to-no cost funded by advertising; transportation in the future may also go in this direction. The result will be the creation of a living internet (LIVNET), consisting of an experience with the varied virtual components of the internet today, but with an added physical and tactile dimension (see figure 27).

Figure 27: The future car will facilitate a living internet with all components of the internet today, but with an added physical and tactile dimension.

Source: Rinspeed

Figure 28: Rinspeed Snap concept delivering a stationary experience.

The eventual impact of this change may be difficult to fully assess. Travel will become more attractive, and as a result, we may want to travel more. With low transportation costs, we may choose to travel full time as costs could be less than a mortgage. Alternatively, since it is easy to deliver a mobile experience, we may choose to not travel and have experiences come to us. For instance, travelers could stay at home and have the wine and cheese pod come to the home and even pick up a few friends along the way. The Rinspeed Snap concept[15] is an example of how an autonomous platform could be used to deliver an experience related to work or play (see figures 28, 29).

The living internet will add a dimension to the challenge of multi-mode traffic management by proliferating the combination of pods needed to deliver multi-experience transportation. There will need to be coordination between traffic management and logistic systems to efficiently manage this highly complex transportation puzzle. No single company can do this alone; government and commercial entities must work together to develop, deploy and maintain vehicles and the required infrastructure. Today's automakers and mobility providers, along with entities experienced with big data and logistics, traffic management and human machine interfaces, need to collaborate for this vision to become a reality. Such a collaboration poses technical and even greater financial and business challenges; communication and forward-looking objectives will help overcome some of the tenacious hurdles.

Source: Rinspeed

Figure 29: An autonomous vehicle could deliver a variety of stationary experiences

Conclusion

We have looked at many positive features the future car will provide society, such as enhancements to the travel experience or more mobility for the elderly and very young. Low-to-no-cost transport will give people greater ability to go where they want and when they want in order to suit their educational, occupational or entertainment needs, regardless of their means. Real estate costs will fall as people are able to live outside of cities and still take advantage of recreational, educational and cultural benefits.

Negative components may arise as well. Unfortunately, some may inevitably want to use SDCs for terrorism or crime. Job elimination will force re-education for many currently dependent on traditional transportation for a living, such as mechanics, taxi drivers and truck drivers.

A smooth transition from today to this much safer future world will require new laws and regulations regarding how pods are developed, tested and licensed. The business model of insurance companies will change from drivers paying for individual coverage systems to service providers purchasing insurance to protect against revenue-losing technical failures. Eventually we will have to accept the premise of giving up the wheel and we will have to explain to our grandchildren why we even put up with a risky, unsafe world in which humans rather than reliable robots drove cars.

Within the next few years, autonomous cars will become more visible in our cities, as occasionally our Uber or Lyft ride may be driverless (although with a human watchdog inside). It will take at least 10-to-15 years for many of the benefits described in this white paper to become commonplace in our largest cities and deliver the positive impact we await. Soon after change will make its way to smaller cities and eventually even to remote rural areas, maybe by 2050 or hopefully even sooner.

In any case, it’s time to get ready for the transportation revolution the future car will bring.

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Siemens PLM Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Suites 4301-4302, 43/F
AIA Kowloon Tower,
Landmark East
100 How Ming Street
Kwun Tong, Kowloon
Hong Kong
+852 2230 3308

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