# Manifesto for the End of Driving

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Worldwide, more and more people continue to purchase and drive motor vehicles. This is the revealed preference of massive numbers of humans as soon as they can afford to do so, implying more congestion, pollution, roads, parking lots, injuries, and deaths. Currently, world vehicle population doubles every 20 years. By 2030, the planet is expected to have two billion motorized vehicles—twice what it had in 2010. Four billion by 2050.

During this same time vehicle technology will change dramatically. Two technical revolutions, the first regarding alternate energy systems and powertrains and the second regarding robotics comprising artificial intelligence and sensor systems, promise to make motor vehicles cleaner and safer. These two changes will also make motorized travel cheaper, more convenient and more appealing. The concomitant risk is that this helps ensure and possibly shorten the current vehicle doubling time to further increase the problem of growing congestion and loss of land to roads and parking space.

*This manifesto describes ways to mitigate this risk.*

At the extremes of the automobile debate are two simplistic future views. Each is misleading and promotes inaction.

The first simplistic extreme is: "Everything is bad and getting worse". Bad-to-worse stories project hopelessness and engender resignation. They seldom leave us empowered and inspired. It is preferable to put this out of mind, a strategy of denial.

The second, and equally simplistic, is: "Technology is coming to the rescue and everything will work out". Technology-to-the-rescue stories tend to relieve our anxiety. Someone is handling the problem. Given such good news, we can safely ignore the issue.

These stories—especially the former sort—grab our attention, sell media and re-shuffle our anxieties, but they seldom illuminate a viable path to solution.

The human tendency to be drawn to such stories originates in our amygdala body, an ancient brain structure linked to both fear responses and pleasure. Especially sensitive to dangers, this tiny bulb of cerebral tissue has helped to keep us, and many millions of our ancestral species, from being eaten before we had a chance to reproduce. Today it both

exaggerates our attention to anxiety-media and conversely invites complacency by contrast.

Specifically, this natural human tendency encourages one side to assert that the automobile is destroying the earth and must be stopped if we are to survive, and the other to declare that the autonomous vehicle—especially if no one personally owns one—would solve the problem. This encapsulation is a simplification, of course, but many of the views for solving "the car problem" tend toward one of these two camps.

The first approach wants people to stop consuming cars and miles by living and traveling differently while the second assumes that new technologies will remove the problem allowing us to continue consuming safely. It is not that these two extreme arguments demand we choose between them—they both have a role—rather it is that they alternately leave us hoping or expecting the problem to work itself out while we wait.

We expect that most consumers and marketers will lean toward the latter approach, since it is closer to the status quo for users and involves a lot of cars for manufacturers—paradigms each are comfortable with. We also think the all-important solution factor that self-driving cars nearly all be robotaxis and very few personally owned is far from preordained. Such an outcome would take a remarkable shift in travel habits, social preferences, public infrastructure, personal space, and many other factors of automobility.

*This manifesto addresses the inherent challenges in carrying out the essential worldwide task of moving most motorized mobility to robotaxis.*

## A note regarding timing

Readers of this manifesto will hold a range of opinions regarding the timing for general availability of L5, the Society of Automotive Engineers Level 5 self-driving vehicle, exemplified by urban robotic taxis that can pickup and drop off passengers and parcels anywhere.

Some new entrants to vehicle design—Google, Tesla and perhaps Uber among them—tend to forecast L5 to within a few years of 2025, sometimes with implications of limited geographic reach on only divided, limited access highways or limited pre-mapped routes. Established automotive manufacturers tend to push L5 out another decade to the mid 2030s.

In order for L5 to safely operate everywhere and in a pervasive manner, hundreds of components, features, preparations and regulations must perform with vanishingly small error rates. A system of 100 critical components with each component having an independent fail-safe probability of one failure in 10,000 per year, means that the annual system failure probability would be one percent—a figure far too high for pervasive, unconstrained use of L5 robotic vehicles that need to travel 100 million miles between fatal accidents in order to be as safe as human drivers.

This point is best made by vehicle-highway automation pioneer Steven Shladover of the University of California at Berkeley in an unpublished paper "Technical Challenges For Fully Automated Driving Systems." He provides a detailed, expert-level compendium of barriers to general deployment of L5 prior to 2040.

In this manifesto, we use 2050 for L5 pervasiveness for two reasons. First, this date approximates the projected time point for the world motorized vehicle count to reach four billion from today's level of just over one billion—and this growth is our key concern, hopefully motivating critical response to our manifesto. The second reason comes from our research-based conclusion that pervasive deployment of shared fleets—the social change we are focused on—will take longer than merely solving the technical issues for L5, even if we are optimistic about human ingenuity finding rapid breakthroughs in robotic technologies.

However, everything in this manifesto is independent of the future date at which pervasive L5 is achieved. Whenever the robo-cab may hit the streets, there is very little time left for massive social innovation to avoid an urban gridlock of private vehicles.

 

## The Manifesto

1. Appreciate that automobility is fundamental to humans
2. Understand and plan for natural saturation levels of automobile populations
3. Be aware that humans are subject to a 5000 year-old budget regime for travel time and money
4. Embrace the complex challenge of satisfying trip demand via shared fleets
5. Find ways to make vehicle sharing appealing to people who prefer ownership
6. Seek diverse ways to share vehicles
7. Find multiple ways to manage shared fleets
8. Focus on behavioral economics above all to achieve massive sharing
9. Disrupt transit first
10. Encourage the private sector to provide urban transportation with equitable access
11. Plan and develop synergies between livability and shared fleets
12. Plan robotic vehicle value for the whole world, not just America and Europe
13. Design vehicles for shared fleets to be highly functional for sharing
14. Design shared fleet navigation to manage congestion
15. Manage shared fleets to address the road and transit funding problem

### 1. Appreciate that automobility is fundamental to humans

Humans have relied on power-assisted mobility since the domestication of pack animals 7500 years ago. Having reached an evolved state—now *automobility*—it is now counterproductive to suggest abandoning the use of powered vehicles. Too few people would listen and even fewer would be interested. There is every indication that humans will make and use more powered vehicles before they begin using fewer. Humanity must find a solution to what's wrong with automobiles since they cannot all be replaced by bikes, walking, or wishful thinking. Autonomous vehicles enable—but do not guarantee—solutions to many of the things that are wrong with automobiles.

### 2. Understand and plan for natural saturation levels of automobile populations

Car populations have a natural saturation point. Research shows that as the human population of a nation or region approaches a given level of GDP, their owned-vehicle count peaks between 0.75 and 0.85 per capita. Even if robotics moves that needle, there will still be an equilibrium point. Either find a way to accommodate that level of ownership in a sustainable fashion (elusive to date) or find a way to satisfy the implied demand for passenger miles traveled with a lower vehicle count. Do not assume that lowering the demand for motorized travel will be enough to solve the problem (although there is no harm in throwing that in).

 

### 3. Be aware that humans are subject to a 5000 year-old budget regime for travel time and money

Humans typically spend—i.e., are willing and able to spend—about an hour per day and about 11% of their disposable income on travel. The evidence for this stretches back to the beginning of civilization, and it remains true for all but the poorest segment of most populations. That implies that more effective and cheaper means of travel – such as will be offered by self-driving cars and shared-vehicle fleets – will mean easier and more comfortable travel, more motorized trips, the ability to go further within the same daily time budget, and sprawling land use patterns. Typical public transit performance in most countries already creates average travel times that are twice as long as that for car trips over the same distance. Marketers like those who engineer the consumption of tobacco and sugar will know how to ensure we consume our 11% and those 60 minutes. They will pitch the consumption of mobility, shifting travelers to this new convenience and going further than ever in a car. Humans with money are easy prey.

### 4. Embrace the complex challenge of satisfying trip demand via shared fleets

Massive shared fleets to satisfy the great majority of passenger miles appear to be an excellent solution for sustainable mobility. The worldwide count of motorized passenger miles traveled is projected to quadruple by 2050, but we'd like to keep the vehicle population count at 2010 levels. This arithmetic means about 80% of all 2050 vehicles must be shared.

But robotic taxis, shuttles and jitneys providing instant trips anytime to everybody going anywhere is not inevitable, nor even probable by default. Humans will make decisions whether to own or share automobiles based on many things besides that which might maximize savings or minimize costs in a personal or family calculation. What makes good financial sense to one person or family may not strike another as important as other factors. While we can expect many people to adopt the use of shared vehicles for personal convenience or financial reasons in the coming decades, it cannot be shown that this will, by default, hold true for a significant portion of humans.

This will be difficult to achieve unless some very attractive shared services are offered since only a minority of humans volunteer to accept something they do not prefer in order to benefit the common good. Even fewer will volunteer continually.

Technology, insurance and regulation will all bear on the growth of vehicle sharing. These factors in turn must support a re-engineering of mobility sensitive to the social and psychological framework of sharing—a framework that reaches far back into the socialization of primates. The sharing economy is popular among some and appears to be growing, but it is not yet for everyone. We must enumerate every barrier to sharing; then find antidotes to each of them.

 

## 5. Find ways to make vehicle sharing appealing to people who prefer ownership

Right now a majority of adult humans prefer to begin owning or continue to own a car, notwithstanding declining car-use trends among young, connected, urban Americans. For every one of these there are a hundred others in the developing world itching to take their place—i.e., that is their revealed preference *when they can afford to do so*. In fact, *there are many more people on the planet who wish to begin owning a vehicle than there are those that already own*. It will take much more than saving money or time to dissuade some people from ownership. In fact, when robotic vehicles inevitably lower *total cost of ownership,* the decline in ownership we wish for would more likely become a rise in ownership.

Finding ways to bring convenient, reliable, cheap, shared mobility to populations that do not own vehicles is essential. We need to do this in ways that turn their stated preference for ownership into a revealed preference for sharing. It is not enough that transit simply be adequate to get low-income workers to factory and office. What is needed is a mobility-on-demand system that would make vehicle ownership superfluous and even undesired—a system that would have its users invest in their housing, health or education instead of a family car. Robotic vehicles can help enable this, but we must nudge the social environment to achieve this. It will not be a windfall.

*We must create more reasons to prefer shared vehicles than there are reasons to prefer owning.* Car owners and car enthusiasts will resist shared vehicles for a lot of reasons. We can enumerate all these reasons and find ways to counterbalance them by a factor of two or more (see section 8 on behavioral economics, below). Here are a few to start:

1. I trust the car in my garage…
2. Everything in my car is how I like it…
3. When I use my car, I know when I will leave and when I arrive…
4. I prefer my privacy each day as I go to work and return…
5. I do several things on each trip: I drop the kids at school, I pick up the dry cleaning, I shop…
6. I have a really nice car. I won't be seen in a shared-car…
7. I keep my clubs in the trunk. You never know when I can play the back nine…

## 6. Seek diverse ways to share vehicles

There are many potential ways to provide carshare services. Already we have uniform pools of vehicles such as offered by Car2Go and slightly variable selections such as offered by Zipcar or Enterprise. But these are structurally inadequate to achieve full optimization since they are currently impractical to tailor to any useful degree. A user may be able to find one nearby and one that is good enough to carry groceries, but seldom one that is a perfect size for the task, or exactly what she wanted to pick up her date. This requires vastly more shared vehicles, orders of magnitude more users, more choice, managed services, and ongoing ICT improvements. Consider how much richer is the experience of book buying online now than it was 21 years ago when Amazon launched. In the next two decades car-share services will have to be improved at least a hundred-fold. Of course robotics will make all the difference since automated and optimized vehicle distribution will be possible.

One frequently stated assumption about the future of shared fleets is that *ridesharing* amongst strangers taking similar trips would be significant. Yet there are some important social barriers to this sort of ride sharing, and the evidence so far is that the reduction in vehicle miles traveled (VMT) would be very small. But that is among car-owners migrating to ridesharing. The acceptability of ridesharing among public transit users already comfortable with commuting beside strangers would likely be higher.

Ridesharing has made little progress until now and has very low participation if ridesharers are few, since opportunities fall off exponentially. Lowered expectations or more work is needed here. Nonetheless, given a combination of far more powerful and specialized social computing (UberX-app times ten), massive fleets and the potential of trip-sharing with last-mile goods (something that DHL has already begun exploring) ride sharing could play a significant role helping to lower VMT while raising the people- or goods-transport value of each mile.

There is no reason to assume that all users of shared vehicles need to use the same app. Affinity groups (targeted re-marketers, actually), each with specialized apps (Wal-Mart Shopper Group, Iron Workers Group, University Alumni Group), could draw from massive common pools of vehicles. Vehicle manufacturers could bid to feed vehicles into managed, aggregated vehicle supply pools that stage, fuel, clean, maintain, re-skin and re-cycle vehicles. Remember these vehicles will remain roadworthy only 20 or 25% as long as cars do today because of high daily usage.

 

There have to be hundreds more angles here. See the Uber-like Shuddle designed for young children by Nick Allen, a Sidecar co-founder. The future of shared automobility is digital, entrepreneurial, optimized, and creative. Buses, especially those with long waits and mostly empty, are done.

## 7. Find multiple ways to manage shared fleets

Shared vehicles will appeal differently to different people. So, we must make them in enough different ways to appeal to most people. Just as there are vehicles on our road that range in value and comfort, so too will shared services need to cater to a broad range of tastes. As shared services mature, the service will become more important to user satisfaction than the trip, just as Detroit learned that the vehicle was more important to user satisfaction than the trip.

If all we make available is the standard two-seat Car2Go vehicle, we will get limited participation in sharing. The same is true for buses and every other vehicle configuration, every vehicle rental model, and every vehicle distribution system. Larry Burns taught us that vehicles should be *tailored*—i.e., sized and equipped "just right" for the immediate purpose. But this is about much more than how many passengers it can carry or whether it can schlep a sofa home from IKEA. Many other matters such as privacy, luxury, cleanliness and style will mean the choice spectrum demanded when ordering up a ride will start to look more like arranging the perfect weekend through Expedia than renting from Car2Go or hailing whatever is nearby from Uber.

## 8. Focus on behavioral economics above all to achieve massive sharing

Not everyone is comfortable or willing to share—especially in societies for which private property and personal space is fundamental, and especially among those who already own the thing to be shared. This is so whether we consider clothing, a bottle of beer, or a car. What causes resistance in the case of car sharing, as opposed to ride sharing? For someone who has long owned a vehicle, or is seeking to own one, the reasons are likely self-evident. But for someone who is already willing to use a shared vehicle or who cannot afford to own a vehicle, such resistance may seem surprising, foolish, or selfish.

But something else is often at work. Not only do humans express a wide variety of attitudes and emotions toward sharing space and artifacts—i.e., privacy and ownership—but some of these attitudes and emotions reflect how humans make decisions—influenced by deep behavioral modes that extend back millions of years rather than just a few thousand as automobility does. Resistance to sharing (or preference for owning) is about more than "just liking to drive".

Behavioral economics teaches us several things about human psychological barriers to what we might consider a *rational* solution of the greater convenience or saving expense of using a shared vehicle. Behavioral economists use the expression *rational* to mean "consistent with some model", rather than the more commonly understood meaning of economically optimal or even "commonsensical". Faced with evidence for any human behavior that does not appear to be economic common sense—minimizing financial loss or maximizing financial gain—behavioral economists provide explanatory models for such decisions.

The many hundreds of experiments that expose and measure behavioral economic decision effects are usually done using money and university students, and the results are routinely interpreted for behaviors regarding sub-optimal investment, mortgage and car-buying decisions. They are also useful to help understand how people make major, but counter-intuitive, surgery decisions.

When thinking about why a person might prefer owning a car to using a shared vehicle—even when it is clearly explained that the cost would be lower and the trip more convenient—several of the effects described by behavioral economists help understanding:

- The *endowment effect* says that a person values more highly that which they already possess—often by a remarkable margin. The

 

car one already owns feels much more valuable than would the fair money to be received for selling it—usually by a factor of at least two.

- *Reward prediction error* means that people notice a large change proportionally far more than a small one. The life-style difference one might appreciate or regret due to being car-less might be imagined as far larger than in reality—again usually by a factor of two or more—causing many car owners to simply avoid the decision to go car-less, perhaps for years.

- *Loss aversion* says that the value of a particular gain is perceived as much smaller than the negative value of a similar-sized loss—again twice or more. The assurance and privacy of owning a vehicle one already owns might feel more valuable than the relief one would experience from no longer having the worry or expense of owning that vehicle.

There are other specific effects, such as ambiguity aversion, habit, inertia, risk aversion, social norm, status quo bias, sunk cost fallacy and several forms of utility biases that would subtly influence the decision process to abandon vehicle ownership. Hence asking someone who owns a vehicle to sell it and change to using a shared fleet is not a simple economic value calculation.

There are ways to address these decision processes—also described by behavioral economists. For example, reduce the influence of *loss aversion* by intentionally targeting user communities for which service offerings can cover all user needs. It is better to have 10,000 members 100% demand-satisfied (and no owned cars) than 100,000 members 60% demand-satisfied who still need to keep a car in the garage. Anyone who keeps their car will use it.

There are other means such as choice architecture, use of halo effects, shaping hedonic adoption, as well as using herd behavior and social proof. The best known among all these is the use of nudges.

The bad news is that if you provide a shared fleet not everyone will come. The good news is that there are ways to market shared fleets to make almost everyone participate. The success of the autonomous vehicle in reducing world automotive population and congestion will have more to do with the application of behavioral economics than the application of in-vehicle sensors and artificial intelligence.

## 9. Disrupt transit first

Shared vehicle services will initially be seen as a step down for most car owners. They can just buy one, anyway. But these same services will be seen as a step up for most transit users. Transit users have a lower expectation of mobility than do car owners. They expect to wait, to walk part way, to get caught in the rain, to carry packages, and to sit beside strangers who ate garlic. They expect to struggle with a baby stroller on a crowded bus. And they expect to stand all the way to work, even though they paid for a seat. An offer of a single-segment, origin-destination ride in a shared vehicle at, say, twice the price of a bus ticket would sell out fast. Private and improved publicly available transportation network services are already taking users from city bus routes and taxi companies.

Car owners have the opposite expectation of mobility. They go where they want, when they want, at what most of them perceive as a small, marginal cost. It would be a poor business decision to target a significant shared fleet to typical car owners initially. The service levels needed to persuade them to abandon the vehicles they own would be untenable. Start where there is comparatively poor service, which usually means public transit. Disrupt ownership later, when there is a compelling service level on offer.

The resistance to affordable, convenient ride sharing would be lowest among transit users, and highest among habitual automobile owners. Well-subscribed shared fleets and growing fleet revenue means greater service levels can be offered sooner. New service levels can mean replacing large-vehicle, fixed-route, fixed-schedule systems with smaller vehicles running on demand schedules and flexible routes. As on-demand, shared services mature and become more flexible, they would begin to attract car owners, especially those perceiving diminishing value in buying another vehicle or maintaining one they have.

Public transit needs to be fully revolutionized into shared small vehicle services—disrupted and rebuilt, not just trialed and threatened—before a substantial subset of vehicle owners will abandon personal ownership and come aboard. This new public transit needs to evolve into light rail, bus, shuttle, taxi, and jitney all rolled into a single service spectrum, going way beyond autonomous buses to a fully-shared, diverse fleet. A focus on transit first yields the quickest path to the holy grail of shared fleets that many advocates currently expect from vehicle automation.

 

### 10. Encourage the private sector to provide urban transportation with equitable access

Improved consumer services – such as providing reliable, affordable passenger travel – thrive on innovation and flexibility. Profit drives private investment and efficiency. So let private sector enterprises provide not just most, but all transportation service. Minimize subsidies except where needed to ensure equitable access. There must be appropriate government and interest group oversight of a level and form that will likely be reached only via discussion, debate, and shared understanding.

The private sector profit motive encourages market stratification and customer cherry-picking, both of which lead to inequitable access. People who can barely afford a bus ticket are not attractive customers. This can be addressed. Vehicles can migrate down the supply chain: new vehicles enter service at higher mileage fees and this fee drops as they age or as user ratings fall. Governments can set up a *Corporate Average Mile Price* (CAMP) configured and audited to ensure a scaled range of services from, say, 15 cents to $1.50 a mile just as the Corporate Average Fleet Efficiency (CAFE) standard in the United States is satisfied by a spectrum of fuel efficiencies.

A transportation network company with a constantly-optimized range of robo-cars from luxury to utility in a number of cities can mange CAMP pricing—even cap-and-trade price targets and vehicles with other companies—all to satisfy the CAMP standard which, audited by Government under rules set by legislation, ensures mobility access for all. Worst-case, such firms can earn subsidies for targeted fleet segments—mobility stamps instead of food stamps.

Access equity likely implies that government needs to audit and enforce, but it does not mean that it must own, operate and subsidize transit vehicles. With rides subsidized under a system of rules, private fleet operators can optimize vehicles, routes and schedules.

### 11. Plan and develop synergies between livability and shared fleets

Livability relates to a community lifestyle of increased safety and health and reduced intrusion and risk from the automobile. As expressed by Obama's first Secretary of Transportation, Ray LaHood, "Livability means being able to take your kids to school, go to work, see a doctor, drop by the grocery or post office, go out to dinner and a movie, and play with your kids at the park—all without having to get in your car." A livable community implies a greater reliance on walking and biking and reduced PMT in a motorized vehicle.

While livability is enormously important in its own right, it also holds some important synergies for moving away from vehicle ownership and toward more reliance on shared fleets:

- Livability reduces PMT demand, which, in turn, reduces the economic motivation for and the status value of ownership. This may reduce the need for frequent automobile use, lower the visibility.
- Livable communities would tend to generate certain behavioral effects such as halo effects, herd behavior, and social proof. These would tend to form nudges further encouraging yet more people to shift away from ownership.
- Livability and non-ownership create a virtuous feedback loop.

It is important to recognize that livable communities still require goods to be delivered, so there would be no community without some exposure to motorized vehicles. This effect can be more easily minimized with autonomous vehicles.

 

### 12. Plan robotic vehicle value for the whole world, not just America and Europe

Many of the popular media articles written about self-driving vehicles position the technology squarely in the developed world, on well-paved streets, with middle-class or well-heeled passengers—the kind of people that already own 2.1 cars per household and might upgrade one of them to a self-driving car (SDC). Often the sense portrayed is that North American, European, and Japanese passengers will be better-cocooned and more productive on the way to office jobs—or even pampered travelers as portrayed by the Mercedes F 015 demonstration vehicle. But this is hardly the democratic, social-good technology needed to address congestion, over-stressed transit and inadequate taxi services that a large majority of the earth's urban populations live with.

Communities that have poor or missing transit systems will have an opportunity to revitalize mobility with a modest but still much better autonomous system. This can be done to ease poverty, promote sustainable urbanization, get people to jobs, and most of all to help car-aspiring mobility service users see that sending their kid to school is a much better idea that buying their own car.

### 13. Design vehicles for shared fleets to be highly functional for sharing

Shared fleet vehicle designs—and many designs will be needed—will not necessarily look like today's cars and light trucks nor will most of them look like the glitzy concept cars turning up at car shows—although some could. Initially, the self-driving car comprised several expensive sensors and some sophisticated software added to existing cars. Soon after, all these sensors with their falling prices and self-driving intelligence are starting to be absorbed more sleekly into the vehicle so that we could expect future SDCs to look essentially like today's vehicles: an elliptical body with windows, sitting on four wheels with room for two to five travelers. According to current YouTube videos, some would be streamlined and sexy like those from Mercedes and Tesla while others would be prim and dorky like the most recent Google self-driving car, a little two-seater bubble with no driver controls. Perhaps we would want one that looks more like a Corolla—or at least priced like one.

But none of these personal-styled designs would work as the majority design in a shared fleet. They are too hard to get into and out of, in contrast to the time-honored designs of the London black cab, and the mini-buses serving parking lots at airports. Interiors need to be rugged, easily cleanable or re-skinable. Owned cars have to look stylish outside and be plush inside. Shared vehicles have to be functional in and out and trivial to maintain inside—many will be cleaned daily, and re-skinned every few months. Shared-vehicle connectivity has to be flexible, high-bandwidth, and have additional security, privacy, and public-use aspects. Shared vehicles will carry people, packages, babies, pets, golf clubs, and furniture. If you are ride sharing how will privacy be managed; when you leave the vehicle, how will you take everything? After you leave what will the next traveler contend with?

So far, the central focus for the SDC has been its sensors, digital maps, and artificial intelligence. But the SDC of the mid 2040s will incorporate many more innovations that will have unforeseeable impacts on the decision to own or share, as well as on designs and availability. Materials such as graphene, developments in wearables, pervasive ICT, innovations in power management and storage, and manufacturing techniques such as 3D printing will influence the desirability of sharing or the efficacy of owning.

Will yet more digital mean still less physical? Or will the physical vehicle remain an aphrodisiac? If owning a car has becoming an albatross to some people already, how much more so will owning become a negative? Interconnected cycles of function, use, materials, regulation, design and

 

social change are both powerful and unpredictable, turning today's artistic and marketing depictions of expected future vehicles into caricatures, like 1950's renditions of flying cars, by the time the 2040s roll around.

The Mercedes F 015, expected in 2017 for about $400,000, gleaned a lot of attention in 2014. But the F 015 is for owning, not sharing. Could you guess? An investment of $400,000 in 2017 dollars in the kind of shared fleet we are describing would provide over three million passenger miles in the 2040s (12 vehicles x 3 years x 65,000 miles x 1.3 travelers). That's about 200 American families-worth of personal travel in 2012. Google's Sergey Brin and Uber's Travis Kalanick probably already know this.

### 14. Design shared fleet navigation to manage congestion

Robotic vehicles provide a powerful way to address congestion and maximize infrastructure value.

Today, users of vehicles choose critical trip details: when to go, which roads/lanes to use. These choices are influenced by travel habits, congestion reports, roads signs, memory, tolls, navigation devices and user error. They are seldom, possibly never, made to reduce congestion for other travelers. Massive shared fleets of self-driving vehicles provide opportunities to optimize trip timing, speed and navigation centrally. Computers provide routing and speed control, and the data generated by and for automated fleets can be used for congestion management, with regional traffic flow control decisions made by a combination of skilled humans and computers. These network control algorithms can use load balancing to maximize the use of existing infrastructure, something that can only be accomplished very weakly with existing technology such as variable message signage.

The best way to achieve this is through massive shared fleets, as centrally directing the route choice of a private vehicle would generally be unacceptable, and in some cases illegal. In a competitive rental environment, shared fleets will require network collaboration among multiple algorithms used by TNCs.

### 15. Manage shared fleets to address the road and transit funding problem

Robotic, connected vehicles provide a new way to address the stubborn problem of shifting away from fuel taxes to road-use pricing as an alternative, user-pay mechanism.

At the present time, an ideal system of variable, mileage-based usage fees (MBUF) determined by time, place, and vehicle-type has two significant barriers: high system cost and low social acceptance. Costs can be engineered and marketed away, but social acceptance has so far proven to be an insurmountable barrier.

Low social acceptance is predicated on perceptions of privacy, "more taxes", user equity and fairness. The perceptions surrounding each of these are strong and negative, perhaps even more so in North America than in the EU. There are many policies and technologies that can address these objections but these require patience to explain and diligence to understand. Significantly, the arguments in defense of road pricing are themselves are frequently untrusted or not believed.

Hence, our inability — in North America at least — to significantly educate journalists and satisfy drivers in the face of government distrust, personal entitlement, privacy fears, and insufficient transit reach. This makes adoption of MBUF highly unlikely in the foreseeable future of fossil fueled, personally owned vehicles.

Judging by the lack of progress we are making toward a shift from fuel tax to MBUF, and the fact that the context of the solution slowly wanders and evolves, we believe that this change, should it ever occur, is two to four decades away—i.e., concurrent with or longer than the deployment timeframe of the autonomous vehicle.

As the deployment timelines for MBUF and the AV will follow parallel trajectories, the AV will serve to diminish the urgency of demand-varied MBUF, as it is currently proposed. As the AV is licensed and taxed for road use, transportation funding planners should look forward to this newer, larger picture instead of dwelling on the faint hope of near-term MBUF. The oft-touted Stockholm and London road-pricing models are not only being snubbed by many, especially in America, their deployment is becoming outdated and they will soon become critically unappealing and eventually dismantled as we approach the 2030s and find better ways to manage pricing policy.

 

Metering the AV for road-use fees is an approach that needs exploration, now. In fact, if the AV can help address infrastructure and funding sustainability, that alone is reason for government to start preparing AV policy and infrastructure—two of the critical components of sustainable automobility in the 2040s.

Consider that the AV will be connected. When an AV is in use (whether owned or shared) time and location will be known at least to a robotics system and these vehicles can be charged a road use fee according to market, replacement or demand value. Privacy can be fully protected in this context.

Such an AV-MBUF fee can be bundled into the robo-taxi fee. If 90 percent of the eventual AV fleet is publicly regulated and commercially operated, users will focus their entitlement demands on rapid, safe, reliable, always-available, low-cost transportation services and less on free roads entitlement and privacy concerns that currently dominate the push-back related to today's MBUF proposals.

*Comments are welcomed at www.endofdriving.org.*

*Please revisit us for updates to this manifesto.*

 