



How autonomous  
vehicles could relieve  
or worsen traffic  
congestion



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# Executive summary

With the number of cars on the road globally forecast to double from 1.1 billion to 2 billion in the next 15 years, traffic congestion continues to be a multi-trillion-dollar drain on the global economy. This whitepaper demonstrates how the introduction of autonomous cars will not in itself fix the problem of congestion. In fact, unless the industry takes action now, there are many reasons why autonomy would actually worsen traffic conditions in the immediate future.

What kind of action is required? As we argue, what is needed is a concerted effort to shift away from 'each-to-their-own' autonomy (where each car is only responsible for itself), and towards Collaborative Autonomous Cars. Only by collaboratively collecting data can the industry and policy makers truly understand the holistic impact of autonomy. Only by sharing rich vehicle sensor data between cars can we build bridges between autonomous and non-autonomous cars. Only by enabling collaborative management of autonomous fleets can societies truly optimize road networks. And, only by breaking down data silos and connecting vehicle data, road network data and infrastructure data such as stop light information can we truly realize the full benefits of autonomy.

Finally, only when the industry finds a way to collaborate in parallel to designing cutting-edge technologies, can autonomous cars be considered to be on the path towards sustainable success.

This whitepaper has been written to help stimulate debate, with a hope that this in turn leads to greater collaboration among all stakeholders.



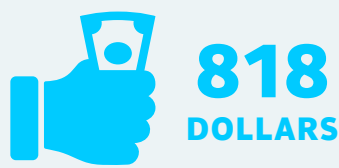
# Traffic congestion: a trillion-dollar problem

Many of the challenges that humanity faces, from diseases to poverty, ease over time as technologies improve and societies become more sophisticated. Paradoxically, traffic congestion is worsening as economies grow and urbanization accelerates. The impact on individuals, business and communities has never been greater, and without drastic action will worsen even further.

According to the World Bank, traffic congestion can cost developed economies 0.5-3% of their annual GDP<sup>1</sup>, and developing economies up to 5%. Traffic jams don't just slow down drivers from reaching their destination, they also slow down the global economy to the tune of \$1.4 trillion annually.



Additional hours spent by the average U.S. urban resident during 1 year due to congestion<sup>2</sup>



Average annual cost of congestion to U.S. commuters in terms of lost hours and wasted fuel<sup>2</sup>



Amount of additional pounds of carbon dioxide dumped into the air due to congestion in 2011<sup>2</sup>

The challenges associated with congested roads and cities show few signs of dissipating, as a perfect storm of growing car ownership and increasing urbanization gathers pace. Despite anecdotal evidence that young people living in Western cities are turning away from car ownership as ride-sharing options multiply, the number of cars on the road continues to grow at a strong 3.5-4% annually, with much of the increase coming from developing markets that already suffer from under-capacity and inefficient road networks. At this rate the number of the cars on the road is expected to double to 2 billion globally by 2030<sup>3</sup>.

In parallel, millions of people continue to flock towards already-congested cities. By 2030, two billion more people will live in urban areas compared to today<sup>4</sup>. This global shift will have profound implications on a wide range of issues, including traffic congestion.

In the face of gridlock, countries are adopting a range of policies and solutions to address the pain – but how effective are they?

# Throttle, share, inform – current solutions to the gridlock

Governments and businesses around the world have identified traffic congestion as an acute pain point, resulting in the following high-level solutions being adopted:



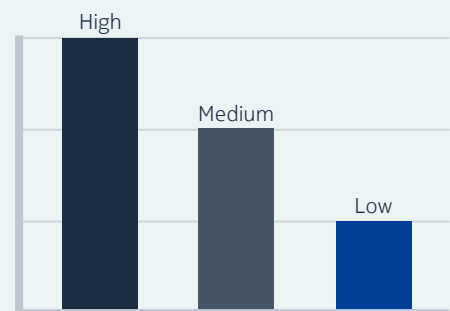
**47 countries** have implemented 'light' throttle policies (tolling), and 10 countries have implemented 'heavy' throttle policies (restrictions)

## Throttle

Local and national governments have implemented policies to varying effects in an attempt to throttle people's reliance on personal vehicles, particularly in busy cities. Tolling has already been in use for decades as both a way to discourage unnecessary trips as well as raising tax revenues, but often creates even more congestion. This has led to newer approaches such as Electronic Tolling that aims to control road usage through targeted taxes while retaining free-flowing traffic. More draconian measures are also being adopted, particularly in emerging markets like China where local governments have capped car sales or limited which days certain cars can drive.

## Impact on congestion by...

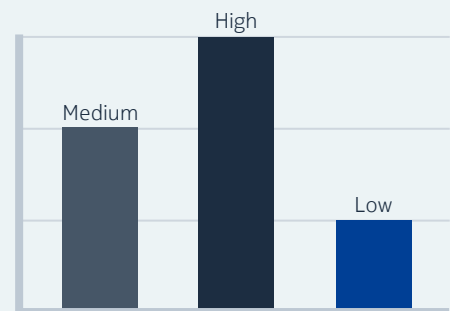
Reducing the number of cars on the road      Increasing the occupancy of each car      Spreading cars across the network more efficiently



**5 million + people** globally are now members of a car sharing community, with a fleet of over 100,000 vehicles<sup>5</sup>

## Share

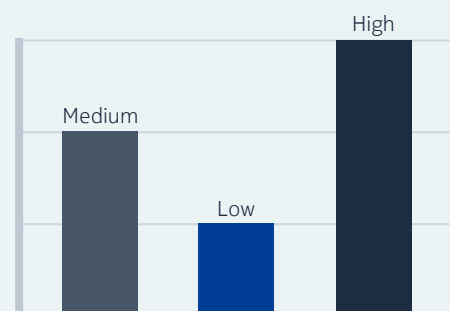
As public transportation networks struggle to keep up with growing urbanization and greater expectations for personal mobility, new solutions have emerged from the private sector to cater for a broad range of consumer needs. Ride-sharing schemes like BlaBlaCar let travellers search for people driving to a similar destination and request a ride. B2C self-service car sharing schemes like Car2Go give travellers the convenience of a car on a pay-per-minute basis, helping them avoid the cost associated with owning, parking, maintaining and insuring their own car. All of these mobility solutions challenge the 100-year model of owning cars, and in doing so have the potential to change road usage and congestion patterns.



**Information** about current traffic conditions and incidents causing delays, including slower than normal traffic flow, road works and accidents delivered to the driver.

## Inform

Keeping drivers informed about traffic congestion is a core pillar in the battle to keep cars moving. Highly accurate traffic data services from suppliers such as HERE enable navigation systems to guide drivers around jams. HERE provides real-time information about current traffic conditions and incidents that could cause delays, as well as innovative new features like Split Lane Traffic which improves decision making and accuracy of estimated times of arrival (ETAs) with lane level traffic information.



Most countries are adopting an ‘all-of-the-above’ approach to battle traffic congestion, and this will continue for the foreseeable future. In doing so it is important to note that all three solutions share one key assumption: the driver remains in control of their vehicle and makes the ultimate decision on how to reach their destination.

But what happens if (or when) that assumption is no longer true? As outlined in the rest of this whitepaper, a steady drumbeat of announcements from car manufacturers and outsiders like Google is forcing all stakeholders to consider how traffic congestion will be affected by the emergence of autonomous cars.

## Enter the Autonomous Car – a new mobility experience

The media is overflowing with news stories anticipating the arrival of autonomous cars and the much-touted revolution in convenience and safety that these new technologies are expected to deliver. In reality, autonomy for vehicles represents a spectrum rather than a binary proposition. According to SBD, 11 million cars in Europe, USA and China will be shipped in 2016 with driver assistance systems that represent an early stage of autonomy, such as Adaptive Cruise Control (ACC), Automatic Emergency Braking (AEB) or Lane Keep Assistance (LKA)<sup>6</sup>.

From 2020, car manufacturers like Volvo have announced that a new generation of autonomous cars will be launched that free up the driver to undertake other activities, although these are initially only expected to function on a very small number of roads and conditions. A fully autonomous experience that works on all roads and in all conditions is some time away, although players such as Google and Uber have bold plans (and clear commercial incentives) to accelerate their development.

### Levels of Automation: Industry Terminology



The industry faces a steep uphill climb before it can successfully realize the autonomous car dream. SBD surveys have shown that consumers will still need to be convinced about their value and reliability<sup>7</sup>. Theoretically, a car could drive itself at a speed that feels too fast and still be perfectly safe – but it may not necessarily make passengers feel relaxed or comfortable. Regulatory frameworks that are required to allow autonomous cars to navigate the roadway at scale will take many years to adapt. Ethical dilemmas will need to be addressed relating to how autonomous cars decide between two bad outcomes in safety-critical situations. Sensor fusion and deep-learning technologies will need to be seamlessly integrated into the overall vehicle architecture to efficiently aggregate and make sense of multiple data streams in real time.

Convincing drivers to relinquish more and more control to the vehicle requires the level of driver trust to rise exponentially. However, despite these challenges, significant progress is being made by car manufacturers and suppliers. For example, the value of maps has been clearly recognized as essential for commercial deployment of highly automated vehicles. Highly precise maps have been identified as a key element to take the “machine nature” out of self-driving vehicles, which in the end can influence driver acceptance and the overall impact of traffic in a self-driving world.

The industry has clearly recognized the need for a new kind of map – one that is not only highly precise, but also living, breathing and updated in real-time. This kind of map can be viewed as an additional sensor, just like a camera, radar, or lidar sensor on a vehicle – helping to extend the vehicles understanding of the road network far beyond the range of on-board sensors. In the end, having aggregated knowledge of the road network, where real-time events (traffic, construction, accidents, lane closures and more) are collected, processed and delivered to vehicles in real-time, is an essential element in making automated driving a reality and helping reduce the negative impacts of increased road usage.

Ultimately, momentum is a powerful thing. Enough effort (and pride) has been invested by the industry to ensure that advanced levels of autonomy will be achieved – eventually. The question then becomes: beyond the clear safety and convenience benefits that autonomy brings, how will each level of autonomy and overall adoption affect traffic congestion?

“If you don’t have a perfect map, how do you know where you are on the road? Once you have the right information, the actual calculations are not that hard. But you need centimeter-level accuracy. If your steering command is half a millimeter off, you might end up in the other lane.”

**Maarten Sierhuis**  
**Director**  
**Nissan Research Center Silicon Valley**

“High-precision digital maps are a crucial component of the mobility of the future.”

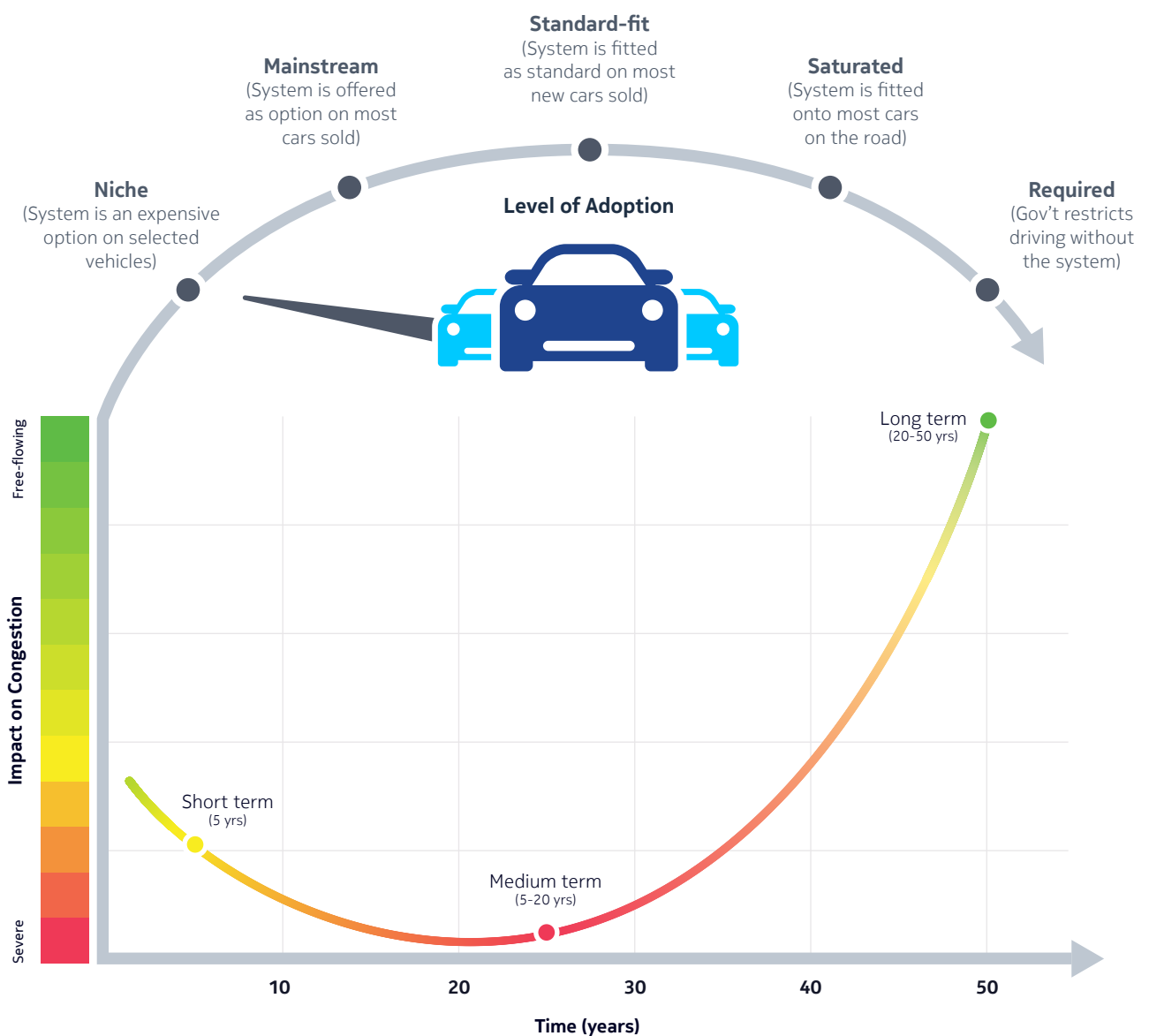
**Dieter Zetsche**  
**Chairman of the Board of Management**  
**Daimler AG**

# Help or hinder – it all depends on adoption rates

Autonomous cars are being developed by car manufacturers primarily to support the personal convenience and safety of drivers. However, the introduction of autonomous cars will also have a profound impact on traffic congestion in the short, medium and long term. The size and type of impact will depend on two main factors:

- 1. The level of autonomy enabled:** as outlined in the previous section, there are five levels of autonomy that progressively take away more control from the driver, each of which will have a different type of impact on traffic congestion.
- 2. The level of adoption achieved:** the impact will vary as autonomy progresses from being an ultra-premium experience, to becoming a standard-fit solution, and (eventually) achieving ubiquitous penetration rates across all cars on the road (possibly driven by a mandate).

As illustrated below, basic levels of autonomy can have a small positive impact in helping to ease traffic congestion, but high levels of autonomy can actually have a detrimental effect on congestion when their penetration rate is low. For this reason, the early days of highly autonomous vehicles could present risks to society's efforts to combat congestion.





## Short-term (next five years) – some benefits felt

Many Advanced Driver Assistance Systems (ADAS) available today already offer quantifiable benefits in terms of accident reduction and improvements in traffic efficiency. Subaru recently released data for the Japanese market showing that vehicles fitted with their EyeSight technology (a combination of Adaptive Cruise Control, Automatic Emergency Braking and Lane Departure Warning) were 60% less likely to be involved in accidents than those without the technology<sup>8</sup>. Such an impressive improvement in safety will inevitably have a positive effect on traffic congestion.

Various academic studies have also analysed the benefits from widespread adoption of existing ACC systems, showing how they can enable roads to operate at higher vehicle density and flow rates. In one early study supported by Volkswagen (Kesting et al<sup>9</sup>), relatively low penetrations of ACC were found to completely eliminate certain types of simulated traffic congestions. Other studies have been less optimistic, highlighting risks associated with mixed traffic scenarios where not all drivers are relying on ACC.

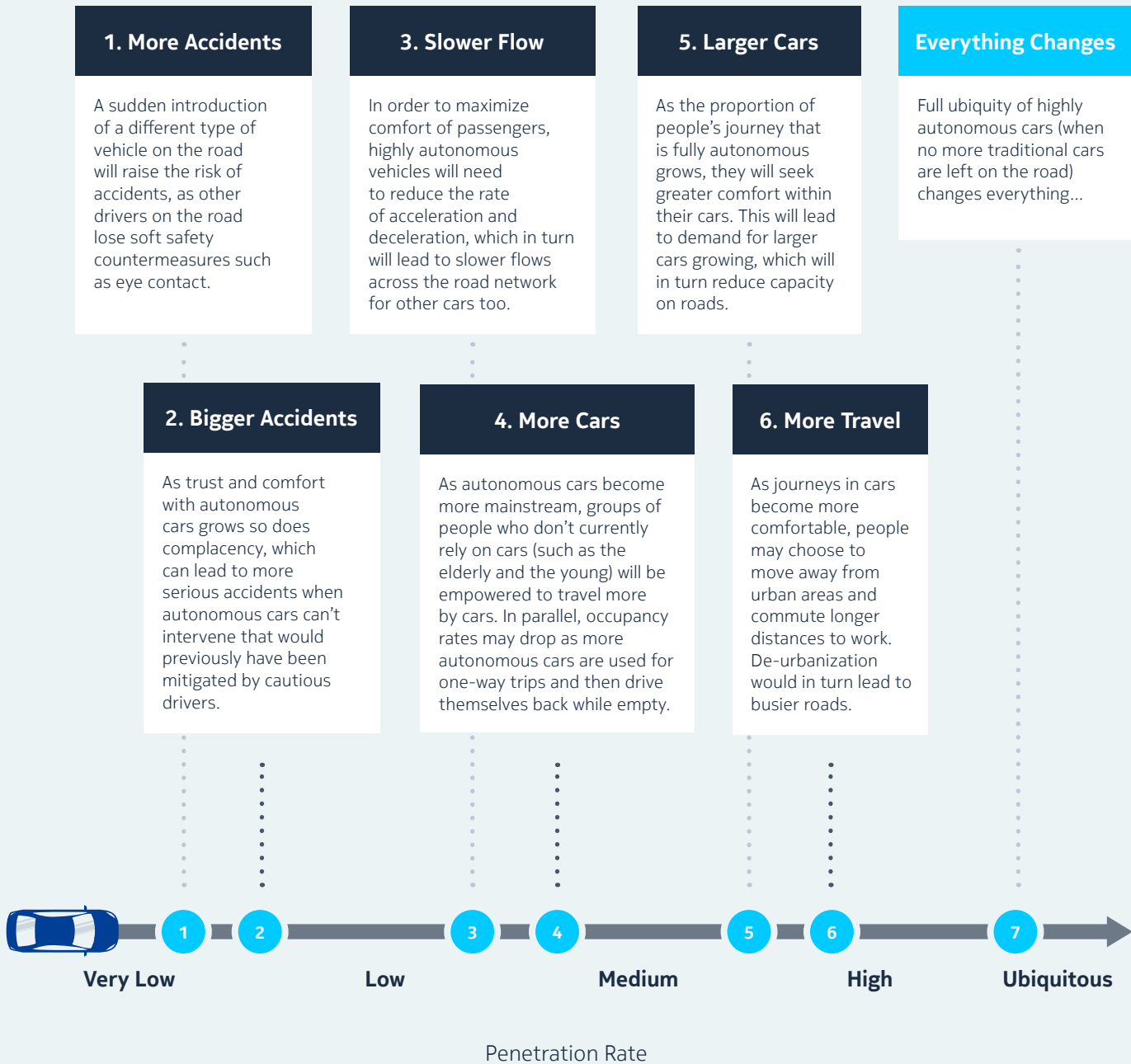
By 2021, SBD forecasts that 17.5 million cars will be sold annually in USA and Europe with applications like ACC and AEB that will play a modest role in helping to alleviate traffic congestion<sup>10</sup>.

## Medium-term (5-20 years) – a risky time ahead

Once car manufacturers begin launching Level 4 autonomous cars, the effect on traffic congestion becomes much less predictable. In the early days, the sudden introduction of a small number of highly-autonomous cars among millions of traditional cars will create unanticipated consequences. Other drivers may be surprised by the different behaviour of autonomous cars, leading to more accidents. Owners of autonomous cars may become over-reliant on autonomy and fail to step in when necessary, with a similar effect. Slower acceleration and deceleration rates among autonomous cars may be required to enhance passenger comfort, but would lead to the overall flow of the road decreasing.

Even as the penetration rate of highly-autonomous cars rise, knock-on changes in travel patterns and human behaviours could also have negative effects on traffic congestion. People who are less likely to drive or own cars now, such as the elderly and young, may suddenly start buying cars leading to busier roads. There may even be changes in the urbanization trends, as people choose to move away from cities and their workplaces as they can use their journey time more effectively.

## Risks associated with the introduction of highly autonomous vehicles



At this early stage it is impossible to holistically quantify the positive or negative impact of highly autonomous cars. Various studies, however, have at least partially investigated the potential side-effects of autonomy. Based on focus groups in the U.S., KPMG predicted that advanced levels of autonomy would result in double-digit increases in travel by people aged 16-24 and over 65<sup>11</sup>. A 2014 study by the University of California (Berkeley) found that a low penetration of platooning autonomous vehicles on normal roads would lead to a slight degradation of the highway capacity<sup>12</sup>.

New vehicle ownership models and changing governmental policies may play a role in counteracting some of these negative side-effects of congestion:

- Car sharing could become significantly easier when cars become more autonomous, allowing cars that are not in use to distribute themselves efficiently to match demand. A drop in vehicle ownership may therefore (in theory) help to reduce traffic congestion, although the associated drop in mobility costs may also lead to people wanting to travel more (thereby increasing congestion).
- Governments may decide to incentivize autonomy by setting up dedicated 'Autonomous Lanes', thereby also preventing negative interactions with traditional cars and encouraging those individuals who have invested in autonomous technology to enjoy the benefits and become more comfortable with the technology. Additionally, government implementations of vehicle-to-vehicle communication has the potential to reduce accidents thereby decreasing incident related traffic congestion. All of these measures, however, bring with them political risk and would be difficult to justify if penetration rates were low.

Further studies and trials will be required to assess the dozens of autonomous use cases, hundreds of variables and thousands of scenarios in order to fully understand how traffic congestion will change. However, policy makers and the industry should fully recognize the many potential impacts that could accompany the positive benefits of highly autonomous vehicles.

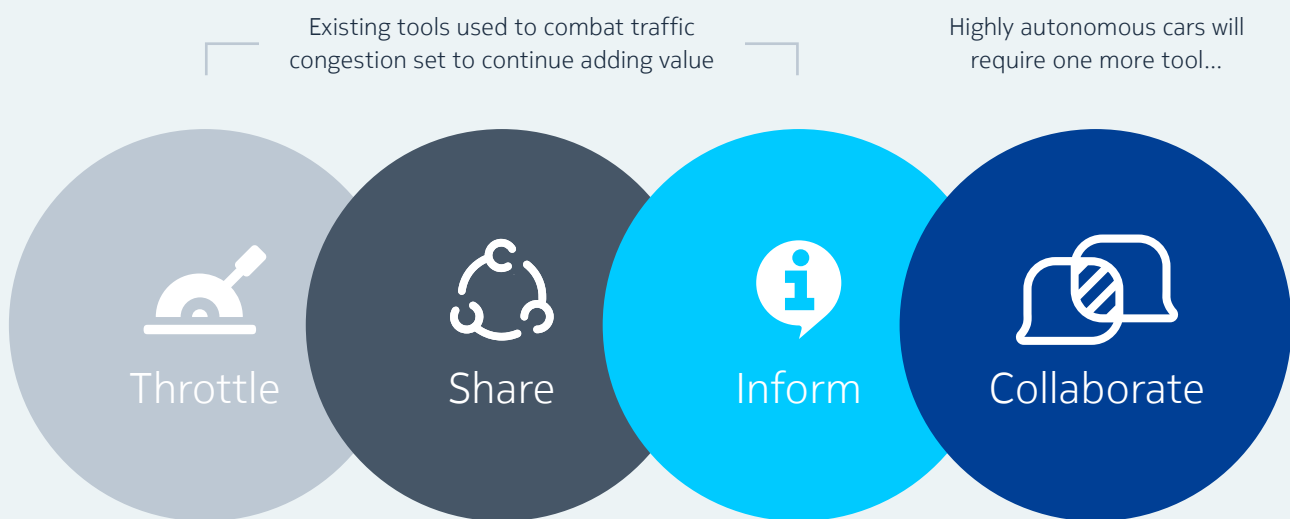
## Long-term (20-50 years) – reaching nirvana

The longer-term outlook for autonomous cars is paradoxically easier to forecast than the medium-term. At some stage in the distant future (likely due to government regulation), autonomous vehicles will become ubiquitous and manual driving will be restricted. At that stage, central management of all vehicle movements will become feasible, and alongside the elimination of traffic accidents, congestion will become a distant memory.

Although fun to imagine, the value of debating how and when this will happen is limited. Instead, the rest of the whitepaper focuses on overcoming the medium-term complexities of managing mixed fleets of autonomous and traditional vehicles.

# Bridging two worlds – from ‘individual’ to collaborative autonomous cars

Autonomous and traditional vehicles differ in functionality, and those differences will grow starker as higher levels of autonomy are launched from 2020 onwards. As outlined in the previous section, many of the pains associated with greater levels of autonomy stem from the need to manage mixed fleets on road networks for the foreseeable future. But these negative side-effects can be addressed by bridging the differences between autonomous and traditional cars, which in turn requires that we add a fourth pillar to the congestion reduction strategies outlined in this whitepaper:



Realistically, governments will need to continue throttling traffic hotspots through electronic tolling or by restricting vehicle sales. New mobility solutions will continue to flourish as the private sector looks for ways to help satisfy the continued consumer demand for personalized travel experiences.

Traffic information will continue to be an indispensable tool for both traditional and autonomous cars, leveraging data from a growing variety of sources (including vehicle sensor data) and informing drivers of current conditions and incidents along their route. The value will grow even further as suppliers such as HERE roll out innovative features such as split lane traffic information, which improves decision making and accuracy of estimated times of arrival (ETAs) with lane level traffic information.

The fourth pillar required to maximize the value of autonomous cars is collaboration. Many car manufacturers are currently developing autonomy primarily as proprietary solutions without connection to other fleets. A collaborative autonomous car, however, has a much greater potential to minimize many of the risks identified throughout this paper. Here are several key areas that will play a crucial role in the adoption of these advanced technologies:

### A culture of sharing

There is reliance on real-time highly accurate road network information as a pre-requisite for commercial deployment of automated cars, and no single car manufacturer has the global scale to do this alone. There needs to be a means by which we can pool certain data into a single system for the collective benefit of safer roads and more enjoyable driving. An important starting point to breaking down the data silos between organizations is defining data standards to make sharing data easier and more efficient. To achieve this, HERE has published a sensor interface specification (SENSORIS) to define consistent parameters for sharing data gathered by vehicles on the road. The result should be fewer accidents and more efficient journeys, as well as moving the industry closer to its aspiration for cars that can fully understand their environment.

### Bridge the gap between connected and traditional cars

Although autonomous cars cannot rely on Vehicle-to-Vehicle (V2V) communications as a safety-critical sensor, V2V can provide a bridging mechanism with traditional cars. The advanced sensors fitted into autonomous cars will be able to collect and distribute valuable information that could and should be used to also support traditional cars. In this way, we can think about using the mobile phone as a data pipeline to the driver and vehicle. Today, there are many government and DOT pilot projects in place that are testing the viability of this thinking. Autonomous-Vehicle-to-Traditional-Vehicle (AV2V) communications will therefore become an important collaborative priority in the coming years.

### Connecting roads, vehicles and infrastructure

Cities generate tremendous amounts of data that is often untapped and the value unrealized. The problem remains that we have many data silos, where data generated by the car resides in the car and traffic signalling data resides with the individual traffic management center. Environmental and safety-related information about city infrastructure will also need to be incorporated. Imagine a pothole detected by a vehicle sensor is automatically sent to the road authority, notifying the agency of the need for repair. Slick roads, a stalled car and traffic light information are examples of other information that can be aggregated and delivered to governments, DOTs, traffic management centers and even vehicles to help make the road network safer and more efficient.

### An open platform for data sharing

An aggregation platform is required to gather and process the data at scale. This platform can allow auto OEMs, governments, traffic management centers and others to benefit from a broad pool of data to help them build high quality data services and products. If we want to unify the disparate elements of our fragmented road networks and fleets, the first major step is to collaborate around this data. The vision for this type of platform can enable a shared data asset to connect the physical and digital world – merging, analyzing and enriching datasets from multiple sources (vehicles, people and infrastructure with unique location insights) – creating actionable and smart location services.

All of the convenience and safety benefits that car manufacturers hope to offer through autonomous cars will be dampened if those very same cars lead to greater congestion and inconvenience for travellers. The only way to push forward with these exciting new technologies is therefore to ensure that we quickly transition beyond closed-loop autonomy and towards collaborative autonomy.

Collaborative data-sharing is the only way to successfully deploy autonomous vehicles and to avoid serious traffic congestion issues during deployment. Only through collaboration of industry players at a global scale can autonomous cars be considered on a path towards sustainable success.



# More about us



## The leading Location Cloud

HERE, the location cloud company, enables rich, real-time location applications and experiences for consumers, vehicles, enterprises and governments. Backed by a consortium consisting of AUDI AG, BMW Group and Daimler AG, HERE believes that location technology will play a critical role in making our roads safer, reducing traffic congestion, and improving the quality of life of people living in cities. To learn more about HERE, including its work in the areas of connected and automated driving, visit <http://360.here.com>.



### **Carrie Cox** - Product Marketing

Carrie has over a decade of experience in technology marketing, and is currently a Senior Product Marketing Manager at HERE. She's held roles in Product Management, Sales and Product Marketing throughout her career. Prior to HERE, Carrie worked at Motorola where she led product marketing for high tier smartphones, technologies and partnerships and drove marketing communication activities globally. Carrie is also passionate about volunteering in her community and serves on the Auxiliary Board of Directors for ChildServ, an organization that helps Chicagoland's at-risk children and their families build, achieve and sustain better lives.



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## Bringing clarity and direction to automotive technology

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### Andrew Hart - Director

Andrew is a strong believer in the role that great market research can (and should) play in helping companies innovate. He is responsible for setting the direction of research within SBD, and ensuring that the key messages are clearly communicated to customers and the wider industry. Andrew works tirelessly with customers and speaks passionately at conferences to encourage consumer-centric innovations.



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