Redefining Mobility Services in Cities
The Impacts of Making Transport Clean, Shared, Automated, and Connected

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Section 1
EXECUTIVE SUMMARY

1.1 The Push for Clean, Traffic Jam-Free Cities

Around the world, major cities have been setting targets to combat the negative effects of local transport on public health, local pollution, noise levels, and greenhouse gas (GHG) emissions. Often, restricting or completely banning passenger cars from extensive areas of cities is seen as the solution to those issues and as a way to reduce traffic congestion and associated demand for limited space in urban areas (e.g., parking). Sustainable mobility plans that take this approach are counting on heavy investments in public transportation and biking infrastructure to compensate for the loss of personal vehicle mobility options.

But what if personal light duty vehicles (LDVs) in cities could be made compatible with the future sustainable mobility system in a different form? Focusing on three key trends in personal mobility—vehicle automation, the push for cleaner powertrains, and the mobility as a service (MaaS) model—this white paper explores their combined prospective effects on the urban environment. Navigant Research finds that, in a MaaS model, battery or fuel cell powered automated vehicles can provide benefits in GHG and air pollutants reduction, reclaimed land value, and reduced energy consumption for transport.

1.2 The Coming Age of Automated Vehicles

Driving automation is already a reality in many industrial vehicle applications, and partial automation is becoming commonplace in all road vehicle classes. However, many governments feel unprepared for the operation of large numbers of vehicle fleets on public roads without people behind the wheel. New infrastructure investments, communication network upgrades, the need for fleets to operate in varied conditions, and concerns about cybersecurity are often cited as primary reasons for government concern.

In the early deployment of fully automated vehicles, a driver will still need to be present to monitor vehicle status and deal with the more complex traffic situations. That period could last 5-10 years in challenging environments. Nevertheless, according to Navigant Research’s recent report Automated Driving Vehicles, markets are inexorably heading toward highly automated driving—which is expected to debut by 2020 and start to grow rapidly as soon as 2025.

The question is whether cities are heading toward a future where small, on-demand, cheap car fleets are used as complementary options in city transport or for a major overhaul where nearly every trip is executed by a personal, automated driver. Economics, convenience, and safety will drive the shift toward on-demand automated vehicle services. If managed properly and coordinated as part of a multimodal transportation ecosystem, this shift could lead to reduced traffic congestion in cities, lowered demand for parking spaces, and beneficial energy and environmental impacts.
1.3 Redefining Urban Transformation

To highlight how this mobility transition will redefine the urban transportation environment, this white paper lays out a high adoption scenario of automated vehicles into the total fleet in a model city with 3 million inhabitants who collectively own 1.5 million personal vehicles. Due to the synergistic effect between driving automation, connectivity, the MaaS model, and the switch to cleaner powertrains, significant improvements can be achieved in a number of areas of concern to city governments and citizens. Figure 1.1 highlights Navigant Research’s analysis on the model city.

*Figure 1.1 Impacts of Driving Automation, Connectivity, and MaaS in a Model City*

![Diagram showing impacts of driving automation, connectivity, and MaaS in a model city.]

(Source: Navigant Research)

1.4 A Bright Future Is Not Inevitable

In light of its prospective positive impacts, the future of automated vehicles appears bright. However, to reach their potential, it will be crucial that automated vehicle fleets are operated as part of a multimodal ecosystem and integrated with public transport options. Together, these provide a spectrum of mobility solutions accessible to all regardless of economic status or location.

Moreover, to fully capitalize on the promised benefits, municipal governments must play a role in the mobility system design. Questions remain in regard to the development of support infrastructure (e.g., charging stations for electric automated vehicles) and there are outstanding legal and ethical hurdles. To make this revolution possible, concerns must be addressed by key stakeholder groups. Navigant Research provides recommendations for each of these groups in Section 5.
Section 2

THE FUTURE MOBILITY NEXUS: CLEAN, CONNECTED, SHARED, AND AUTOMATED

2.1 Automated Vehicles

The concept of automated or self-driving cars has shifted from the realm of science fiction into reality, as showcased by the latest market developments. Figure 2.1 visualizes the progress of automation features over time, with vehicles moving from having one or two independently operating automated features to having multiple features working as a system and to having fully automated driving where no human intervention is needed. Fully automated driving is defined by the US National Highway Traffic Safety Administration as when “the vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.”

Figure 2.1 Automated Driving Technology Progression

As the technology advances rapidly, legislators in different countries and regions are trying to keep up. In France, cars are allowed to be automated if the human driver can override or switch off the computer at any time. A similar law was adopted in the Netherlands, where a person must be able to take control of the vehicle via a remote control device. Dutch provinces and municipalities are further taking the lead in stimulating the development of the technology by investing in Research Automated Driving Delft.

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For comparison, Germany is aiming to lead the debate around liability for accidents by requiring a black box that records the journey underway, logging whether the human or computer driver was in charge at all moments of the ride. Under the current legislation, the driver will be responsible for accidents that take place under their watch and manufacturer for those occurring due to system failure. Since 2017, many other countries in the European Union (EU) have also adopted laws regarding automated vehicles. However, current EU supranational legislation has to be amended to allow for automated driving and this is unlikely to occur before late 2018.

In the United States, a number of states have enacted policies allowing automated driving technology trials or even permitting operation of fully automated vehicles. At the federal level, the US Department of Transportation has issued voluntary guidelines for automated driving but there have been no enforceable regulations introduced. The US Congress is currently considering legislation that would provide exemptions from certain motor vehicle safety standards for limited numbers of automated vehicles and preempt states from enacting such standards. States would remain responsible for licensing and registration of automated vehicles.

The prevailing question is no longer whether these vehicles will come to market, but rather when. The core technology continues to advance—as Navigant Research’s analysis shows—with many OEMs now projecting highly automated driving in limited operating domains as soon as the mid-2020s. In its recent report, Market Data: Automated Driving Vehicles, Navigant Research projects rapid market growth in the decade after full autonomy is achieved, as noted in Chart 2.1.

**Chart 2.1** Annual Automated Driving Level 4+ Light Duty Vehicle Sales by Region, World Markets: 2020-2035

(Source: Navigant Research)
In many countries, personal car ownership has been one of the biggest rites of passage into adulthood and economic status. If legislative and regulatory hurdles to operation of automated vehicles are alleviated, the underlying economics of automated vehicles paired with the mobility as a service (MaaS) model is likely to redefine that. Developed countries with mature car markets may be entering—or may have already entered—an era of peak individual car ownership.

### 2.2 Ride-Hailing, Ridesharing, and MaaS

Transportation network companies (TNCs) like Uber, Lyft, and Didi have disrupted the traditional ride-hailing business model—i.e., taxi service—by pairing consumers directly with non-commercial car owners. While commonly referred to as examples of the sharing economy, these companies can encourage urban dwellers to utilize more private vehicle travel over options like public transit. Although these services have encouraged some urban dwellers to give up their cars altogether, the services have been operating independently of other forms of transportation and have been competing with incumbent transport services such as taxis.

In the future, however, this will change significantly as TNCs develop the MaaS model and if they coordinate with regional public transit systems. MaaS presents a shift away from personally owned modes of transportation toward mobility solutions that are consumed as a service. The rollout of automated vehicles can be the key enabler—and from a consumer perspective it will be all about economics.

This can be considered in two tiers. First, automated vehicles will speed up the elimination of human-driven taxi services. The single largest cost item in transportation services is the driver itself. While automated systems add significant costs to the vehicle, this added cost can be partially offset by eliminating the costs associated with the driver. When calculated on a per-mile basis, the total costs of travel of automated systems can be dramatically lower to the consumer than traditional human-driven taxis.

Total cost of ownership can be so low, in fact, that a second disruption occurs—people will stop driving themselves altogether as it would no longer make economic sense. When costs such as fuel, insurance, parking, and maintenance are factored in, the cost to the consumer of using an automated TNC service will be on-par with personally owned/driven vehicles. This is particularly true in urban areas which are most in need of this sort of transformation.

The cost-per-mile traveled can further decrease if consumers are willing to share their rides with others (i.e., ridesharing or pooling). Intelligent planning technologies could synchronize individual agendas and schedule optimal pick-up times and routing so multiple people can effortlessly travel together in the same vehicle. While this may seem like a costly replication of the existing mass transit model, these services have much greater flexibility, a benefit to both users and operators. Services that utilize smaller to midsize vehicles are more financially viable on lower density or first-mile/last-mile routes that
cannot support larger mass transit options. As these automated fleets will be available on-demand, 24 hours per day, much higher vehicle utilization is likely compared to the currently estimated 4% of the time with individually owned (and operated) cars.

Multiple companies are already conducting pilot tests of automated mobility services with regular riders, seeing the potential of these synergies. Uber opened its Advance Technologies Center in Pittsburgh and recently announced a similar initiative in Toronto. Its biggest competitor, Lyft, recently reported that it is developing its own automated vehicle technology, in addition to having formed partnerships with General Motors, Waymo, nuTonomy, Ford, and Jaguar Land Rover to place automated vehicles into its fleet for testing. Even Apple is in the race. In 2016, Apple made a $1 billion investment in China’s Didi. In June 2017, Apple’s CEO Tim Cook laid out the company’s plans regarding automotive market technologies, concentrating on self-driving technology.

Car manufacturers and rental companies are eager to enter this market, too, as the revenue distribution/redistribution along the transportation value chain might put them under increasing pressure. With much lower replacement part sales, EVs provide lower lifetime net revenue to automakers, which are already looking to expand and diversify revenue streams with carsharing and other digital and mobility services. Daimler, BMW, Ford, and other OEMs already operate their own carsharing or ride-hailing services and more are expected to follow suit.

2.3 The Choice of Powertrains

While the advent of automated fleets is coming, the distribution of powertrain technologies on which the automated fleets will run is unclear. On the one hand, as reported in Navigant Research’s 2016 report, Electric Vehicle Market Forecast, even with current price premiums, battery electric vehicles (BEVs) in most developed markets have cost advantages over traditional and hybrid vehicles of up to $0.30/mile. This advantage is driven by government incentives and fuel and maintenance cost savings. On the other hand, vehicles driving continuously are the essence of a shared fleet, and many currently affordable BEVs still have restricted range and lengthy recharging times. However, the introduction of more affordable, long-range BEVs such as the Chevrolet Bolt and Tesla Model 3 may alleviate that issue by providing sufficient capacity to support all-day service with off-peak nighttime charging. In addition, deployment of fast charging stations along travel routes could enable vehicles to recharge in 20-30 minutes.

Fuel cell vehicles (FCVs) could also help solve this issue. FCVs are currently behind battery vehicles in commercial viability due to the higher cost of the vehicles and the fuel, but also, importantly, the lack of refueling infrastructure. In an automated mobility fleet, these vehicles could be supported by a relatively small number of refueling depots in each city.
Although this still requires upfront planning for infrastructure and investment, an FCV can refuel its hydrogen tank in under 5 minutes, much more quickly than even a BEV charging on a high power fast charger. While FCVs would require manned fueling stations, FCVs could potentially be refueled just once a day, given that their range is over 300 miles on single tank.

Many early automated fleets will likely be operated on hybrid and plug-in hybrid vehicles to minimize downtime and maximize vehicle utilization without requiring significant infrastructure investment. However, BEVs and FCVs have the potential to become competitive technologies in the relatively near future. This will be conditional to development of high power wireless charging systems (or, alternatively, the resurgence of battery swapping, an application that might be viable in a managed fleet composed of only one automaker’s vehicles), and/or hydrogen refueling stations.

Donna Chen, professor from the University of Virginia, has researched the link between automated vehicles and electrification. Her research suggests that the combined costs of charging infrastructure, vehicle capital and maintenance, electricity, insurance, and registration for a fleet of shared, automated BEVs ranges from $0.42 to $0.49 per occupied mile traveled. This implies that the service can be offered at the equivalent per-mile cost of private vehicle ownership for low mileage households, and thus be competitive with current manually driven carsharing services and significantly cheaper than on-demand, driver-operated transportation services.

The synergy between automated vehicles and electrification is also being explored by legislators. For example, in California, which is often the leading edge on new vehicle regulations in the United States, the legislature is considering establishing an advisory board on automated and shared vehicles. This legislation would, among other things, recommend policies to encourage electrification or hybridization of these fleets. If more legislators look to encourage or even require shared automated vehicles to be hybrid or electric, the switch to non-fossil vehicle fleets could occur sooner than expected.
The aggressive scenario in Navigant Research’s *Transportation Forecast: Light Duty Vehicles* report projects that internal combustion engines (ICEs) will remain ahead in the LDV market until 2030, but lose market share to hybrids and EVs. This scenario assumes high penetration of automated mobility services, an aggressive battery price decline, and an aggressive oil price rise. Ultimately, under this scenario BEVs lead among smaller vehicles on the market; FCVs and plug-in hybrids, both of which have competitive advantages in the larger vehicle classes, will see gains as well under this scenario. This scenario, depicted in Chart 2.2, is analogous to the development outlined in this report.

**Chart 2.2 Estimated LDV Sales by Powertrain, Aggressive Scenario, World Markets: 2016-2035**

(Source: Navigant Research)
Section 3

IMPACTS OF THE AUTOMATED VEHICLES AND MOBILITY SERVICES NEXUS

3.1 The Model City

Navigant Research developed a potential scenario of the impacts from the high level adoption of automated vehicles in an urban environment. The analysis is based on a model city with 3 million inhabitants, collectively owning 1.5 million cars, driving 50 million miles a day with 5.8 square miles of parking space.

Early deployments of passenger automated vehicles are expected to be in specific cities where the conditions for their use are amenable. Cities with fleets of relatively underutilized personal vehicles and lacking adequate parking at low costs will likely be the initial adopters. As the concept becomes successfully piloted, however, adoption is likely to radiate out from cities and early markets.

3.2 Societal Impacts

3.2.1 Fewer Cars but Potential Competition for Public Transport

“Urbanization has been great for the economies of cities, but not for their traffic,” says Donna Chen, professor at the University of Virginia, “In many cities, gridlock is a way of life.” Could shared automated vehicles turn the tide?

Development of the total vehicle population in cities will be influenced by both downward and upward trends. On average, personally owned vehicles sit idle about 96% of the time, while in the morning and afternoon, rush hours can often see no more than a single passenger in a car. The higher utilization rate of cars along with adoption of ridesharing will push the number of cars in the streets down, in full effect on the model city presented here: every new automated vehicle will replace six personally owned vehicles.

However, affordability of automated mobility services is likely to push passengers from other mobility modes (public transport, biking, or walking) causing the collective miles traveled by cars to increase. This effect is likely marginal in most North American and European cities, as the share of LDV travel is already high. However, in many developing regions where substantial travel is secured by other mobility modes, this push might be severe. Preliminary Navigant Research analysis shows that for every 10% rise in automated vehicle penetration into the total vehicle fleet, 3.3% of non-LDV travel could be converted to LDV travel.

The overall demand for personal mobility services is expected to increase due to continuous urbanization and growth of cities. Aging populations that might otherwise forgo mobility completely will be able to take advantage of automated vehicles and further contribute to this trend.
3.2.2 Reclaiming Valuable Real Estate

Parking lots currently take up a significant amount of public spaces in the cities, especially near points of interest. Take San Francisco as an example, which has around 442,000 publicly accessible parking spaces and population of 850,000, according to a 2014 census by the San Francisco Municipal Transportation Agency. These spots could represent some 2.2 square miles taken up by parking space—in a city with some of the most valuable land in the world.

Such situations ask for serious optimization. With increasing automated vehicle penetration and ridesharing, less parking area will be needed, even at times when the fleets are at lower utilization levels. Thus, a few strategically placed parking areas near the perimeter of the central core can be sufficient as opposed to the current situation—where large parking areas are localized within a walking distance to points of interest that are used sporadically. Significant areas could then be depaved for other uses and valuable real estate reclaimed. This could present a challenge for business models that depend in part on incomes from parking fees such as airports, amusement parks, or sport stadiums.

Figure 3.1 Oakland Coliseum and Oracle Arena

(Source: Darryl Bush, the San Francisco Chronicle)

3.3 Energy and Environmental Impacts

3.3.1 More Efficient Fleets Requiring Infrastructure Investments

If the link between electric drive and vehicle automation is realized, the shift from liquid-based fuels to electricity will require an infrastructure revamp. There are several dimensions of this dynamic to explore.

First, a competitive alternative to liquid fueling infrastructure is required in terms of speed. Fleets of shared EVs need access to fast charging infrastructure that is currently lacking, although deployment of fast charging stations is growing rapidly. Second, grid reliability may be compromised without incentives for delaying charging as regional charging times...
may coincide with peak hours in power demand, driving electricity costs up and effecting feeder-level resources. Lastly, as automated vehicles are likely to be utilized at high rates, the options for managed charging that would mitigate grid stability concerns might be reduced.

There are potential energy efficiency and resource productivity gains. Fleets of automated vehicles can shift vehicle designs to optimize for space and size, resulting in material, purchase, and energy costs savings. Further, use of electric motors dramatically increases energy efficiency over ICEs (Chart 3.1). However, the overall system efficiency might decrease by pulling people from public transit systems. In other words, four vehicles with 50 mpg efficiency carrying one person is less efficient than one 15 mpg vehicle carrying four people.

In addition, a more rapid vehicle turnover is anticipated due to high utilization rates, enabling fleets to keep up with the latest technological developments making cars more efficient. Compared to personal LDVs, fleets will be maintained on a more regular basis, in central points, enabling further efficiency gains (e.g., keeping tire pressure up at all times).

**Chart 3.1**  
*Energy Efficiency of LDVs for Different Powertrains: 2010-2050*

However, in order to capture the potential benefits of these changes in the vehicle fleet, vehicle architectures will need to be completely rethought to ensure maximum upgradability and reuse or recycling of components, particularly vehicle structures. Automated vehicles built in the traditional manner would dramatically increase the manufacturing energy and resource demands.
3.3.2 Clean Fleets Improve Local Air Quality

Local air quality is a major concern for cities. According to the World Health Organization, over three million people around the world die from ambient air pollution (AOM) each year. One of the major contributors to AOM are diesel and old gasoline cars with high emissions of nitrogen oxides (NOx) and particulate matter (PM). Despite improvements in exhaust performance in the newest conventional vehicles, cities like Madrid, Athens, Paris, and Mexico City have still decided to ban cars and vans that run on diesel. As both BEVs or FCVs have no local particulate emissions or emit harmful exhaust fumes, the city environment can be significantly improved.

The climate impact of transportation can be curtailed, though this depends on the way electricity and hydrogen are produced. In this white paper’s analysis, it is assumed that both electricity and hydrogen are produced from low carbon renewable energy sources. Over the long term, sourcing of green electricity and hydrogen presents a realistic option, whereas significant curtailment of GHG emissions from transport fossil fuels does not.

Chart 3.2 GHG Emissions Vehicle Efficiency for Different Powertrains

Chart 3.2 illustrates the GHG emissions efficiencies for different powertrains based on current electricity mix in the European Union, comparing vehicles using 2010 EU-mix electricity (gasoline DISI 2020+ vehicle).
3.3.3 Increasing Climate Resilience for Vulnerable Groups

The increased use of automated vehicles and carsharing can directly improve the resilience of vulnerable citizen groups to the effects of changing climate. Through improved mobility, vulnerable groups can readily get access to support services and medical care, and be better prepared in advance of extreme weather events occurring such as heatwaves or flash flooding.

3.4 Commercial Impacts

Utilization of automated vehicles and MaaS platforms will likely trigger enormous disruption along the automotive industry value chain with disproportional losses and gains among the effected industries. A decline in oil demand, a shift in the vehicle retail sales model, and a growing demand for platforms (system orchestrators) are a few of the likely effects.

While some of these developments may soon occur (e.g., decline in oil demand for transport), others are not so likely (e.g., decreased revenue of car manufacturers). The incumbent automotive industry supply chain is most directly affected in maintenance services (newly organized by service providers themselves) or by used car sellers and rental companies. Rental companies are already looking at alternative businesses, such as providing maintenance and support to automated vehicle fleets not operated by OEMs. For example, Waymo announced a deal with AVIS to manage its automated vehicle fleet.

As for car manufacturers, they will likely utilize at least part of their existing dealer network in offering maintenance services for shared automated vehicle fleets. The makeup of the OEMs’ product portfolio and the OEMs’ relationship with consumers is likely to change dramatically; however, impacts on overall revenue from vehicle sales is likely negligible. There will be fewer cars on the streets, yet the rate of turnover will vastly accelerate as most cars will have to be replaced or refurbished after 4-5 years. Moreover, the total demand for LDV miles traveled is likely to go up. New revenue streams can be unlocked as additional technology is needed to enable the transformation.
Section 4
STEP-BY-STEP TOWARD MOBILITY TRANSFORMATION: A VISION FOR THE MODEL CITY

4.1 The Pilot Phase

TNCs will deploy their early automated vehicle fleets in a pilot-testing phase rather than compete directly with their people-driven counterparts. In this first phase, the automated vehicle penetration rate (i.e., the share of automated vehicles in the total city LDV fleet) will remain low at 1%, with automated vehicles replacing people-driven vehicles one for one and running on conventional or hybrid powertrains.

The impact of this phase is limited, as the main purpose is to test the consumer adoption process and demonstrate the viability of the concept to policymakers and insurance companies. Further, researchers and operators will have the opportunity to evaluate how automated vehicles work in a real environment and how people interact with these new vehicles. Legislative and ethical hurdles will need to be resolved in this stage before moving toward the next steps of automated fleet deployment. Pre-automated vehicle services such as shared van rides can also be tested here.

Heavy competition can be expected between companies to secure their spot as a first mover—and such development can already be observed today:

- In Singapore, nuTonomy and Delphi launched pilots of automated on-demand car service.
- Delphi, together with Transdev, is also involved in a plan to use automated taxis and a shuttle van to carry passengers on roadways in France. The shuttle will not have a steering wheel or pedals from the start.
- Navya will deliver automated shuttles to the University of Michigan in October 2017.
- Uber's self-driving fleet is picking up passengers in Pittsburgh and Phoenix.
- Waymo launched its early riders program in Phoenix.
- GM’s Cruise Automation unit is now piloting an automated ride-hailing service in San Francisco for company employees.

4.2 The Competition Phase

After the initial trial period, automated vehicles will enter into direct competition with drivers. The penetration rate of automated vehicles as a share of the total vehicle fleet increases to 4%, as some of the early adopters fully embrace the MaaS model and even start sharing their rides. Automated vehicle utilization in miles traveled per vehicle is expected to be double that of regular vehicles, while the average occupancy increases by 50% compared
Redefining Mobility Services in Cities

to the pilot phase. The modeling shows that there could be 100,000 fewer LDVs in the city, but with the overall fleet still covering the same total miles driven.

The first automated vehicles running on hybrid powertrains are retained; however, all new cars added to the fleet are a mix of plug-in hybrid EVs and BEVs as these become distinctively less costly than their counterparts. The impact on local pollution caused by personal transportation is marginal—a huge majority of LDVs in the city are still personally owned and run on older conventional powertrains.

Several centralized charging spots are developed in the city and some parking areas depaved, yet urban planners are mostly in waiting mode and in the middle of analyzing whether the electrification trend is likely to sustain. This is mainly caused by the fear of potential asset stranding, in other words, uncertainty about whether the infrastructure requirements in the early adoption period are the same as in the high adoption phase.

4.3 The High Adoption Phase

With the service model entering maturity, the cost-per-mile traveled gets lower than those of most personally owned vehicles. At this point, a 200,000-automated vehicle fleet is operated in the city. Most people now fully embrace the automated on-demand service. The average utilization rate of the fleet vehicles triples compared to the pilot phase, while average vehicle occupancy rate doubles as intelligent planning technologies are fully employed. Every single automated vehicle operated as part of the fleet now replaces six personally owned, not-shared vehicles.

The high adoption phase presents a point of no return, where automated on-demand mobility services become more economically viable than personal ownership of a car for most users. This has an immense effect on the total population of LDVs in the city—to maintain the same total miles traveled by the original 1.5 million cars, only 0.5 million cars are now are required. Significant area is depaved, some 3.9 square miles of now unnecessary parking spots, or 1.6% of the total city size of Chicago. Assuming commercial land value between $0.5 million and $2 million per acre, the city reclaims land between $12 billion and $50 billion in commercial value and urban planners can decide how to best utilize this gain.

The powertrains used in the overall city car fleet become more diverse while some personally owned vehicles retain conventional engines—most new automated vehicles are BEVs. FCVs are also added to the mix as economies of scale drive down vehicle and fuel costs.

The overall energy consumption stemming from personal transportation in the model city is reduced due to improved efficiencies, from an estimated baseline energy demand for LDV transport of 43 PJ/year to 23 PJ/year in the high adoption scenario. Moreover, the demand shifts dramatically from conventional fuels to electricity and, to some extent, hydrogen. Extensive analysis on the possibility of using BEV and FCV fleets for power grid balancing is underway by simulating peak demands for electricity and transportation. The
development also has a positive climate impact as 3.7 million tonnes of CO₂ emissions are avoided annually, thanks to the cleaner, more efficient, and smaller vehicle fleet. Similarly, emissions of local pollutants are greatly reduced with 4,000 tonnes of NOₓ, 35,000 tonnes of carbon monoxide and 1.1 PM per average mile driven less than in the current situation. The impacts are visualized in Chart 4.1 through Chart 4.4.

*Chart 4.1 Total Vehicle Population Delta*  
*Chart 4.2 Public Parking Spaces Delta*  
*Chart 4.3 Value of Retained Public Land*  
*Chart 4.4 Demand for Energy Carriers Delta*  

(Source: Ecofys, a Navigant Company)
Section 5
RECOMMENDATIONS FOR KEY STAKEHOLDERS

5.1 Implications

The mobility service revolution in cities will have crucial implications for three key stakeholder groups. Before it takes place though, several issues need to be addressed. Navigant Research has developed a set of recommendations for each of the key stakeholder groups.

- **City planners and regulators:**
  - Establish legislative and ethical rules enabling operationalization of automated vehicles and MaaS in the city.
  - Quantify the potential contribution to the city’s goals regarding local pollution, traffic management, and climate impact.
  - Investigate the implications on public transport by focusing on behavioral aspects of city dwellers.
  - Incentivize use of shared automated vehicle mobility fleets over personal vehicles and integrate them with mass transit to achieve optimal societal benefits. Aim to create multimodality systems.
  - Quantify the potential impact on public areas and potential economic gains (e.g., by selling depaved areas to private entities).
  - Investigate the infrastructure and spatial planning needs for charging and/or hydrogen refueling stations.
  - Collaborate with mobility providers to ensure that services deployed meet the unique challenges of each city and its residents. Cities with large numbers of low income residents or lower population density (such as Detroit) have different challenges to address than somewhere as dense as Beijing or Mumbai, or even San Francisco.
  - Hold MaaS providers, manufacturers, and communications responsible for cybersecurity and resilience at all levels from the vehicle to the edge to the cloud. Exploits of vulnerabilities could put many lives at risk and discourage residents from adopting automated mobility services.
• **Car manufacturers and mobility companies:**
  - Determine which cities are best suited to be first adopters based on factors like engagement of city stakeholders with innovative and smart mobility options or city design and geographic characteristics.
  - Examine the disruptive shifts in the value chain revenue model. Identify areas of strategic focus.
  - Define (new) customer groups and their demand patterns, consider expansion to provide new services (e.g., insourced vehicle maintenance).
  - Develop powertrain of the future strategy by combining the knowledge on cost developments and city goals in regard to environmental impacts.
  - Develop a range of services and vehicle types to meet the differing needs of cities based on population density, climate, and demographics.
  - Put safety and security above all else. If consumers are not confident in the reliability and security of automated systems, they may resist adoption.

• **Utilities and energy companies:**
  - Quantify the demand shift for different energy carriers and investigate the impact on current energy infrastructure.
  - Investigate the risk of asset stranding; i.e., will the infrastructure required for the early adopters still be needed in the high adoption phase?
  - Collaborate with regulators and the transport value chain on infrastructure development in the cities. Identify the first movers proactively.
  - Examine the plausibility of hydrogen as a transport fuel. What are the enabling conditions that would make hydrogen competitive with electrical transport?
Section 6
CONCLUSIONS

The building blocks for automated driving systems are available, and Navigant Research forecasts that highly automated vehicles should be ready to deploy in volume by 2025. At the same time, various players from both inside and outside of the transportation sector are active in the development of the MaaS model. More likely, these on-demand automated services will be operating vehicle fleets with electric and/or hydrogen powertrains due to both regulatory and market pressures. These trends combined—fitting well with the principles of sharing and circular economy—have the potential to bring truly positive economic, environmental, and social impacts, all examined in this report. There are barriers present that might slow down the development, most notably infrastructural, legal, and ethical ones, but none of these seem prohibitive for the expected rollout of automated vehicle fleets.

Key to unleashing this mobility revolution in a positive direction will be a collaborative management from a number of stakeholders (city planners and regulators, transportation companies, utilities, and energy companies). The future of city transport must be a multimodality ecosystem with public transport options integrated with automated vehicle fleets, which together provide a spectrum of mobility solutions accessible to all regardless of economic status or location.

Its effects will spread unequally on different service providers. However, strategic positioning of the affected players can open up additional revenue streams (e.g., system orchestration) for some or limit the damage done to others (e.g., oil companies diversifying to green hydrogen production, or car rental companies providing maintenance and support to automated vehicle fleets not operated by OEMs).

More investigation and analysis, in particular regarding the points listed in Section 5, are crucial in order to fully understand and adequately prepare for the future of transportation in cities.
## Section 7

### ACRONYM AND ABBREVIATION LIST

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AOM</td>
<td>Ambient Air Pollution</td>
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<td>BEV</td>
<td>Battery Electric Vehicle</td>
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<td>FCV</td>
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<td>NOₓ</td>
<td>Nitrogen Oxide</td>
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<td>Original Equipment Manufacturer</td>
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<td>PM</td>
<td>Particulate Matter</td>
</tr>
<tr>
<td>MaaS</td>
<td>Mobility as a Service</td>
</tr>
<tr>
<td>TNC</td>
<td>Transportation Network Company</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
</tbody>
</table>
## TABLE OF CONTENTS

**Section 1** ...................................................................................................................................................... 1

**Executive Summary** .................................................................................................................................... 1

1.1 The Push for Clean, Traffic Jam-Free Cities ......................................................................................... 1
1.2 The Coming Age of Automated Vehicles .............................................................................................. 1
1.3 Redefining Urban Transformation ...................................................................................................... 2
1.4 A Bright Future Is Not Inevitable ....................................................................................................... 2

**Section 2** ...................................................................................................................................................... 3

**The Future Mobility Nexus: Clean, Connected, Shared, and Automated** ..................................................... 3

2.1 Automated Vehicles ............................................................................................................................. 3
2.2 Ride-Hailing, Ridesharing, and MaaS .................................................................................................. 5
2.3 The Choice of Powertrains .................................................................................................................. 6

**Section 3** ...................................................................................................................................................... 9

**Impacts of the Automated Vehicles and Mobility Services Nexus** ............................................................... 9

3.1 The Model City ..................................................................................................................................... 9
3.2 Societal Impacts ................................................................................................................................... 9
3.2.1 Fewer Cars but Potential Competition for Public Transport ....................................................... 9
3.2.2 Reclaiming Valuable Real Estate .............................................................................................. 10
3.3 Energy and Environmental Impacts .................................................................................................. 10
3.3.1 More Efficient Fleets Requiring Infrastructure Investments .................................................... 10
3.3.2 Clean Fleets Improve Local Air Quality ..................................................................................... 12
3.3.3 Increasing Climate Resilience for Vulnerable Groups .............................................................. 13
3.4 Commercial Impacts .......................................................................................................................... 13

**Section 4** .................................................................................................................................................... 14
Step-by-Step toward Mobility Transformation: A Vision for the Model City

4.1 The Pilot Phase

4.2 The Competition Phase

4.3 The High Adoption Phase

Section 5

Recommendations for Key Stakeholders

5.1 Implications

Section 6

Conclusions

Section 7

Acronym and Abbreviation List

Section 8

Table of Contents

Section 9

Table of Charts and Figures
## TABLE OF CHARTS AND FIGURES

<table>
<thead>
<tr>
<th>Chart</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chart 2.1</td>
<td>Annual Automated Driving Level 4+ Light Duty Vehicle Sales by Region, World Markets: 2020-2035</td>
<td>4</td>
</tr>
<tr>
<td>Chart 2.2</td>
<td>Estimated LDV Sales by Powertrain, Aggressive Scenario, World Markets: 2016-2035</td>
<td>8</td>
</tr>
<tr>
<td>Chart 3.1</td>
<td>Energy Efficiency of LDVs for Different Powertrains: 2010-2050</td>
<td>11</td>
</tr>
<tr>
<td>Chart 3.2</td>
<td>GHG Emissions Vehicle Efficiency for Different Powertrains</td>
<td>12</td>
</tr>
<tr>
<td>Chart 4.1</td>
<td>Total Vehicle Population Delta</td>
<td>16</td>
</tr>
<tr>
<td>Chart 4.2</td>
<td>Public Parking Spaces Delta</td>
<td>16</td>
</tr>
<tr>
<td>Chart 4.3</td>
<td>Value of Retained Public Land</td>
<td>16</td>
</tr>
<tr>
<td>Chart 4.4</td>
<td>Demand for Energy Carriers Delta</td>
<td>16</td>
</tr>
<tr>
<td>Figure 1.1</td>
<td>Impacts of Driving Automation, Connectivity, and MaaS in a Model City</td>
<td>2</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Automated Driving Technology Progression</td>
<td>3</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>Oakland Coliseum and Oracle Arena</td>
<td>10</td>
</tr>
</tbody>
</table>