**Preparing for autonomous vehicles in Louisville**

**Working document – subject to change**

**Executive summary**

Louisville should prepare its streets and infrastructure for autonomous vehicles (“AV”). Based on the level of testing underway and a raft of announcements from car makers and mobility providers, the commercial availability of AV seems imminent. While projections of how – and how quickly - the technology will be adopted into the country’s cars, vans and trucks is still debated, the potential of AV to have a dramatic impact on moving people and goods to, from and within cities makes a compelling case for research and adoption of a policy to prepare for this technological shift.

Comparing the opportunity for cost saving and efficiency gains across different types of transportation suggests that take-up will be quickest among haulage fleets and that commuter take-up will follow. Personal use will be incentivized by safety gains (and reduced insurance premia) and enabled by cheap products to “retro-fit” current cars with autonomous technology. As the technology becomes widespread, it is likely that new ownership models – transportation as a service, rather than something accessed only through owning the vehicle – and different types of vehicles – better suited, for example, for the delivery of a single pizza than a 4,000lb sedan – will flourish. However these changes arrive, it is clear that AV has the potential to have transformative impact on the way that many work, live and play in Louisville.

This impact will eventually be felt in almost all areas of city life: from where we choose to live, to what work we do; from the safety of our streets to the way in which we finance essential transport infrastructure. Much of the huge amount of our city centers devoted to parking – 31% by one estimate[[1]](#endnote-1) – will become available for more productive uses. In many cases, the net impact of the technology, as well as how these impacts will be felt across different sections of society, is uncertain. As AV poses questions in each policy area, cities must with respond with their own voice to ask: what type of city do we want to live in? How can we work to ensure that the gains of downtown revitalization are supported and sustained? Louisville has already started rising to this challenge with the development of the Move Louisville Plan and the Louisville Strategic Plan.

Securing this vision in the era of AV will require conscious policy choices. Road congestion provides just one example of the challenge and opportunity posed by AV. As AV enables the attention and economic costs of car use to decline, we expect the demand for travel to increase. While inter-vehicle communication may have some positive impacts on congestion (and even then, only at high levels of fleet adoption that are not expected for many years), research suggests that significant reductions in the number of cars on the street will come only with greater use of shared ownership or shared riding models, alongside strong public transit. How can cities act to ensure that technology works to enhance the city experience?

Years from the full adoption of AV, this report does not hope to answer these questions, only to provide a first survey of the road ahead. This is in part because cities, while they will bear the brunt of changes from the technology, cannot shape their destiny alone. Many factors that will affect implementation of AVs, including technology development and legislative action, are not controlled by Louisville. We recommend that the City seek partnerships with the AV technology developers to help meet its mobility goals and needs of residents. We also recommend that the strong partnership with the state of Kentucky be expanded to consider how AV will be regulated and how cities can work with the state to ensure that urban areas remain great places for Kentuckians to live and work.

Finally, we note that there are risks in action, as well as inaction. We highlight the risks associated with premature investment in technology-specific infrastructure and the “second mover” advantage. This prudence mirrors the work of the city in the Smart City agenda, driven by a focus on delivering tangible benefits for citizens. In the rush to AV-readiness we cannot overlook current commuting patterns and issues that impact citizens’ mobility today.

**Summary of policy recommendations**

Following an assessment of potential development trajectories, opportunities and challenges presented by AV technology, several policy recommendations are developed. These are summarized below for convenience:

|  |  |  |
| --- | --- | --- |
| **Policy area** | **Policy options: near-term** | **Policy options: following arrival of AV** |
| **State-level coordination** | * Creation of state-level board for AV technology, aligning city and state responses across regulatory, legislative and fiscal domains | * Formalize input into policy decisions |
| **Safety** | * Monitor development of safety regulation and performance, with a view to enforcing city-level protections for non-car road users | * Consider opportunities for more separated cycleways and pedestrianization of city streets |
| **Road usage** | * Include need to prepare for AV-led mobility patterns in future infrastructure discussions * Explore options for congestion charging, including automated capture of vehicle arrivals and automated vehicles record time of city trips * Work to maintain positive working relationship with existing and new mobility companies | * Update road ordinances to deploy public street assets for policy goals, such as vibrant downtown activity. Some cities are considering restricting vehicles by type and time of day. |
| **Mobility and public transport** | * Explore partnership arrangements with ridesharing companies to foster early integration with local public transport systems * Be mindful of network effects in tendering for mobility solutions; consider multiple contract award * Mandate open data for ridership of public transit and ride-sharing services in the city to facilitate transparency, competition and better mobility. Make this data accessible to all – including riders – to improve the quality of transit in the city | * Support TARC to access cost-effective AV innovations, maintaining an integration with ridesharing services that leverage the strengths of public transport * Consider allocation of street and ex-parking space to rapid public transport lanes |
| **Land use** | * Continue efforts to address zoning, community and financing barriers to in-fill development through the process to update Cornerstone 2020 * Explore changes to tax regime to better deliver development goals, including assessment on potential development value * Use planning process to support development of parking facilities that can be easily re-purposed in future * Begin scoping potential demand for space created by 50% reduction in parking needs in certain areas and form districts, particularly in the Urban Services District and some suburban nodes | * Assess zoning laws for modernization, including walking access and removal of parking space requirements |
| **Economic impact** | * Strengthen job-training and technology readiness efforts in light of continued technology-led disruption * Explore partnership options with local academic institutions; research and development clusters but also coding academies to upskill local workforce * Explore partnership arrangements with technology providers to signal Louisville as attractive, innovative destination for young workers * Recognize AV as part of technological trend that will put pressure on economic development strategies targeting “smoke stacks” over highly-educated workers |  |
| **Household wealth** | * Support continued and enhanced access to mobility through public transit | * Consider phasing out of implicit subsidies for car ownership, including residential parking permits |
| **Public finance** | * Prepare for erosion of current automobile tax base and research options for road user-pricing | * Support State to develop alternative to current automotive revenue base * Work to reduce exposure among public agencies to vulnerable revenue streams, such as traffic citations or parking revenue |

**Context**

Scope of work

Recent work on the Smart Cities initiative and the publication of a twenty-year strategic plan for transportation in the metro area[[2]](#endnote-2) has set the stage for the government of Louisville, KY (the “City”) to begin preparations for the arrival of new types of autonomous vehicles (“AV”).

Despite commonplace predictions of imminent arrival[[3]](#endnote-3), significant uncertainty exists as to the speed and initial breadth of adoption, as well as the economic and societal impact that the new technology will have. Therefore, this paper is designed as an initial survey resource: scoping drivers of demand, potential impacts and areas of policy recommendation, rather than seeking to take a firm view on the future and development trajectories.

The paper is divided into three sections:

1. a review of technology, drivers of innovation and likely development scenarios;
2. a survey of how the roll-out of autonomous vehicles could affect U.S. cities and Louisville in particular: its inhabitants, economy, urban infrastructure and public services; and
3. outline recommendations for regulatory and policy responses to the use of AV by those that live in, work in and visit the city, including across city services.

A note of caution: levels of uncertainty

Predictions associated with any transformative technology must be treated with caution. In considering future policy related to AV it is useful to demarcate three separate, incremental levels of uncertainty and impact, which should be kept in mind when considering future policy recommendations.

* **The speed of technological development and take-up.** When will AV of different levels become available? Which transportation sectors will be first to adopt these? How quickly will technology penetrate the market?
* **Primary applications of AV and their impact**. How will user behavior change given the potential of AV to deliver “better sameness”[[4]](#endnote-4). What opportunities are presented to cities in the use of AV to replace current transportation?
* **Disruptive changes created when AV technology enables entirely new modes of behavior and service delivery.** Such impacts include combinatorial impacts of technology: new ownership models, new vehicle form factors and new models of working and commuting.

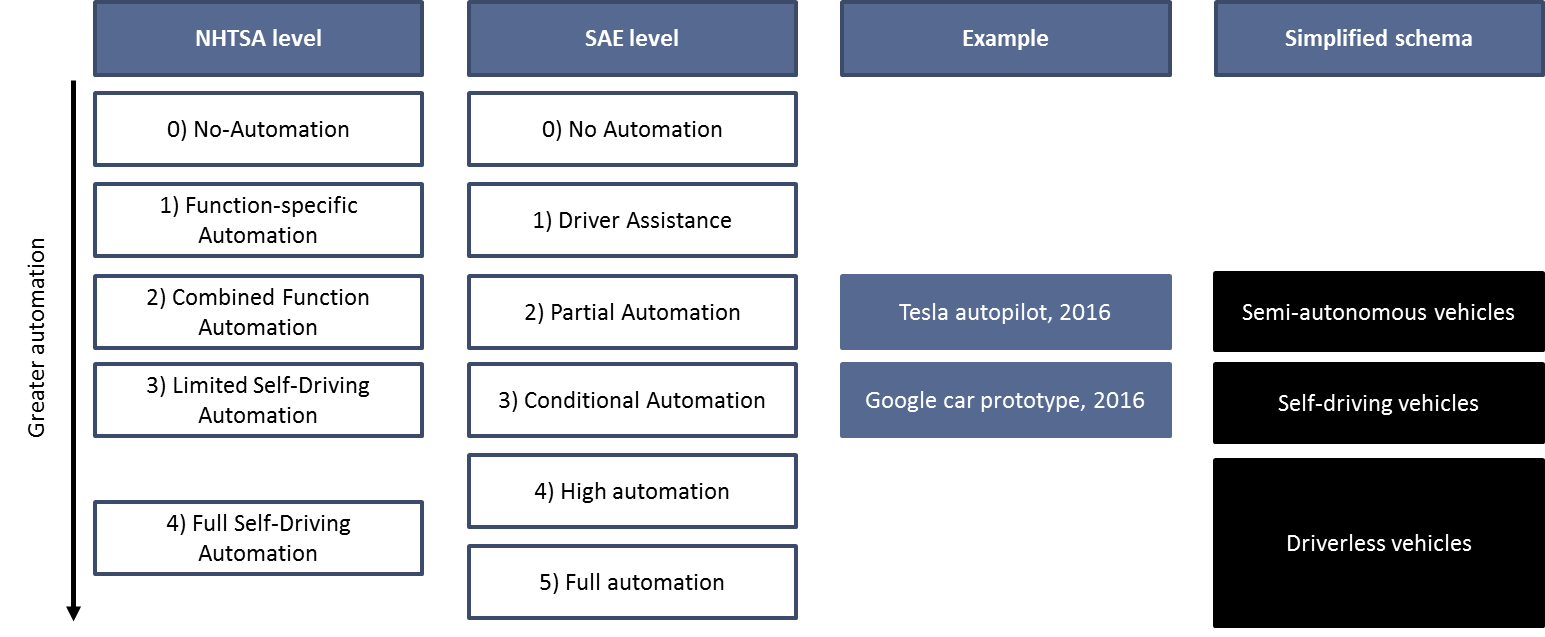
**1) Background on the technology**

Clarity on terminology

A common vocabulary is essential for a meaningful discussion. Both the U.S. Department of Transportation’s National Highway Traffic Safety Administration (“NHTSA”)[[5]](#endnote-5) and the Society of Automotive Engineers (“SAE”) have developed typologies of AV; developers and commentators have in-turn criticized these[[6]](#endnote-6) or used terms flexibly, blurring important distinctions[[7]](#endnote-7). Following Professor Kornhauser and for the purposes of this paper, we will use the following simplified schema to distinguish between levels of automation[[8]](#endnote-8):

* **Semi-autonomous vehicles.** More than one primary control function is automated but driver attention is still required. Drivers may be called upon to take control of the vehicle at any point. Such automation is already commercially available in “autopilots”[[9]](#endnote-9) and cars combining adaptive cruise control with lane centering.
* **Self-driving vehicles:** driver control can be ceded for defined situations; human control could be required for urban settings or in pre-defined conditions.
* **Driverless vehicles.** Driver input is no longer required in any driving situation that could previously have been handled by a human driver. Complete redesign of automotive vehicles is possible (though not required), including removal of driver control apparatus.
* **Autonomous vehicles (“AV”):** Collectively, self-driving and driverless vehicles.

*Figure 1: comparison of levels of vehicle automation (arranged by broad equivalence)*



Such a schema does not imply a simple linear progression of technology, though automobile manufacturers have to-date pursued a gradual, incremental development[[10]](#endnote-10). Some technological developments will drive take-up of AV technology and innovation (see below) are orthogonal to this scale. Intra-vehicle communication (when implemented, also described as “networked vehicle” or “connected vehicle” technology) has been credited with the potential to enable new modes of travel, such as platooning and live traffic management[[11]](#endnote-11). Automated safety features, such as fully automated collision avoidance and braking, are systems that could be widely available before even self-driving cars and could deliver huge economic and societal benefits.

Aggregate drivers of demand for AV

Economic demand for AV technology is driven by opportunities to reduce three significant costs of current automotive travel:

**The cost of crashes**. 6.3 million motor vehicle crashes occurred in 2015 in the U.S., killing 35,092 people and injuring more than 2.4 million others[[12]](#endnote-12). Beyond the human cost of such suffering, such crashes cost the US economy some $242 billion in 2010[[13]](#endnote-13) (excluding quality-of-life impacts). Approximately 94% of vehicle crashes are the result of human error and 29% were accounted for by alcohol-impaired driving[[14]](#endnote-14). Developers of autonomous vehicles have publicly targeted a 90% reduction in traffic crashes[[15]](#endnote-15).

**The cost of human attention**. Today, automotive travel incurs labor costs: expressed either as the opportunity cost for a driver/operator or wages in for-hire vehicles. Once human attention is not required, humans may not need to accompany cargo, allowing changes in form factor and smaller, more efficient vehicles to transport small, time-sensitive cargo[[16]](#endnote-16).

**The cost of waste.** On average, cars remain parked 95% of the time[[17]](#endnote-17). One study estimates that as much as 30% of traffic in urban centers is directly related to looking for parking[[18]](#endnote-18). A report from McKinsey predicts that more gradual braking and accelerating by driverless cars could deliver fuel savings of 15-20%[[19]](#endnote-19). In enabling new models of navigation, fuel management and of trip-sharing, Google’s AV program seeks to reduce “reduce wasted commute time and energy by 90%” and “reduce the number of cars by 90%”[[20]](#endnote-20).

Barriers to the development of AV technology are now surmountable

Analysts report that remaining technical barriers to self-driving cars are primarily those of refinement and of cost-reduction that will enable mass-market availability[[21]](#endnote-21). These include the development of the human-machine interface, better modes of mapping and geolocating, faster processing of its environment[[22]](#endnote-22) and more reliable sensors that will be required for commercial production[[23]](#endnote-23). AV prototypes, such as the Google car, are currently costly custom solutions; in line with other mass-market technologies, cost premiums must fall to stimulate adoption.

As technical barriers fall, regulatory barriers to implementation become central. Several states have moved to support testing and development of AV but important questions remain. NHTSA is clear that states will retain traditional responsibilities for vehicle licensing and registration, traffic laws and enforcement[[24]](#endnote-24). Nine states have passed legislation or issued executive orders related to autonomous vehicles, including relaxation of driver requirements in appropriate circumstances[[25]](#endnote-25). NHTSA identifies important gaps in state regimes, including regulations covering, occupant safety, motor vehicle insurance, liability, motor vehicle safety inspections, education and training and vehicle modifications and maintenance[[26]](#endnote-26).

Public acceptance and willingness to pay for AV technology is yet to be fully tested, but as with other labor-saving advances acceptance is likely to come over time[[27]](#endnote-27). Though surveys are a notoriously incomplete advanced guide to preferences, early results serve as a guide to sentiments which may need to be overcome: a 2014 consumer survey reported general support for the concept of vehicle automation alongside significant concerns about privacy and safety, and relatively low reported willingness to pay extra for self-driving capability features[[28]](#endnote-28).

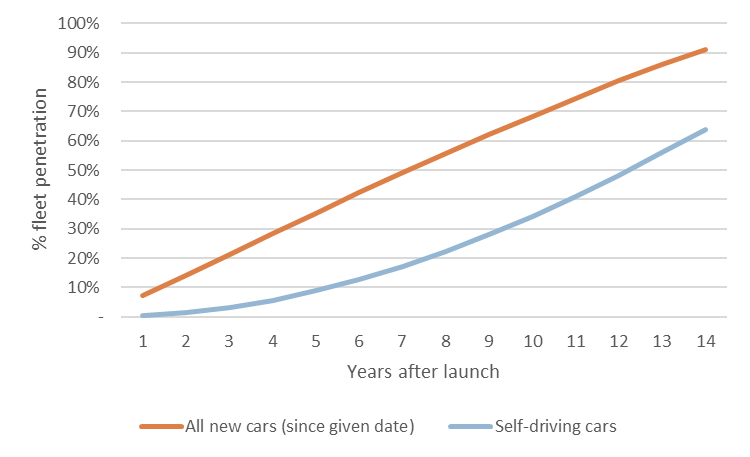
Road infrastructure – beyond perhaps clear lane markings[[29]](#endnote-29) - is not likely to be a barrier. Technology to automate speed and lane control on major highways modified for the purpose has existed since the 1960s where implants had been made in roads[[30]](#endnote-30); such technology was obviously never widely implemented. The current generation of AV has been designed explicitly to operate on existing infrastructure. Efforts by the U.S. Department of Transportation to promote its vision of a connected car fleet - a scenario in which cars and roadside infrastructure are equipped with wireless transmitters to share data[[31]](#endnote-31) - have encouraged some to equate AV with widespread roll-out of vehicle-to-vehicle (“V2V”) or vehicle-to-other (“V2X”). As discussed below, proposals for technological investment in transport infrastructure to facilitate AV solution should be treated with caution.

First commercial availability is imminent, but full-adoption of vehicle fleets could take decades

Estimates for commercial availability of self-driving vehicles cluster between 2020 and 2025[[32]](#endnote-32). Many companies have announced self-driving market offerings by 2020, though the precise level of the technology remains unclear[[33]](#endnote-33). The automotive market research firm IHS project the first sales of self-driving vehicles will begin around the year 2025[[34]](#endnote-34); the Victoria Transport Policy Institute anticipates availability from 2020[[35]](#endnote-35).

Robust forecasting of market penetration rates is hampered by uncertainty around cost and user demand, but current rates of car fleet replacement can provide a baseline for prediction. In 2013 some 7.1% of cars were less than a year old[[36]](#endnote-36); as per-capital car ownership has plateaued in recent years[[37]](#endnote-37), rolling-forward this rate of fleet replacement (including attrition rates for new cars) provides a useful anchor in roll-out forecasts. Figure 2 below graphs this roll-forward and illustrates AV fleet penetration given an assumptions on market share of new car sales: 2.5% the year after launch, increasing by 2.5 percentage points each year. Such growth in market share is ahead of that estimated by IHS, which estimates that ten years after first availability, only c.10% new cars sold will be AV (and that after 2050, almost all new vehicles sold will be autonomous)[[38]](#endnote-38).

*Figure 2: simple projection of car fleet replacement and AV penetration*



Using the adoption of other vehicular technology as a guide, some analysts forecast an even slower rate of fleet integration, highlighting the significant durability of non-autonomous vehicles. Tod Litman writes that “new vehicle technologies normally require three to five decades to be implemented in 90% of operating vehicles… deployment will probably follow the pattern of automatic transmissions, which took nearly five decades to reach market saturation, and a portion of motorists continue to choose manual transmissions due to personal preferences and cost savings [[39]](#endnote-39). He estimates that given first availability from 2020, by 2050 driverless cars will make up 80–100% of new car sales. However, the durability of current vehicle fleet suggests that that even at this stage, 40–60% of the cars on the roads will still be those driven by humans[[40]](#endnote-40).

Changes in ownership models and exogenous factors may fuel market penetration

Such projects rely upon implicit models of acquisition and economic ownership that can be questioned. Operators less sensitive to upfront costs than individual consumers – for reasons of financial liquidity or of higher utilization levels justifying high costs of acquisition – such as mobility or freight providers are likely to lead adoption (see below). An associated early take-up of AV technology among high-volume vehicles will mean earlier capture of trip-share than of fleet-share. The power of consumer demand for new, convenient modes of transport that could be enabled by third-party ownership should not be under-estimated. Despite launching in only 2011 (in one city), by the end of 2015 there were half as many Uber drivers as taxi drivers in the U.S. [[41]](#endnote-41).

Further, the same factors may lead to a division of passenger automobile fleets between privately-owned semi-autonomous vehicles and fleet-owned AV. Robust automated safety features can be captured before full automation is perfected; costs to move to full automation may be unattractive to many private consumers. High unit-cost and high-utilization ride-sharing fleets could develop and serve different trip-type or socio-economic segments.

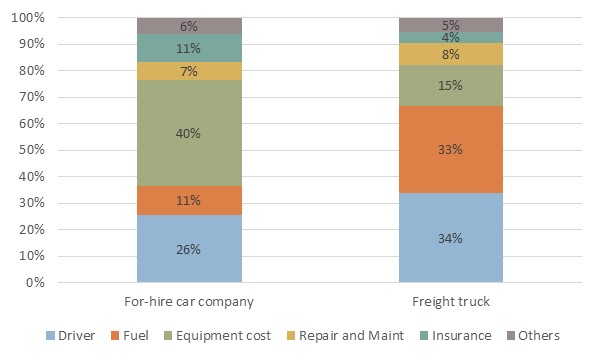
There is a strong possibility that market penetration will be driven by after-market solutions, de-coupling penetration from new car sales; a model of roll-out more akin to that of GPS[[42]](#endnote-42) than that of automated transmission. All new cars sold in the U.S. since 2012 have been fitted with Electronic Stability Control[[43]](#endnote-43); requiring an electronic interface to the control of steering, acceleration and brakes that could be commandeered for an aftermarket automation solution[[44]](#endnote-44). Such a model is being pursued by non-OEM AV players such as Cruise Automation, which claims to be able to achieve a cost of only $10,000[[45]](#endnote-45).

Exogenous factors – particularly around safety – may further accelerate or slow take-up. If self-driving technology can robustly be demonstrated to be safer than human drivers, federal and state legislation may mandate use of the technology in a growing number of situations; alternatively, high-profile safety breaches could inspire a moratorium on use. Given the scale of economic opportunity presented by safety improvements (see above), economic incentives from car and health insurance companies may have similar impact. Discounted premiums could, for example, become available to young, male drivers who chose to operate vehicles with smart safety software enabled.

Different economic incentives may lead to earlier adoption of driverless and connected technology among freight companies

Differences in operating cost structure between passenger and freight transit will likely lead to different take-up pathways. Greater durability and higher average utilization rates of haulage vehicles will make cost reduction from automation (driver) and platooning (fuel) greater imperatives than in typical passenger vehicles (see figure 3 below).

*Figure 3: Illustrative breakdown of per mile operating costs – for-hire car company and freight trucks[[46]](#endnote-46)*



In haulage, early adoption of technology - particularly aftermarket solutions - will be supported by high unit capital costs. Full, national, integration may be delayed by greater infrastructure needs, such as reliable LTE (or 5G) signal across the entire highway network required to deliver platooning functionality. In some areas, the relative strength of trucking labor interests vs. for-hire car drivers may delay full automation. Though crashes involving large trucks have increased[[47]](#endnote-47), using insurance costs as a proxy for the full cost of accidents suggests that safety will be a greater driver of uptake for passenger vehicles than of freight. This could cause the haulage industry to skip any slowdown of adoption in passenger vehicles that is driven by an early capture of safety benefits (see above) and the “pleasure of driving”.

AV deployment models and fleet replacement will accelerate adoption of other automobile technologies, particularly electrification

There is no necessary connection between AV and technologies such as connected vehicles or a move to electric power sources. However, where AV technology encourages fleet replacement or models of utilization that favor greater efficiency in running costs[[48]](#endnote-48) we can expect to see a commensurate growth in such innovations. Ride-sharing companies are already leading take-up of electric vehicles as benefits become realizable on short commuter trips[[49]](#endnote-49).

**2) Scoping potential impact in Louisville**

The brief survey of AV technology above makes clear both that change will be progressive and that its range and impact is uncertain, particularly with second-order innovations enabled by the technology. This uncertainty lends itself to a survey of potential impacts framed as both threats and as opportunities to the City’s core priorities and prosperous future growth. A summary of these impacts is presented as figure 4 below:

*Figure 4: summary of potential city-level impacts associated with AV*

|  |  |  |
| --- | --- | --- |
| **Policy area** | **Threat** | **Opportunity** |
| **Road usage** | * Reduced marginal cost of car travel increases road demand and congestion * Breadth of new vehicle types congest road with on-demand deliveries | * Maturity of ridesharing and driverless cars reduce road demand and wasted circulation time * Freight and delivery rescheduling to off-peak hours reduces traffic |
| **Mobility and public transport** | * Uptake of AV further marginalizes support for public transport * Dominant mobility provider undercuts public transportation * Existing regulation stifles development of ride-sharing services offering greater mobility | * AV supports public transit in addressing ‘last mile’ problem * Under-served communities connected to public transport * Lower cost mobility solution available for disadvantaged groups |
| **Land use** | * Low-density development accelerates, supported by reduction in commuting costs | * Parking spaces can be re-purposed for higher-value use * Easier access to urban core stimulates economic activity, in-fill development * Concentrated vehicular traffic allows repurposing of road space |
| **Economic impact** | * Net reduction in jobs across transport-related industries, particularly among low-skilled workers * Economic opportunity from innovation missed in LV * Freight and logistic advantage of the city undercut | * Increase in productivity during commuting time * Greater and more equitable access to economic opportunity in the city (and outside) * Economic opportunity created by applications of new technology |
| **Safety** | * High-profile accident slows up-take of safer AV technology * Information security risks have safety consequences | * Sharp reduction in crashes * Strict direction of AV to maintain pedestrian and bike spaces |
| **Household wealth** | * High initial barriers (such as cost, others?) to participation reinforces inequalities | * Ridesharing models make mobility more accessible than today |
| **Public finance** | * Parking revenues and bonds * “Unbundling” of costs of owning and using cars: cars may be bought and maintained out of state, and charged to users within-state * Reduced gas tax revenues from electrification * Expenditure on rapidly-obsolete infrastructure | * Increased property tax revenues * Pay-per-use model and greater trip data provide opportunity to tax congestion and pollution, rather than he vehicles themselves |

Safety: significant potential benefits from new technology, but interactions with other road users to be resolved and new points of vulnerability

A central claim by advocates of AV technology is the potential to reduce crashes. Ahead of full automation, incremental safety technologies such as intelligent speed assistance[[50]](#endnote-50), automatic emergency braking[[51]](#endnote-51) (including for cyclists and other road users[[52]](#endnote-52)) and blind spot detection for large vehicles[[53]](#endnote-53), will support this goal just as technologies have improved safety over the last ten years[[54]](#endnote-54). With more robust sensor and control technology enabled by AV, greater improvements in safety and reductions in crashes should be possible[[55]](#endnote-55). Indeed, public take-up of AV will likely be predicated on demonstrable safety improvement over human control[[56]](#endnote-56).

In 2016, there were 33,197 crashes in Jefferson County of which 670 were considered severe. These crashes resulted in 100 fatalities in the Metro area. Since 2006, the five-year rolling average for crashes, severe crashes, and deaths in Jefferson County has risen each year from 27,462 to 30,820 in 2016, with fatalities rising from 74 to 82. Assuming that these crashes follow the national trend of overwhelmingly being the result of driver error[[57]](#endnote-57), even a fifty-percent reduction in accident rates could restore $23m annually to the Louisville economy[[58]](#endnote-58).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | 2006-10 | | 2007-11 | 2008-12 | 2009-13 | 2010-14 | 2011-15 | 2012-16 |
| Crashes | 27,462 | | 27,694 | 28,024 | 28,497 | 29,019 | 29,974 | 30,820 |
| Fatalities | 74 | | 70 | 67 | 69 | 73 | 75 | 82 |
| Severe Crashes | | 739 | 712 | 701 | 689 | 678 | 665 | 650 |

In addition to automobile collisions, pedestrian and bike crashes are a major cause for concern. Since 2006, the number of pedestrian and bike crashes have risen from 541 to 646 in 2015. Of the 646 crashes in 2015, 92 were considered severe and they resulted in 72 serious injuries and 20 deaths.

The interaction with other road users of such technology is as yet unclear. To fully deliver upon potential safety improvements, advanced crash avoidance systems will need to identify smaller vehicles and those less able to take evasive action. The European Cyclists’ Federation notes that while safety technologies offer “a great opportunity to reduce speed and stop crashes from happening… There is no understanding yet of how… connected vehicle technologies can presently or would in the future incorporate active non-equipped modes like cycling and walking”[[59]](#endnote-59). Conversely, greater adherence to road rules - such as not blocking cycle lanes - possible with AV could offer greater protection to all road users.

The path to this reduction will not be smooth. Little public research exists on the impact of authority transition between human and automated systems that will characterize the development of semi-autonomous vehicles[[60]](#endnote-60). New threats will emerge, such as the hacking of AV systems. Owners and operators of AV will require robust data protection strategies to ensure both the privacy and the safety of users. While precise specification of potential issues is not yet possible, this requirement will extend to civic infrastructure where systems develop to communicate digitally with autonomous vehicles. Such instructions which may be accepted without verification by AV, create new points of failure in transportation systems. As a benign example, a faulty or corrupted remote traffic report describing gridlock on Interstate 64 could cause AV to take more circuitous routes downtown. Inequitable access to AV technology across the socio-economic spectrum presents the risk of exacerbating disparities between rich and poor, as well as associated car and health insurance costs.

Road usage: significant congestion benefits will require market penetration or further development of ride-sharing models

Judging AV’s net impact on peak road demand requires estimation of two competing forces: increased road capacity enabled by the new technology (decreasing aggregate demand for road space) and increased travel demand from reduced time, attention and discomfort costs of road transportation. Such an approach implicitly assumes that transportation modes will remain constant: in the long-term this is challenged with potential expansion of alternate modes, such as pooling of vehicles, automated overnight freight, or reduced form-factor vehicles for same-hour delivery within cities.

Simply decreasing the cost of commuting will tend to increase demand and congestion[[61]](#endnote-61). Conversely, AV and intra-vehicle communication technology could increase road capacity by optimizing the spacing, speed and sorting of traffic, as fleet penetration increases[[62]](#endnote-62). Studies of the impact of cooperative adaptive cruise control (“CACC”), a system in which vehicle control is shared with an automated system that includes vehicle-to-vehicle and vehicle-to-infrastructure communications, allowing it to coordinate and adjust longitudinal control through throttle and brake activations[[63]](#endnote-63), partially illustrate this effect. They suggest that significant gains are likely to happen only at high-penetration rates for the technology. Outside of high volume roads[[64]](#endnote-64), one study identified significant impact on road capacity only from CACC penetration rates of 40% and above[[65]](#endnote-65). Another study identified impact at lower levels of penetration at – at 10% penetration, increased throughput of 3% - but with increasing marginal returns up to an increase in throughput of 68% at full penetration[[66]](#endnote-66).

Some peak road capacity could be unlocked as driverless cars reduce the need to circulate for parking. Estimates vary, but the 3.5-14 minutes spent searching for parking by those looking for curbside parking “congests traffic, causes accidents, wastes fuel, pollutes the air, and degrades the pedestrian environment.”[[67]](#endnote-67). Though Louisville city-center is well-endowed with public parking[[68]](#endnote-68), residents are familiar with the sight of those new to the city circulating on one-way streets looking for parking and with the additional circulation of vehicles parking at large events. Being able to automatically route this traffic could bring significant benefits.

Research suggests that effectively managing increased demand from AV will depend on the development and uptake of vehicle-sharing models. An International Transport Forum paper suggested that although AV could deliver current levels of urban mobility with only 10% of current vehicles, full automation would lead to a 6% increase in vehicle miles travelled in cities with public transit, or an 89% increase without high-capacity public transit[[69]](#endnote-69). The commensurate impact on congestion will depend upon the extent to which vehicle distances travelled can be made efficient through ride-sharing[[70]](#endnote-70). As such, it will be important for Louisville to continue to implement land use policies and zoning requirements to reinforce compact nodes that support multiple modes of transportation. Using formal modelling of traveler preferences based on data in Delft, Netherlands (and simplified location data), researchers predicted significant increase for demand in travel that would lead to only slight increases in congestion if vehicles could be pooled. They also noted that the reduced cost of travel might lead to greater utilization of routes that had previously been unviable, reducing the effect of greater travel demand on congestion[[71]](#endnote-71).

Even with the ride-sharing offering from mobility companies, the power of ride-sharing remains untapped prior to the development of AV. Using actual New York City taxi trip data (rather than models of total urban mobility demand) research has demonstrated that optimizing vehicle allocation could serve 98% of rides currently served by over 13,000 taxis with just 3,000 taxis without service delay. Allowing for 2-minute and 5-minute service delays could, respectively, reduce required taxi capacity to two people (from four) and improve on the 98% service rate[[72]](#endnote-72). This level of fleet contraction would likely require changes in user behavior – such as tolerance for waiting – that are cost and alternative dependent and have not been tested with consumers. As with the impact of fleet penetration above, policy-makers will face important choices between equal access to roads and delivering full benefits from the technology.

These choices will have real economic and quality-of-life implications for those living and working in Louisville. In common with many U.S. cities, cars dominate commuting choices in Louisville. 90% of those living in the Louisville metro area commute to work via private automobile (82% driving alone), with an average commuting time of 22 minutes[[73]](#endnote-73). A recent study has suggested that among major US cities, Louisville ranks 17th in the potential benefits for AV. This is based on the assumption that electric shared-use autonomous vehicles would be most effective when used for shorter intra-city trips, that are particularly common in cities such as Lousiville.[[74]](#endnote-74)

Consumer and business demand will shape new freight possibilities enabled by AV technology. Driverless freight vehicles will make responsively-scheduled overnight and off-peak delivery scheduling easier. Where new form-factors can reduce the cost of near-instantaneous delivery, traditional cars may compete for road capacity with road-based drones carrying small, time-sensitive deliveries.

Transit and mobility: Integrating public transport with AV for last-mile solutions

Where ride-sharing services enabled by AV technology are able to compete with public transport, public transport may lose ridership. Though most transit agencies do not solely rely on fares, a loss of ridership could marginalize remaining users of the service and undercut support for public funding public funding where used). This is a risk where a dominant local mobility provider, building on economic network effects, is able to undercut public transportation to such an end[[75]](#endnote-75).

An alternative trajectory is feasible where AV supports public transit in addressing the ‘last mile’ problem. A USDOT 2013 study[[76]](#endnote-76) of the potential impact of fixed-route shuttle AVs suggested that among neighborhoods with similar access to regional rail services, AV usage grew at the expense of driving, biking and walking. The greatest reduction in driving was forecast in the lower-density neighborhoods, supporting the view of AV as a contributor to the first and last mile problem rather than a necessary competitor to public transport. This would mirror the roles taken today by companies offering

private bus solutions or for-hire cars connected to transit lines[[77]](#endnote-77) and could connect under-served communities to public transport at a lower cost than extending transportation networks. The opportunity is particularly attractive in Louisville where providers have at times struggled to provide robust connectivity to major employment centers outside of the city centers[[78]](#endnote-78).

In reducing operating costs of for-hire vehicles, AV could provide a lower-cost mobility solution for disadvantaged groups, building on opportunities presented by ride-sharing services today[[79]](#endnote-79). Existing regulation of the for-hire taxi market may inhibit the development of ride-sharing services outside of those awarded central mobility contracts. Interviews suggest a currently productive relationship between the City and ride-sharing services[[80]](#endnote-80), but state engagement presents a source of uncertainty[[81]](#endnote-81).

Land use: significant changes to urban land use as technologies mature

The planning implications for AV technology are notoriously uncertain[[82]](#endnote-82). In the urban core, shared ownership and driverless cars offer the potential to increase the utilization rates of cars and thus reduce demand for parking; even if not pooled, cars could be redirected for other household use after delivering a commuter. The typical parked car consumes, on average, 14 square meters of space (excluding access road requirements)[[83]](#endnote-83). A study of forty major U.S. Central Business Districts assessed that an average of 31% of space is devoted to parking (including access needs)[[84]](#endnote-84). Though highly dependent on assumptions around the changes in fleet requirements, McKinsey has suggested that parking demand could be reduced by as much as 50%[[85]](#endnote-85), allowing new development and greater contributions to property receipts. Over the longer term, some analysts predict a long-term opportunity to reclaim road spaces; channeling automobiles into narrower, single lane channels and allowing alternate transit or green-space use[[86]](#endnote-86).

In common with road-use patterns, a battle between competing forces will shape the impact of AV on land use patterns in the metro area. The reduction in the cost of commuting may stimulate a new wave of low-density development as seen with the development of the interstate highway system. Alternatively, the trend toward urban migration and regeneration could be reinforced by reduced urban traffic. Unlocking commuting time for administrative tasks[[87]](#endnote-87) and easier access to urban nightlife (without impairment or timing restrictions) may stimulate greater demand for urban leisure pursuits[[88]](#endnote-88). In such a scenario, of particular interest will be land dedicated to parking in valuable urban spaces and potential for in-fill development.

Economic impact: huge economic disruption and opportunity from the new technology

AV represents significant change in an industry which has historically accounted for 3-3.5% of U.S. GDP and in manufacturing alone employed 0.9m people in 2015[[89]](#endnote-89). Even further, a range of industries will be directly affected by development of AV technology. Most directly, truck drivers and for-hire taxi drivers – some 2.5m workers nationwide[[90]](#endnote-90) – are directly at risk. Where crashes become rarer and AV more complex, simple maintenance may not easily be performed locally: garages and parts stores may come under pressure and new ownership models may challenge auto dealerships. Such exposures are mirrored in Louisville. Some 13% of jobs in the metro area are directly related to transportation provision, servicing or manufacturing[[91]](#endnote-91).

Industries employing higher-skilled staff will not be immune from impacts. The car insurance market and legal professionals will face significant disruption as risks, pricing and liabilities associated with new technologies are understood.

New industries and job opportunities will emerge. Some analysts foresee new industries writing applications for AV, and innovations with food services and appliances designed for in-car use[[92]](#endnote-92). Mirroring other technology-enabled trends within the labor force, it is likely that these jobs will require higher levels of formal education than those they replace. Similarly, productivity bonuses that could arise during AV commutes are likely to disproportionally accrue to knowledge workers. However, new ownership models may see mobility gains across the income spectrum, undercutting the impediment that car ownership (at a cost of some $9k p.a.[[93]](#endnote-93)) puts on low income households.

Public finance: primary exposures are not to City government

Cities do not appear to have the greatest identifiable fiscal exposure to AV. Impacts on property tax revenues will depend on changes in land-use as identified above. Marginal savings could accrue from safety benefits: according to the NHTSA, 7% of all motor vehicle crash costs are paid from public revenues: federal revenues accounted for 4% while States and localities paid for approximately 3%[[94]](#endnote-94).

Working directly with state and federal representatives will be critical. Taxes on automotive activity contribute more than 10% of Kentucky State government tax revenue; together with the federal government[[95]](#endnote-95), state funding plays critical role in funding of transport infrastructure for the city. Amid a reliance upon gasoline taxes and the prospect of greater electrification, the State will need to balance a desire to remain competitive and stimulate take-up of new AV technologies with a replacement of this revenue. Implementation of other revenue-generating tools such as a Vehicle Miles Travelled (VMT) Tax, congestion pricing and tolling will likely need to be implemented to offset declines in the gasoline tax and licensing fees. Otherwise, AV represents yet another source of tax base erosion that will add to State funding pressure that traditionally “flows downhill” [[96]](#endnote-96) to cities.

Other public sector agencies have more direct exposure. Agencies such as the Parking Authority of River City have direct exposure to parking revenue[[97]](#endnote-97). Local courts may experience declines in revenues from improved safety: forty-four percent of all 2013 Louisville Metro Police Department citations - some 28,832 citations - were issued by its traffic unit. It is likely that some of this exposure will be offset by the ability to reallocate parking lots and garages to development, generating land sales tax and enhanced tax revenue from ongoing use.

**3) Framing of City policy and management responses**

**In due course, develop a strategy which is linked to objectives but also embeds planning in all city services.** Comprehensive citywide approach to AV would link areas of impact in this report to the range of current and future policy objectives, and also establish a mechanism for ensuring that major initiatives are congruent with the potential disruption. This is particularly relevant within city services, such as EMS or waste disposal, that operate with automation but may be relatively isolated from policy and innovation discussions.

**AV represents technical innovation of global impact and significance; inevitably, many policy decisions critical the take-up and regulation of AV are not controlled by the City**. Driving regulations are set at the state level; federal agencies are responsible for national safety rules. Louisville is not home to large AV companies, but has significant exposure to their decisions: of particular salience are the twelve Ford Motor Co. facilities that are an important source of employment in the metro area. Planning for AV in the City should encompass three levels of opportunity:

**The opportunity to influence.** It is worth reiterating that functions that will be critical to the development and successful uptake of AV reside at the State level: automotive licensing, regulation of ridesharing companies, automobile revenue-raising and infrastructure funding. As a key driver of economic activity in the state, the threats and opportunities facing Louisville form AV technology need to be central in the deliberations of the state government. A state board for AV technology – coordinating state-level taxation and regulation efforts with representatives from major urban centers – would enable coordination between cities and states that will be vital to deliver a united response to the technology.

**The opportunity to position Louisville as a center of innovation.** Given the stage of technological development, there is not likely to be significant opportunity for the City to stimulate local development of the first wave of this technology. However, the technology is here to stay. Other cities have entered partnerships to test emerging technology (Pittsburgh, PA with Uber[[98]](#endnote-98)) to bring early adoption of mobility solutions to residents (Altamonte Springs, FL [[99]](#endnote-99)). Similar opportunities will be available with new market entrants or to expand necessary testing[[100]](#endnote-100) to highlight Louisville as a center of innovation and attract new investment.

**The opportunity to revisit important policy objectives.** The scale of potential changes enabled by AV present new opportunities – and threats – to achieve policy goals. There are many competing interests and unknowns as AV technology emerges. For example, there is potential to support goals for living car-free or car-lite for residents. At the same time, there is a threat that VMT and reliance of single-occupant vehicles will actually increase. Louisville will need to strategically invest in improving multi-modal transportation infrastructure while updating its land use policies and regulations to reinforce compact, walkable nodes that can easily be served by transit.

Avoiding costly mistakes

As above, the current development of AV should give policymakers pause before large-scale investment in enabling hardware or infrastructure, mindful of the second-mover advantage. USDOT is still in consultation over V2V and V2X requirements due in new cars from 2021[[101]](#endnote-101); even once implemented, early effectiveness will be severely hampered by low penetration rates[[102]](#endnote-102). Hardware technologies rapidly and inevitably become obsolete while automobiles have long useful lives; GM’s OnStar service was dependent on 2G signal which has been discontinued by cellular providers[[103]](#endnote-103).

Specific policy areas recommended for investigation

Even as the development of AV technology remains uncertain, the threats and weaknesses identified above lend themselves to areas of policy that should be investigated by the city. A list of exploratory recommendations are summarized in figure 5 below; in many domains, these should be seen as opportunities to support existing agency objectives, rather than AV-specific recommendations.

*Figure 5: initial policy recommendations*

|  |  |  |
| --- | --- | --- |
| **Policy area** | **Policy options: near-term** | **Policy options: following arrival of AV** |
| **State-level coordination** | * Creation of state-level board for AV technology, aligning city and state responses across regulatory, legislative and fiscal domains | * Formalize input into policy decisions |
| **Safety** | * Monitor development of safety regulation and performance, with a view to enforcing city-level protections for non-car road users | * Consider opportunities for more separated cycleways and pedestrianization of city streets |
| **Road usage** | * Include need to prepare for AV-led mobility patterns in future infrastructure discussions * Explore options for congestion charging, including automated capture of vehicle arrivals and automated vehicles record time of city trips * Work to maintain positive working relationship with existing and new mobility companies | * Update road ordinances to use public street assets – whether cub access or complete streets - for policy goals, such as vibrant downtown activity; restricting vehicles by type and time of day * Land use policies should incentivize infill development along and adjacent to transit corridors * Parking maximums should be instituted in activity centers to discourage usage of single occupancy vehicles. |
| **Mobility and public transport** | * Explore partnership arrangements with ridesharing companies to foster early integration with local public transport systems * Be mindful of network effects in tendering for mobility solutions; consider multiple contract award * Mandate open data for ridership of public transit and ride-sharing services in the city to facilitate competition and better mobility | * Support TARC to access cost-effective AV innovations that could secure its competitive position against ridesharing companies * Consider allocation of street and ex-parking space to rapid public transport lanes |
| **Land use** | * Continue efforts to address zoning, community and financing barriers to in-fill development * Explore changes to tax regime to better deliver development goals, including assessment on potential development value | * Begin scoping potential demand for space created by 50% reduction in parking needs * Assess zoning laws for modernization, including walking access and removal of parking space requirements |
| **Economic impact** | * Strengthen job-training and technology readiness efforts in light of continued technology-led disruption * Explore partnership options with local academic institutions; research and development clusters but also coding academies to upskill local workforce * Explore partnership arrangements with technology providers to signal Louisville as attractive, innovative destination for young workers * Recognize AV as part of technological trend that will put pressure on economic development strategies targeting “smoke stacks” over highly-educated workers |  |
| **Household wealth** | * Support continued and enhanced access to mobility through public transit | * Consider phasing out of implicit subsidies for car ownership, including residential parking permits |
| **Public finance** | * Prepare for erosion of current automobile tax base and research options for road user-pricing | * Support State to develop alternative to current automotive revenue base * Work to reduce exposure among public agencies to vulnerable revenue streams, such as traffic citations or parking revenue |

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**Appendix B: levels of automation**

NHTSA five-level framework defining levels of vehicle autonomy (published May 30, 2013)[[104]](#endnote-104):

**NHSTA Autonomy Level 0:**

*No-Automation:* The driver is in complete and sole control of the primary vehicle controls—brake, steering, throttle, and motive power—at all times.

**NHSTA Autonomy Level 1**

*Function-specific Automation:* Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.

**NHSTA Autonomy Level 2:**

*Combined Function Automation:* This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.

**NHSTA Autonomy Level 3:**

*Limited Self-Driving Automation:* Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time.

**NHSTA Autonomy Level 4:**

*Full Self-Driving Automation:* 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.

The Society for Automotive Engineers (“SAE”)[[105]](#endnote-105) automation guidelines:

**SAE Autonomy Level 0:**

*No Automation.* The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems

**SAE Autonomy Level 1:**

*Driver Assistance:* The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task

**SAE Autonomy Level 2:**

*Partial Automation.* The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task. Automated driving system (“system”) monitors the driving environment.

**SAE Autonomy Level 3:**

*Conditional Automation:* The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.

**SAE Autonomy Level 4:**

*High Automation.* The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.

**SAE Autonomy Level 5:**

*Full Automation.* The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

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