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Get Ready! A Policy Primer for the Coming Transportation Disruption

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The disruption of road transport by a new business model, Transport-as-a-Service (TaaS), has the potential to provide cities, states, and the US economy with their biggest boost in a century, while helping solve some persistent social and environmental problems at zero cost. Fleets of autonomous electric vehicles, owned by fleets (not individuals) will offer ways to transport people at much lower cost, leading to a boost in disposable incomes of more than $5,600 per household (or $1 trillion in aggregate per year), with a further $1 trillion per year boost to GDP from productivity gains. These gains will be spread far more evenly across society than tax cuts and will flow back into the economy, with the potential to create many new jobs, helping to compensate on a larger scale for those lost. This is a technology disruption – not just an energy shift – and the infrastructure for it is already mostly here.

TaaS will be life-saving and life-giving for many, enabling people with disabilities, the elderly, and low-income families to access more affordable transportation and to participate in the economy. Road deaths and accidents will be greatly reduced and air quality (which kills even more and contributes to disease in yet larger numbers) will dramatically improve. **Large expanses of cities devoted to parking and road infrastructure will be freed up, offering a once-in-a-century opportunity to redesign cities for the ways we want to live**, also reducing infrastructure costs. Transportation could largely be decarbonized by 2030.

A race is developing to lead this transformation. Those who lead will benefit from the gains that come with global leadership of an industry that affects the entire economy: the wealth, taxes, prosperity, job creation and global influence. The US currently has a lead in technology, but risks falling behind in execution and roll-out. Future competitiveness depends on leading. To do so, California and the US must recognize the potential of and remove barriers to test, develop, and adopt the technology. **Policymakers control critical outcomes of the transition; whether it will overburden existing infrastructure; the cost of TaaS; and the speed and extent of the benefits.** To capture these gains, clear direction and expectations are needed to communicate to the market, fast-track the development of AV technology, and remove barriers to adoption. Key recommendations:

- **Enable widespread AV pilots to speed technology development**. AVs learn by doing, and the more miles they cover, the quicker they learn. Learning happens exponentially: lessons learned by one vehicle are quickly shared with every vehicle in its worldwide network. Maximizing learning per vehicle in these first years is thus paramount to quickly improving safety throughout fleets of shared-ride vehicles. Allowing widespread pilots in different regions and conditions will accelerate the development of AV technology.

- **Remove barriers to adoption of AVs.** Clear frameworks allow TaaS companies to provide TaaS to consumers at scale by clarifying and removing barriers to insuring AVs, clarifying rules around liability and accelerating approval of vehicles to operate on roads.
- **Ride-sharing** (carrying multiple people to their destinations and avoiding single occupant or empty use) will be essential **to maximize efficiency of both vehicles and roads and avoid over-burdening infrastructure**. This can be driven by price and/or regulation.
- **Underpinning data infrastructure services should enable interoperability, competition and innovation** while delivering privacy, security and accountability. Transportation services should be integrated and coordinated across vehicles, modes, operators and geographies. This integration depends upon thoughtful system planning, physical connections and combined mobility information, allowing for efficient, convenient and seamless trips for a wide range of travel needs.
- **Enable high-definition mapping development.** High-definition mapping will help accelerate AV technology development, especially over the next few months and years. Policymakers should encourage open data initiatives and public-private partnerships that can help develop and share high definition mapping amongst a wider set of AV providers.

Decision-makers will also want to consider and work toward fair user fees and efficient use of vehicles, lanes and curbs, so that every vehicle and mode should pay its fair share for road use, congestion, pollution and use of curb space. For instance, current subsidized parking policies encourage a highly inefficient use of prime city real estate that can be heavily used for curbside pickup and drop-off. This can, in turn, increase revenues from usage fees of public curb space.

Promoting equitable access and public education and involvement is also key, as cities/agencies monitor and strive for equitable physical, digital and financial access to shared transport services, prioritizing people and interconnectivity over the use of traditional single-occupancy cars. Cities and mobility need to be planned together as these choices determine mobility needs and how they can be met.

Background

RethinkX's recently released report, "Rethinking Transportation 2020-2030," highlights achievable benefits to the US economy and consumers from a pending disruption of car ownership by Transport-as-a-Service (TaaS). **TaaS will result from the convergence of electric vehicles, self-driving technology and ride-hailing, to deliver** a mobility solution – an autonomous ride-hailing service – that **costs much less than individual car ownership. It will mean that people will no longer need to own vehicles, and instead will access rides only when needed.**

This disruption can happen far faster than is generally understood. We forecast that within 10 years of the introduction of autonomous vehicles, **95% of U.S. passenger miles will be travelled by TaaS, representing one of the fastest, deepest and most consequential disruptions of transportation** in history – a disruption with the power to reshape the world's energy economy, increase mobility and health, and restructure our cities. And as cost goes down, demand and use go

up – congestion will too, but can be managed with adequate early attention to frameworks – creating even better streets and livability. Old sector jobs will be lost.

If TaaS transforms mobility at the speed and extent we foresee and shared mobility can be encouraged, there will be enormous economic benefits for countries and regions, for consumers, and for society. However, many existing industries will need to transform themselves to remain competitive. Jobs will be on the line. The global nature of the industry means that those countries that adopt a supportive regulatory framework that encourages both the development of the technologies and the adoption of them will reap huge benefits in economic competitiveness and the creation of wealth and jobs and increased health, mobility, and quality of life. Those that do not lead or prepare will see industries destroyed and jobs lost – without the benefit of new ones in their place. A global race to capture the benefits is developing and attempts to slow down the adoption of TaaS could have profound consequences on America's future.

Lower cost, economic benefits and market forces will be the key driver of consumers adopting TaaS, creating an inevitability to the disruption. But policymakers play a significant role in its outcome and how it can relieve or worsen burdens on infrastructure and budgets. Such outcomes depend on choices made now and will determine **the cost of TaaS, the speed of roll-out, and the extent of the benefits that result, as well as how public streets and highways are better for it.**

RethinkX's analysis, based on technology shifts and the interconnections among them, differs from mainstream analysts in its ability to accurately forecast the arrival of disruptions seen to date (such as growing cost-effectiveness of PV and batteries) and arriving ones such as EVs and AVs. The speed and scope of the coming transportation disruption is beyond what nearly all expect. An appendix on our methodology and the reasons we have confidence in our justifications is attached. In summary, while mainstream analyses rely on linear incremental forecasts, ours better reflects the reality of fast-paced technology-adoption S-curves and the systemic nature of change, both of which are central to understanding the nature of technology disruption and social uptake.

This document highlights why policymakers would want to support a fast disruption and transition to TaaS, as well as critical considerations and decisions they can make to influence its progress. It also warns of potential adverse consequences that can be mitigated with foresight and planning. We set out below both the potential benefits of the TaaS disruption and the adverse consequences.

The Benefits of the TaaS Transportation Disruption

Global competitiveness and leadership

- ***Technology leadership gains:*** the countries, states and cities that gain first-mover advantage will develop the technologies and businesses that will deliver TaaS globally. **Leadership ensures that businesses in these jurisdictions will be best placed to capture the wealth, taxes, prosperity, job creation and influence associated with this global transportation disruption.** Without it, cities and states will face greater challenges.

Economic gains

- ***Productivity gains:*** **140 billion hours will be freed from driving**, allowing people to work or engage in other productive activities, leading to an increase in U.S. GDP of $0.5-2.5 trillion annually. Faster transportation and action to manage congestion will create further productivity gains.
- ***Consumer disposable income gains:*** **the average household will save $5,600** from this lower cost form of transport. This is equivalent of a huge tax cut or after-tax pay increase, but spread out far more evenly than tax cuts. **This figure will increase as costs go down further to total over $1 trillion annually by 2030**. This could be the biggest single boost to American family disposable income and spending in history.

This twin boost to the economy can create significant employment, especially if action is taken to ensure there is competition among providers and interoperability among vehicles. This helps direct gains from lower cost transportation to households, where re-circulated spending in local economies has a bigger economic multiplier and job-generation potential. Policymakers will want to consider how to strengthen their cities and states and direct resources appropriately.

Other gains

- ***Reduced public sector costs*****:** TaaS fleets will mean that the need for road space will decline dramatically, leading to lower highway infrastructure costs. Policies that tilt these fleets towards shared occupancy of vehicles can help reduce infrastructure costs further by reducing the number of vehicles required even more.
- ***Opportunity to redesign cities:*** TaaS vehicles will be in operation far more than existing cars (which are currently stored 95% of the time) meaning a vast reduction in parking requirements and a “land bonanza” for cities as parking and some roadways become available for bike lanes and enhanced green or public space, affordable housing or other uses. For example, Los Angeles has 200 square miles of parking space, much of which can be repurposed (20-30% land area is common for cities). The expected vacant parking parking space in Los Angeles could fit three cities the size of San Francisco. TaaS offers a once-in-a-lifetime opportunity for planners and the public to design the cities they love and want for the 21st Century.
- ***Quality of life gains:*** from improved mobility for the elderly, the disabled and others who may be unable to drive themselves; newly affordable access to transportation, jobs and economic opportunities for people with lower incomes; cleaner air; fewer road fatalities and injuries; and decarbonization at zero cost as a ‘by-product’ of this disruption, while increasing economic strength and disposable incomes. Everyone will have more time, which is currently spent driving or stuck in traffic.

The costs of TaaS transportation disruption

While the overall benefits of TaaS disruption will be enormous, widespread and lasting, any technological disruption creates challenges for threatened businesses and jobs:

- ***The need for transformation of the Auto industry:*** the automotive sector faces radical change. As individual car ownership wanes and vehicle lifetimes are extended beyond 500,000 miles, demand for new vehicles will drop and 70% fewer passenger cars and trucks are likely to be manufactured each year. Many automakers are already starting to invest in TaaS. Others may become high-volume assemblers of automated electric vehicles. But employment in the automotive industry and throughout the transport value change will shift radically. Driving jobs and gas stations will become obsolete. Car dealers whose business model relies on repair and aftermarket part revenues and selling to individuals may evolve into fleet managers. Because electric vehicles have so many fewer moving parts than internal combustion engine vehicles, oil change and repair shops may cease to exist or be linked to fleet garages. And because automated vehicles eliminate driver error and individuals won't own cars anymore, auto insurance companies will have dramatically less business.
- ***Energy sector disruptions:*** The energy sector will also face radical change. With the rise of autonomous electric vehicles, oil demand could peak at 100 million barrels per day by 2020, dropping to 70 million barrels per day by 2030 and sending oil prices plummeting to $25 per barrel. High-cost oil fields will become uncommercial. Jobs throughout the oil industry value chain will be threatened if oil companies fail to adequately prepare and adapt.

While all this is happening, huge business opportunities will open up because of TaaS. Fortunes will be made in vehicle operating systems, computing platforms and TaaS fleets, as well as new products and services built upon this new transportation technology infrastructure. TaaS companies will become leading transportation brands. New business opportunities will emerge as travelers freed from having to drive seek out cafes on wheels, mobile entertainment and commute-time workspaces. Low-cost transport might encourage business currently tied to high-cost real estate to move to a 'mobile' platform – which could lead to large increase in traffic volumes. Governments may have to take care to avoid having empty vehicles taking up road space as well, but if managed right, cities can add more sidewalk space for people and restaurants, art, leisure and more, including green parks, affordable housing, new businesses and protected bike lanes. Leading cities will increase quality of life and attract businesses. And leadership will allow American companies to create the technologies, products and services that can be exported globally.

Overall, the benefits will be enormous – and because of economics, the TaaS disruption is inevitable. The question is: what are the effects on jobs, budgets and public infrastructure, and how long does the public have to wait for cheaper, easier, more accessible transportation, better health and access to jobs? Policymakers can make choices that bring forth the benefits and ease the consequences of the transition for workers, businesses and cities. With proper planning, it is possible to harness the enormous potential of this disruption to create wealth, health and stability for society. In cities, it can mean better cities for all. But failure to foresee or to plan for it could delay the benefits while still creating short-term unemployment, public outcry and demands on infrastructure.

Regulatory Context

As technology for autonomous vehicles has matured, increasing attention has focused on the regulatory environment. Since 2012, at least 41 states and D.C. have considered legislation related to autonomous vehicles.[1] In 2017, 33 states have introduced legislation, and all told, nineteen states, – from California to Alabama to Vermont – have passed legislation related to autonomous vehicles. Four states have executive orders on the subject.

At the federal level, a series of bills currently moving through Congress with bipartisan support allows automakers and tech firms to deploy thousands of self-driving vehicles on the road while federal regulators develop safety standards. It would also prohibit states from regulating the mechanical, software and safety systems of autonomous cars, pre-empting existing state rules.[2] **While federal policy leadership is desirable to ensure that states do not slow down the transformation, state level policy should be allowed to drive the disruption faster. Competition between states will help ensure America leads. Federal regulations can provide a 'floor' and interstate standards.**

Less attention has been devoted to changing demands on infrastructure and revenues – increased demand for curb space, declines in parking usage and revenue and gasoline taxes. Agencies might get ahead of some of these challenges by planning for routes now (for instance allowing AV usage of expansion of HOT/HOV lanes) and also indicating expectations or requirements for ridesharing and how arterial space will be repurposed for other modes and uses.

Electric vehicle policy varies from state-to-state in the U.S. Some states offer rebates and incentives. Others require automakers to sell zero-emission vehicles. Still others require registration fees. **Lead agencies that are transitioning vehicles to A-EVs in their own fleets already will be less likely to be stuck with stranded assets in the transition**.

The imperative to lead

The United States was an emerging economy in 1900 and went on to become the 20th Century's economic and military superpower, based in part on the strength of its auto industry. By the 1950s, the U.S. auto industry produced more vehicles than the rest of the world combined. In 1960, the automotive business was America's largest industry, employing directly or indirectly one of every six working Americans – though Detroit has just half that population now. **America has often embraced the future and driven innovation and entrepreneurship**, with special attention to creating a market-friendly environment. The risk of not leading this transportation disruption is that China, India or Europe develops the technologies of the future and captures the jobs, wealth and economic competitiveness that will accrue to leaders, replacing America in global influence,

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[1] http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

[2] https://www.bloomberg.com/news/articles/2017-07-19/self-driving-cars-get-boost-with-unanimous-vote-by-house-panel

technology and prosperity. It is important that policymakers at all levels of government are aware of the stakes.

All of the technologies associated with TaaS are global. The TaaS disruption will be a worldwide disruption. The technology adoption lifecycle suggests that there will be innovators, early adopters, mainstream adopters, late adopters and laggards. If one country or region bans or fails to approve autonomous vehicles, the disruption will still happen in another country (China?), state (California?) or city (Singapore?). Whatever barriers prevented the adoption of AVs will be erased as the technology develops exponentially and as the world witnesses the benefits that accrue to early adopters. Late adopters will be forced to follow closely behind the mainstream adopters, but will have lost the economic gains and influence that come with leadership**. TaaS is not a matter of IF its adoption will occur, but WHEN and HOW.** Who will be the leaders?

What can policymakers do to speed attainment of the benefits?

Change is not linear, though most of us have been taught to project it that way. There will be an inevitable disruption point (the creation of viable autonomous vehicles) in the future that will open a divergent pathway, making current investments in infrastructure – parking structures and also new roads if ridesharing incentives are in place – redundant. This requires planning and policy attention to emerging facts. There is a need to invest in current systems (*without* creating obstacles to the future or investing in assets that will be stranded) in the period before a new system with new requirements becomes completely evident and takes over. For example, TaaS will require a more centralized, high-speed charging infrastructure that serves fleets, which will make charge points at offices and homes redundant. Already owners of EVs who have their own homes and garages prefer to charge there, but on-street public charging may not be as needed as TaaS appears. A primary function of charge connections at work or shopping in the future may be to provide grid stability at low cost, and that may only exist in an interim phase until AVs and TaaS arrive. **Decisions made now can affect the timing and the speed of the transportation disruption and the choices, quality of life, and infrastructure demands that occur** (whether over-demand for roads from excess VMT or less congestion and more space, with incentives for vehicle-sharing or right-sizing).

Capturing the benefits of the TaaS transition and mitigating adverse consequences will require proactivity. The following actions may be taken at multiple levels of government:

Accelerate TaaS Adoption and Shared Mobility

1. Fast-track learning and technology development

The key to unlocking TaaS is vehicle autonomy. Without self-driving vehicles, the low-cost, fast-paced disruption of transportation will not happen. The introduction of autonomy requires both technological development and regulatory frameworks, and even technology improvements depend

on testing and regulation. Autonomous vehicles learn by doing. The more cars on the roads in pilots and the more miles they cover, the faster they learn and the faster TaaS vehicles are ready for introduction. We expect simulation technology to be developed which allows autonomous vehicle learning and progress to be accelerated. The University of Michigan claims to have developed a system, incorporating data from 25 million miles of real-world driving, that cuts the time needed to evaluate AVs' handling of potential hazardous situations by 300 to 100,000 times. We are aware of Chinese plans to have tens of thousands of autonomous electric vehicles on the roads by 2020 to speed up the development process. Support for trials is thus critical to the fast development of TaaS.

Attaining the safety, mobility, clean air, time and cost savings benefits of the technology depends on learning and development. Economic leverage depends on leadership and first-mover advantage, which, in turn, depends on widespread autonomous vehicle pilots & testing.

2. Remove barriers and enable rollout

Regulatory frameworks that clarify uncertainties with regard to liabilities for accidents and provide clear testing and permitting requirements are critical. Such standards are often set at state or city levels, and regulators need to work together to ensure harmonization.

Clear, standardized rules (set at the highest possible level) are needed to clarify accident liabilities and to set clear requirements and testing frameworks for permitting of AV use. Clarifying rules and liability related to cyber-security breaches is also critical.

3. Accelerate adoption and benefits that can be achieved with fleets of shared vehicles

Adoption of TaaS can be accelerated beyond what market forces alone would deliver through a number of measures, including special lanes or avenues for AVs. AVs have the potential to slash travel times, reduce congestion and increase the traffic loads that roads can accommodate (by driving in closer proximity, reducing the number of accidents, etc.). However, the full benefit of AVs is only fully reached when AVs operate as fleets of shared vehicles, with another degree of cost-savings when human drivers are eliminated or restricted. A mix of human and autonomous vehicles does not reach these benefits, and in fact could lead to more congestion. The cost of TaaS is also affected by speeding up travel times. By increasing the speed of travel, and thus the number of miles covered, the cost per mile is reduced.

Allowing AVs access to HOV/TOV lanes would be a first, inexpensive step. Encouraging AVs to be used mainly as fleets of shared vehicles will also help. The creation of either AV-only lanes within urban areas would speed development and adoption as travel times decrease in comparison to human-driven vehicles. This would not need building special new roads but rather repurposing inefficiently used infrastructure such as taxi-only road lanes and parking space.

4. Replace lost government revenues

Governments will lose revenues from gasoline taxes, parking and reduced new sales and registration taxes as the transition occurs. With planning, this can be offset by a reduction in infrastructure spending and freeing of urban land as fewer parking spaces and less road space are needed. Gasoline revenues could be recovered by a tax on TaaS of only one cent per vehicle mile. While it is easier to impose costs on sectors when numbers and interest groups are still small, decision-makers should also keep in mind that it is possible to "pluck the goose" too early. Overall, vehicles should be treated fairly; every vehicle and mode should pay their fair share for road use, congestion, pollution, parking, and use of curb space. Taxes on VMT could help encourage higher occupancy of vehicles and reduce congestion.

Review the net gains/losses to government revenues from TaaS and plan for introduction of replacement taxes in which each vehicle and mode pay their fair share for road use, congestion, pollution, and use of curb space. Care should be taken so that new revenue application does not slow the speed of adoption and transition. Taxation of Internet commerce provides a case study where policymakers decided to avoid early taxation to allow the industry to innovate and build scale.

Provide Regulatory Certainty

5. Tackle planning with transit, promptly

TaaS will cost less than riding buses and trains, and will offer direct, point-to-point service without transfers. Early coordination and planning can ensure that TaaS supports a backbone of public investment that has already occurred in fixed guideway transit. Still, future investments by transit agencies and cities should be made consciously and carefully to avoid over-investing where assets could be stranded (definitely new gas or diesel-powered buses, possibly larger buses altogether, except on particular routes, which will all be EV). The TaaS Pool model (sharing vehicles with others) will likely lead to a "merger" with buses, as TaaS vehicles are built in all sizes, from two-seaters to vehicles that can seat 40 people or more. Planning urban transport holistically, taking advantage of the street improvements that can be made with new space available, will be important; walking, cycling and TaaS will become more viable in cities. Versions of TaaS that work like buses (providing transportation along fixed routes rather than point-to-point transportation) could provide another alternative.

Transit agencies should begin planning for the TaaS transition – both the opportunities and the challenges it presents – to ensure the greatest long-term health and use of public assets and the most accessible service provision. Planning how these alternatives will work together in advance will be beneficial, as infrastructure decisions made today could impact their development and viability.

6. Give policy direction to enable investment and consumer adoption

Leading policymakers who attract innovation set discernible direction. Decisionmakers can signal commitment to the implementation of TaaS and some of the benefits that may accrue, like more protected bike lanes and areas with fewer vehicles and less congestion by starting to implement such zones now, developing videos and PSAs, setting a clear vision and planning direction, and encouraging businesses and consumers to invest and adapt. Signaling support for TaaS in legislation, public pronouncements and plans can help create this certainty. Urban planning frameworks could include locations for centralized charging networks, drop off points and how existing parking spaces may be re-used. This kind of signaling also allows consumers to make informed choices today – new gasoline vehicles bought today risk being entirely worthless before the end of their lives. It can give time for those affected by the disruption (drivers and others) to plan for their futures and save money on stranded assets. It creates confidence that positive new directions are possible and even a sense of inevitability.

Share vision and plan for TaaS; e.g., how existing parking spaces may be re-used or re-purposed, such as protected bike lanes or additional green or public space added. Develop videos or PSAs on how more people can get around and live life fully.

7. Ensure a competitive marketplace

TaaS operating systems (the self-driving intelligence) and platforms (the Uber-like interface between car and consumer) could tend toward monopolies or oligopolies, due to the network effects that are inherent with these technologies. Policymakers should ensure that the data infrastructure underpinning shared transport services enables interoperability, competition and innovation (while delivering privacy, security, and accountability). The development of open source operating systems (like Linux and Android) would ensure that new TaaS fleets can enter the market using lower-cost operating systems and cost savings are passed on to consumers in the form of lower prices. Also, ensuring that shared vehicles share data across fleets and operate as fleets will (i) maximize learning per vehicle in these first years and thus safety; (ii) help manufacturers sell early AVs to large-scale buyers before manufacturing supply increases, prices fall, and autonomous vehicles can be widely marketed; (iii) ensure that vehicle maintenance and software upgrades are monitored and managed by professionals; (iv) ensure that the benefits of autonomous travel are available to all and extend access; and (v) maximize efficiency of both vehicles and roads.

The data infrastructure underpinning shared transport services must enable interoperability, competition and innovation, while delivering privacy, security, and accountability.

8. Consider universal access

TaaS will dramatically change the role of public transportation authorities (PTAs). Their role will shift from one of managing assets (buses, trains, parking garages) to one of managing TaaS providers to ensure universal access for all. There may be consumers who are left out of the benefits provided by TaaS. For instance, rural customers will face higher prices (due to redundant journey legs) and longer wait times than urban consumers, and they will represent less attractive markets for private suppliers. However, access to TaaS offers benefits to consumers, including cost savings,

productivity gains, and access to jobs and economic opportunities and participation. In the same way that our society provided subsidies for electric utilities, postal service and telecom companies to offer universal service, regulators might consider providing universal access to to TaaS through subsidies to PTAs offering services to rural and other users left out of the private TaaS market.

Monitoring and striving for equitable access to shared transport services will help measure progress. Policymakers should encourage transportation services to be integrated and coordinated across vehicles, modes, operators and geographies. This integration depends upon thoughtful system planning, physical connections and combined mobility information, allowing for efficient, convenient, seamless trips for a wide range of travel needs.

9. Incorporate TaaS into infrastructure and urban planning

A TaaS vehicle fleet has slightly different infrastructure requirements than the existing fleet – and planning to meet these needs without over-investing in the parts of the system that become redundant is a key challenge. Critically, TaaS fleets will need less urban parking infrastructure, but point-to-point transport will require the ability to drop passengers off without causing congestion. Road striping needs are changing. Centralized charging stations with adequate capacity in numbers of superchargers and electricity capacity will be required. Homes and offices will require less (or even no) parking, and parking requirements will need thorough review. Working with TaaS providers and the public will help planners understand how vehicles will be distributed and where waiting areas should be created, to ensure TaaS vehicles not in use do not clog the roads.

In the short-term, revisions to road striping policies and parking requirements should be re-examined. The next steps are to begin planning for the roads and a wider range of modes, use, and public users in the future, including the curb space TaaS will need, the road space that will be freed, and supercharging and garage/readying space for TaaS in circulation.

10. Envision a better city, and plan for it

TaaS has the potential to foster cleaner, more active and vibrant cities with more public space that might also encourage more people to live in city centers and along arterials. This possible future will take vision and decisive action. Without it, improved travel times and the ability to work productively during commutes might lead to people living farther away, in greener areas, outside of cities. Decision-makers should begin to plan now for the new space that will be freed for public use and new development, and how to achieve this (and avoid costly pressure for road-widening) by committing to and planning for shared-ride fleets of A-EVs. Affordable infill housing, green spaces, cycle lanes, sidewalks, community or indoor farms might be possibilities. The transition before us offers a once-in-a-lifetime opportunity to reimagine our cities and give them the attributes that people appreciate most – liveliness but quiet as well, more green space and interesting places to bike, walk, and socialize with others. This opportunity is not to be missed, but could be if not planned for and managed.

Decision-makers should begin to plan now for the new space that will be freed for public use and new development, and how to achieve this (and avoid costly pressure for road-widening) by committing to and planning for shared-ride fleets of A-EVs.

Plan for Community Vitality and Ways to Cope with Job Losses

11. Plan for job losses and ways to boost community vibrancy and reinvestment

AV technology presents a real threat to many types of jobs and can probably only be justified by the increased safety, access, convenience, health and cost savings that are likely to result. It is essential that policymakers realize and plan for the extent of job losses that comes with AV technology, potentially 3 to 5 million jobs by 2030. While disposable incomes and GDP will rise overall with these changes, job replacements and local needs will remain. Ensuring that those affected are supported through this transition with both social programs and retraining and that community reinvestment occurs will be important. Realizing the potential *speed* and scale of transportation disruption is a critical first step for decision-makers. It is far more honest to recognize, communicate with and support those affected than to stumble headlong into the disruption. Take this research as an early-warning signal**. Succumbing to pressure to protect these jobs through policy intervention will cause the loss of far more jobs across the economy as the US loses early mover advantage and economic competitiveness.**

Consider how jobs will change. Local jobs at repair shops, dealerships, and in insurance will be lost, as will most driving positions. Car-cleaning and delivery-receiving positions will become available, as will other new positions. 3-5x the local funds and taxes stay in the community with locally-based businesses and local investments; encouraging more of the latter will help cities stay healthy and vibrant.

Communicate and Engage with Stakeholders

12. Educate and engage with all demographics - all voices need to be heard

The skepticism greeting AVs is there for any new technology. Ten years ago the skeptics asked: “Who would buy a new $600 iPhone when you can buy a $100 Nokia?” The opportunities and benefits with AVs are so profound, however, that, a concerted campaign to answer public concerns and communicate TaaS’s benefits to public health, safety, and access, as well as household budgets and time could be in order (e.g., agency videos with residents about access it will provide and how it may change their lives, air pollution and noise impacts, options for street changes).

Engage with stakeholders. Residents, workers, businesses and other stakeholders will feel direct impacts in their lives, their investments and their economic livelihoods by the unfolding transition to shared, electric, and autonomous vehicles. All voices need to be heard and can help plan for the change that is coming, and positive changes that can be made in their communities.

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Summary

RethinkX provides a detailed analysis of the convergence of autonomous vehicles, electric vehicles and ride-hailing platforms. The resulting business model – mobility or transport-as-a-service (TaaS) – has the potential to greatly change the transportation landscape. It could end individual vehicle ownership and reshape the world's energy economy. A transition to autonomous, electric vehicle (A-EV) fleets providing TaaS will increase mobility, cut traffic accidents and deaths and – if governments implement policies and incentives for vehicle and data sharing – can result in far more efficient use of vehicles and roads, easing congestion and freeing up enormous space in cities. RethinkX's analysis shows that A-EV fleets providing on-demand transport will have ten-times-higher vehicle utilization rates than current vehicles, 500,000-mile vehicle lifetimes and far lower maintenance, energy, finance and insurance costs. This will result in transportation at a fraction of today's price, driving rapid consumer adoption. An anticipatory policy structure can help usher in a new era of affordable personal mobility and offer cities new choices and a "second pass" on earlier ones.

TaaS-related policy might be driven at the federal level, state-by-state, or city-by-city. Supportive national policy would help to fast-track the transition; however, it is not a precondition for widespread TaaS. As some cities lead this process, the benefits of low-cost, accessible transportation will become so evident that policymakers elsewhere will face societal pressure to jump aboard. The enormous economic, social and environmental benefits – as well as the gains that come with leadership – will drive a competitive policy environment, with countries and cities vying to lead the disruption and capture the associated benefits. America's leadership in the 21st century depends on decision-makers embracing the positive change we can make, to drive innovation and plan for the new economy with this rapid shift.

Appendix - Background for planners, policymakers, investors, businesses and other decision-makers

Decision-making in the dark

Decision-makers usually face an impossible task: making long-term decisions about policy and investment while being fed information that is inadequate and fails to recognise the potential speed and extent of disruptions. **Mainstream forecasters fail to understand how technology disruptions unfold. Their models are suited to incremental change, but in an era of ever-increasing technological progress and constant disruption, traditional models are ill-suited to their basic task of providing data, scenarios and information on which decisions about the future can be based**. These models consistently miss "Minsky moments" when asset values collapse, like the global financial crisis of 2007-2010, or the demise of once-mighty companies like Kodak; and even when change is more gradual, they fail to comprehend its speed and extent over the long term.

General mistakes forecasters make

Linear progressions mistake

Mainstream forecasters have become adept at understanding the exponential nature of problems such as growth, emissions, deforestation or pollution, but they fail to recognize the exponential nature of solutions. The solutions – technologies – are adopted in S-curves. These are driven by feedback loops, network effects and tipping points, which act as powerful accelerators to adoption and drive non-linear pathways. Furthermore, technology convergence leads to disruption points **–** where suddenly new business models or products become possible **–** and change happens fast. Just as the smartphone was enabled by a number of technologies reaching a point in price and performance, so too **–** and soon **–** will autonomous vehicles be feasible as artificial intelligence, sensors, communications and computer processing come together to enable it. This will create a disruption point where the costs of mobility plummet, Transport-as-a-Service (TaaS) becomes viable, and economic realities make rapid adoption inevitable, even if the timing of this inflection point is uncertain. With technology disruption playing a much larger role than when planners were trained, this is a new factor that must be incorporated now.

Misunderstanding the systemic and interrelated nature of change

The second mistake most forecasters make is to assume that technology improves in cost and utility at an exponential rate, but that "all else remains equal." In fact, everything is dynamic and interdependent. This mistake means forecasters see factors as constants and not variables, or ignore the systemic implications of this dynamism across society. For example, they view the public's skepticism of autonomous vehicles (based on surveys conducted today) as a constant brake on adoption. This fails to recognize that over time, through increased exposure to AVs and to information about them, public opinion might come to view human drivers as reckless and unsafe in comparison. If every fatal accident involving a human driver comes to be seen as an unnecessary and avoidable tragedy, political pressure to accelerate adoption of AVs will grow, and change will accelerate.

Similarly, mainstream forecasters fail to recognize how business incentives and metrics change when you move to a new ownership model (TaaS). Reducing travel cost per mile becomes the new economic driver, and car manufacturing moves from planned obsolescence to longevity and a circular model. This can drive further cost savings, and create new business opportunities built on a low-cost transport infrastructure **–** just as the internet created untold business opportunities based on low-cost communications infrastructure, like Amazon, Google, and Facebook. It might be that the winners are those who can develop new revenue streams to subsidize the costs of mobility and profit from them (for example, on-board advertising, entertainment, grid services, data monetization and product and services sales). Early exposure to this new system is critical for future participants, given the network effects (and hence early mover advantage) of many of these new models. Failure to lead this transition will mean that the Fords, GMs, Exxons and Googles of the future are created elsewhere.

Assuming an energy transition and not a technology disruption

Some claim that this is an energy transition, and that past analysis of energy transitions "prove" that they take 30 years to get to 1% of the energy mix, and decades more to reach materiality. There are many problems with this analysis, including the fact that it looks at figures on a global scale when most previous transitions have happened locally and then gradually spread out.

But most importantly, **it misdiagnoses the issue. Energy transitions are slow because they require the associated infrastructure to be built**. To replace horses with cars, for example, you needed roads, gas stations, oil wells, refineries and pipelines as well as the production capacity and supply chains for cars. For the rollout of electricity, you needed power stations, distribution networks and cables to every home. But **for the coming TaaS transition, the roads are already built, electricity already serves every part of the country and every household, and the vehicle-production supply chains already exist**. Fewer car-size vehicles are likely to be produced, not more. Less road space will be required, if planning and supportive requirements for data-sharing and ridesharing occur. Rather than resembling a traditional, gradual energy transition, **the coming changes in transportation will represent a technology disruption and will therefore move along an S-curve (as discussed above) far faster and further than a mere change in fuels**.

Mistakes forecasters make that are specific to AVs

Our forecasts differ dramatically from mainstream thinking. We foresee that 10 years from the disruption point **–** that is, from the widespread regulatory approval of AVs **–** 95% of US passenger miles will be travelled in autonomous shared electric vehicles in a model we call Transport as-a-Service (TaaS). It is important to understand why **analysis of intersecting technology disruptions and consumer uptake of technology produces different results from ordinary/older planning and analysis methodologies**.

Modelling the wrong disruption

Most forecasts model only the disruption of the gasoline vehicle by the electric vehicle (EV) in a like-for-like, one-for-one substitution. These forecasters assume the cost savings and utility improvement of EVs over internal combustion engine (ICE) vehicles are minor, so there is only very slow adoption, as ICE cars are only replaced gradually in new car sales over the course of decades. However, the more meaningful disruption will arrive before this first disruption is anything like complete. It is a business and ownership model disruption **–** with Transport-as-a-Service (TaaS) replacing car ownership (of both ICE AND EVs). With TaaS, the cost savings are dramatic, and undercut both new car sales AND the cost of keeping the existing fleet on the road. TaaS travel will be at least twice as cheap as operating a new car; used cars, even if given away, won't be competitive on price. Existing vehicles will be abandoned and the fleet totally transformed at a much faster pace that most forecasters assume.

Under-estimating cost savings of TaaS

The scale of the cost savings that will drive fast adoption of TaaS are not broadly appreciated. These cost savings come from a reduction in vehicle degradation which leads to lower maintenance costs and longer lifetimes. We conservatively base our cost assumptions for maintenance and vehicle lifetimes on what is possible now. Because **an EV has only 20 moving parts compared to 2,000 for a car with an internal combustion engine, there is less friction and there is far less to go wrong. There is also less heat and vibration that cause degradation. This means that electric vehicles can last for 500,000 miles vs. 150,000 miles for an ICE vehicle, as well as costing 80 percent less to maintain. Spreading the initial vehicle purchase cost over more miles driven leads to a dramatically lower cost per mile.** However, we would expect that the change of business model which delivers a new economic metric **–** where cost per mile is the number that matters, rather than upfront cost **–** will create new business incentives that deliver even greater savings than we model. We also believe **EV lifetimes will improve to one million miles, while the cost of maintenance will hover at about 10% of what it costs to keep a gasoline-powered vehicle in good shape**.

Mainstream forecasts are generally obsessed with the crossover point in EV vs. ICE upfront costs or lifetime costs, which they see happening in the 2020s. However, this misses the point entirely. **Cost per mile is the new key metric; upfront cost is only one factor in its calculation**. Of far more importance is vehicle lifetime, and EVs offer a dramatic improvement (to 500,000 miles immediately, increasing to one million miles as incentives move from planned obsolescence to low cost per mile). Further savings come from reduced insurance costs (fewer accidents and no theft), reduced finance costs (greater capital efficiency as 10x more miles are covered per vehicle per year), and lower fuel costs (electric motors are far more efficient and electricity is cheaper than gasoline per joule). Economics is the main driver of this disruption, and there are few barriers in terms of supply or demand. The speed of adoption will be driven both by the huge cost savings (a large proportional increase in disposable income) and the systems dynamics that kick in as adoption begins.

Ignoring systemic and dynamic factors – all else is NOT equal.

Once adoption unfolds, systemic dynamic factors drive it ever faster. But most analysts fail to account for the feedback loops, tipping points, network effects and other dynamics that drive the non-linear S-curve shape of adoption.

Everything is dynamic and interdependent. The factors that influence key stakeholders, including consumers, policymakers and businesses are constantly changing and are interrelated. Changes to any variable ripple through the system, impacting all others.

Another example of a feedback loops is the potential death spiral of the gasoline car. Once an early tipping point in TaaS availability is reached and people in cities realize that a car is always available when needed, we can expect people to begin to sell their used vehicles. As used-car supply increases (and demand drops), used car prices will drop. It will become cheaper for potential buyers of new gasoline cars to buy used instead (if they don't move to TaaS). This will cause new car sales to drop. Economies of scale in car manufacturing will begin to unwind, increasing the cost of ICE vehicles and reducing sales further. R&D in ICE will stop as manufacturers focus on TaaS vehicles

(ICE drivetrain designers are already seeing lack of demand for new models), meaning ICE cars won't develop and will become less attractive. Eventually the supply chain will break down, and ICE sales will cease entirely. Later in the cycle of adoption, as another tipping point is reached, gas stations will begin to close, spare parts will dry up, insurance premiums will rise (as human drivers are perceived as reckless) and using an ICE car will become ever more expensive and difficult. This might be accelerated by policy as human drivers are confined to special lanes or restricted to certain times of day, or even banned completely. ICE cars left in the fleet might also be banned or restricted as the number of ICE defenders diminishes and the political space to ban ICE vehicles opens up (as the UK and France recently set dates for, in confidence it will actually happen much earlier). The number of countries signalling these types of restrictions will increase and the dates proposed will move up.

The importance of proper forecasts, and the risks of being wrong

Self-fulfilling nature of forecasts

Forecasts can become self-fulfilling. This happens for a number of reasons. Decisions made without sight of a better alternative can lock in a high-cost, uncompetitive infrastructure that makes a change of course harder at a later date. **Short-sighted decisions can also use up money and political capital that could have been used to accelerate the transition to TaaS, rather than encouraging investments that create barriers to change**. Furthermore, regulation is critical to both the implementation and the development of autonomous vehicles, which are the critical enabler of TaaS. In terms of implementation, regulation is needed to approve the use of AVs and clear barriers to adoption, and potentially to further accelerate and regulate TaaS to ensure monopolies don't abuse power and that universal access is assured. Regulation is also key to development, because AVs learn by doing – the more cars on the road and the more miles covered, the faster they learn and the faster they can reach the critical safety threshold. This learning requires the ability to practice, and hence the need for real-world pilots. The more and the broader pilot programs are, the faster the necessary learning will occur. Public opinion and expectations can also affect the pace of adoption. Addressing concerns and communicating a bigger vision can help create the political space needed to accelerate adoption.

Forecasts from Shell, BP, the IEA and other mainstream consultants and analysts tend to presume that transportation disruption will happen gradually as the EV replaces the gasoline car over many decades. This misses the more important disruption, which is Transport-as-a-Service based on autonomous electric vehicles (robo-taxis) replacing car ownership entirely. This is a business model disruption and can happen far faster – within a decade – with far greater benefits for the economy and society than is generally realized**. It is very easy for consultants and businesses to hide behind this common viewpoint and not challenge the common wisdom; in fact, their business incentives dictate that it is safer to be close to what others are saying.** The danger for policymakers is that they may take these forecasts as correct and allow them to become self-fulfilling, thus missing out on the opportunity to lead, implement and

see key benefits in the transition. As Warren Buffett says, “You pay a high price for a cozy consensus.”

So how do policymakers balance the need to invest in the current system, until at some point in the future, when a new infrastructure and system is required? That’s the central challenge. As the speed of progress heats up, this balancing act becomes more difficult. Some find the safest course, career-wise, is to base decisions on the overwhelming consensus. As the saying goes, nobody ever got fired for choosing IBM; however, there is real danger of getting left behind and there is a real and urgent need for courage and vision.

RethinkX is established as a not-for-profit, and has no intention to profit from our analysis. Our analysis is provided as a public good, and we hope decision-makers can use it to make better choices. We are very happy to clarify any issues raised here, or to engage with policymakers free of charge (subject to time constraints!).

RethinkX
Disruption.
Implications.
Choices.

About RethinkX

RethinkX is an independent think tank that analyzes and forecasts the speed and scale of technology-driven disruption and its implications across society. We produce compelling, impartial data-driven analyses that identify pivotal choices to be made by agencies, investors, businesses, policymakers and civic leaders.

RethinkX provides evidence-driven systems analysis that helps decision-makers who might otherwise have to rely purely on mainstream analysis. Decisions made based on the latter risk locking in investments and infrastructure that are sub-optimal, and that make societies poorer by locking them into expensive, obsolete, uncompetitive assets, technologies and skill sets.

We focus on understanding the dynamics and the systemic nature of disruption across key market sectors, according to a highly evidence-based approach. This approach is designed to facilitate decisions that maximize the benefits and minimize the costs - economic, social, and environmental - of technology disruption.

Rethinking Transportation is the first in a series of reports that analyzes the impacts of technology-driven disruption, sector by sector, across the economy. A copy of the report is available for download free of charge on our website.

We invite you to learn more at www.rethinkx.com.