Autonomous Vehicle Plan for the I-5 Seattle/Vancouver B.C. Corridor

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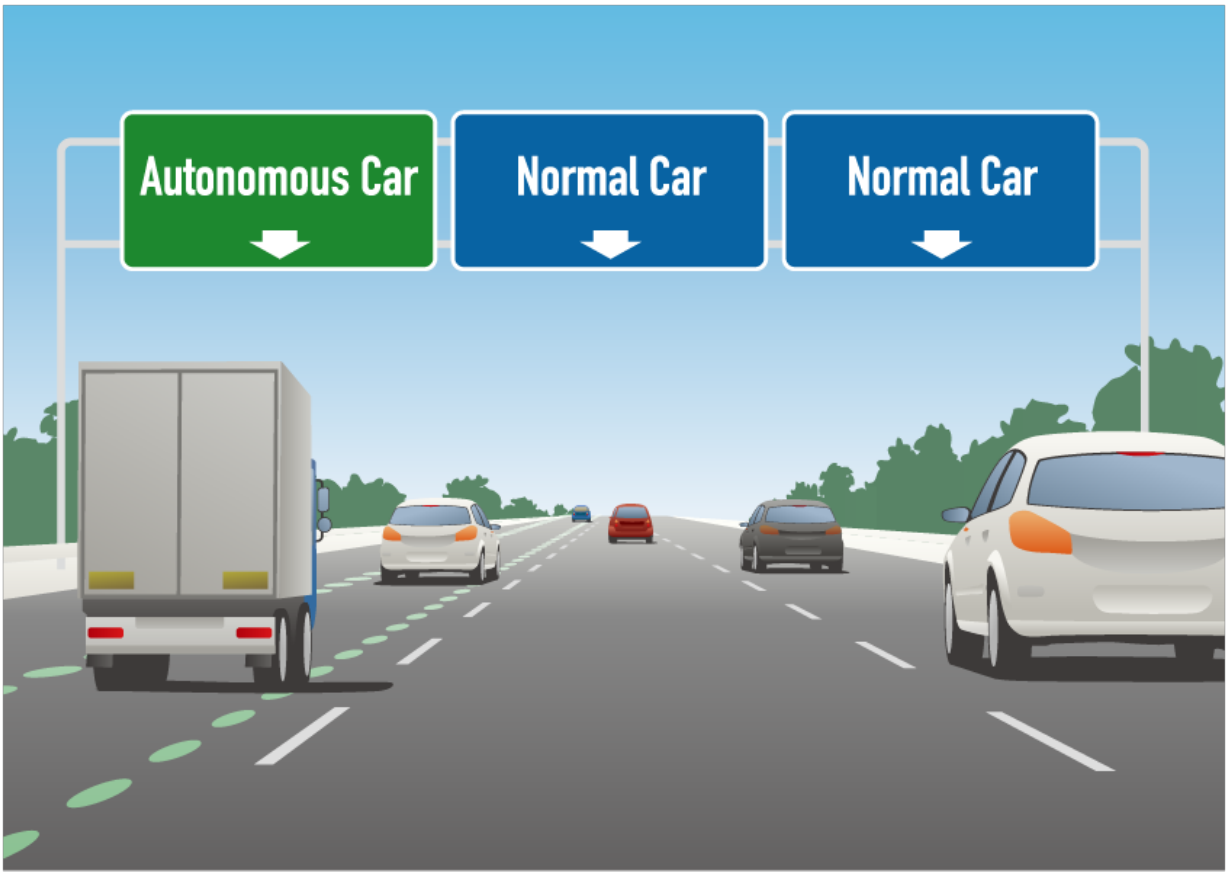


Executive Summary

Seattle and Vancouver have a huge opportunity to reduce congestion, improve the travel experience, reclaim productive hours and reduce accidents on the I-5 Cascadia Corridor by implementing a plan over the next decade that accelerates the introduction of autonomous vehicles on the corridor. Committing to this vision would not only benefit all who use this corridor but would also demonstrate to the world our Cascadia region's status as a leading global center of innovation where governments and private enterprises can work in partnership to solve human problems.

Leading technology companies, such as Tesla and Uber, and traditional auto companies, such as Ford and GM, are rapidly developing and testing new technologies in sensors and software that will make fully autonomous vehicles feasible and safe within the next five to ten years. Governments from Pittsburgh to Singapore, plus the U.S. Department of Transportation, are authorizing street trials and encouraging and even mandating that vehicles be equipped with autonomous technologies. The governments of the Cascadia Corridor would dramatically seize a leadership position on autonomous vehicles by committing to an innovative autonomous vehicle plan for I-5.

An autonomous vehicle plan for I-5 could initially allow autonomous vehicles to share the HOV lanes. Over time, with more and more autonomous vehicles on the road, this would evolve into HOV lanes being exclusively for autonomous vehicles. The final step as autonomous vehicles largely replace existing vehicles would be to exclude non-autonomous vehicles from I-5 except for certain defined times when highways are not congested such as most of weekends and 8:00 p.m. to 4:00 a.m. on weekdays. The first phase of this plan could begin to be implemented immediately and the final phase could occur in ten to fifteen years.

I-5 has a minimum of eight lanes (and sometimes 10 lanes) from downtown Seattle to the northern boundary of Everett and then six lanes to the southern boundary of Mount Vernon, all of which could accommodate dedicated lanes for autonomous vehicles. North from Mount Vernon I-5 is four lanes up to the border-crossing in Blaine, WA, where it becomes Highway 99 with four lanes in British Columbia. Traffic planners in the future may want to add additional lanes to the four lane portions from Mount Vernon to Vancouver (82 miles) to support dedicated autonomous vehicle lanes.

The last eight miles on Highway 99 from the Vancouver airport into downtown Vancouver present a challenge for any intercity travel because it consists of city streets with traffic lights. This could be alleviated when travelling by autonomous vehicle from Seattle by having your autonomous vehicle drop you off at the SkyTrain Bridgeport Station in Richmond near the airport and go park itself at the nearby park and ride lot or elsewhere or pick up another passenger. The SkyTrain departs every 6 minutes most of the day and takes 18 minutes to downtown. SkyTrains in Vancouver are fully autonomous without drivers.

There are many benefits from autonomous vehicles, but the principal benefit is that it allows drivers to recapture all the time otherwise spent behind the wheel. This is at least two and one half hours from Seattle to Vancouver. Imagine being able to watch a video or sporting event, prepare for a business meeting, work on your novel or plan a game with your children. It is difficult to place a dollar value on this but one source has estimated this at more than $1 trillion a year in the U.S. Because of wireless and software technologies we can be entertained or productively engaged wherever, whenever.

Other very significant benefits from autonomous vehicles include substantial reductions in vehicle accidents and deaths, less environmental damage, increased capacity of existing roads, reduction of the need for more freeways and lanes, increased use of shared vehicles, reduced congestion and lower transportation costs for consumers.

Although accidents have occurred in the early use of autonomous vehicles, in the longer term the number of accidents and deaths will be reduced. U.S. Transportation Secretary Anthony Foxx recently said that as many as 25,000 road deaths could have been prevented last year if driverless cars were in operation. Annual cost savings for the United States from reduced traffic collisions, including medical costs, have been estimated at several hundred billion dollars.

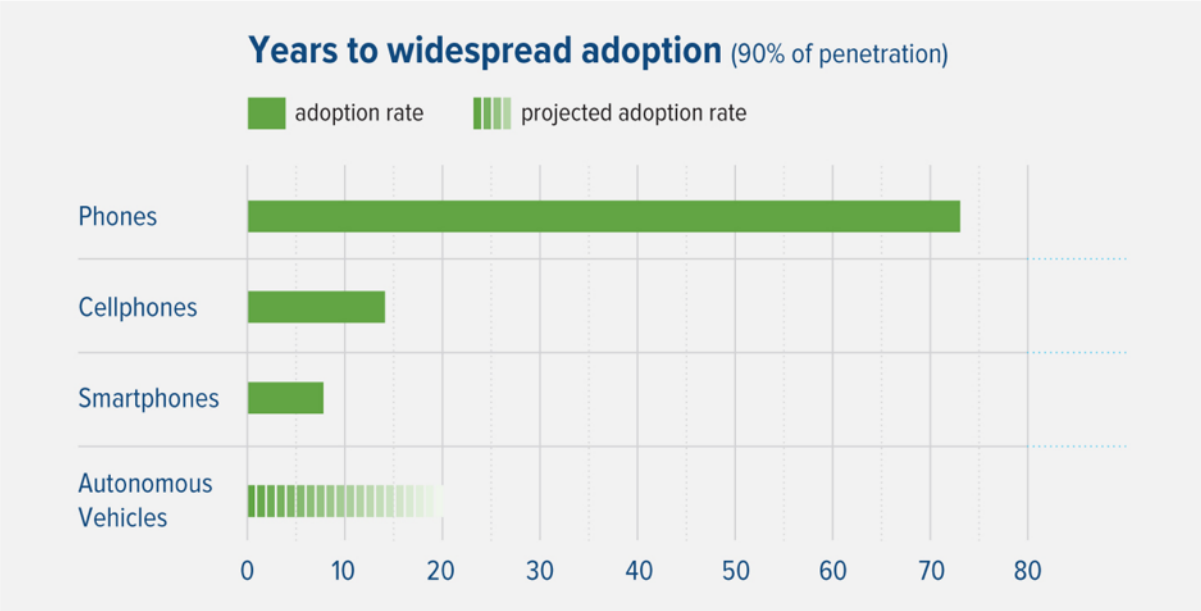
With autonomous vehicles, the capacity of roads is increased by closer spacing and platooning of vehicles, narrower lanes, reduction in the wave effect of braking, faster average speeds and fewer accidents. Major and minor accidents cause substantial traffic tie-ups.

The availability of autonomous vehicles will likely cause more people to travel in vehicles, including the elderly and infirm, but we expect this will be offset by more vehicle sharing by individuals and through commercial services. Using apps, mobile devices, data analytics, mapping technologies and the cloud, new ride sharing services are already becoming available through companies such as Uber and Lyft. With travel times shortened and the cost of drivers eliminated, buses will be more attractive and the introduction of new autonomous mini-bus and van services would likely occur. Autonomous vehicles will also include trucks of all kinds. When trucks are autonomous, there will be more flexibility on scheduling

and incentive structures could be created to encourage trucks to travel in non-congestion time periods.

Although not the focus of this paper, all the benefits of autonomous vehicles on I-5 also apply to commuting in the major metropolitan areas on the corridor including Seattle and Vancouver. Moreover, this plan should be extended to serve drivers on the I-5 Corridor between Seattle, Tacoma, and Portland.

This proposal will initially be highly controversial because of the public's natural concern about the likelihood and timing of autonomous vehicles, initial accidents and failure to recognize the benefits. All of the fundamental technologies required for autonomous vehicles, however, are available and only require refinement which are occurring at a rapid rate. Compared to the cost of improved and high speed rail, estimated by others at upwards of $30 billion, the cost of this plan would be orders of magnitude less and consumers would begin to benefit decades earlier.



New technologies that benefit consumers tend to be adopted quickly once made widely available. Automobile ownership in the U.S. went from 10% of households to 67% of households in 14 years – and since then, adoption rates have accelerated. To reach 90% penetration in the U.S., wired phones took 70 years, cell phones 15 years and smart phones 8 years. App-based rideshare services

only started 4 years ago, and they are already ubiquitous in most major cities across the globe. We cannot predict the specific adoption rate for autonomous vehicles but with many major vehicle manufacturers announcing that they will be selling autonomous vehicles within five years and the advantages of autonomous vehicles, we expect very significant penetration in ten to fifteen years.

Accordingly, we recommend that our local and regional governmental entities along with private companies form a joint commission to develop a plan for accelerating the introduction of autonomous vehicles for I-5. They could engage the University of Washington's new Mobility Innovation Center and a comparable group from the University of British Columbia to assist in developing recommendations.

Section 1: Background

Seattle and Vancouver: Economic Partners

Seattle and Vancouver, BC have had a long complementary economic relationship. Situated only 120 miles as the bird flies from each other, they share an environmental and cultural heritage. They have two of the largest ports in North America, and as West Coast cities both Seattle and Vancouver are important gateways to and from the Asian continent. Their cooperation with a touch of rivalry has made the Pacific Northwest a vibrant international hub in a globalized world, and their relationship continues to grow even as they transition away from the harbor and resource industries that were once their bedrock, and towards technology and service economies.

This is especially true of the tech industry. Seattle has long been a leading tech hub in the United States, boasting the headquarters of Amazon and Microsoft. Vancouver is a new and growing tech hub; the tech industry is the second fastest growing industry in British Columbia, according to KPMG. In 2015, Seattle and Vancouver both ranked in the Top 20 world's leading startup cities according to Compass, as they did in 2012.

Seattle and Vancouver do not only have a similar heritage of technology and entrepreneurship; they also work with one another. In 2007, Microsoft opened a large office in Vancouver, Canada, which has since been expanded, and they have

considered moving their Canadian headquarters to Vancouver from Mississauga, ON. Amazon has also had a presence in Vancouver as early as 2008; they opened an official Amazon office in 2011 and expanded in 2013 to accommodate up to 1,000 employees.

This is in part in order to attract talent and to keep it near to them in the Pacific Northwest. Vancouver and Seattle boast some of the best supply of tech talent in their respective industries; three of the top five computer programming universities in Canada are located around Vancouver and Seattle's University of Washington was named the most innovative public university in the world by Reuters. Their historical ties to Asia are also very important; they both have had a long presence of Asian immigrants, which makes Seattle and Vancouver attractive to Asian and Indian tech talent.

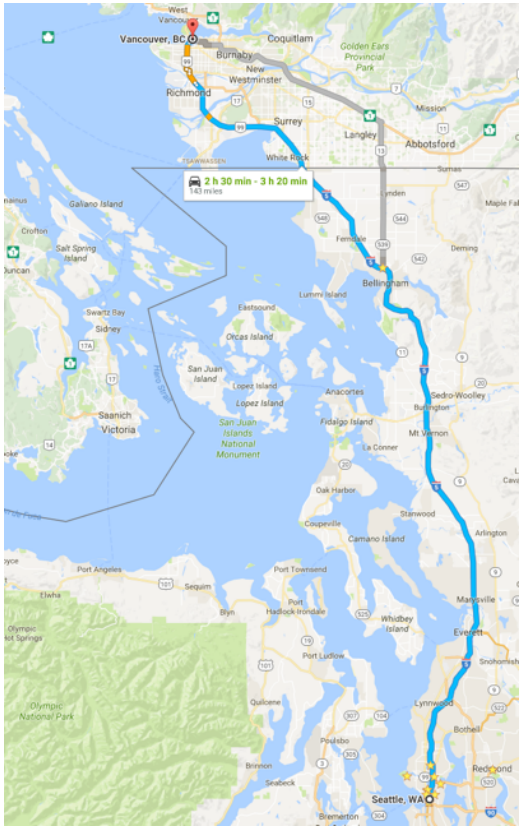
When Microsoft opened its Vancouver office in 2007, it emphasized that the company was motivated by frustrations with U.S. immigration and visa restrictions, particularly pertaining to high-skilled labor and the H-1B Visa cap, and so it hired in Canada where immigration restrictions were more relaxed. Hiring in Vancouver meant that Microsoft could locate talent just a short distance from their headquarters without the headache of U.S. restrictions, while taking advantage of the tech workers that were already there. Amazon seems to have been motivated in part by the same reasons.

Notwithstanding these connections between Vancouver and Seattle, a recent study of LinkedIn data surprisingly indicated that connectivity of business people between the two cities is low relative to connectivity with other cities. "Among the cities with the strongest connection to Vancouver, Seattle ranks #11, behind three other US cities. Similarly, Seattle has stronger connections with 26 other cities, compared to Vancouver." Overall cross-border talent flow is also limited even though Microsoft and Amazon have large offices in Vancouver.

Transportation Problem

Seattle's and Vancouver's tech and startup companies would benefit greatly from greater ease of intercity transportation. The connectivity of the digital era has not diminished but seemingly has rejuvenated the value of physical location and meeting in person. Improved transportation from Seattle to Vancouver is not

merely about leisure and travel; it's about making sure Seattle and Vancouver maintain and improve their competitive edge in the modern economy.



Yet in spite of the need for high speed, convenient transportation, the options available have not kept pace with the economic growth in Seattle and Vancouver. The Amtrak Cascades trains are renowned for their views but take up a four-hour trip, at a $40-$70 standard ticket. Greyhound buses are cheaper but take at least as long. Air Canada and Alaska Airlines offer flights between Seattle and Vancouver that cost hundreds of dollars per trip for an hour in the air, but with travel to and from the airport and the additional hassle of check-in and airport security, the total time spent can be three hours or more.

Beyond that, there is driving. And here is where Seattle's infamous congestion comes into view. A 140-mile commute which could take 2 hours and 20 minutes is stretched an extra 30 minutes to 90 minutes during working and rush hours – a delay that is costly in both gas and lost productive working hours. The present difficulties of driving between the two cities significantly reduces tourist and business travel and interchange.

The Rise of Autonomous Vehicles and Services

A few years ago, it was still a major question whether autonomous car technology would be feasible and even if feasible it was not considered likely for 30 or more years. But today we already have self-driving cars from Google, Tesla, and Uber driving on our roads. Although initially led by these tech companies, all of the major auto companies have joined in to develop autonomous vehicles. Seemingly every day we read news articles about auto

manufacturers announcing plans to introduce autonomous cars or pilot projects being planned in various places. Here are some of the companies involved with autonomous vehicles.

In August 2016, Uber announced that their first fleet of self-driving vehicles would be launched in Pittsburgh. Home to the National Robotics Engineering Center at Carnegie Mellon University, Pittsburgh will host Uber's most ambitious step yet to integrate fully autonomous vehicles into their service. The custom-built Volvos will be supervised by humans in the driver's seat for now, but if the experiment is successful, Uber aims to gradually replace their 1 million human drivers with autonomous systems.

Transportation in cities is on the verge of large-scale transformation, according to the President's Council of Advisors on Science and Technology (PCAST), through the effort to develop connected and fully autonomous vehicles. New technologies that benefit consumers tend to be adopted quickly once made widely available. We cannot predict the specific adoption rate for autonomous vehicles but we believe that widespread adoption of autonomous vehicles is inevitable and will be here sooner than most observers expect.

Ride Sharing

Uber and Lyft are introducing ride sharing services in many cities using innovations in mobile and cellular technologies. Consumers are responding favorable to the lower prices and convenience and in some cities in California, Uber and Lyft report that more than 50% of rides are shared.

Ride sharing by individuals, commercial companies and transit authorities will be further stimulated by the introduction of autonomous vehicles. Entrepreneurial individuals will be able to rent their autonomous vehicle to others or share a ride with them. New operators of autonomous mini-bus and van services can be launched.

Section 2: Our Vision

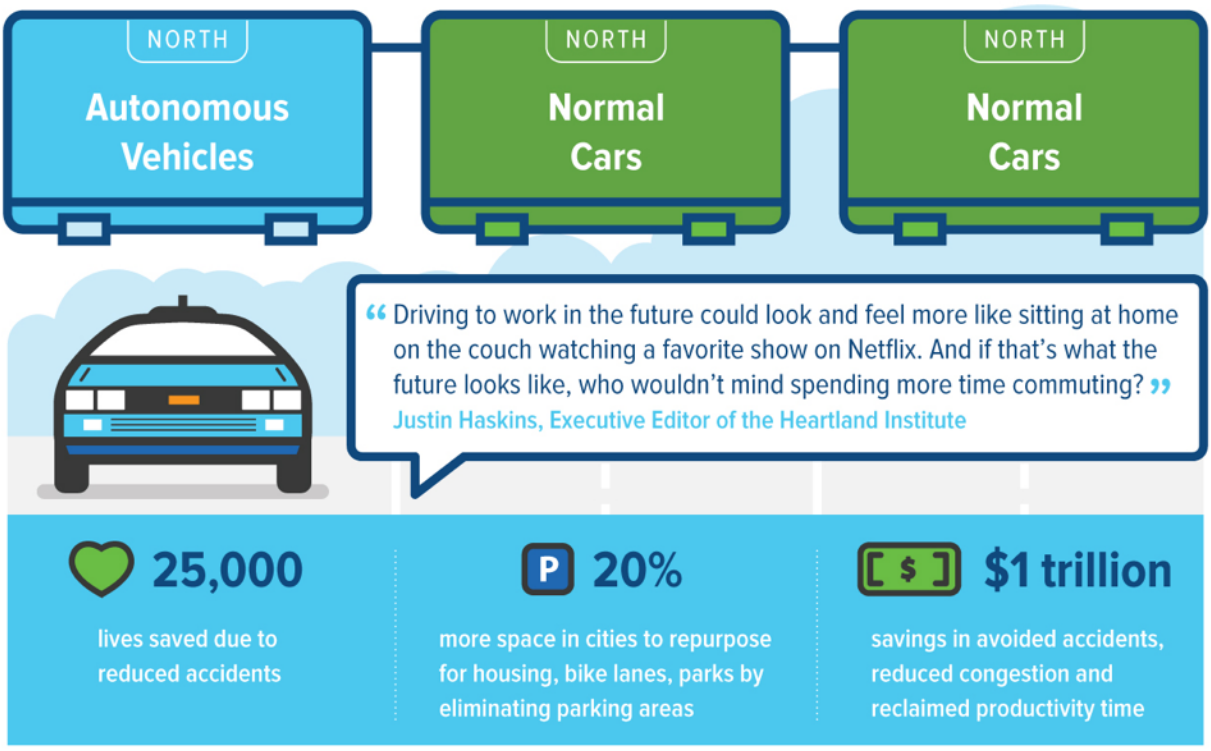
We propose that local, state and provincial governments on both sides of the border collaborate on a plan to accelerate the introduction of autonomous vehicles on I-5. Initially autonomous vehicles should be authorized to share the HOV lanes. Just as traffic planners incentivized carpooling this would incent the purchase of autonomous vehicles and use of autonomous vehicle services. We recognize this would require a sizeable collaboration between several governmental agencies. But doing this sooner rather than later would not only allow residents of the Cascadia Corridor to reap the direct benefits sooner it would better connect the two cities and send a message that Seattle and Vancouver embrace new ideas and new ways of thinking, further cementing a reputation for innovation in the Cascadia region.

If phased in with the growth of the number of autonomous vehicles being purchased, this plan will be less disruptive of existing usage than might be feared.. At the first stage, autonomous vehicles would simply join in use of the HOV lanes. I-5 from downtown Seattle to Everett is at least eight lanes and could accommodate a shared HOV lane. This is also likely true north of Everett to Mount Vernon which has six lanes. As more autonomous vehicles are introduced, this shared lane could become exclusively for autonomous vehicles. At a later stage, transportation authorities could consider building additional lanes in sections of I-5 north of Everett. Ultimately, I-5 could become exclusively for autonomous vehicles except during certain low traffic times at night and on weekends. Taking on this project, even though ambitious, would set Seattle and Vancouver on the path to be the example for the future of transportation, and to set the standard for major cities and corridors in North America.

Section 3: Benefits and Risks of Autonomous Vehicles

When discussing autonomous vehicles, there are different levels of autonomy with anywhere from a single function being automated, such as automatic

braking, to the highest level where the car can drive itself without a person supervising or even present in the vehicle. It was not long ago when even the first level seemed like a major innovation, but R&D have pushed us to the point where full unsupervised autonomy will be in mass produced vehicles as soon as five years from now. We are focused on this highest levels of vehicle autonomy – effectively self-driving cars.



Benefits

What would the greatest benefit be of having your own personal chauffeur? Sure, that chauffeur might be a better driver; you might get to your destination more quickly, and safely. But for many people, the greatest benefit of all would be a better riding experience and a recapture of lost time. Maneuvering in traffic behind the wheel takes time away from your work life and your personal life, and replaces it with anxiety and frustration. That is bad for business and health. But if you were driven around, it would not only reduce the time spent in traffic; it would give the time spent on the road back to you.

You could relax. Would you use that time to do work in the car? Catch up on a TV show? Safely take a phone call or read and send texts? Play Angry Birds? You decide. You are freed up from being cramped behind the wheel, worrying about gridlock. That's the benefit of being chauffeured from place to place, and that is what autonomous vehicles will provide. The only difference is, this chauffeur is built into the car.

There are many social benefits from road safety to reduced congestion and energy use. According to the Insurance Institute for Highway Safety, up to a third of traffic fatalities could be reduced with forward collision prevention and side view assists alone, and greater automation could reduce the United States' yearly 32,000 traffic fatalities even further by replacing the primary cause of road accidents: human error. Furthermore, automated vehicles can accelerate and decelerate more quickly, which improves fuel economy, and would likely greatly enable the use of alternative fuel sources. At a possible future high level of the technology, the disadvantages of electric power and fuels cells could be mitigated by allowing fully autonomous self-driving cars to drop off their passengers and automatically find a station to refuel.

Autonomous vehicles also facilitate and optimize connectivity. Put simply, autonomous vehicles can join a network and coordinate with each other. This increases travel lane capacity, reduces fuel waste, and reduces travel delays by avoiding quick unexpected stops that cascade through traffic.

The potential cost savings from autonomous vehicles are very significant – and not just by reducing delays, improving fuel economy and facilitating alternative energy sources. Autonomous vehicles will also reduce the number of accidents. Nationwide, the cost of traffic collisions is approximately $300 billion a year. Vehicular congestion costs about $124 billion per year in the U.S., as well as tens of billions of associated healthcare costs. These do not include the opportunity cost of productive hours spent in traffic, which is estimated at $1.2 trillion per year, or the costs of parking spaces. 31% of the space in central business districts of major cities currently is devoted to parking. Autonomous vehicles will be able drop off their passenger, and immediately pick up a new person or find a place to park – which need not be close to the destination. If the car is low on fuel, it can drive itself to a station and fuel up.

It is also useful to point out that dedicated autonomous lanes multiply the benefits associated particularly with connectivity. They facilitate larger convoys of closely spaced autonomous vehicles – caravans" or "trains" of sorts – which enable road efficiency, higher effective speeds and fewer accidents.

Risks

As with most beneficial innovations, there are risks. For example, autonomous vehicles will make it possible for people incapable of driving because of age or infirmities to use vehicles thereby increasing the total number of vehicle miles traveled. Of course, providing a means for these people to travel or visit friends and doctors is itself a social benefit. Such usage will also be offset by increases in ride sharing in private autos, Uber-type services, and mini-buses and buses which would reduce the number of vehicles on the road.

Also, given that autonomous vehicles depend on network systems that would presumably be standardized, this might make them vulnerable to computer crashes and hacking although mechanical breakdowns and malicious hacking are already a risk for standard vehicles. Also, autonomous vehicles will cause economic disruption in manufacturing and employment, as disruptive technologies have done in the past.

Autonomous vehicles may not be as affordable for all classes of people. Tesla and Ford, however, are working on launched autonomous vehicles that cost less than $35,000. Policy makers could also provide subsidies through vouchers for low income groups for them to use autonomous vehicle services.

We hope policy makers will recognize the benefits far outweigh the risks.

Section 4: Comparison of the Alternatives

There is some movement to make better and faster rail options. Notably, the Washington State Department of Transportation (WSDOT) is using funds from the American Recovery and Reinvestment Act (ARRA) to improve Amtrak service from Portland, OR to Vancouver, BC. One of their goals is to increase maximum speeds from 79 mph to 110 mph but because there is only a single track from Everett to Vancouver and it is shared with freight trains, their plans would only reduce trip

times by five percent. New overpasses are also needed in Everett, Marysville, Mt Vernon and Bellingham.

For several decades, many local officials and economic development organizations have advocated proposals for true high speed rail from Portland to Seattle to Vancouver, BC. This would provide fast service between train stations.

According to various estimates. high speed rail costs between $125 million and $1 billion per mile, depending on the surface and location. Using these numbers, there is a projected a cost of $20-30 billion total for a high speed rail between Seattle and Vancouver, which may still be optimistic.

Large-scale transportation infrastructure projects typically take decades to envision, plan, and build and have traditionally taken much longer than originally projected. For example, in 2012, Amtrak proposed a $151 billion plan to redevelop high-speed train travel in the Northeast corridor that would be not be complete until 2040. California's $68 billion high-speed rail project has been described by a Bloomberg columnist as "an expensive social science experiment to test just how long interest groups can keep money flowing to a doomed endeavor before elected officials finally decide to cancel it."

Not only does this delay the economic benefits, but it also exposes the project to greater economic risks. The challenges of regulatory and public approvals, construction funding and likely needed operating subsidies even with one-way fares exceeding $100 per person raise questions as to the feasibility and desirability of high speed rail. By the time the high speed rail is completed, new technology might completely change the transportation paradigm.

This is not to reject the promise of high-speed rail. The dream of one-hour travel by rail between downtown Seattle and Vancouver is worthy of considering. We welcome consideration and discussion of such a proposal. However, we should not limit ourselves to conventional prescriptions to transit needs. Policymakers have to think beyond 20th century solutions to new solutions being made possible by rapid innovation.

By way of comparison, for $30 billion we could buy every household in Seattle and Vancouver a new Tesla with autonomous driving features or buy Delta Airlines at its market cap of $29 billion. Of course, these are outlandish suggestions that serve only to illustrate the fact that traditional transpiration projects are much more expensive than observers typically realize.

Building additional autonomous vehicle lanes would be far cheaper and less time-consuming. These take advantage of the infrastructure that is already built around HOV and expands on it. It is also an incremental, flexible project, whose benefits will be felt much earlier and would provide point to point solutions from where you live or work to the specific location of where you want to go.

Another worthy but limited proposal for speeding movement between Seattle and Vancouver is to institute regularly scheduled seaplane service from South Lake Union in Seattle to Coal Harbour in Vancouver. Currently, there are no direct regular seaplane flights from Seattle to Vancouver, BC, although Kenmore Air operates dozens of flights a day from docks at South Lake Union and Harbour Air likewise handles many flights from docks at Coal Harbor which is adjacent to the downtown business district.

Charter flights are allowed between these destinations, but they are prohibitively expensive for even most business people. But a daily scheduled service easily

could be instituted comparable to the cost of the international seaplane flight from Seattle to Victoria – that is, $160+ one way, which is regularly used every day by business people and tourists. Facilitating a seaplane service between Lake Union and Coal Harbour would be a convenient, quick and scenic option from Seattle to Vancouver. Its utility, however, is severely limited in scale. Kenmore Air and Harbour Air, the largest American and Canadian seaplane services in the Pacific Northwest respectively, have fleets of 24 and 43 planes respectively. More importantly, most seaplanes only fit 6 to 7 passengers at a time. Even assuming eight daily flights this would only mean about 50 passengers per day. Nonetheless, these flights would provide an attractive alternative to conventional travel, particularly for business people and tourists.

Section 5: Conclusion recommending joint US/Canada I-5 Planning Committee and advocating for forward thinking regarding autonomous and ride-sharing infrastructure projects

As leaders in the global information economy, the Cascadia region needs to explore innovative ways to incorporate new technologies into our transportation planning process that can significantly reduce the cost of transportation and improve connectivity within the region.

Most technology industry experts believe that the widespread adoption of autonomous vehicles is a “when, not if” question. Indeed, we are already seeing public pilots of autonomous vehicles ferrying passengers to their destinations both domestically in Pittsburgh and internationally in Singapore. As transportation planners examine different options to connect the Cascadia corridor that may take 30 years or more to build, it is critical to consider the impact of these autonomous vehicle technologies in that planning process.

Autonomous vehicles will drastically change the way people get from Point A to Point B, and major transportation and technology companies are investing heavily in an autonomous future. Recently, GM paid more than $1 billion for the autonomous vehicle startup Cruise (more than 2% of its $50 billion market cap), and Uber acquired a self-driving truck company for $680 million. Our local, state, and federal governments need to understand this technology and invest accordingly as well. As the region moves forward in exploring different ways to connect the Cascadia region, autonomous vehicle technology needs to be a major

consideration in any transportation plan.

We recommend that lawmakers enact legislation that allow autonomous vehicles to operate in the state of Washington and the province of British Columbia with clear guidelines. We also recommend establishing a joint US-Canadian commission composed of private and public sector leaders who could engage the University of Washington's Mobility Innovation Center and a comparable group from the University of British Columbia to make recommendations on the best ways to incorporate autonomous vehicles in transportation planning and specifically to implement a plan for I-5. (9.19.16)

References

Anderson et al., *Autonomous Vehicle Technology: A Guide for Legislators*, RAND Corporation, 2016.

Foxx, Anthony, *Remarks on Automated Vehicles at the Detroit Auto Show*, Department of Transportation, January 14, 2016.

Insurance Institute for Highway Safety, "New Estimates of Benefits of Crash Avoidance Features on Passenger Vehicles," *Status Report*, Vol. 45, No. 5, May 20, 2010.

President's Council of Advisers on Science and Technology, *Technology and the Future of Cities*, Office of Science and Technology Policy, February 2016.

Shoup, Donald C., *The High Cost of Free Parking*, Planner's Press, 2005.