Thoughts on the [Second] Revolution: An Update on Autonomous Vehicles.

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Elaine Herzberg, a 50-year-old woman, who was pushing a bicycle with groceries against traffic, was killed by a driverless test automobile in March of 2018 in Tempe, Arizona. As it turns out, the sensors in the autonomous automobile did not detect the presence of Elaine in the roadway and the car failed to brake. Sitting in the back seat, the safety driver neglected to take control of the vehicle. Ms. Herzberg died because of her injuries. Elaine Herzberg's death has punctuated the debate about the "second revolution" of the automobile, namely automation in trucks and cars.

The first automobile revolution was the invention and development of the automobile, which replaced the horse as a means of transportation - the machine that changed the world. Production automobiles began appearing in 1887 when Karl Benz developed a gasoline-powered automobile. Within a few decades, automobiles replaced the horse as a means of transportation.

Today, we are amidst a second revolution in the world of automobiles and trucks. After decades of development, we are closer to the goal of fully autonomous vehicles (AVs) operating in our city streets. In the same manner as the development of the automobile, the new paradigm-driverless/autonomous vehicles - is gaining momentum as numerous companies are in the late stages of autonomous vehicle development. Today, fully autonomous (i.e. no driver) Waymo robotaxis are

licensed and operating in the streets of San Francisco, Phoenix and limited use in Los Angeles. Additionally, Uber announced that they will begin providing driverless vehicle ride sharing in Atlanta in 2025.

In certain respects, the future is now. The development of autonomous vehicles has advanced to the late stages. We will be hearing about new car companies, so-called "mobility companies" such as Zoox, Pony AI, Nuro, replacing or working with the historical car makers such as Toyota or General Motors. For instance, Uber, the popular ridesharing company, is in a partnership with Toyota. Waymo, a Google project, is using Jaguar SUVs for their robotaxis in San Franciso. How fast will we adopt the new technology and how receptive will consumers be to the new paradigm?

There are six levels (categories) of driver assistance. Today, some of us own and drive cars that are at level 0- that is no automation. Level 0 has options such as cruise control, tire pressure sensors, rear-facing cameras, keyless ignition switches, and so on but no automation. An increasing number of car buyers are purchasing automobiles at level 2 with features such as adaptive cruise control, the vehicle automatically adjusting speed depending on the distance from the vehicle in front. Other autonomous features you may recognize are lane centering, pedestrian detection, blind spot warning, and smart parking. Mercedes has a level 3 in commercial use and Tesla promotes a level 4, which is high driving automation, basically performing most functions if you keep your hands on the steering wheels.

You probably have already ridden in an autonomous vehicle. Minneapolis Airport has a train shuttle that moves passengers between several concourses and the main terminal. These shuttles are driverless. We have similar driverless trains in Atlanta, Denver, and other airports. Disney World in Orlando has a driverless "people-mover" that circles the park. In the same manner, the National Highway Transportation Safety Administration (NHTSA) reports that driverless vehicles are currently being used in restricted operations such as mining, farming, factories, and warehouses.

Some semi-autonomous projects include Volvo *Pilot Assist* with steering, acceleration, and braking functionality. Cadillac promotes *Super Cruise* for hands-free driving, providing you have a subscription, a working electrical system, cell reception and a GPS signal. It is the convergence of technologies that provide the means for autonomous vehicles including advances in electric vehicles; sensor and battery development; solar and wind power use, which will reduce the cost of electricity at some point. Other trends are the continued increase in ride sharing and the curious trend, as reported by the *Morning Brew* podcast, of the decreasing number of younger people getting driver's licenses.

In 2007, Android and Apple introduced smart phones. Author and researcher Tony Seba says this occurred because of the convergence of various technologies including data storage, computing power; touch screens, lithium-ion batteries and digital imaging. In the same manner, the development of autonomous vehicles will depend on several converging technologies including electrical power replacing the internal combustion engine. Seba further explains that there is a phase change in process for electric vehicles that is a precursor to automation. Other key technologies are maturing including AI/machine learning, robotics, and batteries

and sensors, which provide the necessary infrastructure for electric vehicle transformation and consequently, autonomous vehicles.

Autonomous vehicles operating in restricted operations such as mining is one thing, but what about driverless cars operating on our highways, next to other drivers? Driverless cars and trucks on our highways is a big idea - automation is "coming out." What are the benefits? McKinsey, a global management consulting firm, predicts that with automation, accident rates will be reduced by 90 percent. Keep in mind that robots are not affected by human factors such as impaired or distracted driving habits. McKinsey further reports that 1.2 million people a year are killed in car accidents and predicts that automation could save one million lives a year. Emissions could be cut by up to 60 percent mainly using electrical vehicles and ride sharing. What is not to like?

Moreover, according to the NHTSA, 94 percent of serious crashes are due to human error. In the same manner, DuPont, a leading safety authority in the workplace, calculates that approximately 96 percent of workplace injuries are attributed to unsafe behaviors of employees. In short, people make mistakes. Will autonomous cars make fewer mistakes?

Detractors and skeptics among consumers cite safety as a primary concern. We learned about the dangers of automation failure with the story of the woman who was killed in Arizona. Other people have been injured and killed by autonomous type vehicles. And big questions remain including ethical questions on programming decisions; regulatory questions; and cyber security concerns. When is safe "safe enough?" Does the system have to be perfect? Robots may not drive impaired but could be susceptible to computer hacking.

Human factors research, which focuses on the capability and limitations of people, analyzes the interaction of autonomous vehicle technology with human drivers. Could autonomous vehicles simply get stuck in heavy traffic? We depend on eye contact when we drive – how will human factors be programmed? What happens when these vehicles inevitably break down? These questions will eventually need to be addressed and solved.

Some critics warn that driverless should not mean human-less. Why would we trust anyone to develop a safe enough vehicle when we struggle to paint the lines on our roads? Furthermore, there will be a mix of driverless and driver-controlled vehicles until the infrastructure, currently designed for human driving, is fit for autonomous purposes. And, of course, who will pay for the infrastructure? Who gets to make the rules? What are the unforeseen consequences of this autonomous trend?

What about the average consumer? Do we want autonomous vehicles? Mintel, a research agency based in London reminds us that U.S. consumers in general are cautious of hybrid and electrical vehicles, which are necessary for autonomous vehicle development. American Automobile Association (AAA) reports that 66 percent of Americans are skeptical of autonomous vehicles. On the other hand, Mintel predicts that Gen Z and millennials will be “likely adapters”.

There has been much hype for some years and failed promises. The reason for the hype, as Walter Isaacson explains in his biography *Elon Musk*, the electric car entrepreneur, is that Musk and others feel it necessary to give bold predictions to encourage investment. If they admit that a project such as autonomous vehicle engineering will take a long time, then “nobody will rally around [the project].”

Musk has admitted on a recent earnings call that "the process had been harder than he expected [back] in 2016." He is now saying the key will be the development of AI. We'll see.

However, consider the trend that just a few years ago, we were at level 2 at best. Today, level 4 is available, and level 5 is now in use in San Francisco and Phoenix. American consumers are buying cars with semi-autonomous features. Consumers want these features such as lane assist and parking assistance just like we wanted cruise control before cruise control was standard. Arguably, technology is catching up to consumer demands.

Mark Kurlansky, in his book *Paper: Paging Through History* describes the technological fallacy that technology changes society. Kurlansky argues, convincingly in my view, that it is "society [that] develops technology to address the changes that are taking place within it." For instance, paper became the vehicle for providing a tool to record stories. The change -recording stories- had already taken place.

Has the change already taken place in our society to adopt driverless vehicles? Are we demanding driverless cars and trucks? James Womak, in his book *The Machine that Changed the World*, namely the automobile, describes the benefits of new technology. Womak reports that the benefits of technology, and presumably the automobile, include more choices for the consumer; changing and improving the nature of work; and changing the fortunes of companies. In my view, we could say the same about the second revolution- autonomous vehicles.

Significantly, the increase in AVs will result in the loss of jobs and the shifting of roles in many occupations. In fact, this reduction in employees will be a driving factor in the rate of acceptance. Many jobs that automation will replace may be dull, dirty, or dangerous, but they are relatively good-paying jobs. Like job losses in coal mining; robotic factories; and farms; autonomous vehicles will contribute to a loss of delivery drivers, truckers, cab drivers, and so on. Gerald Seib, in a Wall Street Journal article, argues that these jobs are the traditional path to the middle class for many Americans; these workers feel that they are losing control of their economic future."

This reminds us of the story of the Luddites, the textile workers who revolted when machines took over their craft jobs in England in the 19th century. These workers believed that machines would replace them- these workers were right. The machines did replace the workers. Economists remind us that the Luddites acted rationally from an economic point of view. They were losing their jobs. In the same manner, and in my view, people losing their jobs today such as truck drivers and delivery drivers will likely oppose this change in technology. Labor union organizations, who depend on membership, will oppose.

On the other hand, other benefits are reported savings of millions of hours of driving time, less parking space needed, less cost of accidents, and reduction in vehicle injuries and deaths. AVs could help solve the lack of reliable workers in many industries today. With AV technology, we could work or play games in the car, and other possibilities. Disabled people could benefit from the potential changes with the availability of robo-taxis, etc.

What is Next? The proponents of automation in vehicles predict that we are close to acceptance and use, most likely in parcel delivery, trucking, and low-speed shuttles such as bus transportation. Car sharing is predicted to reduce car ownership; driverless vehicles simply drive all the time- rarely parked. On a side note, Uber finally posted a quarterly profit in the second quarter of 2024, a big step for the ride-sharing company and their quest for autonomous vehicles. Some analysts had predicted that Uber would never make a profit. They were wrong and the increase in ridership is increasing.

In any event, and in my view, driverless vehicles on our roadways is a matter of time. The supply chain will benefit from reduced labor costs, the gift that keeps on giving, providing lower-cost goods and services. After all, robots are available to work, do not call out sick and do not require wages or benefits.

Truckers will be likely the first to feel the impact. Long over-the-road trips will likely be automated as the industry accelerates its hub-and-spoke strategy. Currently, a Pittsburgh company - Aurora Innovation - is testing 18-wheel tractor-trailers. The big bet is that they can convince a skeptical market that these new trucks will be safer. The payoff will be productivity gains as there will be no requirement for mandatory rest periods for drivers. They expect fuel savings also and eventually a lower cost of capital. Significantly, the Department of Transportation is developing standards including cyber-security, manufacturer claims, and future infrastructure.

For those interested in engineering, Tesla, one of the leading companies in this field, has a technological engineering approach by utilizing cameras. Other manufacturers are relying on a technology called LIDAR, a combination of lasers and sensors to map the roads. Conceptually, driverless trucks will not need an

accelerator, seat, or windshield. A driverless truck may not need doors. One big change is that driverless cars will be programmed to drive to the speed limit, which will be a change for us as many of driver tend to drive over posted limits.

A list of companies currently working on autonomous vehicles includes Tesla, General Motors, Jaguar, and many others. Tesla has a big advantage since their fleet of electric powered cars all communicate to each other- accelerating the knowledge. As a result of this leverage, Tesla is building data from its one million cars on the roads today, comparing what the computers would do and what the driver does- in other words, machine learning.

The investment in autonomous driving is significant. Anticipation is growing. Risks remain including the lack of centralized standards and an infrastructure currently designed for human driving. On the other hand, we should be able to leverage findings from other industries such as mining and aviation. As I mentioned earlier, the burning question is when is safe "safe enough." How will our regulators act and how fast?

Elaine Herzberg's story recalls the story of Bridgett Driscoll. Bridgett, a 44-year-old mother from the United Kingdom was the first reported pedestrian killed in an automobile accident in 1896, a demonstration car moving probably no more than ten miles an hour. The local coroner reportedly said that "he hopes [death by automobile] will never happen again." The point of this story is that it can be difficult to predict all the consequences.

In summary, and in the same manner as the development of the smart phone, the convergence of the latest technologies including electric cars, AI/machine learning, robotics, batteries, sensors coupled with societal trends of lack of worker availability and the never-ending quest for cost reduction will accelerate the development of fully autonomous vehicles despite the challenges and the skeptics. Technology is disruptive like when the automobile replaced the horse. In the end, society will have more choices.

In my view, the big bet will be on safety and the economic push will be cost reduction. Safey is the concern and the expected improvements in traffic safety will eventually support the transition to autonomous vehicles.

We will still have the optimistic hype and ambitious timelines but in the long run, the new paradigm that has already started in California and Arizona, will become the norm. In short, and as Kurlansky reports, “Luddites never win.”

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