Autonomous Cars: Social and Economic Implications

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One of the major issues with autonomous cars is their future impact on society as well as on the research community, academia, and industry. As interest in autonomous car technology grows, the social and economic implications of this technology will affect various stakeholders, including its commercialization. The authors critically review and analyze both the economic and social implications of the autonomous car. The significance of these implications will play an important role in the future of autonomous cars among consumers.

The unexpected growth and interest in autonomous cars over the past decade have attracted the attention of various stakeholders including the automobile industry, consumers, lawmakers, service providers, businesses, and governments. Multi-faceted artificial intelligence-based sensing, detection, perception, planning, and actuation techniques are being leveraged in autonomous car design to enable them to operate without drivers. The main reasons for the interest in computer-controlled self-driving cars are numerous: safety on the road, growth in population, increase in the number of vehicles, lack of infrastructure, inefficient time management and utilization, fuel economy, and environmental pollution.

To improve traffic safety and to cope with a few of the aforementioned challenges, connected car technology where cars communicate with each other and with their surroundings will play a pivotal role. Such communication and exchange of information enable drivers to make correct and timely decisions in emergency situations. However, connected car technology could not make it to deployment due to the lack of a holistic approach towards infrastructure, consensus among stakeholders, policies, consumer satisfaction, security, and privacy, to name a few. Similarly, the ownership of cars poses other serious challenges to traffic safety in addition to the need for new infrastructures and resources, and the increase in environmental pollution.[1]

According to the World Health Organization, there will be 2 billion vehicles on the roads by 2030.[2] The exponential increase in the number of vehicles will not only require new infrastructure but will also increase the probability of accidents and fatalities. To address these issues, the National Highway Traffic Safety Administration defined five levels of cars from autonomy and control perspectives, where level 0 has no automation, level 1 refers to

functional-level automation, level 2 combines functional automation, level 3 defines the autonomy of safety-critical functions under some particular environment, level 4 refers to self-driving cars with possible human intervention when needed, and level 5 is the fully autonomous car without any human intervention.[3] A fully autonomous car is a complex distributed system that integrates various computation, communication, and storage domains with a focus on intelligence and capability of decision-making. The "nuts and bolts" modules of the autonomous car include object detection, perception, learning, path planning, and execution.

There are numerous applications of the autonomous car, ranging from safety to comfort. Despite the high complexity of autonomous cars, they are paving the way for new value-added services. Autonomous cars are poised to substantially reduce the number of road accidents, thereby improving road safety. Furthermore, with autonomous cars, new business opportunities such as mobility-as-a-service (where the ownership of cars is expected to reduce) will emerge. This phenomenon will also help alleviate the parking space problem in urban environments. Furthermore, mobility applications such as rental cars, taxis, carpooling, social drive, and car-sharing will all benefit from autonomous cars.[4]

To date, remarkable results have been achieved in both academia and industry toward the realization of autonomous cars, and pilot versions of level 5 autonomous cars have already traveled millions of miles in test drives. Some of the key market players and investors of autonomous cars include Google (Waymo), Apple, Intel, Nvidia, Uber, Lyft, Baidu, Honda, nuTonomy, Mercedes, Tesla, BMW, Volvo, Ford, Volkswagen, Bosch, Delphi, GM, Audi, Toyota, Hyundai, Kia, and many others who are investing in the commercialization of this technology. However, most of the efforts dedicated to autonomous cars are focused on the technological aspects.

The idea of the autonomous car is indeed ambitious; however, the consequences and ramifications of autonomous cars are gradually emerging as a result of debates that consider the social impact of the technology. It is still not known as to how society will be affected by the proliferation of this technology. In this article, we focus on the social and economic implications of autonomous cars and analyze the existing literature that addresses social and economic issues related to autonomous car technology.

SOCIAL IMPLICATIONS OF AUTONOMOUS CARS

Autonomous cars are not the future but the present, and the transition to full deployment of self-driving vehicles (level 5 automation, according to SAE[5]) on city streets will not be slow but sudden. Here, we discuss the social benefits and ethical and moral issues of autonomous cars.

Social Benefits of Autonomous Cars

The promise of safety is the main benefit that autonomous vehicles are guaranteed to bring. Advanced driver-assistance system (ADAS), popularly deployed by many manufacturers, minimize human errors and, therefore, increase road safety. ADAS has many features including intelligent speed adaptation, hill descent control, driver drowsiness detection, and automatic braking, to name a few. Cars with some of these features are reported to have 14% reduced property damage liability claims,[6] whereas autonomous cars will improve operational safety and avoid human-error-based accidents.

To this end, one of the big changes that the automation of driving will bring is greater accessibility to public and private transportation. Once full autonomy is implemented, both public and private vehicles will be driverless. This transition affects various aspects of society including a lower demand for parking spaces, the inclusion of the disadvantaged, reduced congestion, and improved fuel efficiency. Autonomous cars also make car sharing much easier to afford. Past experiences have showed that many traditional businesses that failed to foresee technical trends disappeared from the market; therefore, automakers need to redirect their strategies.

Moral and Ethical Issues

When it comes to making important decisions, humans trust human drivers more than machines. This distrust stems from different reasons. First, most drivers prefer to have software that prioritize drivers' safety over other cars and passengers, while they also want other self-driving cars to have systems that consider the social and environmental safety. Second, drivers have different decision principles, especially when it comes to ethical situations. Since enumerating all possible driving scenarios is infeasible, engineers need to program the systems in advance to follow certain ethical principles. Traditionally, only humans were allowed to make moral decisions and machines mechanically followed step-by-step instructions from humans. Now, machines are becoming independent from humans, yet we do not want to let machines make decisions instead of us. This dilemma can only be solved when we allow each user to reflect his or her own legitimate ethical principles to the system. Third, people trust machines less because the information they use to make decisions comes from (sometimes unreliable) sensor-based perceptions.

From the consumer perspective, the autonomous car will have both positive and negative social implications. Positive implications include saving time, comfort, safety, prestige, and improvement in lifestyle, and negative implications include distance among social status of people, moral and ethical challenges, jobs loss for drivers, and addressing human behavior, to name a few.

ECONOMIC IMPLICATIONS OF AUTONOMOUS CARS

Autonomous cars will redefine the economic model of many businesses related to the automotive sector as well as the social well-being of citizens. The world's economy can be abstractly divided into two broad sectors: the service sector that includes major services in our daily lives such as retail, business, travel, healthcare, and food, and the goods sector that is related to logistics and includes construction, manufacturing, mining, automotive, etc.[3] Most of the world's economy is shared by these two sectors. When we put autonomous cars into this perspective, Tien *et al*. introduced a new term ("servgood") that refers to a physical tangible good supported by services that make this good more useful, smarter, adaptive, and customizable.[3] Furthermore, the addition of more computation and communication power to servgood results in a more service-rich servgood, henceforth referred to as a "sensed servgood." According to Tien *et al.*, a nation's economy evolves in four stages: mechanical and electrical (which correspond to the production of goods), and information and Internet (which correspond to the sensed servgood).[7] To this end, in addition to other industries, the autonomous car can be considered as one of the most suitable candidates for sensed servgood that has evolved and matured over the past decade.

During the past decade, the autonomous car industry has attracted many investors from the automobile industry, academia, and other businesses. According to the Brookings Institution, around $80 billion was invested from 2014 to 2017 in different deals (both at business and corporate levels).[8] Apart from these investments, Figure 1 presents a summary of the key market players of autonomous cars and their volume of investments in autonomous car technologies.

The analysis of the economic impact caused by autonomous cars in different industries is also important. Clements *et al.*[9] reviewed different industries that have first-hand stakes in autonomous car technology. Without loss of generality, the automotive industry is directly affected by the emergence of autonomous cars both positively and negatively. For instance, autonomous cars will reduce the prices of travel to about $0.57 to $0.74 per mile in the US.[10] Another strategic shift is expected in the automotive industry wherein more investments will be made in software and artificial intelligence rather than in the car itself.

Similarly, the software industry will experience significant growth, especially in the fields of control, artificial intelligence, deep learning, and computer vision. The volume of revenue from this aspect of autonomous cars is estimated to be $26.4 billion in the US, which also contains $680 million to $15.8 billion in software revenue (up to 2040); the revenue in other technologies such as digital mapping services will reach $10.6 billion by 2040.[11] Similarly, the health sector will be adversely impacted by autonomous car technology (from a medical business perspective) because of the reduced rate of
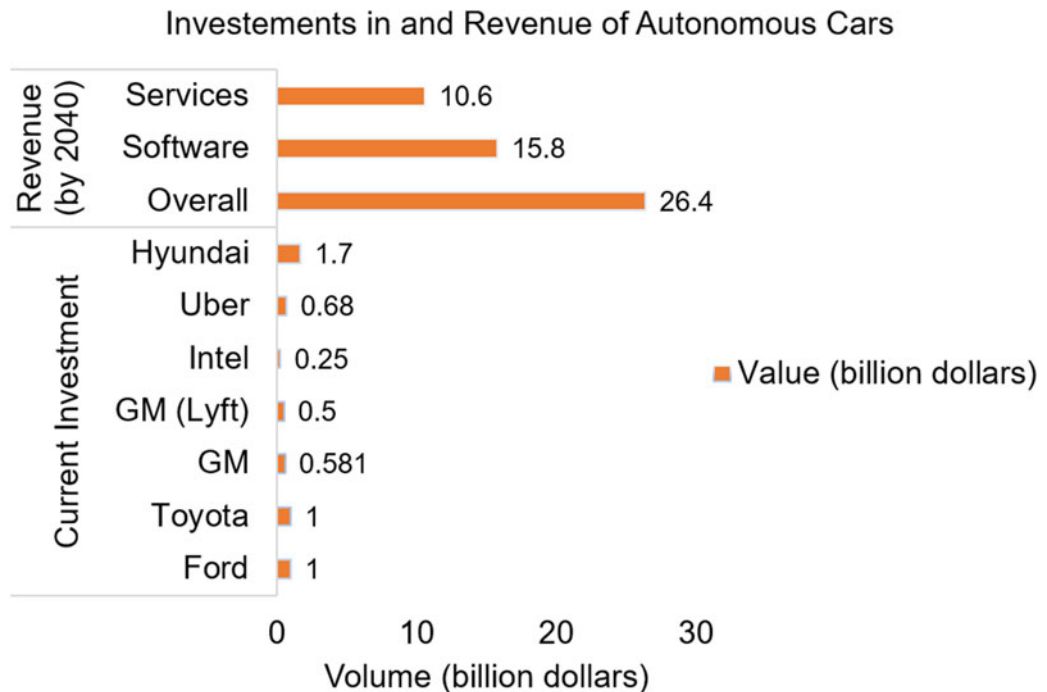
Investements in and Revenue of Autonomous Cars

Figure 1. Investments in and revenue of autonomous cars (https://www.techemergence.com/self-driving-car-timeline-themselves-top-11-automakers).

accidents, leading to a reduced rate of hospital visits. Nevertheless, from the user perspective, it will reduce user expenses.

In short, the autonomous car technology is a double-edged sword. On one hand, it provides enormous opportunities to industries in the economic sector, whereas on the other hand, it will likely cause a reduction in revenue for certain industries. More precisely, the paradigm shift will cause some disruption to the world's economy, and there will be both winners and losers. However, after the autonomous car technology matures, it will add up to $7 trillion to the global economy in different forms, some of which have already been covered in this work.[12]

FUTURE CHALLENGES

The mayhem caused by competitors through their relentless pursuit to be pioneers in the commercialization of autonomous cars has exacerbated, at least to date, the possibilities of its roll-out. It is also debatable whether the existing test drives can be extrapolated to commercial products. In this section, we briefly discuss the social and economic challenges ahead for the autonomous car industry. Table 1 summarizes some of these challenges.

Social Risks

The desired outcome of a new technology is largely determined by its adoption by its direct consumers, and most importantly the will for a change in the mindset of the society. Therefore, innovation involves societal risks. The initial deployment stage of the autonomous car is more susceptible to errors (or security issues) in software, control, and actuation that may lead to disastrous circumstances and consequently lose the trust of consumers.

Social risks for autonomous cars can be divided into seven dimensions: user-level risk, system-level risk, financial risk, job market risk, accessibility risk, security and privacy risk, and dependency risk.[13] At the user level, in the case of an accident, the consumers of an autonomous car will be at risk (albeit

Table 1. Summary of challenges for the deployment of autonomous cars.

Risk type	Challenges	Possible solutions
Social risks	Consumer dissatisfaction due to software errors Liability in case of accidents Loss of jobs for drivers Social injustice	In-depth investigation of context-aware artificial intelligence-based solutions Combination of technology and legal framework
Insurance risks	What/who to ensure? Loss of current insurance businesses Handling and managing traffic incidents will be difficult	Paradigm shift of insurance businesses Role-based liability distribution: the liability will be distributed among different stakeholders such as manufacturer, software designer, etc.
Economic obstacles	Automotive industry will be badly affected (reduced sales of cars) Decrease in automobile production Economic gap among citizens will increase (drivers will lose their jobs)	Alternate economic benefits to citizens (especially drivers) Initial deployment stage must be managed very carefully Steady deployment of level 5 with huge awareness campaign
Data-related issues	Data ownership Data privacy and abuse Data storage and sale Type of data to share, with whom, and to what extent?	GDPR and similar regulations Implementation of regulations Conditional revocation

it is the sole motive of autonomous cars to reduce accidents). Furthermore, in the case of autonomous cars, it is still unclear who will be responsible for different aspects of accidents. At the system level, this technology is likely to add more risks to the existing infrastructure. In essence, the autonomous car technology leverages the intelligence of software and likely Internet connectivity (both of which are susceptible to different security risks). Therefore, should something go wrong with the autonomous car, the repercussions will be catastrophic for the normal traffic infrastructure as well.

Insurance With Autonomous Cars

In the current setup, insurance is a well-established business where both cars and humans are insured through policies. In case of an accident, the primary party responsible and the other liable entities are typically humans. In the US alone, almost $180 billion was spent in insurance costs, claims, medical costs, and damages in 2015.[14] However, the insurance business will likely experience a setback due to autonomous cars, where a significant shift from the conventional norms in insurance will compel the industry to rethink its business model. The key question is who will be ensured in the case of an autonomous car—the car itself, its occupants, or the owner? On the other hand, KPMG forecasted that

autonomous car technology will shrink the insurance market by roughly 60%.[15] Although it is beneficial to reduce traffic incidents, the economic repercussions caused by the recession in the insurance industry is also a problem from the business perspective.

Economic Obstacles

Many existing industries will also be economic obstacles for the autonomous car industry, and the transition from the traditional mindset of consumers, investors, and business stakeholders might not be easy. For instance, the automotive industry itself will be adversely affected due to the likely decrease in their production and the increase in the culture of ride-sharing. From another perspective, the added benefits brought about by the autonomous car might further increase the economic gap among people with different social statuses. Currently, this economic gap is reduced by offering jobs such as taxi drivers, public transport drivers, or personal drivers, but with autonomous cars, it will be difficult (at least at the initial deployment stage) to reduce this gap. On the positive side, it can be inferred that these obstacles will likely not be permanent and will settle with time because the affected industries will evolve with new business models that can adapt to the autonomous car technology.

Data-Related Issues in Autonomous Cars

Autonomous cars collect data through various components for identification, authentication, value-added services, and comfort applications. The term "data is the new oil," coined by Clive Humby, perfectly fits in the context of autonomous cars, where service providers not only have access to user-identifiable data, but they can also sell it to third parties. Such data not only reveals the private aspects of individuals' lives but also reveals patterns that could be used for likes, dislikes, interests, etc., for business purposes. In many countries, using private information of users and tracking the location of citizens is protected by laws, but these laws are at odds with the autonomous car functionality because location information is essential to provide location-based services.

To address such issues through the legal system, the European Union recently introduced and implemented the General Data Protection Regulation (GDPR), which gives customers more control over their personal data. According to GDPR, companies that store customer information have to get consent from their customers about their data storage and have to inform the customer in case of a data breach. Furthermore, GDPR enables customers to have the "right to access," the "right to be forgotten," "data portability," and to exercise privacy by design. As one of the strictest regulations on personal data protection, GDPR will play a pivotal role in the protection of personal data; however, in the context of autonomous cars, the service provisions to the customers will have a significant setback because of the strict consent required from the customers. The service providers need to build enough trust with customers to get their consent for storing and processing their personal data.

Furthermore, autonomous cars will drastically reduce car ownership, which means that autonomous cars will be available for rent and for lease. In this case, when the lease is over or when the car is sold to anyone else, what happens to the data of the previous owner/leaser? Thus, there are still gray areas even in the legislation that needs to be addressed. Intel Corporation predicted that an autonomous car could generate 4000 gigabytes of data every single day[16] from its on-board sensors. If such data is misused by the service providers, it can lead to catastrophic consequences. Given that changes to the legislation take time and can be quite complex, both legal systems and technologies (such as blockchain) are essential to address the aforementioned issues.

CONCLUSION

Competition in the autonomous car industry has motivated competitors to develop novel solutions, but it has also led to the emergence of social and economic issues from both consumer and business perspectives. In this paper, we discussed the social and economic implications of autonomous cars and make the following conclusions.

- Autonomous car technology will have significant societal implications (both positive and negative). To realize a commercial autonomous car, the industry, governments, lawmakers,

and academia must take concrete steps to address the challenges that directly affect consumers.

- The stakeholders must develop effective rules, regulations, and laws that safeguard the interests of consumers and businesses.
- There will be no absolute winners or losers in the commercialization of the autonomous car. Different stakeholders need to agree on some consensus.
- We anticipate that as autonomous cars are commercialized and the technology matures, there will be more social and economic issues that will need to be addressed.

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