

# THE FUTURE OF TRANSPORTATION - AUTONOMOUS VEHICLES

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## **Abstract**

Autonomous vehicles are currently among the most important activities in research and transport industry development. Being at the stage of prototypes undergoing extensive testing, these vehicles have the potential to replace human drivers in the next decade. This survey analyses all the aspects linked to the implementation of these new technologies. One by one, we will analyse the benefits, the costs and the risks that will arise following the transition from human driven automobiles to those operated completely autonomous. Moreover, another important element of this paperwork is the analysis of predictions and future trends in this field. We will highlight the changes produced at the level of transport activities and also the way in which these innovations will transform our society from other points of view. The impact that the introduction of autonomous vehicles will have on people will be a very strong one and, according to predictions and estimations, this transformation is closer than we think.

**Keywords:** autonomous vehicles, transport, technology, innovation, future trends

**JEL Classification:** L62, L91, L63, Q55

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## **1. Introduction**

Autonomous vehicles have been, for quite some time, an important segment of Science-Fiction movies and books. As with many other technologies prefigured in this manner, gradually emerging under a form or another in our society, we can both observe and anticipate the extraordinary technical progress in the field of autonomous vehicles. This field is developing at a much faster pace than previously predicted, and experts claim that autonomous cars will become truly usable on a large scale in the next 10 years. The largest auto companies are in full process of technology development and have successfully tested numerous prototypes. We can expect, in a very short period of time, a gradual and cumulative increase in the autonomous abilities of vehicles.

The technology of autonomous vehicles will significantly change the industry of Transportation. The implementation of more and more automatic functions will lead, at some point in the near future, to completely autonomous vehicles, in which the passengers will have no driving responsibilities. Besides the technology itself, which is mostly available today, there are numerous other issues that need to be solved, like the adaptation of infrastructure to this type of vehicles, the implementation of legal aspects, as well as other regulations and matters relating to risk management.

The purpose of this paperwork is to analyse the current status of autonomous vehicles, to present the benefits, costs and risks generated by the transition from human-operated vehicles to those completely autonomous in this imminent transformation at global level and to frame predictions and future trends in this field.

## 2. What are autonomous vehicles?

The development of technologies has made that, over the last years, many vehicles have integrated various automatic functions such as cruise control, automatic gearbox, satellite navigation, parallel parking assistance, etc. As more and more functions automate, control slowly moves from the driver to precise and complex computer systems. This is a significant step towards full vehicle automation.

A completely autonomous vehicle can be defined as a vehicle that can perceive the environment, decide the route to destination and drive completely without any human assistance. This way of transportation will bring important changes in the way we travel, because, since the need for a human driver no longer exists, all the occupants can be passengers. Thus, the vehicle can operate even without humans on board. (KPMG, 2012)

The completely autonomous vehicle is designed to use all the functions needed for safe driving and to monitor the road conditions for the entire journey. This type of design implies that the passenger only sets the destination, and, subsequently, his involvement from the point of view of vehicle operation will no longer be necessary. This fact applies to both when the vehicle is occupied, or not. By construction, all the functions relating to safety during displacement are ensured by the computer system. (Anderson, § i alți, 2014)

The technology of autonomous vehicles is in full evolution and close to full commercial implementation. That is why, in the proximate future, we will witness the emergence of a series of new policies supporting this transformation. The attention from mass media, of which companies like Google, Tesla, Audi, etc. benefit, companies that have proven the progresses made in this field, will lead to the implementation of these technologies at the level of all large auto companies, which already plan projects featuring autonomous vehicles. Another aspect for which the development and the implementation of autonomous vehicles is very important is constituted by the fact that the great majority of accidents (approximately 90% of all traffic accidents) are caused by human error, and the number of global traffic fatalities rises to 1,24 million people, yearly. (Waldrop, 2015)

There are numerous progresses made every year regarding the complete automation of vehicles, the process being in full development. Many companies, such as Tesla, Google, Audi and Ford are in the testing phase of some vehicles that are autonomous under certain conditions, such as pre-established routes under favourable weather conditions and the possibility to transfer control to a human driver in case of necessity. This high autonomy level is an essential step in order to obtain a vehicle that can be fully autonomous. The transition from these prototype vehicles with very high autonomy to those completely autonomous will take more time, according to the estimations of the auto companies involved, predictions indicating the beginning of the next decade.

Autonomous vehicles need a high level of performance requirements. Sensors, computers and software have to be extremely well tested, redundant and enduring. Even after the manufacturing, in the proximate future, of a fully autonomous prototype, more time will pass and numerous tests and adjustments will be needed until the regulating authorities and the public opinion will gather trust, and that will only happen after the vehicle has demonstrated with certainty it has the abilities necessary for operating under any conditions. (Bilger, 2013)

As the automation of banking services, which started in the '90s, changed the way in which people interact with financial institutions, we can preview a similar transformation in the case of autonomous vehicles. Automated banking services have significantly reduced the number of employees and have made more effective numerous banking operations and related activities, although there are situations where clients need and/or prefer to interact with the banks' staff, because in some cases, it can be faster, more accessible or more

pleasant. The implementation of autonomous vehicles will probably follow a similar pattern. Mass access to this technology will make transportation more effective, but the transition process will be extended over a couple of decades. It is less probable that the incorporation of new technologies will totally replace current technology in a very short amount of time. Moreover, another similarity would be the existence of both benefits and expenses that are not related to the autonomous vehicles themselves, but to the infrastructure and the legal regulations.

### **3. Benefits**

The transition from driver operated vehicles to fully autonomous ones will bring multiple benefits. One of them will be the optimization of passenger comfort by decreasing stress levels among the passengers, whose time will now be solely reserved for rest and work.

The great majority of accidents (approximately 90%) are caused by human error. By implementing autonomous vehicles, the main cause of accidents and therefore of casualties, will be removed, resulting in an important increase in passengers' safety during the journey. A direct consequence of the decrease in number of accidents will lead to reducing costs in traffic management and activities related directly to traffic accidents, such as the field of car insurance.

The infrastructure will be adapted to the new conditions: groups of vehicles will be able to move at a smaller distance from one another, the lanes will become narrower and traffic jams will be considerably diminished. Therefore, the capacity of public roads will increase, resulting in more effective traffic management and the reducing of infrastructure costs. Also, maintaining constant speed levels will result in a reduction in fuel usage and, as a direct consequence, a decrease in pollution levels.

Another benefit will be that the decrease in the number of drivers will significantly reduce costs for taxi services and freight transport.

Parking a vehicle will no longer be an inconvenience, because the passengers will be able to get out at the desired destination and then the vehicle will find a parking place by itself. In addition, autonomous vehicles will increase efficiency regarding how we park and store cars. The number of parking places will increase considerably, because storage space will be organized in a much more efficient manner.

Autonomous vehicles will increase mobility among people who do not have a driving license and people with disabilities, resembling more of a public transport service. Through this transformation, a reduction in the number of private vehicles is estimated, therefore in the number of vehicles owned by each family.

Since the need to own a car in order to benefit from its services will no longer exist, the number of vehicles will be considerably reduced, because they will be used as a taxi service, therefore eliminating a big part of the time in which many cars remain parked and are not being used. (Fagant & Kockelman, 2013) This efficiency will have as a direct result the reduction of the total number of vehicles on the streets, because the number of parked cars will be drastically reduced. Their removal from public roads will improve traffic conditions, decreasing the time needed for traveling.

According to an estimate, if one vehicle would be used by multiple family members, in which the car would transport the members of the family one at a time, depending on their needs, instead of each of them having their own car, the number of vehicles held as private property could decrease with up to 43% (from 2.1 to 1.2 vehicles/ family). This will result in the increase in the time the vehicle spends in motion by 75% (from 11661 to 20406 miles per year/vehicle). (Sivak & Schoettle, 2015)

All these benefits are hard to predict in full, because the transition in transport services from human driven automobiles to fully autonomous vehicles will bring in a series of new difficulties and issues, as well as the related costs. A more accurate assessment of the benefits will take place once most of traffic will be comprised of autonomous cars. Nevertheless, we can definitely observe by now many advantages offered by the current level of large scale implementation of systems that are progressively increasing car autonomy. With the implementation of more and more systems that increase this autonomy, benefits will gradually begin to appear, accompanied inevitably by the emergence of new challenges, risks and costs.

#### **4. Estimated costs**

It is hard to estimate with certainty how the auto industry will develop from the standpoint of costs in this transition to autonomous cars. Nevertheless, we can see how large scale implementation of current advanced technologies increase the market price of a car. In this category we can mention GPS technology and telecommunication systems, video cameras, automated gearboxes, navigation and security systems.

Autonomous vehicles will need all this technology. Moreover, a significant number of additional services and equipment will be required. A fully autonomous vehicle will need the following: automated gearbox, a multitude of sensors (optical, infrared, radar, ultrasonic and laser) capable of operating under any conditions (rain, snow, unpaved roads, tunnels etc.); wireless networks both for inter-vehicle communication and for accessing maps, software upgrades, road conditions updates and emergency messages; navigation systems (GPS and special maps); automated control of the car (steering, braking, light signaling, etc.); servers and specialized software; testing, maintenance and additional service for essential components, such as car controls and sensors. (Litman, 2015)

Because system errors in the case of autonomous vehicles might be fatal for traffic participants, all the essential systems and components will have to be manufactured according to a high quality standard. These services include the construction, installation, repair, test and maintenance of components, and standards will match those of the aerospace industry. Moreover, the operation of vehicles will require periodic subscriptions to special navigation and map services.

Therefore, all the technology and services needed to safely operate an autonomous vehicle will increase automobile prices by thousands of dollars at purchase, to which several hundreds of dollars will also be added for maintenance and annual services. (Litman, 2015) But according to estimations, large scale implementation of these technologies and services will render them considerably less expensive. (KPMG, 2012) Also, prices may further be lowered by increasing efficiency in fuel consumption and reducing insurance costs.

At the beginnings of implementing autonomous vehicles on public roads, it will be necessary to adapt the infrastructure in order for it to properly address the needs of these new vehicles. Moreover, new regulations will be necessary so that the legislation will cover new situations and issues occurring due to this transition. These endeavours require public investments and supplementary efforts to ensure the fastest and most efficient adaptation to the new technologies.

After the implementation of autonomous vehicles on a large scale, we could witness a major decrease in users' costs, by applying the concept of shared vehicles. This involves the use of autonomous vehicles as a taxi service. The consequence of this could be a drastic reduction in the number of vehicles held as private property.

A study of the Columbia University estimates that, by using 9000 autonomous vehicles, the entire taxi service in New York might be replaced. Passengers would wait an average of 36

seconds to benefit from this service, and the fee would be 0.50 dollars/ mile. (Burns, Jordan, & Scarborough, 2013) The reduction in waiting time and price could make vehicle ownership inefficient and almost inconceivable, and accessing autonomous cars could become, in a short time, the dominant form of transportation, replacing both the personal vehicle as well as other forms of public transportation. Subsequently, the number of vehicles in traffic will be considerably diminished and the time necessary to reach one's desired destination will decrease. As a result, the entire transportation process will become more efficient and that might determine, again, a decrease in costs.

## **5. Risks**

A part of the risks associated with autonomous vehicles is similar to those of traditional cars. Nevertheless, the nature of risks will be different. An important factor in the future of autonomous vehicles will be constituted by a correct evaluation and subsequent removal of these risks.

A significant argument for introducing autonomous characteristics in vehicles is that, by this process, traveling aboard these vehicles will become safer. The great majority of accidents are caused by human errors and, in theory, by removing human control and replacing it with specially programmed computers, the risk of accidents will be substantially reduced. (Smith, 2013). However, issues might occur in the case of technology failure (failure of some systems or of the vehicle itself). Although computers can do more things than a human driver could (they may see through fog or darkness, they are not susceptible to tiredness and distraction), they can still fail.

The major risk of a system failure is the same as in traditional vehicles – the risk of accident. In order for autonomous vehicle technology to be a success, the frequency of accidents has to be extremely low among them, much lower than in the case of human-operated vehicles. Therefore, numerous tests are necessary and redundant systems must be installed to properly manage the situations when something malfunctions. Also, the car has to be functional both in unfavourable weather conditions and in poor road conditions. Situations in which unusual severe accidents may happen as a result of sensors failure also have to be considered (situations which a human driver might avoid instinctively).

Another important risk factor in our digitized society may be represented by the interference with the computerized systems of the vehicles, action that might have considerable repercussions on the safety of traffic participants. In order to fight the cyber risk, performant information-coding systems will be necessary. (Glancy, 2013) Because autonomous cars will operate with large quantities of data and they will be connected to existent technologies (smartphones and tablets) as well as to other vehicles in traffic and to the infrastructure itself, there is a high risk regarding the possibility of unauthorized individuals accessing information.

As the network is extended and vehicles become more and more interconnected, it will be possible for hackers to access personal data or to interfere with the functioning systems of vehicles. For example, after finding out the whereabouts of an individual at a specific time due to accessing vehicle data logs, thieves could more easily gain access into that person's house. There is also a potential risk for terrorism. For example, a large scale mobilization of autonomous vehicles on public roads might have disastrous consequences. (Yeomans, 2014)

In the proximate future, we will have more and more semi-autonomous vehicles in traffic, in which men and computers alternatively operate the vehicle. In this situation, people still keep some responsibilities and it is necessary for them to remain able to take control when needed. By gradually transferring responsibilities from the driver to the car, there is the risk

that the driver, not knowing in full the limitations of the vehicle's functions, will misjudge the situation and make incorrect decisions under certain circumstances. (Barry, 2011) Moreover, the implementation of technologies increasing vehicle autonomy generates the risk that the driver may not be attentive when he has to.

Another important aspect in the category of risks is the reputational risk for the auto companies manufacturing these vehicles. Because the possible failures of autonomous vehicles are directly affecting people's safety, in case of an accident, the reputation of the manufacturing company may be significantly affected. This is also the situation in the case of traditional vehicles. However, once responsibilities are transferred to computerized systems, this kind of risk will be higher. This is explained by the fact that people are less tolerant when the vehicle is responsible for the accident, not them. (Yeomans, 2014) The absence of a driver will generate a series of questions related to assuming responsibility and subsequent legal consequences. For example, who would be responsible if an autonomous car would be parking itself and would hit a pedestrian?

In addition, conditions related to the field of insurance will significantly be changed. Presently, the amount paid for auto insurance is mainly calculated on a combination of two factors: driver behaviour in traffic and driver profile. It will be interesting to see the change in the auto insurer's policies in the context of large scale use of autonomous vehicles. It is possible that the financial protection offered by the insurer to rather shift to the auto companies and the companies managing infrastructure. With the significant diminution in the number of accidents and their related costs brought by large scale implementation of autonomous vehicles, we can expect that the insurance industry in its current form will become obsolete.

## **6. Predictions and future trends**

At present, we are in the technology testing stage. There are numerous prototype vehicles already performing in ways that 10 years ago seemed unimaginable.

The autonomous vehicles of Google have already registered 700000 miles without causing any accident. (Davies, 2015) The German companies Mercedes Benz and Audi are already testing autonomous vehicles. A vehicle with 560 hp, the RS7 model from Audi, has reached speeds of up to 150 miles/hour on circuit, without being piloted by a driver. (Eckardt, 2015) The German Ministry of Transport recently announced starting a project meant to transform a portion of the A9 highway between Berlin and Munchen in a test track for autonomous vehicles. On that portion, equipment for communication between vehicles will be installed and part of the frequencies band that will be dedicated to radio communication between vehicles will be freed. (Ulieriu, 2015) Similar projects are already in development all over the world, but, until now, no one has attempted the usage of a highway portion as important as the one between Berlin and Munchen in such a way. This certifies that the Germans are extremely determined in transforming the vehicle and transportation industries.

Nissan is planning to offer consumers, by the year 2020, vehicles that are fully autonomous. (Davies, 2015) Also, other companies, such as Tesla, Jaguar, Land Rover and Ford estimate that they will present their own autonomous vehicles to the general public in the next 5-10 years. (Hars, 2010)

This technology will experience a gradual increase between 2020 and 2035, as more and more people will have access to it. (Davies, 2015) Once the achievement of reducing the rate of accidents, made possible by the implementation of these vehicles, will be accomplished, less repairs will be necessary. That also means that the insurance companies will change their strategies in order for them to adapt to the new situation. Another

plausible prediction is that the professional truck drivers will be replaced by these new autonomous systems.

Americans spend about 111 hours yearly/driver in traffic. (INRIX, 2015) Once relieved from the task of driving, time spent in traffic will be used in a more efficient and productive way.

Beginning with 2040 it is forecasted that autonomous vehicles will become our primary method of transportation. It is estimated that up to 75% of vehicles in traffic will be autonomous by this time, driverless vehicles becoming the most viable form of intelligent transportation. (IEEE, 2012) This would bring numerous changes. Because autonomous vehicles could park themselves much closer to each other, approximately 75% of the space that we presently reserve for parking vehicles will be freed. (Manyika, et al., 2013) Another change will be represented by the cars' design, which will be fundamentally modified, because forward-viewing positioned seats, mirrors, pedals and the steering wheel will no longer be necessary.

Moreover, our entire perception on vehicle ownership as private property will be changed. Presently, cars stay unused about 95% of the time. (Manyika, et al., 2013) By applying the concept of shared vehicles and using cars as a taxi service, the total number of vehicles will be drastically reduced. Therefore, road conditions will be very much improved, leading to a reduction in time spent in traffic and increased comfort. This change will potentially create new businesses in the form of companies that will purchase many cars and then make them available for public use at a cost (much like a taxi service). Under these conditions, the respective companies will take over the responsibilities of owning the vehicles. Among these, we can mention periodic maintenance check-ups, necessary repairs, cleaning the cars and other such responsibilities.

With the disappearance of numerous garages, car dealerships and bus stations, millions of square km will become available in locations adequate for metropolitan development. In addition, a reduction in the number of vehicles would highly diminish pollutant emissions. Moreover, autonomous vehicles will probably be mainly electric, which would lead to the elimination of large scale usage of gasoline and oil in automobiles.

Although we can speculate, it is difficult to exactly predict the way in which these new technologies will generate new industries and services that are hard to imagine at present.

## **7. Conclusions**

Autonomous cars represent the next step in the way we transport people and goods on public roads. Technological progress over the last years has made the creation and testing of prototypes possible, and car companies are predicting with certitude the presence of autonomous vehicles in traffic by the beginning of the next decade.

Even if there are still enough challenges which require practical solutions (technological aspects, legal regulations and safety-related issues), this technology, once mature, will radically transform the society which we live in. The benefits are countless, but the costs and risks are not to be neglected.

We could imagine a society, not very far in the future, in which transport services will be readily available at a mere push of a button and the mobility created by these services would significantly increase the efficiency in many other areas of activity. We can confidently assert that our society is at the beginning of a radical transformation process, and the next generations will consider driving automobiles rather a sport or a hobby, than a necessity.

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