Autonomous mobility for people with disabilities

Nelson Alexandre Paulino
Faculdade de Engenharia de Sorocaba.

Thábata Regina ProsdosKimis
Faculdade de Engenharia de Sorocaba.

ABSTRACT

Mobility is the ability to move, to go away and come back. Where many people do not have this freedom of mobility, because of this people there is any special necessities, and an interaction between cities and people, since cities are made for people and made about them. This is not depending of the environment in which they are inserted or as they move, including all physical or mental conditions. Based on this concept, everything that interferes with human locomotion (modes, roads, signs, laws, accessibility, etc.) must be thought of with the objective of progressively offering smarter and safer mobility, which values quality of life and welfare.

Accessibility is the quality of what is accessible, in other words, it is what is attainable, which there is an easy access. It is intrinsically linked to the provision of conditions for people with reduced mobility or disabilities, for the safe and autonomous use, fully or assisted, of public or collective spaces, the locomotion fair and the use of transport whether public or private, to work or leisure, giving a better quality of life to a public so far forgotten about such conditions, in this context we can also include the elderly and those who suffer from epilepsy.

Bellow it will be shown the reality that was found which the technology applied to autonomous vehicle can make to make easy the daily mobility of these people. So it was made a study which possible vehicles were analyzed, that they already exist available to get, with a hight degree of autonomy with the possibility of being adapted to be accessible. And how it will can efficiently assist the locomotion of visually, hearing, physical, intellectual, and even elderly people with reduced mobility, without they need for a help.

APPLICABILITY

The Autonomous vehicles goal isn't only to improve the access of the users mentioned above, but also the application refers to the integration of assistive technology systems and devices in an autonomous vehicle.

Another really important application is the sharing of the autonomous vehicle searching to minimize costs, since today autonomous vehicles are for a few people who has as kind of more money than the others, whether through car rental companies, clinics and private entities, government assistance agencies, and or others. At this moment, as the focus would be on medical appointment, some medical, this vehicle could be in possession of a hospital clinic or an entity in which that institution would be in charge of scheduling, transferring and monitoring the people who would use the vehicle.

THE HISTORY OF THE AUTONOMOUS CAR

Over the years, the man has always tried to dominate the machine and make it work as efficient as possible, the first time it was heard about autonomous it was about the year 1925, the first, although they dismissed the "driver", depended on special external resources, were radio-controlled by another vehicle that followed it close. In the 1940s the introduction of automatic transmission in passenger vehicles showed the public how much technology could be beneficial in terms of comfort and safety.

In 1958 Cruise Control allowed vehicles to maintain speed without driver interference. In 1971, ABS brake systems were implemented for the first time in automobiles with the purpose of increasing vehicle safety and that managed through sensors the possibility of locking the wheels, acting, when necessary, and so that this would not happen.

Between 1970 and 1980, the first autonomous cars that liked with that we know today, vehicles equipped with sensors, actuators and processors are necessary for them to move without special external interference. In the 90s, the universities took the lead in studies in order to improve the technology for autonomous vehicles, image processing became a great ally in the first autonomous driving systems.

In the 2000s, many companies emerged investing in technologies aiming to develop increasingly better autonomous driving systems, new ways of recognizing images through artificial neural networks, digitizing images and longer tests were making autonomous vehicles safer and more efficient.

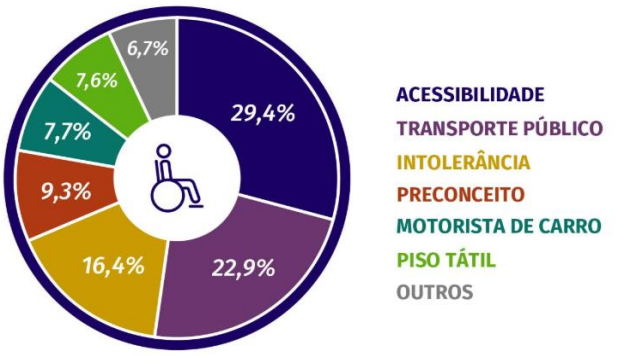
In the last 10 years as large automakers develop to invest more in autonomous technology for their vehicles, together with them technology, information, logistics companies are betting on this new world trend for vehicle mobility, companies like Google, Apple, Amazon, Baidu, Samsung and others, which previously had nothing to do with the automotive industry, are now part of an emerging and promising market.

We can observe that since the beginning, when the first idea of an autonomous vehicle appeared, a lot has changed due to the evolution of technology, with that, little by little the drivers started to get rid of small commands while driving their vehicle, at the same time that the vehicle's interaction with the surrounding environment began, the adoption of increasingly efficient and fast sensors and actuators began to make the fact that the car could move without human intervention a reality. The reality found today is the result of the work carried out for many years which, between mistakes and successes, has been adjusting and converging towards a common goal.

The great challenge of the automobile industry is to create a vehicle for specific use to the public the person with disabilities, the low demand for vehicles, the high development costs and exclusive projects combined with a technology that currently requires high investments that it creates hurdle for the realization of an autonomous vehicle aimed at the disabled and the elderly.

The creation of a unique architecture that could serve PCDs and the elderly does not exist either, each type of disability has different characteristics, a vehicle that serves a visually impaired person would need voice commands and also Braille keyboards, a hearing impaired person in turn. written and luminous message commands that attract attention when needed. This shows how difficult it is to have an apparently unique product to serve a specific audience with an exclusive condition that in turn represents 6.2% of the country's population.

HURBAN MOBILITY AND PERSON WITH DISABILITIES – A survey carried out by the "Comunica que Muda" of the Nova / Sb agency found on the internet a survey with the mention People with Disabilities and Urban Mobility and the result was that the most commented theme was Accessibility followed by Public Transport with 29.4% and 22.9% respectively, 1607 posts on social networks were analyzed and the result, as shown in Figure 1, shows that themes such as intolerance and prejudice are being left aside and that the concern when the subject is disability becomes accessibility and transportation.



(Figure 1 - Search made about urban mobility and person with disabilities)

Brazilian urban centers have always had infrastructure problems to provide people with the most diverse disabilities with minimal security, poorly designed spaces and roads that do not serve this audience, sidewalks and guides with structural problems and without undercuts for access, public transport aimed at people with disabilities and the elderly, they are only seen in large centers and yet accessibility to them is precarious, people who work with these vehicles often do not receive the necessary training to serve special users and become targets for complaints, the lack of respect also with parking spaces, all this is added to the fact that an adapted vehicle is unable to serve the majority of this public, on the contrary, due to the high cost of such a vehicle, few can have this facilitator of mobility.

This missing of attention to PCDs (person with disabilities in Portuguese) and the elderly is a challenge to be faced by society as a whole, advances are being made but the pace is still slow, there is a need for people, companies, entities and government agencies to come together with the purpose of promoting changes to make mobility for PCDs and the elderly more inclusive.

The proposed work seeks to show that it is possible to combine assistive technology, urban mobility, accessibility and autonomous automotive technology with a single purpose of creating a vehicle that can serve the public PCD and the elderly, in partnership with companies, the government and entities with the objective to facilitate and bring quality of life to people with certain mobility limitations, whether physical, visual, hearing or intellectual, permanent or temporary.

In Brazil, the technology aimed at autonomous vehicles is still in its infancy when compared to the USA, Europe and China, there are already legislation aimed at or being modified in order to serve this new market niche, partnerships with assistance entities, government and companies work together in order to creating laws that serve autonomous vehicles, their research and development, many companies already test their vehicles on public roads, some of which even design and test these vehicles to serve PCDs and the elderly.

Google for example performed a test with a visually impaired person with only 5% vision, Steve Maham, and drove him for approximately 300km on the roads of the state of Milwaukee in the USA. Other tests with autonomous vehicles are being carried out with the purpose of improving the technology of these automobiles, making them safer and more reliable, but the challenge is still enormous and a lot of work.

An autonomous vehicle (AV) is a machine that operates and travels without the need for a physical driver. In theory, an autonomous vehicle should be able to drive, change lanes, drive, brake and park without human assistance.

A major problem in conventional use of autonomous vehicles is the lack of confidence in self-operating machines. Security concerns include, GPS errors, Seat arrangements that work for various types of disabilities, protection of pet's service, crash test mainly for wheelchair users, remote operators who can intervene and assist in emergency, user training, and licensing of specific autonomous vehicles and how it can impact its users, the PCDs, as active seizures, who are not allowed to drive.

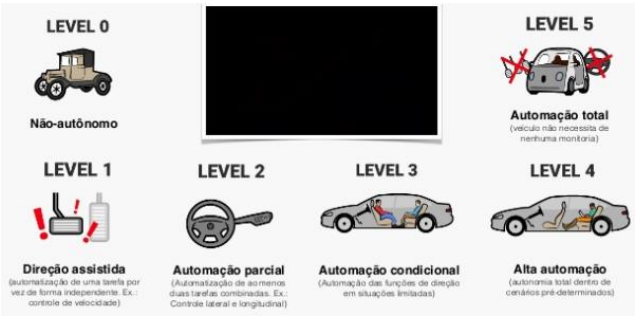
On the other hand, studies show that with autonomous vehicles the accidents would decrease by 35%, which is a considerable number when it comes to saving human lives. Now taking these numbers and bringing them to a Brazilian reality, where in 2019 alone we had 235,456 people with permanent disability caused by some type of traffic accident and cases with death reached 40,721 people. In terms of gross values, it is estimated that approximately 1.45 billion reais were paid out of damages alone, that is, the savings that it would bring in the medium and long term with lower compensation values due to the reduction in the number of accidents per se. it would already justify an investment by government agencies to invest in infrastructure to receive autonomous vehicles.

The big concern that still hangs over this whole mobility issue is how long will the return be invested in the entire process to make available an infrastructure capable of receiving the autonomous vehicle and the vehicle itself adapted with all available technology, be it assistive or of total automation. When we think of all the public involved in the project, whether PCD, elderly or epileptics, we must not forget that behind them there is a much larger audience that are their family members and their entire network of contacts, which increases the number of people and the number of people. autonomous mobility is reached and benefited with this accessibility, which becomes a showcase for the presentation of a product or service with an extremely high degree of reliability.

Currently all research on the development of autonomous mobility works in partnerships from different areas, all converging to a common point, presenting a product different from everything we have today and with a quality of service that does not allow errors. Figure 2 shows us the areas involved both for development, as in control and as a beneficiary with the development of autonomous vehicle technology, but realize that there is a lack that in our point of view would be one of the most benefited with all this technology, Mobility for PCDs and the elderly.

(Figure 2 - Autonomous vehicle impacts)

With the current levels of autonomy found in vehicles today, we can highlight two to be used by the public PCDs and the elderly. Level 4 of high automation, where the vehicle has autonomy is total within a predetermined space and level 5 of total automation where the vehicle does not need any monitoring. In view of this scenario, we can design a series of possibilities for the performance and application of an autonomous vehicle for a person with a certain type of disability and limited mobility. The automation levels of a vehicle can be better translated according to figure 3.



(Figure 3 - Autonomous level)

According to the needs of the driver or passenger of the car, adaptations are necessary, as each disability has its particularity, a wheelchair user for example needs a vehicle with a higher roof and a specific system to lock the chair close to the vehicle floor. A visually impaired person needs a system that uses voice commands and also Braille commands to identify certain components inside the vehicle, but does not have the freedom to sit in front of a steering wheel and drive a car, a hearing impaired person has to need for monitors and keyboards to communicate with the vehicle in addition to a more striking visual

identification, intellectual disabled depending on the degree of disability could have a remote aid and external control monitored by cameras and last and not least the elderly group where Larger commands and keyboards would facilitate access and control due to loss of contact sensitivity over the years.

A vehicle with a unique architecture that can serve all groups of users, whether they have special needs or not, which is the great challenge of the project. Another example is with a visually impaired, Braille commands on the door would make the first contact between machine and occupant, inside the vehicle more Braille commands and also voice command in order to access internal controls and define routes and route destination.

Elderly people would use the vehicle according to their restricted needs, voice commands and larger commands and identifications that facilitate touch and visualization would be of great help.

Intellectual disabilities and with epilepsy, in turn, may be the group that needs special attention and remote assistance, since the range of variation of this type of disability is large, for this case we will find a great challenge, since we would return to the problematic of exclusive cars, which would hinder the future sale of the car.

For the hearing impaired, the commands and controls with monitors and keyboards and apparatuses and light signals that draw attention when necessary. Adaptations made for certain groups can facilitate the construction of the vehicle because all this assistive technology already exists on the market, they only need to be incorporated into the project according to their need, in order to meet by creating a customization model for each of these groups.

The biggest challenge is the issue of vehicle autonomy level 4, which currently does not exist in Brazil, the project of the work presented is to create a single route on selected main roads, so the idea of customizing each vehicle to a predetermined route, where the power the public would be in charge of providing the necessary infrastructure for these routes to receive the autonomous vehicle, the companies involved in the construction of autonomous mobility would be in charge of preparing the vehicle for level 4, adaptation companies would make the necessary changes to personalize the service to the groups that would be used. of these vehicles and the entities that would be benefited together with the users would provide necessary information for the adaptations, definition of routes, initial accompaniments and creation of routines and protocols of attendance for the reception of the users with the vehicles, entrances and exits inside the vehicle, exchange of information between man and machine in order to create an environment pleasant between them and also give feedback in order to improve this union between the parties involved.

AUTONOMOUS VEHICLE PRESENTATION

The vehicle chosen for our project is the Hitech model e.coTech4 Autonomous, as it is the first autonomous electric vehicle developed in Brazil. The original model has a capacity for two passengers, reaches a maximum limit of 50 km / h with a range of up to 100 km on a battery charge, has a range of 4 and can travel through previously mapped regions without the need for a driver.

The vehicle will maintain its original characteristics requiring only a few implementations for conditions of use for PCDs, such as the voice command for closing and opening doors for example and also some physical adaptations for access to the interior of the vehicle and also space for wheelchairs. that is, the vehicle would be an autonomous electric vehicle adapted for PCDs.

The model can travel along a predetermined route, with no need for any change to the road infrastructure, and according to the manufacturer, nor the use of GPS.

(
Figure 4 - e.coTech4 Autonomous)

During the route, previously determined, the vehicle has the ability to recognize fixed and mobile objects and obstacles, such as other vehicles, pedestrians, parts of the infrastructure of the roads such as poles, gutters, sidewalks, pedestrian crossings, traffic lights, among others, and previously making decisions and giving priority such as: stopping at a traffic light when it is red, dodging a car stopped in front of you, performing evasive maneuvers of nearby objects and others, always trying to keep the safety of passengers and people as a top priority close to the vehicle.

The e.coTech4 Autonomous model has the advantage of being an electric vehicle, with levels of carbon emission in the atmosphere close to zero, it also has the advantage of being much more economical, while the cost of a traditional vehicle is around 100 reais per km run the Hitech model makes the same stretch for 4.50 reais on average, and its

batteries can be charged in a simple 110 V or 220 V outlet through a 3-pin plug in a 6-hour time, and its maintenance cost tends to be cheaper also due to the low number of moving parts.

The vehicle can be controlled remotely through a mobile application, according to the manufacturer, it detects obstacles at a maximum distance of 50 meters, its location accuracy of 0.1 meter and with a reaction time of 0.1 second. With the support of companies such as Lume Robotics, specializing in autonomous robotics and artificial intelligence, as well as Positivo Tecnologia and High Performance Computing Laboratory at the Federal University of Espírito Santo, the autonomy project for the creation of e.coTech4 Autonomous can become a reality , but this model still does not serve the purpose of our work, which is the application to make it fit to be used for the mobility of people with disabilities.

The next step in our project is to define the necessary technical specifications and the physical adaptations and adaptations and the introduction of new electronic commands, such as the voice command for opening and closing the doors, online conversation between passenger and remote attendant when necessary, real-time visual monitoring of the vehicle's interior and surroundings, all in addition to the existing controls on the vehicle that already allow it autonomy.

E.COTECH 4 AUTONOMOUS TECHNICAL ESPECIFICATIONS – The manufacturer is Hitech Electric. The development partners is Positivo Tecnologia and High Performance Computing Laboratory at the Federal University of Espírito Santo (UFES). The model is e.coTech4 Autonomous. The type is, compact vehicle, with autonomous steering and powered by electricity. There are 2950mm of length. There are 1380mm of width. There are 1620mm of height. There are 160mm of ground clearance. It weighs 460kg. There are 2165mm of length between the axles. The brake system is disk brake on all wheels with servo assisted system. The suspension system is Macpherson, independent (front) and spring scale (rear). The bodywork is made of steel tubular profile, and inside the panels are made with injected polymer: PP, PC and ABS. The painting are electrostatic (chassis), greenhouse (panels). The glasses are laminated in the front and tempered in rear. The lighting is dual stage LED headlights, with additional position LED. The panel display is equipped with speedometer, battery level and voltage, power consumption indicator and lights. The audible alert is the horn. The wheels are light alloy, and the tires is 155/70R13. The electric motor is alternating current (AC), asynchronous, 72V. Maximum speed: 50 km / h. Power: 6 KW. Maintenance-free 120Ah battery, 1800 cycle lithium-ion. Plug type: Brazilian model with 3 common pins (NBR 14136). Luggage compartments: trunk and side luggage compartment. Safety: three-point belt for four passengers and double front air bag. Sound: sound and media receiver with Bluetooth + Android. Heating: hot air with optional air conditioning. Degree of Protection: IP65. LiDAR - Light Detection And Ranging. Camera Full HD. 9DOF Inertial Measurement Unit. GPS RTK.

Drive by wire – Autonomous mode lock switch, autonomous mode on / off button, emergency stop button, acceleration control, braking control, steering control, shift control (drive / neutral / reverse), arrow control and flashing - alert, headlight control, horn control, windshield wiper control, door opening sensor, door opening and closing control, voice command by the user, voice warnings by the vehicle, display Braille, speech synthesizer and Braille screen reader, facial recognition system, biometrics system.

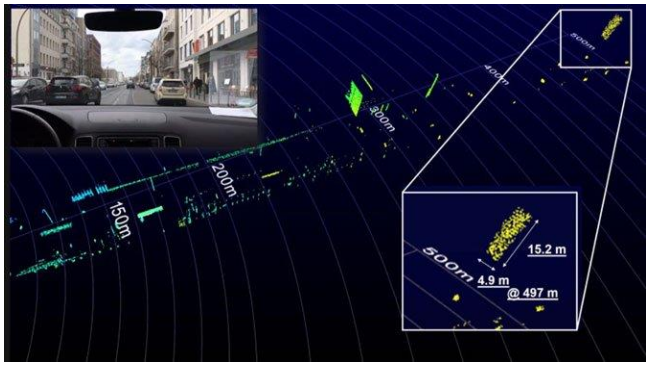
Processing server – Occupation mapping via sensor data fusion, reflectivity mapping via sensor data fusion, precise location on grid maps via laser sensing, route planning, movement planning, movement control, obstacle detection via data fusion sensors, pedestrian detection via computer vision, traffic light state detection through computer vision, treatment of mobile obstacles, treatment of fixed obstacles, treatment of speed limits, treatment of mandatory stops, treatment of traffic lights, treatment of pedestrian crossings, treatment of speed bumps, breakage treatment.

Mobile app – Sending transport requests to the autonomous vehicle, monitoring transport requests, canceling transport requests, tracking the route, viewing the vehicle's interior, viewing the vehicle's surroundings.

Remote Monitoring Module – Monitoring of multiple autonomous vehicles by telemetry.

The autonomous technology applied to the vehicle includes the most current on the market, an example is the application of LiDAR, which when using two systems from the manufacturer DJI, the Horizon and the Tele-15, both complete a 360º view from a distance detection of objects up to 500m and scanning 99.8% of the area within its field of view working with operating systems such as Linux, Windows, ROS and development languages such as C, C ++ and Python.

Other sensors such as ultrasonic, presence inside the vehicle, door openings, external and internal temperature sensors, these with technology already well known in the automotive environment, working together with actuators that will perform the function of promoting the opening, closing and door locking, voice commands (NLA technology), currently widespread in the automotive market, aims to bring security to the user but in addition to facilitating communication between the PCD who cannot use manual commands and needs this technology to interact with the vehicle.



(Figure 5 - Vision of a LiDAR DJI sensor)

(Figure 6 - Vision comparison of a LiDAR DJI sensor)

GPS navigation system is already well known and used in everyday life, whether on smartphones or automotive systems, it provides us with a precision location between 5 and 10 meters, exchanging data with satellites positioned around the planet, however some factors can influence the quality of the signal like terrain relief, climatic conditions among others and this can be very worrying when we try to know the exact location of an autonomous vehicle. For this reason, we have added a system that seeks to reduce the distance by up to 2 cm in location, thus mitigating possible failures that may occur with the GPS, it is the RTK - Real-time Kinematic system, widely used in geoSensorization systems, assisting the analysis work of topography of an area and precision agriculture.

The concept of positioning by RTK (Real Time Kinematic) is based on the instant transmission of correction data from satellite signals, from the receiver (s) installed in the vertex (s) of reference to (s) receiver (s) that travel (s) the vertices of interest. In this way, it provides real-time knowledge of precise coordinates of the raised vertices. Positioning by RTK can be done by the conventional method or in a network.

Networked RTK technology has spread since the development of GSM, 3G and GRPS cell phone technology.


(Figure 7 - Global Navigation System – GPS)

Auxiliary systems of autonomous technology in conjunction with assistive technology will be adapted in order to meet the needs of users of the autonomous vehicle, therefore the versatility and flexibility of the systems and of great importance for the success of the project.

Regarding the adaptation of assistive technology to the vehicle, modifications will be necessary in order to meet each project, tilting access ramps for wheelchairs, internal space to accommodate a guide dog, increased door opening or modification in the position of the hinges causing that the opening facilitates the access, removal of the column “B” with the same objective of facilitating the access to the interior of the vehicle, modeling of the floor for anchoring the points of fixation of the seat belts to secure the wheelchairs, microphones and speakers for communication between user and vehicle and between user and attendants not present on the spot, light signaling to draw the attention of the hearing impaired when necessary, opening and closing doors automatically with presence sensors doing the monitoring.

All these systems working with the purpose of offering the user all the necessary safety so that driving is done in a simple way and without causing any type of adversity or embarrassment, always striving for normality creating an environment of total inclusion.

The preference for choosing an electric vehicle is due to the fact that it presents better conditions for implantation of electric and electronic devices, due to a better compatibility with the autonomy technology, it is a worldwide trend for electric vehicles, in the medium and long term the costs are compared to a combustion vehicle, as it circulates on pre-established routes, it is estimated that it will run for distances smaller than its capacity for battery charge autonomy, it does not need to take you to a gas station to refuel, your refueling can be carried out at a time of non-use and within the parking lot or garage, the cost of maintenance is lower compared to a combustion vehicle and apparently the adaptation tends to have a lower cost as the vehicle has a more simple.

The cost of an adapted vehicle today varies widely because of the type of adaptation to be carried out to serve a specific person with a disability, being of almost exclusive use. The work presented seeks a solution where the same vehicle can serve a larger number of people with the most diverse disabilities and that with small changes can increase this number of people served, at first it may seem more expensive than the conventional adaptation carried out today, but as one of the objectives is to share this vehicle, costs tend to be lower as more people are served.

Regarding the necessary infrastructure to meet the application of this project, the route to be used does not tend to be long distances, they will be pre-defined according to the location of the users' home until the place they aim to reach and the return to their home again. The entire route will need to be modified, if necessary, in order to meet the automation level 4, the stops must be prepared to receive the vehicle and the user, with signs and identification that can make the connection between both to enter and to stop. get out of the vehicle.

The route has to be carefully planned to avoid a very heavy traffic flow and the schedules also defined in order to avoid the same problem, therefore, information from the Traffic Department regarding the times and points of peak traffic are of great importance in the development of this project, and any and all modifications or implantation of signage that may be suggested to the responsible agency needs to be analyzed together with all involved.

This can be the first step so that autonomous mobility can serve a specific audience, and that this becomes a reality, and can expand to other models of mobility services, with other larger vehicles for transporting people on longer trips, transportation of materials and products, that the infrastructure employed in this study can serve as an example and be used for other purposes always seeking to improve the quality of life of people and the environment.

CONCLUSION

When we talk about mobility, we think about how easy our mobility has become with the aid of automotive transport, but when we stop to think about those people who have some kind of special need, from weak to moderate, this mobility becomes slightly difficult, but today nowadays it is already possible to include adaptations to these vehicles, so that a disabled member of the upper or lower limb, for example, can drive, including pedals, handles and or ramps, having back their freedom to come and go, a negative point, it is only when these people have to sell their cars, because that is when this activity becomes time consuming and complicated, since other users do not want to buy cars with these adaptations.

But when we have serious PCDs, their rights are withdrawn, or they need help from other people, so that they can carry out common activities such as going to supermarkets, shopping malls, such as giving themselves to medical follow-ups, which are usually performed with a certain frequency. Often these people fail to carry out their activities, because they think they are bothering someone, they feel frustrated, because they do not have their right to travel, assisted.

In order to avoid adaptations, electric cars (which has been a trend in recent years) were thought of, autonomous, specifically at that time, to serve this public, so needy and so forgotten at the same time. These systems mentioned above, added to the vehicles, aim to allow their mobility, regardless of what special needs the user has, whether he has a physical, mental, visual, hearing, intellectual, old age, or even some type of disability health problems such as epilepsy, or sudden illnesses, without the need for help from another person, or to place him inside the vehicle, or even to drive the vehicle for him. These systems can be included in one go, facilitating sales in the future, and can be used even for people who have no special needs.

Therefore, if a vehicle is autonomous at level 5, it will also be easy to be used by NGOs and clinics specializing in the treatment of people with special needs, to design routes to pick up their patients according to the needs of each one, by appointment and proximity to each other, without the need to have a friend or family member who has to leave their workday for example to take and bring that person. This vehicle sharing will enable attendance to your patients' appointments, security, and will provide a sense of freedom, of being able to sit in front of a steering wheel, and the autonomy to literally speak where they want to go.

Another very important issue with the implementation of autonomous cars, is the reduction of the incidence of traffic accidents, thus reducing the number of disabled people that are the result of these accidents, since these vehicles will be autonomous aiming at driving safety, eliminating the factors sleep and tiredness of the equation.

In other words, this project's main objective is to provide unrestricted mobility for people with special needs, then to share these vehicles, which can be used in clinics specializing in the treatment of people with needs, but as mentioned above, this initiative goes a long way. besides just helping them. It is an aid to the whole society.

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