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ScienceDirect

Procedia Computer Science 115 (2017) 375–382

Procedia Computer Science

www.elsevier.com/locate/procedia

7th International Conference on Advances in Computing & Communications, ICACC-2017, 22-24 August 2017, Cochin, India

A Study on Implementing Autonomous Intra City Public Transport System in Developing Countries - India

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Abstract

The rise of autonomous vehicles (AV) will revolutionize the transportation industry and it will transform the society itself, much like the nineteenth century shift from horse-carriages to automobiles. The automobile industry as well as governments/authorities all around the world are trying to create vehicles and road traffic infrastructures to support this futuristic public/private transportation technology. In our paper we are putting forward a feasible method of implementing the autonomous vehicular technology in a developing country like India as a public transport system in itself or as a feeder system to public transport systems like metro by using the concepts of safe state and kill switch.

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Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances in Computing & Communications.

Keywords: Autonomous Vehicles(AV); Safe State ; Kill Switch; Feeder Road; Release issue;

1. Introduction

Fully autonomous vehicles (AV) are defined as vehicles capable of completing journeys safely and efficiently, without drivers, in all normally encountered traffic, road and weather conditions. The developed countries are the front runners in the research and implementation of this technology. The developing countries due to their lack in a

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1877-0509 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances in Computing & Communications
10.1016/j.procs.2017.09.093

well-organized road infrastructure have largely laid behind in this technological race both at the technological and government/authority level.

1.1. Need of AV's in Developing Countries

The AV technology when implemented will drastically reduce the number of road accidents, will provide better traffic flow, will have more efficient fuel consumption and also will reduce environment pollution. All these advantages will help the people of developing countries to have a better and healthier life. Available statistics show that most number of fatal road accidents happening in developing countries are caused by the negligence of drivers, which can be avoided or drastically reduced by using AV. In all the surveys conducted so far by different international agencies, people from developing countries are more willing to accept and try AV than their counter parts from developed countries. All these factors show us that the possibility of implementing AV in developing countries like India is something which needs to be considered and tested.

1.2. Difficulties in implementing AV in Developing Countries

The common difficulties faced by the government/authorities and private companies if they try to implement AV in developing countries are absolute lack of standardization in road infrastructure, poorly planned road network, lack of lanes and road barriers, lack of on-ramps and exit systems, lack of directional, informational and warning signals, abundance of potholes and random speed breakers, poor mapping of roads and locations of interest, free-for-all, democratic access to roads for motorized and non-motorized vehicles, animals and pedestrians . All the currently existing algorithms which are being used and under research in the field of AV require very structured set of road traffic/infrastructure to work as they are intended to be used in developed countries where everything is well structured. Another issue which is typical in developing countries like India is the possibility of unemployment due to an autonomous technology replacing a human worker.

1.3. Solution

The objective of any transportation system in a developing country should be to create a system with minimum cost that is safe and reliable and which minimizes its adverse effect on the environment [19]. The system is composed of various elements: the infrastructure itself, the norms for access and use of the infrastructure and the vehicles that move on the infrastructure [19]. The AV require a structured infrastructure of road traffic, which currently do not exist in most developing countries. To wait for such kind of an overall change in road infrastructure for implementing AV will not be practically feasible, so our suggestion is to use the existing infrastructure with minimum modifications at certain critical roads/lanes of the city road traffic to implement AV as a public transport mode of transportation. . This mode of public transport system can also very effectively be used as feeder transport system to other more huge public transport systems like metros and trains in bigger Tier I & Tier II cities [15] .This will help in improving the resident's quality of life in developing countries and will also aid in more creative research into this field of huge importance in developing countries. This kind of public transport system even though is autonomous and does not require human beings in its running, will create technical employment opportunities in the manufacturing and maintenance phase of AV. It will also require people as back up drivers and to coordinate the transport system when it is implemented.

1.4. Advantages

The advantage of this approach is compared to European or American cities where roads have a structured infrastructure which has to be considered when trying to implement such disruptive technologies like AV, the critical road/lane in a developing country can be modified or structured according to the infrastructural requirements of an autonomous vehicle which will run on it. This kind of public transport system can also reduce the huge investments which are planned in most of the modern developing Tier III cities [15] with completely new infrastructures like metros, hyper lopes, trams etc. Instead of this kind of new infrastructure based public transport systems, take a very

critical road/lane in a viable part of the city and implement with minimum modifications an infrastructure set up which will help an autonomous vehicle to run along cities. Instead of expanding metros AV can be used as feeder systems in Tier I & Tier II cities [15], thus reducing the investments drastically. This mode of public transport system is hugely flexible as it can be easily expanded to different roads/lanes with minimal time requirements and can also efficiently satisfy the dynamic demands of the traffic system by increasing the frequency of vehicles on the go. Other major advantages of AV in an urban scenario are that the accidents will reduce and it will make the urban traffic system more efficient by reducing the fuel consumption, making the traffic flow more deterministic and by reducing the parking area requirement. It also promotes vehicle sharing as more people will start using public transport systems. The implementation of this mode of advanced and futuristic transport system will make the cities in developing countries more environment friendly and organized , thus in totality increasing the quality of life of people living there.

1.5. Organization of the paper

This (1) introduction part of the paper is followed by a (2) literature survey on the status of autonomous vehicles in developing countries then there is a discussion on the (3) Current intra city transport systems in developing countries. These sections are followed by the details of the (4) Proposed System and then the (5) Implementation Methodology. Finally the paper ends with a (6) conclusion. This is followed by acknowledgments and references.

2. Literature Survey

2.1. The Test kilometers issue

One of the most important challenges currently facing the large scale adoption of autonomous vehicular mode of transportation by different governments and authorities is that it is very difficult to prove that the autonomous vehicles are really safer than the currently existing method of transportation by real time testing [1]. Extensive testing on public roads is essential for developing and evaluating AV, given their great complexity and the diversity and the unpredictability of conditions in which they need to operate [3]. The theoretical values of test kilometers calculated for this in developed countries like Germany is around 6 billion kilometers which are based on the data of number of fatal accidents happening per 100 million driving kilometers [5]. This seems to be practically impossible in near future.

According to latest statistics of World Health Organization (2015) India has approximately 16.6 deaths per 100K people per annum, which is very high compared to developed countries in European and American continents which have around 5 to 6 deaths per 100K people per annum [12]. There is very little information on the number of fatal accidents happening per driving kilometers in India. Road injuries are ninth major course of death as per the GBD 2013 Mortality and Causes of Death Collaborators, 2015[8].According to the data available from road safety status in India status report, 2015 the approximate kilometers an autonomous test vehicle has to run in India without accidents to prove that it is safer than the current non autonomous vehicles will be around 5 lakh kilometers [11]. This value is much lesser and feasible than the values obtained in developed countries like Germany. But the infrastructure of the roads in India are not suitable for fully AV as they are less structured and as of now AV can run only on well-structured road infrastructures. The advantage of implementing AV in developing countries like India is that we will be able to design AV with reduced speed requirements as it will fit to regular speeds in less structured roads and the kilometers required to prove the technology will also drastically reduce.

2.2. Consumer Surveys

Another important data which supports the implementation of AV in developing countries is the reaction of consumers to self-driving vehicles. According to a survey conducted by Boston consulting group in 2015, around 75% of surveyed Indian people were ready to try a self-driving car which was very high compared to most other

developed countries. In a survey conducted in Pakistan more than 50% where ready to try self-driving or autonomous vehicles [4]. Again around 80% of Indian consumers were willing to switch to a car from tech companies like Google & Apple based on a survey by Capgemini. All these indicate to the fact that AV should be tried out by government/authorities and by private companies in developing countries like India.

2.3. AV current status – International

The Society of Automotive Engineers (SAE) defines six levels of automation for on road vehicles starting from Level 0 (no automation) to Level 5 (Full Automation) [14] .Level 1 is defined as driver assistance, Level 2 as partial automation, Level 3 as conditional automation and Level 4 as high automation. Until Level 2 driver is assigned with dynamic driving tasks with automation aiding him in doing it. From Level 3 onwards system will take over the dynamic driving task with human driver acting as a back-up. In level 5 there will be no human driver involved as all driving related tasks will be performed by the system without any support from the human driver. Most of the car manufacturing companies are currently providing Level 2 autonomy at international level. Level 3 and Level 4 is being hugely researched and Level 5 is something for the future with even tech companies like Google, Apple along with Uber, Tesla and other automotive giants all trying to find solutions to problems in this level. The German Highway Institute (BASt) defines only five levels of autonomy by taking Level 0 of SAE as Level 1 and avoiding SAE Level 3 altogether.

Many cities in developed countries are trying to implement the AV or intelligent transport solutions on their roads as public transport systems by providing supportive infrastructures and city roads. City Mobil2 was an interesting project which implemented an automated road transport system to run for six months at five sites across Europe from 2011 to 2016 [18]. The cities involved in this project prototyped and tested autonomous vehicles which can carry up to 12 passengers and achieve speeds up to 40 km/hr. [18]. Helsinki, Austin, Los Angeles, Nashville, Washington DC, Buenos Aires, São Paulo and Tel Aviv has started a global initiative aimed at enhancing the ability of cities for the emergence of autonomous vehicles [7]. They believe that planning for the intelligent transport solution will enhance resident´s quality of life and improve social challenges. There are around eighteen cities whole around the world who are doing self-driving vehicle testing and deployment [17] .The only presence of cities from developing countries are Buenos Aires, São Paolo and Tel Aviv, but they are only in the planning phase and nothing has been achieved in the implementation front as of now. According to a survey in United Kingdom shared AV could increase available urban space by 15 to 20 percent, largely through the elimination of parking spaces [6].

The four trends changing automotive competition are radically new technologies at low prices, fastness of the new entrants in automotive market, new mobility concepts of increasingly urban customers and evolving regulatory policies by Governments/Authorities [6]. The field of autonomous vehicles at the international level is a very competitive and evolving field with disruptive players like Google, Apple and Tesla, trying to directly implement fully autonomous vehicles and the automobile giants like Daimler, Volvo, Hyundai, Ford, Audi, etc. trying to implement autonomous features into their vehicles in a step by step manner.

2.4. AV current status – India

Even though India is the fourth largest vehicle manufacturer in the world according to the data of 2016, there has not been much happening in India when it comes to AV both at the Government level and in the private sector [9, 10]. There are small steps being taken by both these parties lately i.e. around the mid of 2016. In order to aid industries the testing of autonomous vehicles, the Indian government has proposed amendments to the motor vehicles law which will empower the government to permit the testing of such vehicles. The government is planning to allow testing of these vehicles on a case-by-case basis once the law is in place. The new provision is part of the Motor Vehicles (Amendment) Bill, 2016, which had grabbed headlines for its focus on safety and hefty penalties for traffic violations. The move will allow Indian carmakers and technology firms to join the global race to develop self-driving cars. The Bill has been referred to a parliamentary standing committee. Once cleared, any innovation in transport sector such as

semiautonomous and fully autonomous vehicles, both passenger and commercial, could be tested in India. Such tests will require the permission of the transport department of the union roads ministry.

The two private sector companies who are working in the domain of autonomous vehicles in India are Mahindra and Tata; both have not put much details in public domain. Tata Elxsi, the Tata Group's design and technology firm is said to be testing a prototype model by integrating autonomous features into Tata´s already existing models of vehicles in Bangalore, India according to unconfirmed paper reports. Mahindra is trying to implement autonomous features in their tractor models which of course has fewer technical requirements compared to cars and other types of vehicles. Educational institutes like Indian Institute of Technologies (IIT) and private universities like Manipal Institute of Technology (MIT) are also working on certain prototype models in their campuses. In cooperation with Aalen University (Germany), Rajagiri School of Engineering & Technology (Kerala, India) & Kerala Technical University (Kerala, India) are preparing an initiative for metro feeder traffic using self-driving vehicles.

3. Current intra city transport systems in developing countries-metro

One of the most common and hugely popular intra city traffic system being used in almost all developing countries today is the metro rail system. Estimated cost for various metro projects and time of execution is shown in Table 1

Table 1. Cost & Time Information of metros.

Metro Name	Cost (in Cr. ₹)	Cost (in Mio €)*	Time Frame(years)
Delhi Metro – Phase I	10,571	1,510	4
Delhi Metro- Phase II	18,783	2,683	5
Hyderabad Metro – Phase I	15,957	2,280	5
Bangalore Metro- Phase I	14,405	2,058	5
Bangalore Metro – Phase II	27,000	3,857	6
Kochi Metro- Phase I	5181.79	740	6
Kochi Metro- Phase II	2,024	289	5
Lahore Metro	10,000	1,429	2

*→1€=70 ₹

All the currently existing and implemented intra city transport systems in developing countries like India require huge infrastructural investments and time for implementation. Metro is the most popular mode of public transport implementation which is being used in most of the cities in developing countries. Metro is financially viable for very big cities (Tier I and Tier II) but for the smaller ones like Tier III and for extensions/feeders to the main public transport systems it will be a huge financial burden for developing countries as is evident from the table shown above. Metro is a current technology and not a future one but autonomous vehicular traffic is something for the future so investing in a future technology should be more profitable in the long run rather than on the one that is currently existing. Metro is a rail based system which covers large areas of city and construction happens in parallel which creates a lot of inconveniences to the commuters and citizens of these cities during the construction time. Metro can never be implemented as a door to door traffic system and it also requires huge parking areas near stations if it has to be really effective. Finding a huge parking area in the center of a city in a developing country like India is quite infeasible both in terms of practicality and in terms of financial viability.

4. Proposed System

The proposed method of intra city transport system using autonomous vehicles will help the developing countries to leap forward in transportation technological advancement with minimum possible investments. The idea as mentioned in the introduction part of this paper is to convert an important road/lane in the city to autonomous vehicular

traffic with an infrastructure supporting safe state concept as a starting point in Tier III cities. In Tier I & Tier II cities use autonomous vehicles in the feeder roads to metros to avoid more investments on infrastructure for further metro extensions. Once the autonomous vehicular technology becomes provable and safe in this one road/lane it can be easily expanded to more roads.

A private sector company/university can prototype and develop an autonomous vehicle which will run on the road/lane which has to be transformed according to the requirements of the autonomous vehicle. This will aid companies/universities in their study of autonomous vehicular technology and they will be able to fund the project in a huge way. Instead of implementing a completely new infrastructure base, start with small modifications on the existing road traffic system with as much minimal changes as possible. In the initial stage of development humans must be used on a standby mode for dealing with any critical scenarios which might come up, further increasing the safety of the whole system and also providing an employment opportunity to people.

The commuter on this road/lane will get into an autonomous vehicle provided by a service provider and will be dropped at an end point or a stop on the way. The autonomous vehicle in this road/ lane should be a battery powered electrical vehicle. This will drastically reduce pollutions due to emissions and noise. Since AV will travel between well-defined places charging centers will be easy to implement. The vehicular speed can be kept at a minimum as speed requirements in such road/lanes will be low, thus making the system more safe and viable. It can be implemented as a pilot project in one of the roads/lanes and then expanded according to the requirements. The autonomous lane can be made in such way that only AV will be allowed to move through this lane, thus making the whole system very deterministic with respect to time. The AV based system will have central monitoring station which will help in tracking the safety and efficiency of the system by dynamically varying the frequency and time of arrival and departure of AV running in this lane.

4.1. Advantages of the proposed system

The development cost of this method of public/private transport system can be very low compared to any other methods currently existing in developing countries. The second major advantage will be the energy saving and pollution control that can be achieved as these vehicles can be designed with very stringent energy and pollution control requirements. This implies that AV based public transport system can be very ecofriendly compared to any other transport systems. The third one and the most important one is that this will allow future technologies to enter into developing countries in the most viable way. The AV based public transport system as of now is incapable of replacing large public transport systems like metros and trams but they can surely support them in an effective way. They can be very effectively used as feeder transportation systems to bigger public transportation systems like metros. This will help to increase the number of people using these public transport systems even from the outskirts of the city, thus reducing the pollution and parking problems associated with private vehicles. It will also aid in the research and testing of a promising advanced transport technology which can be very useful for developing countries. An AV based public transport system is a very flexible and dynamic system as the number of vehicles and frequency of vehicles can easily be adjusted based on real time demand.

5. Implementation Methodology

The implementation and release of AV requires it to meet all safety standards [2]. Our suggestion to solve this issue is to introduce the concept of safe state that is whenever AV faces critical scenarios move it to a safe state designed with the help of infrastructure. Make sure that there is a possibility of movement to such states provided by the infrastructure (Like the third line concept of Autobahns in Euro rail systems). The safe state concept will enable the automobile makers to create AV and prove that it can be practically released into real world scenarios. Details will be

developed during the planned initiative by Aalen University (Germany), Rajagiri School of Engineering & Technology & Kerala Technical University.

The release issue or to prove that AV can deal with all possible environment scenarios is something which is hugely researched all around the world. Once the safe state is implemented at the infrastructure level the test case scenarios can be relatively reduced as lots of test cases can be grouped together and the proof required will be movement to safe state rather than any action. Along with this we have the kill switch option which is an ability to externally move the vehicle to safe state, so altogether both these features will make the autonomous system a very safe and provable technology. The European Union has already made legislations to include a kill switch option in all systems which use artificial intelligence [13].

The major technical advantage of this method of implementation is that for all the safety critical cases instead of going back to the driver in the case of driver assisted autonomous vehicles, it will look for an infrastructure setting which will help the vehicle to move to a safe state. The safe state can be defined and build in such a way that it will work when anything and everything of AV fail. The safe state can be either automatically attained due to some critical issues or can be forced upon the vehicle by a higher authority using the kill switch option.

Some of the viable modifications of infrastructure for implementing safe state can be a physical marking on the road which can be easily detected by a sensor set on the vehicle and moving the vehicle to the most nearest parking slot available on the road. The vehicle which is in a safe state can also give out visual and sound warnings for the other AV similar to a safety car concept in F1 racing. With the availability of humans as staff in these areas of autonomous vehicular implementations, the system should be very safe for the commuters inside these vehicles. Another implementation option simpler in terms of infrastructure, will be for the vehicle to just stop. This will require the other autonomous vehicles to overtake it and move forward. The autonomous vehicle will then be taken care by a human driver. An autonomous vehicle coming from behind can move the vehicle in the safe state by docking it with itself and pushing it forward to a safer place. This is similar to the vehicle platooning concept which is currently being tested out by all European truck companies.

5.1. Case Study – AV as feeder vehicles to Kochi metro

Kochi is the industrial and economical hub of Kerala. Kochi is the first metropolitan state in Kerala where a metro based rail system has been constructed and is currently almost ready to start operations. Kochi is a very vibrant city with a population of around 2.3 Crores and having the highest density of population in Kerala. According to Road accidents in India 2015 data from govt. of India, Kerala ranks third among all the states in India in death caused by road accidents [11]. Kerala has seen an increase of 20% in the number of road accidents from year 2015 in the year 2016 as per the data presented by Deputy General of Police (DGP), Kerala Loknath Behra According to the data available from Kerala police regarding road accidents in 2016, Ernakulam city area which includes Fort Kochi has witnessed 2573 accidents from 01/01/2016 to 31/12/2016. Another important data which proves the need of AV is that out of the 4287 deaths caused by road accidents in Kerala state in the year 2016, 3659 was caused due to the fault of the driver which is 85.5% of the total deaths caused by road accidents [16]. There has been a steady 5% decline in the use of public transport system in Kochi city in the past 3 years according to Kochi Metro Rail Limited (KMRL) data of 2016. It is in this context that we propose the use of autonomous vehicular corridor in some parts of the Cochin city. Metro and AV as feeders will drastically reduce the accidents on the roads which are mainly caused by the fault/negligence of drivers and will also encourage people to use public transport than private transportation option.

The one corridor under study for this is the Fort Kochi to Jose Junction corridor. Fort Kochi has the maximum number of roads, mostly narrow in nature, due to presence of several heritage properties and thickly populated areas. The practical advantage in implementing an AV based feeder system in this corridor is that it has two parallel bridges of which one can be used for AV implementation without much infrastructural changes. Extending metro to this part of the city will cost a huge amount of money due to the water bodies around it. In this context we find this corridor to

be ideal for an AV feeder transport system implementation. In order to keep the infrastructural changes minimum a lane based AV implementation on existing roads can be tried. This will keep the infrastructural cost and time requirements at the minimum. This lane should have only AV running on it and should be separated from other non AV motorists.

6. Conclusion

In this paper we have proposed a public transportation system for implementing AV in a developing country like India. We have listed out the need and advantages of such kind of a public transport system in India with enough statistical data. We have also proposed a viable corridor in Kochi city where an AV based feeder system for metro can practically be implemented and the reason behind the selection of this corridor.

Acknowledgements

We would like to express our heart full gratitude to Aalen University, Germany for providing us an opportunity to work in the field of autonomous systems at their research center. I would also acknowledge my parent Institution Rajagiri School of Engineering & technology, Kerala India for allowing me to do my research activities in Aalen University, Germany.

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