Information and Communication Technology in Urban Electric Transportation

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***Abstract* — This paper is a first attempt at assessing the impact of information and communication technology in transport, with an accent on electric public transportation. Information and communication technology is present in all spheres of human activity. Transport systems are made of vehicles and infrastructure. Modern vehicles are filled with complex technology, such as electric drives, mechatronics, artificial intelligence and information and communication technology. And the infrastructure currently numbers only the roads and traffic lights, but the evolution of things leads to Intelligent Transport System. A technology that would connect vehicles and infrastructure to make transportation on land safer and more efficient. Electric vehicles require special attention to motor control. Power converters driven by intelligent modules allow an efficient control of the motor. A series of electronic systems for trolleybus and tram control, the SDMC, were made in Chi□inău by the Informbusiness Company. The SDMC systems are intelligent system, built on microprocessors and CAN communication protocol. Modern ICT technology allows simultaneously to ensures diagnostics, monitoring and protection of all components; to store the current state of the elements; to provide information means for the driver and passengers and ensure good function of complex control algorithms. Information technology is present also in intelligent transportation systems with smart or even driverless vehicles. Technologies such as GPS and Wireless Networking allow optimizing urban transport, and are basic stones in the future of transport, which includes Intelligent Transport Systems and Driverless vehicles.**

Keywords*: electric vehicle, information and communication technology, control, communication protocol, efficiency, intelligent transport system, driverless vehicle.*

1. Introduction

Information management is collecting, transmitting, storing and processing information. Information technology (IT) is a technology of information management based on computers. Since the development of networks communications between computers became an undividable part of IT, thus it is more common to refer to as Information and Communication Technology (ICT).

In present, ICT is present in all of human activities; it has transcended the limited use of technology and now may be referred to as an undividable part of society.

The computer is an electronic device, which is programmed to carry out sets of logic and arithmetic operations. Subsequently a computer based information system consists of two parts: hardware and software. The hardware is the system of physical devices which form the computer itself, but which cannot function without the second part – software. Software is the program that processes information and the operating information itself.

An isolated computer has naturally limited access to information, while a network of computers can exchange information (Fig.1). The data transmission can be made through regular cables or wirelessly. There are many types of networks [1], some of those are: Local Area Network (LAN), global network (Internet), or Controller Area Network (CAN).

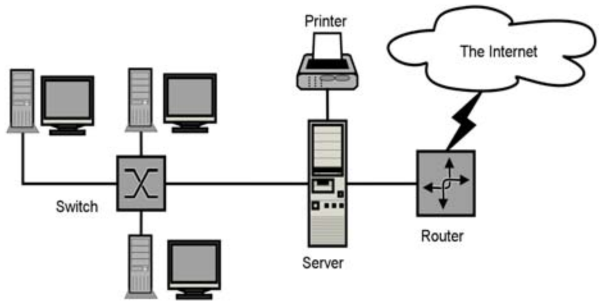

Fig. 1. Local network connected with a global one, the Internet.

The software and hardware combine to make the most performant device in human history. The performance of the computer system depends on each part's performance individually, and theirs is in turn interconnected. For example to have a fast processing of a complex program one needs to have performant hardware: a high frequency CPU and memory to match it. However, a well designed and engineered software can make best use of available hardware [2].

One of the most prominent field derived from the science of information technology is robotics [3]. Robotics is the field combining mechanical and electrical engineering, and computer science. It focuses on the design, construction and application of robots; and computer systems for their control, including feedback from sensors and information processing. In modern industry (Fig.2) and agriculture, processes tend to be more and more automatized, which means a wider use of robots and automation systems. ICT and information management plays a vital role in robotics. The data gathered by sensors must be transformed into information and processes in order for the actuators, usually electrical machines, to do their job properly and to maximum efficiency.

In the area of robotics and ICT was started the concept of Artificial Intelligence (AI) [4]. This concept is described as designing and engineering machines capable of intelligent response to external factors.

The advantages that come with vast implementation of information technology in all of human activities are based on processing and transmitting information. Ultimately, this leads to increased efficiency of processes in common spheres like economy, medicine, education, industry, transport and day-to-day life.

Fig. 2. Industrial robots in automated processes.

Information technology is present in all human activities and industrial spheres. Its range includes fields like economy, management, education, transport, industry, daily life, medicine and many more.

ICT is so versatile due to the technologic advancement in the field of computers and electronics. The hardware capability of computers is enormous and the networking allows offices and people from all the world communicate and work faster, together.

One of the most impacted spheres of human society by ICT is the economy. With the development of network communications [5], the economy evolved from industrial to networked economy. The developing factor is the infrastructure, specifically computers and networks. Informational systems allowed a faster, wider and more efficient communication in trade. Networked economy uses enhanced, transformed, or new economic relationships based on computer connectivity and human knowledge.

A newer part of ICT in networked economy is the mobile phone. These devices have evolved to a level, where they can be addressed as pocket computers. New telecommunications technologies, like 3G and 4G, allow phones to transfer data at an estimated 100 to 300 Mbps [6]. In 2013, Gartner estimated the worldwide mobile payment transaction value to surpass $235 billion [7].

A vital part of human civilization greatly improved by ICT is medicine. With the help of modern tools and equipment based on electric devices and computer control. Doctors are now able to help people in ways never imagined before. Some of the most known modern medical devices are the X-Ray scanner [8] and MRI (Fig.3) [9] (magnetic resonance imaging). These devices helped greatly in diagnostics of human conditions without the need of invasive surgery, thus saving millions of lives since their discoveries.

Another important field that the ICT has greatly influenced is the automotive industry. Nowadays cars have computational devices that drive electric motors or just manage and process information from sensors in every element of a vehicle. This also applies to electric city transport. Vehicles like trolleybuses, trams and subway trains all have implemented intelligent control systems. Considering that the total traction motor power engulfs a wide range for city electric transport: from 100 kW, for trolleybus, to 200 kW, trams, and 750 kW, for subways, [17, 22, 23]; the appropriate control systems have to be quite different and versatile. The powers of the vehicles alone demand special attention. If these vehicles were to function inefficiently or have bad protection systems, they could firstly endanger the passengers, and secondly cost a lot of unnecessary financial losses.

Fig. 3. MRI Machine.

The aim of this paper is to present the different means of contribution of ICT in electric vehicles, based on current achievements worldwide and locally; and foresee how it will change the concept of passenger transportation in the future.

2. ICT IN ELECTRIC VEHICLES

Modern vehicles can be based on different kinds of energy. There are three distinct categories combustion engine, electric and hybrid. Besides the traction motor, many other pieces of equipment make the vehicle work. In today's car there are also many sensors, electric motors and computers. This makes modern vehicles safer and more comfortable to ride.

As part of a vehicle's electric system, there are sensors, which collect data (Fig.4) [15]; electronic control units (ECU), they process information and give commands; execution devices, like lights, speakers or electric motors; and communication equipment.

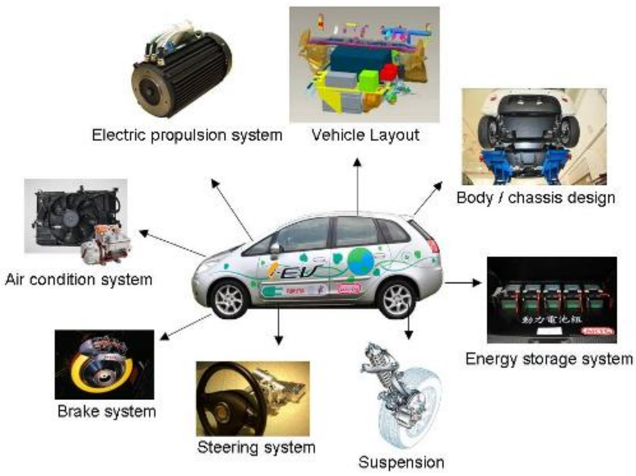

Fig. 4. Main systems of a vehicle a vehicle.

The information system existing in the vehicles includes data transmitting and processing. For data transmitting there are different technologies, such system as the CAN and CAN bus (Fig.5) [13]. Microcontrollers are dedicated computational devices of limited functions, which are perfect for applications with narrow specifics [14]. Microcontrollers process data, while the bus ensures data transmission between network access points. At any time in the CAN bus may be as many as 2000 signals, which microcontrollers can access at any time [12].

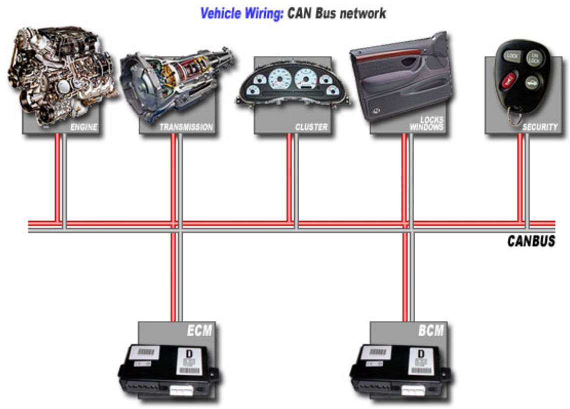

Fig. 5. Example of an information system with CAN bus communication protocol.

The sensor system of a car has mainly safety and legal objectives. A car must always monitor the emissions, as to not be extra-polluting, according to the law. Sensors also monitor vital car parameters like oil pressure, engine and coolant temperature or exhaust emissions. If some of these parameters are outside of admissible ratings, the driver is informed through visual and audio signals. Modern information systems also store the acquired data, for later analysis by specialized personnel. This allows specialists to analyse and determine the cause of technical issues, and remove any abnormalities of a car's functioning.

Besides safety and legal reasons, there is also the luxury motive in car electronics. Rolling windows, parking sensor, air conditioning; functions such as these make travelling by car very comfortable, and less tiring.

Traction control is a matter of efficiency and power. This makes monitoring and controlling the function of the engine vital. In combustion engines and in electric motors different factors affect the torque and performance of vehicle movement. For combustion engines fuel and oxygen proportion and timing of injection lead to the magnitude of developed torque and rotation speed of the shaft. A specialized controller the timing and dose of fuel injector, according to a programmed diagram, and depending on the level of gas pedal.

For electric cars, torque control is a different task entirely. One of the reasons for that is the multitude of electric motors types [16, 18] and different methods of control. In electric vehicles the most commonly used electric motors are the Asynchronous Motor (AM), Brushless Direct Current Motor (BLDC), Direct Current Motor (DCM) and, recently, Switched Reluctance Motor (SRM) [17, 30]. The particularities of each of these motors require for individual electronic devices and control algorithms of voltages and currents to have a quality control of torque [19].

Of all electric motors, the one to be spread the most in public electric traction, is the AM; while for personal vehicles the more common one is BLDC. The reasons for this trend are high energy density, reliability and efficiency, with appropriate control. The difficulty in implementing AM and BLDC for traction is they require intelligent control. Basically they require extra electronic devices and a more sophisticated software engineering for control.

Present electric motors are mostly used in electric drives, which include also electronic converters. The electronic converters are the devices feeding the motor. The basic construction elements for converters are semiconductor devices, such as transistors. The computational device controls the state of semiconductor devices, which in turn set the voltages and currents through the motor. The voltages and currents of the motor make the motor function as required by the driver or the programmed computer.

The most forward control method for the AM is Field Oriented Control [20], though Direct Torque Control is catching up fast due to its easy application in traction.

As for the BLDC, the inverter has to operate in such a form, that the succession of triggered semiconductors make the optimal rotor speed, at required torque.

Electric vehicles also require management of power supply. For autonomous electric vehicles, there must be an intelligent power management system that would monitor and balance the charge of batteries. An unbalanced battery system for electric vehicles causes malfunctions and faster deterioration of individual batteries. For vehicles that do not have an autonomous power source, like trolleybuses and trams, there needs to be permanent monitoring of supply voltage. Fluctuations of supply voltages may appear of many reasons, and if the vehicle is not protected, it may be damaged.

An informational system present in many vehicles nowadays is the GPS (Global Positioning System). It allows a device to determine its relative position on the globe, in reference to several satellites and a stationary point on Earth. Modern vehicles have built-in computers and displays which have the option of GPS navigation. For public electric vehicles a GPS system is useful by determining and exact position of the vehicle, information that passengers can access freely.

Fig. 6. Driver's informational panel on Tesla Model S.

ICT is also present in vehicles in media form: displays, audio systems, cameras and interactive displays (Fig.6). In public electric vehicles displays are used to show commercials, which can add revenue to the administration of public transport; and audio devices are used to inform passengers about the route, or simply play ambient music.

Some of the most advanced and popular electric cars made are Tesla company's products [21] (Fig.7). Besides advanced traction control using two motors, it has a very advanced form of autopilot. Its computer can analyse the surroundings on the road with a radar. The benefit of it is that the computer can determine the surrounding regardless of visibility factors like fog and rain. Besides the radar, the Tesla car has video cameras with image recognition and a 360 degree sonar. All these systems were implemented to make possible the autopilot. A computer that knows the surroundings, with appropriate algorithms, can drive without the action of driver.

Fig.7. Tesla Model S.

Tesla cars, along with an overwhelming majority of hybrid or pure electric vehicles, use BLDC [30]. The functioning of these motors is useless without an inverter and intelligent control. Intelligent control allows developing exactly the necessary mechanical characteristics at the shaft of the motor, so the vehicle moves accordingly to the driver's action on the gas pedal.

3. ICT IN URBAN PUBLIC ELECTRIC TRANSPORTATION

Information technology touched all the elements of command system for electric city transport. Elements such as the control of the electric motor traction system, diagnostics, system monitoring and passenger information are some of the most common. These elements are widely implemented in common urban public transport such as trams, trolleys and metro.

Modern transportation systems also monitor the electric vehicles through GPS, be it on rails or road. Such a system allows better control and management of transportation, which leads to better efficiency, reliability and safety. In public transport, it is important to have efficient vehicle control. Due to the large number of vehicles in city transportation, total energy consumption can raise very much. For people to use public transport, the cost of travelling by public transport must be reasonable.

There are still regions, where electronic control is not yet fully implemented for public vehicles [17]. In this situation, it is acceptable to upgrade only the control system and not the entire fleet of vehicles. Modernizing electric vehicles with electronic control decreases energy consumption per vehicle by 30%.

The team at "Informbusiness", a company in Chi□inău, developed its own control systems for electric city transport - the SDMC series [34]. These control systems were developed mainly for trolleybuses and trams, on AC or DC motors. The SDMC is an intelligent modular system (Fig.8), with CAN bus communication between the modules. Each module has its own Fujitsu microprocessor on 32 bit Fujitsu, such as the traction control processor MB91F467 [26].

Fig. 8. SDMC-103-03 trolleybus control system.

The SDMC system is divided in two parts: the power module, and peripheral devices. The power module is an intelligent system, whose main task is the control of traction and monitoring of the power system inside the vehicle. The most advanced control system is used for AC motors. The motor is controlled with Field Oriented Control (FOC) [30] algorithms, which ensure a precise control of torque when accelerating or braking, and also has implemented the regenerative braking feat. The monitoring of the power system goes from the supply lines, to the inverter and, lastly, to the motor. For a fast response, the functions of traction and monitoring are done by separate processors from Fujitsu [26]. The monitoring processor evaluates the state of the system non-stop and performs protective measures if necessary.

The most advanced system at Informbusiness is the SDMC-103-03. Its main features are:

- Dual-core modules with MB91F267 and MB91F467 processors
- The power module is controlled by the MB96F356 processor
- LCD graphic module with JADE MB86-R01 video processor
- CAN communication protocol inside the system
- FOC for traction AM

Fig. 9. PBG on-board driver's panel.

Currently the SDMC-103-03 control system works with the PBG (Fig.9). PBG is an on-board panel based on Fujitsu graphic microprocessor [29]. It is a technology of software development on Windows, CE and Linux operating systems. The panel has a JADE MB86R-01 processor, dedicated to graphic software [26]. The PBG module permits the connection of media peripherals like analogue cameras and speakers.

Currently there is an experimental graphic module being developed, based on LIME processor (Fig.10). It is designed to be compatible with older communication systems and graphic modules. The graphic core processor is graphic display controller LIME MB86276 of Fujitsu [29]. The display used for the nw pannel is TFT LCD 8.4" Hitachi display.

Fig. 10. Experimental on-board panel based on Fujitsu "Lime" MB86276.

One of the most important features that the SDMC-103-03 trolleybus control system has is the advanced control. The engineers have designed the system to feed a 3 phased AM, through an inverter, and controlled with FOC (commonly referred to as vector control) method [20].

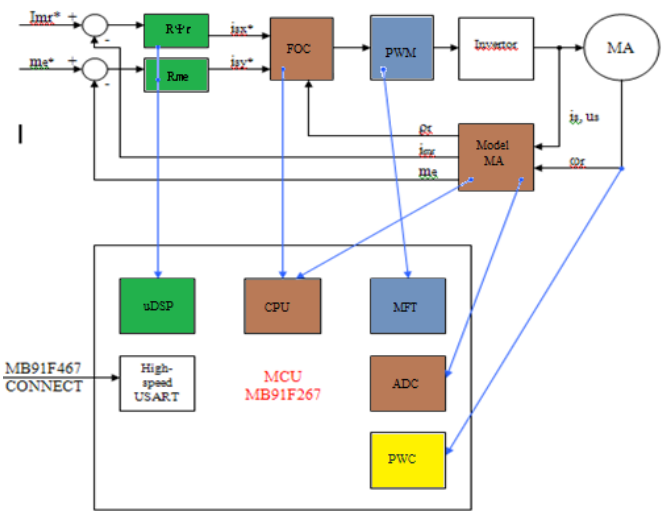

Fig.11 Division of MB91F267 processor resources in FOC.

The division of the MB91F267 processor's resources to control (Fig.11) are as follows:

- ADC converts analogue signals into digital
- MFT – multifunctional timer that forms a high frequency PWM
- PWC – calculates the speed of the rotor
- uDSP – PI control
- CPU – state observer of Model MA and FOC controller
- Flash memory – storage of software
- RAM – storage of variables and motor parameters

CAN bus requires a CAN controller on each node of the network (Fig.12). The microprocessors from Fujitsu are connected to the CAN network through an MCP2551 chip. The MCP2551 is a high speed CAN transceiver, whose main function is to decode the data on the CAN bus into a form that the processor can understand. In the case of SDMC equipment, there are 2 CAN busses, of which one is for back-up.

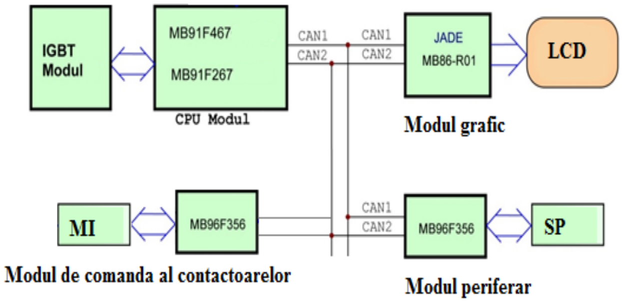

Fig. 12. The communication system of SDMC103-03.

The SDMC control system, is meant to be an efficient and reliable piece of equipment. Besides its basic functions, the SDMC is designed and programmed to improve the comfort of travelers in riding, but also with information. Some of the comfort factors are:

- Setting optimal control and energy consumption
- Eliminating inertial shocks
- LCD information pannels for passengers
- AUDIO speakers information
- Implementing Wi-Fi acces to internet (testing)
- GPS monitoring of public transportation, with internet acces (testing)

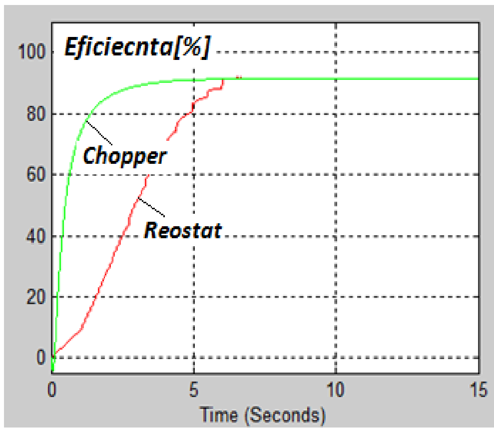

Fig. 13. Efficiency of electronic and rheostat commands.

Comparing to the classic rheostat command and DC drives, which were used almost exclusively a few decades ago, modern control algorithms present the advantage of higher efficiency and reliability. The graph shown in Figure 13 represents the efficiency of DC traction with an electronic control, of the SDMC-103-01; and old rheostat command previously implemented in the same ZIU-9 trolleybus.

4. Intelligent Transportation System

A more progressive use of ICT in electric transport is V2X communication (vehicle-to-x). It includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrian (V2P). In combination with GPS technology, V2X leads to create Intelligent Transportation Systems (ITS) (Fig.14) and driverless vehicles [31, 32].

Fig. 14. Intelligent transportation system.

Intelligent Transport Systems and Services (ITS) refers to the integration of information and communication technologies with transport infrastructure with the aim of improving economic performance, safety, mobility and environmental sustainability.

One of the main problems of today cities that ITS was aimed to solve was traffic. Due to constant traffic congestion, especially at rush hours; vehicles can be on the road for hours. This is inefficient use of fuel and time. ITS can process the data on the roads and optimize transportation.

Another point of interest for ITS is safety insurance. With the help of tens of sensors each new vehicle becomes individually more safe. But this does not mean that it can react to any unforseen situations. With communication between vehicles (Fig. 15) and infrastructure ITS can inform vehicle's computers and drivers of possible warning on the road so the driver can be aware and act accordingly before the harm is done.

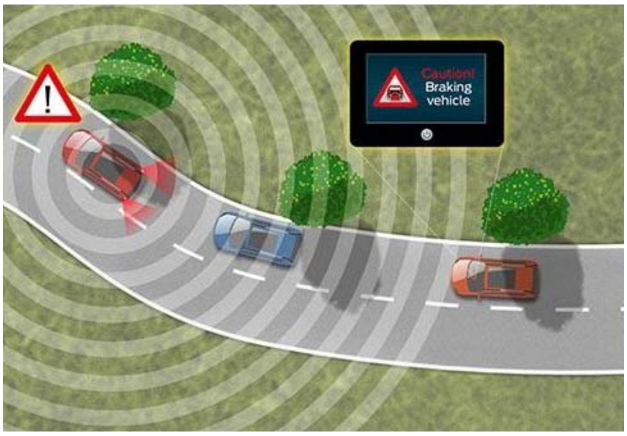

Fig. 15. Vehicle communicating about braking.

The possibilities of ICT lead to Artificial Intelligence (AI). And AI implemented in transportation infrastructure can lead to driverless vehicles. Even though today there exist technolgies that allow vehicles to control themselves, driverless vehicles are a thing of the future. The main reasons for that are safety and ideology. It is a relatively new technology, but on which many lives could depend, thus it has to pass a longer testing period. Developers do not hesitate to implement and test them. A clear example for that is the VAL (VAL - Véhicule Automatique Léger) from Siemens (Fig. 16) [32]. Siemens created two types of vehicles: Cityval and Airval. These are completely driverless light railway vehicles, controlled by operators from a distance. Operators that could be situated in a single control centre. Such systems would allow an efficient traffic control, and synergy of an entire city railway system; thus making transportation through cities faster and more reliable.

Fig. 16. Cityval, Siemens' driverless light railway vehicle.

A much known example of first driverless small vehicles is the Google Self-Driving Car (SDC) (Fig.17) [40]. This car is functioning in Nevada State, of the USA. The reason for that is that this particular state was the one of the first states to adopt a legislation towards driverless cars. Now SDC performs the functions of the regular Google Car, but without the need for drivers. The SDC was first set on the road in 2014. It has neither wheel, nor pedals. The car is partially controlled by an on-board computer, with some operations being made on remote computer farms.

Fig. 17. Google Self-Driving Car.

Nearly half of the car's cost is for the LIDAR system. The multitude of sensors allows the car to form a 3D model of the surroundings. This helps the car to function on the road, detect obstacles and presents itself as a safe car in traffic.

Nowadays there are 23 SDC on the road. Since July 2015 the Google SDC's were involved in 14 minor traffic accidents. All the accidents were proven to be caused by human interaction. Most of those were provoked by other traffic participants who did not stop at stop signs or traffic lights, and one was when an employee was driving the car on remote. Thus far, the SDC proves to be a safe participant in traffic.

At the September 2009 ITS World Congress in Stockholm, András Siegler, Director of Transport for the European Commission's DG Research, estimated that widespread introduction of intelligent systems and services could reduce congestion by up to 15 %, CO2 emissions by 20%, and road fatalities by up to 15 % [35].

A leader in implementing ITS is the USA. The United States Department of Transport has adopted two strategic plans on ITS in 2010 and 2014 [36]. While the first strategic plan on ITS had an emphasis on current state of policy, economy and safety research; the second one is aimed towards research of connected vehicle and advanced automation.

5. CONCLUSIONS

ICT is a modern technology that greatly improves the functioning of an electric vehicle. Using powerful microprocessors and complex control algorithms allows the vehicle to work at high efficiency rating. As comparison to old DC drives with rheostat command, modern control algorithms raise the efficiency with an average of 30%. The possibility to use BLDC motors for traction, motors that have a power factor of 1 and are of top efficiency and energy density.

Another major factor that benefits from implementing ICT in vehicles, public or private, is safety. Using a multitude of sensors, such as radar, sonar, or laser; computers inside vehicle can determine factors of risk and inform drivers, or act independently if the driver can not react in due time.

Using GPS and wireless communications, the intelligent vehicle can become part of an intelligent transportation system. A network such as this would reduce traffic congestion in big cities. Considering constant urbanization, it is a very important factor for economic growth, sustainability and overall happiness of the populations. In terms of safety, ITS would greatly diminish the risks that appear on the road due to factors like low visibility, or human factor; and thus greatly reduce the number of accidents on the road. Vehicle computers advance in a rapid pace. This leads to driverless vehicles in integrated networks. Driverless transportation already started in railway transportation, due to the fact that rail vehicles have a prescribed path. Later driverless technologies will be integrated in personal cars and vehicles on the road. An ITS with driverless vehicles for public transport is the future of city transportation. ITS is a necessity that comes out of growing population and economic and ecologic state of urban areas. Implementing an intelligent transport infrastructure will lead to better overall transport efficiency, which in turn improves the ecological state of cities, local economy and reduces the time spent on the road for people.

ICT also allows to implement luxury elements in vehicles. Video and audio announcements, media entertainment or access to the internet via Wi-Fi can make riding public transport very comfortable.

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