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SMART MOBILITY ASSETS FOR ROAD NETWORKS IN URBAN AREAS

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Abstract

Rapidly increasing capacities, decreasing costs, and improvements in computational power, storage, and communication technologies have led to the development of a multitude of applications carrying increasingly large amount of traffic on the global networking infrastructure. What we have seen is a rapid evolution: an infrastructure looking for networked applications has evolved into an infrastructure struggling to meet the social, technological and business challenges posed by multitude of bandwidth hungry emerging applications. Smart city applications are at the forefront of these developments. A smart city cannot be aspired without smart roads and a smart city with smart roads together can provide citizens with smart mobility. The road sector faces major challenges in this century such as what makes a road smart and what technologies and infrastructure can be used to make it smarter? The aim of this research is to present and appraise smart highway technologies regarding future prospects and its benefits in smart cities. Their implementation requires supporting the interests of all concerned parties entail industry, transportation authorities and professional organizations. Adding mission-critical information and communication technologies (ICT) to roadways can offer potentially smarter highways and cope with pressing challenges.

Keywords
Smart City, Smart Roads, Highway Technology, Mobility of the Future

1. Introduction

Since few years, the use of the term “smart” has become a prevalent practice at all levels. We use smart phones, smart televisions, smart cars, smart elevators, smart planes, and there would be hardly such citizens who do not aspire a

Smart City having smart buildings within and even energy to be smart. Therefore, roads also need to transform themselves so as to play a pertinent role in this "revolution" (Villanueva *et al.,* 2013). As a smart city is improbable without smart roads and together a smart city with smart roads can equip citizens with smart mobility.

Smart cities have stipulated the high-tech approaches for today's' urbanization which emerged from the advancements carried out under the umbrella of knowledge based economy, and consequently under the idea of digital and intelligent economy. Smart cities cover all aspects of futuristic daily life, transportation, healthcare, leisure, occupation, business, social interaction, and governance. Smart cities need to exploit concrete and digital infrastructures, in addition to the intellectual and communal capital, for societal development. Precisely, smart cities are complicated system of systems which relies on congregated and ubiquitous infrastructure. The concept of smart cities is originated from several co-dependent trends including a prime need for environmental sustainability, and peoples' growing demand for self-validation, mobility and high quality of life (2017).

The idea of savvy city can be expanded to shrewd society; i.e. carefully empowered, learning based social orders, overseeing and working for social, ecological and monetary maintainability. Since innovation and human capitals are at the core of brilliant urban areas and shrewd society's improvement, one of the greatest difficulties of urban living have been traffic with vehicles, cars and trucks stopping up each real roadway. Notwithstanding the bother and lost time, the perils of expanded contamination and roadway fatalities additionally pose a potential threat in the brains of the present drivers. Subsequently, it is nothing unexpected that city administrators around the globe are vigorously centered on tending to these difficulties, with shrewd thruway and traffic the executives programs developing at the highest point of the motivation of many savvy city activities.

Adding mission-critical information and communication technologies (ICT) to roadways offer potentially smarter highways and address pressing challenges. Additionally, a smart road or highway has many features that are integrated with the road networks to provide a smooth, safer and convenient road journey for travelers. The first in this sequence is Vehicle infrastructure integration (VII). It is the branch of engineering which covers the applications of a series of techniques (Yeon *et al.,* 2012). relating road vehicles and their physical surroundings so as to enhance road safety.

Its purpose is to provide a communication channel between vehicles on the road through On-Board Equipment, among vehicles and the roadside infrastructure through Roadside Equipment in order to improve the safety, competence, and expediency of the transportation system (Lee *et al.*, 2012). It supports widespread deployment of an ordained short range communication and a direct connection among vehicles on the road and their defined vicinity (Villanueva *et al.*, 2013), (Yeon *et al.*, 2012). By driver's intent, these vehicles can even communicate and exchange data with each other on speed and orientation.

In addition, the system is designed to collect complete, real-time traffic information for the entire network, queue management and as well as feedback to vehicles (Lee *et al.*, 2012), Razo Jacobsen, 2016). Vehicle infrastructure integration can make roadway markings and signs obsolete this way.

In VII's development, the interests of all concerned parties should be supported by a business model (Akhegaonkar *et al.*, 2013). especially from industries, transport authorities and professional organizations. This initiative has major priority to evaluate the business model together with deployment scheduling by the stakeholder's acceptance; to validate the technology as per deployment cost; and to develop the legal structure and policies in order to enhance the system's potential towards success over the longer term.

These results have been achieved to some extent, in different trials performed around the world with the use of GPS, cell phone signals, and transport registration plates. GPS is becoming benchmark in several new high end transports and an option on many low and mid-range transports (Ghosh et al., 2012). However, GPS and cell phone tracking devices are not reliable source for data gathering.

This technology is working as an active safety in numerous ways by relying on vehicles based radar and vision system (Ghosh *et al*., 2012). It can lead to perceptible increase in the operational efficiency of transport network (Lee *et al.*, 2012). While vehicles are connected jointly with a resulting diminish in reaction time, the headway between them can be reduced resulting in enhanced traffic capacity of the road network.

Tolling is another prospect for VII system as it might enable highways to be autonomously tolled (Razo Jacobsen, 2016)-(Ghosh *et al*., 2012). Data related transaction, and shortest and fastest route to destination can be transmitted over in-vehicle screen display collectively based on real-time conditions.

Despite various prospects, this technology has some short comings. It is somewhat limited to sense only the mean distance and speed of vehicle within the direct line of sight of camera and the sensing range of radar. It is almost utterly ineffective for inclined and left-turn collisions.

After VII, the 2nd broad concept in smart road modifications is Structural Health Monitoring (SHM). The implementation of damage detection and characterization approach for engineering structure is referred to SHM (Ward & Duvelson, 2010). Here damage is categorized as changes to arithmetical properties of structural systems, periphery conditions and system connectivity, which can negatively affect the technology's performance.

The SHM process involves the examination of a system over time using sampled active response measurements at regular intervals from a group of sensors, the mining of damage-sensitive features, and further statistical analysis to establish the current state of system health (Ward & Duvelson, 2010). It is essentially noteworthy that there are stages of growing difficulty that requires the knowledge of previous stage, i.e. Detection of damage existence on the structure, tracing the damage, and identification of the types and severity of the damage. It is crucial to appraise employed signal processing and arithmetic classification of converted sensors data on infrastructural health status into damage information.

The idea of smart roadway is impractical without Intelligent Transportation Systems (ITS) (Lee *et al*., 2017). ITS usually refers to the employed information and communication technologies in the domain of road network, together with infrastructure, transports and travellers, and in mobility management with other modes of transportation enables users to be more informed and makes safer, coordinated, and smart use of highway network.

ITS varies in deployed technologies and basic management systems such as traffic-signal control system; container management system; variable communication signs; auto number-plate identification or speed check applications; and in complex applications those collect live data and response from a number of other sources, such as parking regulation and information systems; weather forecast; bridge de-icing systems; navigations etc. Additionally, predictive systems are being designed to support advanced modelling and comparison with chronological baseline data some of these tech-nologies are (Jang *et al.,* 2010).

1.1 Wireless Communication

Several kind of wireless communication technologies have been introduced for intelligent transport system. In order to achieve short to long range communications within ITS, the radio-modem communications on UHF and VHF frequencies are broadly in use.

1.2 Computational Technologies

Most recent progressions in vehicles are setting a pattern to move towards less however progressively capable PC processors on hardware. Commonplace vehicles in the mid-2000s more likely than not been somewhere are in the range of twenty and hundred independently organized microcontroller/ Programmable rationale controller modules with non-ongoing working frameworks. The present patterns are towards less however expensive microchip modules with equipment memory the board and continuous working frameworks. Perhaps the substantial for Intelligent Transportation Systems is artificial intelligence.

1.3 Sensing Technologies

Sensing system is one of the efficient systems designed for IT Sare vehicle- and structure-based networked systems. Featured sensors have long-lasting devices like in-road reflectors. These are embedded in the road or surrounding the road and may be manually distributed through in preventive road continuous or by sensor injection machineries for sudden instalments. That Vehicles-Sensing system contains instalments of infrastructure-to-vehicle and vehicle-to-infrastructure electronic sources to identify communication. It can also engage videos and automatic number plates recognition technologies to increases sustained monitoring of vehicles running in critical zones.

1.4 Inductive Loop Detection

In order to detect magnetic fields, inductive loops are supposed to use in a roadbed to recognize any vehicle as it passes from the magnetic field of loops. The detector can easily count the number of vehicles in a time frame that pass through the loops. Moreover, some featured sensors are capable of estimating the acceleration, distance, and class of vehicle and the gap between them.

1.5 Video Vehicle Detection

An automatic accident and traffic-flow detection using a video camera is another domain of vehicles detection method. Videos from cameras are implemented into processors. The processors analyse the varying attributes of the video images as vehicles pass. The cameras are structured over or adjacent to the roadway.

1.6 Bluetooth Detection

One of the inexpensive ways is Bluetooth in order to measuring time period of travelling. It analyses start and destinations. Bluetooth device in running automobiles are identified by sensing systems on the road. If each and every sensor is connected with others they can measure travelling duration and access information for beginning and ending matrices.

1.7 Efficiently Massive Computation

HPC play a vital role in smart cities development. In (Ashraf et al., 2017) a tri-hybrid HPC model was proposed to support massive computation in smart cities. The tri-hybrid model was composed by MPI, OpenMP and CUDA where MPI is responsible to distribute messages over a large cluster system, OpenMP to control CPU threads and CUDA to program GPU devices. Similarly, another tri-hybrid model was proposed by (Ashraf *et al.,* 2018). Although this tri-level hybrid model was proposed to parallelize Exascale computing systems applications, however it was much supportive to promote smart and massive computations.

2. Smart Methods

This study has discussed existing smart approaches including the sensor for cars and sensor network fitted along the road but there are many smart features still not incorporated in any road network. A combination of those new technologies is presented and appraised in order to make a road even smarter.

2.1 The Photovoltaic Pavement

The method of generating electricity from solar power panels in the form of footpath is known as Photovoltaic pavement (Jang *et al.,* 2010). This material is helpful in Parking lots, walkways, driveways, streets and highways.

2.2 Solar Road Panels

It is designed to replace solar asphalt roads with Solar Systems panels. Energy from the sun generated, used in houses or factories. These are connected to the system indeed. Charging stations can be increased with more panel units for electric cars only if the stations are connected to the solar system ways (Singh *et al.*, 2015). It is capable of vocals to utter some words like "Reduce Speed" or "Traffic Ahead" to control the traffic incidents. There are 3 layers that make up the solar panels (Madni, 2014), (Axelrod, 2017), (Navvab *et al.*, 2018).

2.2.1 The Road-Surface Layer

This is the High Strength layer that has the photovoltaic cells which attract the sun's waves, and has traction to avoid sliding off the roads for vehicles, plus its water-proof feature is constructive enough to protect the layers below.

2.2.2 The Electronic Layers

These layers include a mini-microprocessor board that assists in controlling the heating part of the panels which in turn helps to melt the snow by using this technology. It is expected to benefit hazardous road conditions that will no longer be an issue in snowfall regions.

2.2.3 The Base Plate Layer

The Base Plate Layer is the one that gathers the warmth from the sun and circulates the vitality to the homes or organizations which are associated with the sun powered roadways. This can likewise be utilized to exchange the ability to vehicles as they roll over the strip to revive the battery.

List of benefits of solar roads by analyzing their power generation capability in relation to their cost is equipped (Jin *et al.*, 2014). (Centenaro *et al.*, 2016).

- 1 mile of 4 lane road is enough to provide power to almost 428 homes
- If all roads were replaced, it would generate 13,900 billion kilo watt hours of power per day
- Such a massive power generation would easily solve our energy crises.
- This system will cost less to implement then to maintain roads, once it is manufactures on a large scale.
- Over 20 years of life span of a single tile, it will have paid for its price
- Tiles will be able to refurbished and reused for even cheaper price
- Having discussed the benefits of solar roads, a comparison is made with already existing asphalt roads that we all know about i.e.
- Asphalt roads are petroleum bases and their prices have increased almost 500% in last 10 years
- They always require repair works
- No return at all, of any sort
- These roads have no safety features

After the concept of smart roads, it is essential to bring wireless charging of car into light as this smart driving will revolutionize the world.

2.3 Wireless Vehicle Charging

Electric vehicle has long been a potential choice for sustainable transportation and a part of eco-friendly system. Likewise fuel based cars, they also need energy with is provided by the rechargeable batteries fitted inside these cars. And these batteries need often recharging for making a car moveable on road. More mileage requires more power which means a bigger size of battery with considerable recharging time. More is the size of battery, the more expensive it will be.

KAIST (the Korea Advanced Institute of Science and Technology) provides one of the best solutions. If electrical circuits are installed onto the roads, it can supply energy to suitable adapted automobiles with electromagnetic induction charging (Albouq & Fredericks, 2017).

The main advantage of this technology is that with wireless charging means electric buses used for public transportation can have its own light, cost saving battery in place of bulky and pricey one and no time wastage in recharging (Mejia *et al.,* 2017). After getting equipped with this feature, highway will be capable of constantly powering vehicles.

Even though, this technology is immature yet but still can ease the three major challenges of cost, weight and range which have been holding back the adoption of auto powered vehicles worldwide for more than a century. Firstly, It is the role of researchers and developers to demonstrate its "inductive charging" feature and convince that it is cost effective enough to be deployed on highways because as long as it unaffordable and costly it's not going to be launched any sooner.

In addition to smart roads, the importance of road signs to help motorists cannot be ruled out.

2.4 Road Markings

One of the main tasks of the driver is to follow the road. During the day, when the visibility on the roads under good weather is undisturbed, it is not difficult. However, at night on unlighted roads is not simply to identify flow of traffic. Therefore, the drivers often complain on insufficient signaling in the terms of night driving. Quality solutions to specific local traffic problems can have a significant impact on the quality of the entire flow of the network traffic, increased security in closer and wider area.

2.5 Glow in the Dark

Instead of spending a big budget on road lighting or other illumination options that cover only limited range of miles, the idea to use glow in road markings is more appropriate alternative in dark. These markings are made of paint that contains sign aluminizing ingredient that "charges up" with sunlight in day time. Such glow markings can stretch over 500 m distance and can glow for up to 8 hours every night.

2.6 Interactive Light

With the idea of motion-sensor lights, it is easy to light up certain section of the roads when car reaches particular location. If cars come closer and the glowing light would slowly dim away as it crosses. This responsive and Interactive Light effect is perfect for highways where travelling is less compare to other roads.

2.7 Wind-Powered Lights

Apart from interactive light activities, wind-powered lights can be energized (powered) by using pinwheels to produce electricity. It is done by couple of wind drafts from cars-crossing into electric-flow of charges. The lights on the pinwheels would be turned on by the generated electricity. As wind is the source of power, it is understood that the wind-powered-light would only light up when car passes by the area. To make it happen, these pinwheel generators would be placed on the path at the roadside of the cars. It will help to keep the light continuous.

2.8 Solar Roadways

As already discussed earlier, solar roadways fitted with LEDs can glow at night to guide drivers and even display safety messages to guide drivers at night.

3. Analysis

By going through the smart technologies which will be incorporated in near future to our road networks, the study has furnished few analyses:

- The enhanced technical capabilities will facilitate motorist safety benefits by providing him information regarding fast approaching closing vehicles and even in dire circumstances the brakes will be automatically applied to stop two colliding vehicles.
- Overall situational awareness of drivers on roads will be increased. A driver will be aware of his surrounding traffic, road blockades, shortest routes to his destinations and automatic tolling.
- Motorist and travelers in smart cars will be able to travel non-stop without any refueling due to the advantage of wireless charging on roads. This increase the comfort of travelers by decrease in overall travelling time
- More use of smart car will promote an overall eco-friendly system by fewer emissions of carbon mono oxides.
- No technology comes without any disadvantage, Intelligent transportation system being computer programmed are prone to malicious software / viruses, hacking and jamming.

Presently, No-where in the world these smart features are fully incorporated in any road network due to the cost of the infrastructure overhaul (Reinthaler *et al.*, 2014), (Fabbri & Mascioli, 2014). That would be needed to bring this patent into reality.

4. Recommendations

After putting up the analysis, few recommendations for transportation and road network of Pakistan are presented.

- Pakistan government should look into the prospects of smart road technology, and in corporate them in existing motorway network and future construction of highways. They should try to introduce at-least a minimal standard of smart highway system for the initial understanding of drivers.

- To make them abreast with the smart road technology, Pakistan government should encourage foreign investors to invest in auto mobile industry for the production of smart cars.
- Pakistan is already on the verge of fuel crises, since being a major importer of oil, Induction of smart electric cars will provide a source of fuel conservancy.
- Smart cars will not only provide comfort and luxury of travel to motorist but also they contribute towards making an eco-friendly environment.
- Solar roads are great source for producing energy production that can be used for domestic sector. Pakistan is already facing crunch in power generation sector. Rural population is suffering the most from this crisis. Construction of solar roads will not only ease the burden on our national grid, but will also provide electricity to nearby area.

5. Conclusion

Smart roads are liable to shape the mobility of the future. Specifically, smart roads rely on a flawless connection between smart vehicles and smart infrastructure. Vehicles are upcoming significant actors in the current industrial revolution, stipulating new challenging applications, from security to traffic control and infotainment. In this challenging situation, accuracy in traffic and road monitoring through novel sensor networks are expected to play a vital role in the deployment of innovative smart road network. Now, a road is no longer remained as a medium to travel from one place to another. We can use it to charge electric cars and generate solar energy due to its large exposed surface area. New technologies are introduced to keep sections of the roads well illuminated now with more energy efficient, cost saving and environment friendly methods.

Consequently, Smart Roads are the solution to address the people's highest expectations relative to road transport and, in doing so, there is need to define a model for a highway of tomorrow that would adapt to societal demands.

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