



UAF College of Engineering & Mines

Future Infrastructure Needs for Automated and Electric Vehicles

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Abstract

The purpose of this research is to write a summary and analysis of options for transportation infrastructure that can be adopted to optimize the integration of new innovations in car design, specifically smart, electric and autonomous vehicles, and the use of smart infrastructure. These changes in transportation technologies offer the possibility for innovations in safety, environmental friendliness and efficiency in future highway design. This review discusses specific policy changes in infrastructure development, including the introduction of Shaped Magnetic Field in Resonance technology into roadway projects along highly trafficked thoroughfares and public transportation routes, variable speed limits informed by smart vehicles, and the use of the communications capabilities of smart vehicles to identify hazards such as a break down in traffic flow or an accident, and communicate conditions to drivers or autonomous vehicles.

Introduction

When Bertha Benz proved the viability of the then-revolutionary automobile by driving more than 120 miles, she could never have predicted that, less than two centuries later, self-driving cars capable of replicating her route would be on the roads. In 2005, four vehicles continued in her tradition and provided the proof-of-concept for autonomous cars by creating cars that could navigate and drive independent of human control over a more than 132 mile desert course (Darpa, 2007). The introduction of the Tesla Roadster in 2004, the first highway capable electric car, is also a notable landmark in automobile history (Drori, 2008). The suite of car improvements, making cars autonomous, and the more common hybrid and electric vehicles have the potential to drastically change highway design in the future.

Discussion

The contribution of human error to crash rates has been a defining characteristic of highway design for more than a century. For example, many accidents on horizontal curves can be traced back to deficient driver skill, exceeding the design speed, failure to maintain lateral position making a turn, incorrect driver anticipatory behavior going into a curve, and incorrect hazard assessment (FHWA, 1997). These are factors that have the potential to be reduced with the adoption of Autonomous Vehicles (AVs), such as the Tesla Roadster, shown below left (NRMA Drivers Seat, 2014). AVs also bring added advantages such as potentially integrating external information to increase perception distance without an increase in sight distance when paired with a smart network. The introduction of AVs will eventually offer new flexibility in highway design as a result of this, as well as new ways to communicate with and coordinate traffic. AVs do not reach their full potential, however, without a network able to communicate between them, allowing for congestion mitigation, drafting, and adaption to variable speed controls.



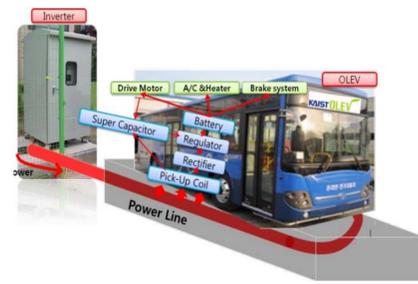
Qiu et al., 2012)

Autonomous and smart cars offer additional tools for Active Traffic Demand Management (ATDM). ATDM uses tools such as ramp metering (and in the future, the built in communication capabilities of modern cars) to adjust variable speed limits based on current road, traffic flow, and weather conditions. Variable speed controls have been linked with improved safety, but can also be used to achieve a more uniform distribution of traffic density across freeway links. New Jersey already uses such a system with about 120 signs warning of slow traffic, hazards, and accidents. (Hadiuzzaman and Chien and Zhang et al. (1997) suggest that drivers cause congestion through inappropriate speed choices, and that many traffic congestion issues could be resolved through the use of a computer control system optimizing traffic flow by controlling the vehicle, as well as its surrounding vehicles. In this article, they argue that methods using on-ramp metering and advisory message boards are rudimentary. As an alternate, they propose an automated roadway traffic controller model to guide traffic to homogenize traffic density in congestion. This could be accomplished by communicating with smart vehicles or controlling autonomous vehicles which speed is optimal for the traffic flow. As vehicles with the ability to interface with this automated roadway traffic controller become more prolific, the results on congestion become more profound and wide reaching.

Electric Vehicles are even now being implemented in many areas of the world, but there are many ways infrastructure can positively impact this development. Modern electric vehicles with rechargeable batteries have considerable shortcomings in mass scale uses, including inconvenience of recharging, weather safety concerns, long charging time, limited driving distance per charge, and battery design issues in high cost, weight, and volume (Dorrier, 2013, Suh, I., 2011a). This may create overall trends towards short-range travel by personal vehicle over time as electric vehicles become more widespread, or limit the adoption of electric vehicles, but there are some alternatives.

Shaped Magnetic Field in Resonance (SMFIR) technology can be installed into existing and new road construction to allow for the use of On-Line Electric Vehicles (OLEVs) in mass market volume. These systems reduce battery size (currently by about 20%) by allowing vehicles to charge from power cables beneath roads, generating a shaped induced magnetic field that can be picked up by vehicle-installed coils and converted at 83% efficiency to electric power to recharge the vehicle in transit (Suh, I., 2011b, pp. 13-27). Two test buses are running as of August of this year in Gumi, South Korea, and the system is expected to expand in the near future (KAIST, 2013). The figure on the left illustrates the basic components of this system (Suh, 2011b, pp. 14).

Another alternative for the implementation of electric vehicle is through exchangeable batteries. This, unlike the OLEV system, is already widely commercially available, and is easier to implement in areas with less traffic density such as rural highways. Switching batteries makes the range theoretically unlimited, allowing for freedom of transit while limiting emissions. The electricity cost is often less than gas. (Better Place, 2013) It may require infrastructure, like charging stations and battery switch stations subsidized by the government on a regional scale to make this viable. Israel, where a large scale electric car venture recently failed, did not significantly support electric cars, whereas Denmark, which has seen more success, offers a \$40,000 tax break for the cars (Sales, 2013). California has also legislated some electric vehicle friendly codes, which has resulted in between one and three thousand plug in electric vehicles, with that number projected by the California Electric Transportation Coalition to jump to over 125,000 by 2015 (Smith, 2012).



The Vision



Take a minute to picture this. A rural highway stretches to the horizon in front of you. Only slightly discolored strips betray the presence of an OLEV system. The gas station down the road looks much the same as it always did except with the addition of a couple racks of charging car batteries along one wall. Discrete outlets are located in front of the parking spaces. The air smells more of ripening crops than diesel and the roads are quieter as the vehicles move through the sleepy small towns of America. Early morning traffic includes OLEV buses headed into cities and truckers hauling the goods that make America run with automated systems that enable coordination and adjustment of traffic control. A horse trailer passes you. It can transport livestock hundreds of miles to a show without ever seeing a red light, leaving hardly more of a carbon footprint than the animals it's hauling. For the traveler, the guilty pleasure of a long drive is transformed by innovation into a journey that evokes a heady sense of the freedom of the road.

The overall conclusion is that there is enormous potential for both further research and implementation of policy changes and new systems recommended by current research, in the pursuit of safer, more efficient transportation in the modern era. The infrastructure of tomorrow must include features for non-traditional vehicles, including electric and autonomous cars. As engineers, it is our responsibility to keep issues like safety and innovation balanced, and there is nowhere that is more apparent than on this frontier of design. As citizens and policy makers, it is our responsibility to vote, not for the infrastructure changes needed today, but for the infrastructure we want for the future.

Adapting to the status quo

Elements of innovative infrastructure design are being applied to some designs. However, the policy making paradigms still look first to traditional solutions to problems such as congestion, rather than to GPS based congestion pricing or variable speed controls that might be a better design option. Some of alternates already starting to be implemented include:



- Installing cameras, ramp monitors, RFID, etc
- Traffic density sensors
- Electronic speed displays
- Automatic toll readers
- Variable speed controls, shown in the image on the left (Federal Highway Administration, 2014)
- Interactive signs communicating details of road conditions
- Dynamic Traffic Light Sequencing

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