A COMPREHENSIVE SURVEY OF EMERGING TECHNOLOGY FOR NEW YORK METROPOLITAN AREA

Technical Memorandum 2: Initial List of Emerging Technologies

Prepared By:

Name(s)	Project/Organization Role
Satish Ukkusuri	PI
José Holguín-Veras	Co-PI
Gitakrishnan Ramadurai	Student Researcher
Lili Du	Student Researcher

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TABLE OF CONTENTS

1 Summary

In this task, a comprehensive, initial list of emerging technologies to improve transportation systems will be prepared.

Emerging technology included in the present study can be classified under the following categories based on the development stage of the technology:

1. Technology that is already developed and implemented elsewhere but has not yet been adopted in the NYC region.
2. Technology that has been prototyped but has seen limited to no real implementation.
3. Technology that is still at the conceptual stage.

We explain the methodology and rationale for choosing the list of technologies in each of the above categories.

Since 15 to 20 years is a long time in transportation technology cycle, the project team undertook a visioning process. The visioning process was done in two steps. First, it was recognized that technology advancements in several fields are likely to impact transportation and travel. Therefore in the first step, these broad technological domains and their general trends were identified. The broad technology domains studied include:

a) Nanotechnology
b) Energy and Fuel technology
c) Communication technology
d) Computing and Internet technology
e) Transportation, Vehicular and Automotive technology
f) Sensors
g) Freight technology

The second step of the visioning process involves identifying the potential impacts of the technological developments on transportation in general and transportation technology in particular. Further, fact-sheets of each technology were prepared which include details on features, timeline/costs, transportation applications, and challenges.

2 Methodology

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The methodology for choosing the different technologies is as follows: technologies in category 1 and some of the technologies in 2 were primarily identified based on the comprehensive literature review carried out as part of task 1. In task 1, a literature review of implemented as well as emerging transportation technology was carried out which included international studies. Several of these technologies have not yet been implemented in the NY metropolitan region but have immense potential.

The rest of the technologies in category 2 and the technologies in category 3 were identified based on a visioning process. Since 15 to 20 years is a long time in the transportation technology cycle, the project team undertook a visioning process that required intelligent, information supported extrapolations of possible future developments. The visioning process was done in two steps. First, it was recognized that technology advancements in several fields are likely to impact transportation and travel. Therefore in the first step, these broad technological domains and their general trends were identified. The broad technology domains explored include:

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We first present a brief summary on each technology domain and identify general trends. We then provide the fact-sheets for technologies identified under each of the domains.

3 Broad technology domains and trends

3.1 Nanotechnology

Nanotechnology is the study of matter whose dimensions are 1 to 100 nanometers (10^{-9}m). A nanometer is one-billionth of a meter; a sheet of paper is about 100,000 nanometers thick. At the nanoscale, the physical, chemical, and biological properties of materials differ in fundamental ways from the properties of individual atoms and molecules. Nanotechnology R&D is directed toward understanding and creating improved materials, devices, and systems that exploit these new properties (1). Nanotechnology has as yet only limited applications. Nano-materials have found applications in electronics, biomedical, pharmaceutical, energy, and materials applications. Current successful application of nanotechnology includes chemical polishing, magnetic recording tapes, sunscreens, automotive catalysts, electro-conductive coating, optical fibers, and disinfectants (see (2) for a detailed list of nanotechnology in consumer industry). Several examples of nanotechnology research in developing new technology abound. These include:

a. Molecular switches (3) that will eventually help make electronic devices even smaller and more powerful.
b. Nanowire LEDs (4) that could eventually be used for telecommunications and for faster communications between devices on microchips. The approach could also pave the way for a new type of bright, efficient display.
c. Denser data storage using nanorods and nanowires (5)
d. Nano weapon to fight cancer (6),
e. Flexible organic LED displays (7),
f. Fuel cell catalysts (8),
g. Self-cleaning, fog-free windshields (9),
h. Materials that reflect no light (10) which has applications in solar cells, camera lenses, and LEDs
i. Nanosensors (11) that could provide simple tests for cancer or bioterror agents,

The above list indicates the diverse applications of nanotechnology. In general, nanomaterials appear to enhance the strength, durability, and other physical attributes of materials allowing development of smaller and cheaper applications. These technologies can have myriad different impacts on transportation (12, 13):

- Carbon-based fibers which are 100x stronger than steel, at only one-sixth the weight provide light-weight yet stronger options for construction of bridges and vehicles.
- Nanocoating of metallic surfaces to achieve super-hardening, low friction, and enhanced corrosion protection
- “Smart” materials that monitor and assess their own status and repair any defects resulting from fatigue, fire, etc.
- New materials that will permit ultra-miniaturization of space systems and equipment, including the development of ‘smart’ sensors and probes.
- Nanosensors to monitor vehicle emissions and trigger traps for pollutants;
- Nanoparticle-reinforced materials that replace metallic components in cars;
- replacement of carbon black in tires with nanoparticles of inorganic clays and polymers, leading to tires that are environmentally friendly and wear-resistant;
- Carbon-based nanostructures that serve as ‘hydrogen supersponges’ in vehicle fuel cells.
- Nanofilms for water-repelling windshields

- High-brightness nano-enhanced polymer displays for in-vehicle displays
- Ceramics with improved catalysts for reduced emissions
- Air purification systems that can be fitted over air vents in cars.
- Hybrid Electric Cars Powered by Nano-Engineered Batteries
- Paint and Clothing that can generate electricity

The University of Houston conducted a study (14) for the Texas Department of Transportation on the potential nanotechnology applications in highway pavements. Two different categories were investigated: smart materials for pavement construction and sensors for transportation and pavement infrastructure condition monitoring. In order to demonstrate the applications of nanotechnology in transportations systems, a fully functional smart stop sign was developed and tested. This smart stop sign is able to detect any malfunction including direction change, fall down, or tilt and report wirelessly to the TxDOT office using nanosensors and MEMS radio technology.

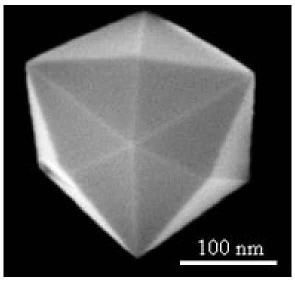
The Volpe Center’s transportation strategic plans (15) vision document on future transportation lists the following impacts of nanotechnology in transportation:

- Nanotechnology will yield advanced materials that will allow for longer service life and lower failure rates. Among the key applications is nanocoating of metallic surfaces to achieve super-hardening, low friction, and enhanced corrosion protection; "tailored" materials for infrastructure and vehicles; and "smart" materials that monitor and assess their own status and repair any defects resulting from fatigue, fire, etc.
- Nanotechnology has great potential to support advanced communications that maximize the benefits of intelligent transportation systems and obviate the need for some travel altogether; sensors that continually monitor the condition and performance of roads, bridges, and other infrastructure; and "brilliant" vehicles that can avoid crashes and improve operator performance.
- New materials developed through nanotechnology will permit the ultra-miniaturization of space systems and equipment, including the development of "smart," compact sensors; minuscule probes; and microspacecraft. Applications include economical supersonic aircraft; low-power, radiation-hardened computing systems for autonomous space vehicles; and advanced aircraft avionics.
- Nanotechnology has the potential to reduce transportation energy use and its impacts on the environment. Applications include nanosensors to monitor vehicle emissions and trigger traps for any pollutants observed; nanoparticle-reinforced materials that replace metallic components in cars; replacement of carbon black in tires with nanoparticles of inorganic clays and polymers, leading to tires that are environmentally friendly and wear-resistant; and carbon-based nanostructures that serve as "hydrogen supersponges" in vehicle fuel cells.
- Breakthroughs in nanotechnology also should make possible quantum computers, which will exceed the limits on the speed and miniaturization of conventional computers by exploiting the quantum nature of reality.

The FHWA multiyear research program identifies Nanoscience research as one of the important research areas. Specific research areas include:

- Materials that perform well under extreme conditions of temperature and pressure. These can be strong, tough, ductile, lightweight, and low-failure materials.

- Smart materials such as paints that change color with temperature.
- Radiation-tolerant materials.
- Self-healing materials: Research is ongoing at the National Aeronautics and Space Administration's Langley Research Center on self-healing materials development to develop materials that will mend themselves if subjected to high-velocity projectile penetration. This technology has the potential for structural applications in bridges. Nanoscale self-healing materials can be developed to be embedded in structural materials that become activated at the site of a fracture, etc., and self-heal the material.



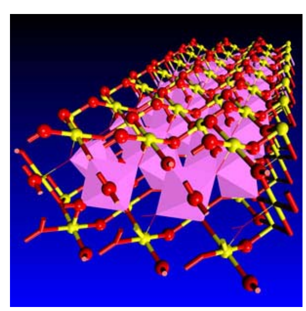
24-sided platinum nanoparticles – fuel catalyst
Source: http://www.technologyreview.com/Nanotech/18669/

The Nano-modification Workshop held at University of Florida and sponsored primarily by National Science Foundation explored the used of Nanotechnology applied to cementitious materials. Nanotechnology for safe and sustainable infrastructure is divided into two categories. Nanotechnology-based construction materials and intelligent materials based sensor system. Nano-modified Construction Materials include materials with high tensile strength and ductility, Super-high compressive strength, Low shrinkage, Engineered hydration processes, High durability, Low permeability, Fiber reinforcement instead of steel, Economical high reactivity additives, Green economical recycling.

The technology fact-sheets in nanotechnology have been grouped under three broad categories: Nanofuels (section 3.1.1), Nanosensors (3.1.2), and Nanomaterials (3.1.3).

Nanofuels include nano-sized batteries, nano materials that serve as fuel savers, and nano materials for fuel-cell catalyst. Nano-sized battery fuel cell measuring just 200 nanometers across that potentially can be integrated on a chip to supply power from a hydrogen reservoir for decades. Nano Fuelsaver uses revolutionary nano-technology to treat petrol or diesel entering the engine in order to enhance the combustion process, saving 10-20% fuel/diesel in cars, trucks, boats, motorbikes. Nano fuel-cell catalyst could lead to cheaper catalysts for making and using alternative fuels.

SnO_2 nanoribbon
Used as ultra sensitive nanosensors for various gases, e.g., NO_2, O_2, and CO.



> The Golden Gate Bridge now has an experimental sensor network of approx. 200 small sensor 'motes', each with an accelerometer that measures movement such as traffic, wind, or seismic loads

Nanosensors have potential to track bio-terror agents, stress in materials, and detect polluting agents in the atmosphere and tailpipes. Nanosensors could be used in transportation to monitor pavement conditions, bridge conditions, pollution deduction, bio-terror agent detection, air quality monitor etc. The feasibility of "Cyberliths", or Smart Aggregates, as wireless sensors embedded in concrete or soil is being studied. Researchers at Johns Hopkins University's Applied Physics Laboratory have developed a robust wireless embedded sensor, suitable for long term field monitoring of corrosion in rebar, particularly in bridge decks.

> Coatings which mimic the surface of the lotus leaf - to which nothing adheres - will lead to signage and work zone barricades which shed dirt and grime and never need to be washed

The Lotus Effect

Nanomaterials that are of interest in transportation include carbon-fibers that are 100x stronger than steel, nanocoating of metallic surfaces to prevent corrosion, nano-reinforcements in vehicle body, pavements, and other transportation infrastructure, and automatic healing materials that have potential to be used in guardrails that heal themselves, or concrete or asphalt that heal their own cracking.

3.2 Energy and Fuel technology

The Department of Energy forecasts that the global demand for energy in 2030 will increase by 70 percent compared to demand in 2005. Transportation energy use will grow by 1.4 percent per year from 2005 to 2030 (about the same as the growth rate from 1980 to 2005), despite relatively high fuel prices. Increases in travel by personal and commercial vehicles will only be partially offset by vehicle efficiency gains (18).

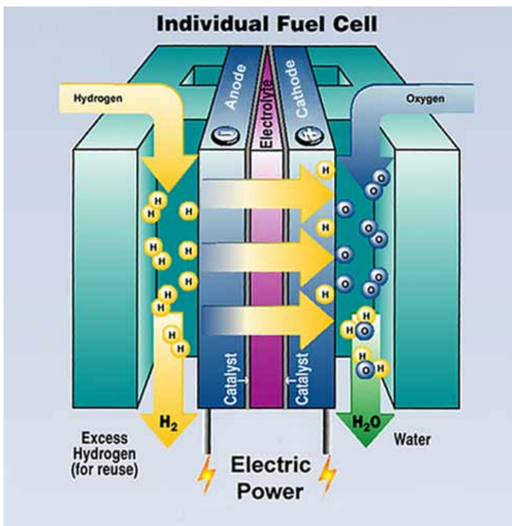
The primary technological developments in the field of energy/fuel technology in transportation are:

> Transportation energy use grows by 1.4 percent per year from 2005 to 2030 (about the same as the growth rate from 1980 to 2005)

- **Hybrid Vehicles**: Present-day hybrids are equipped with ICEs and electric motors. However hybrid technology has been restricted to cars in the commercial market. The NREL Advanced Heavy Hybrid Propulsion Systems project focuses on improving hybrid fuel technology for heavy trucks and buses. Overall, the developed technologies are projected to save more than 20 million barrels of oil in 2010 and 250 million barrels of oil in 2020 (15).
- A **fuel cell vehicle** (FCV) is an electric vehicle that uses a fuel cell rather than a battery to provide electricity that powers motors at the wheels. A fuel cell is an

electrochemical device that produces electricity by separating the fuel (generally hydrogen gas) via a catalyst. Fuel cell vehicles are zero-emission vehicles. Appropriate tax incentives are likely to popularize the use of fuel cell vehicles. Most major car manufacturers have demonstrated prototype hydrogen fuel cell vehicles. Hydrogen fuel cells may also be fitted into motorcycles and bicycles (16). The website http://www.alternative-energy-news.info/headlines/transportation/ provides current developments in research and industry in alternative energy sources in transportation.

- **Aircar**: The Aircar (17) incorporates bi-energy (compressed air + fuel). The compressed air technology (CAT) Vehicles have increased their driving range to close to 2000 km with zero pollution in cities and considerably reduced pollution outside urban areas.



A hydrogen fuel cell
Source: http://p2library.nfesc.navy.mil/issues/emergeoct2005/index.html

700 IEEE Fellows were surveyed in a joint study by the Institute for the Future (IFTF) and *IEEE Spectrum* on the future of different technologies. Among the energy experts (180 respondents) 55% said fuel cells will be widely used to power cars in the next 10 to 20 years.

A joint survey by Institute for the Future and IEEE *Spectrum* magazine among 180 energy experts indicated that 55% believe fuel cells will be widely used to power cars in the next 10 to 20 years.

Here we summarize current available alternative fuels, several emerging fuels and the corresponding alternative fuel vehicles. Specific information for each fuel can be obtained from the tables.

Alternative Fuels: Currently, there are dozens of available alternatives and advanced fuels. Their common characteristics are

- Clean-burning
- Nontoxic
- High potential for domestic production

Use of these fuels can significantly increase fuel security and alleviate air pollution. Consumers, including government-regulated and voluntary private fleets, are now showing a growing interest in them. These fuels are defined as alternative fuels by the Energy Policy Act of 1992 and are currently, or have been, commercially available for vehicles:

- Biodiesel
- Electricity
- Ethanol
- Hydrogen
- Methanol
- Natural Gas
- Propane.

Emerging Fuels
In addition to the above alternative fuels, several emerging vehicle fuels are in early stages of development. Even though few of these fuels are applicable now, many of them are also considered alternative fuels and promise benefits such as increased energy security, reduced emissions, higher performance, or economic stimulation.

- Biobutanol
- Biogas
- Biomass to Liquids (BTL)
- Coal to Liquids (CTL)
- Fischer-Tropsch Diesel
- Gas to Liquids (GTL)
- Hydrogenation-Derived Renewable Diesel (HDRD)
- P-Series
- Ultra-Low Sulfur Diesel

Alternative Fuel Vehicles
Advanced technology vehicles using various light- and heavy-duty alternative fuels are currently on U.S. highways today. They are used by state and federal agencies, private companies, and consumers alike. Advanced vehicles run on a number of different alterative fuels which are summarized below.

1. Vehicles fueled with alternative fuels as defined by the Energy Policy Act of 1992:
   - ◊ Electric Vehicles (fueled with electricity)
   - ◊ Flexible Fuel Vehicles (can be fueled with ethanol)
   - ◊ Natural Gas Vehicles (fueled with natural gas)
   - ◊ Propane Vehicles (fueled with propane).
2. Alternative Fuel Blend-Capable Vehicles:
   - ◊ Diesel Vehicles (can be fueled with biodiesel)
3. Other Advanced Vehicles:
   - ◊ Hybrid Electric Vehicles
   - ◊ Plug-In Hybrid Electric Vehicles
   - ◊ Fuel Cell Vehicles (fueled with hydrogen).

3.3 Communication technology

It is envisioned that communication technology will be revolutionized in primarily two ways: growing speeds of data transfer and ubiquitous wireless broadband communication. These developments are likely to have impacts on several travel dimensions including: how individuals interact with one another, telepresence that includes telecommuting as a special case, the use of anytime-anywhere networks to stay online always, and vehicle-vehicle communication that enable safety and automated vehicle applications.

Terabit optical networks will be common. Next generation optical networks will transfer data at the rate of 10 gigabits per second (gbps) to 100 gbps. Such **ultra-high-speed networks** will enable immersive collaboration environments, resource-sharing, real-time computation-intensive simulations, HDTV-quality video on demand. These developments will also provide advanced telecommuting options, advanced traveler information systems and traffic management capabilities, and result in possible drastic changes in life-style that could significantly affect demand for travel.

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The other significant advance in communication is wide area wireless communication including WiMax, Mobile WiMax, Ultra Mobile Broadband (UMB) and UMTS.

WiMAX provides large coverage distances of up to 50 kilometers under line of sight (LOS) conditions and typical cell radii of up to 5 miles/8 km under Non-LOS conditions. Mobile WiMAX can provide tens of megabits per second of capacity. The high data throughput enables efficient data multiplexing and low data latency. Attributes essential to enable broadband data services including data, streaming video and VoIP with high quality of service (QoS). Universal Mobile Telecommunications System (UMTS) is the European standard for 3G mobile communication systems which provide an enhanced range of multimedia services. UMTS supports up to 1920 kbit/s data transfer rates.

The advances in wide area wireless communication will enable several transportation applications including: in-vehicle communication, inter-vehicle communication, anytime-anywhere connectivity that allows for personalized real-time information dissemination, encourages telecommuting and provides greater work flexibility.

The advances in communication technology are also enabling vehicles to talk to each other (19). Vehicle-to-vehicle communication holds immense promise for safety applications and for improving network throughput by providing online traveler information and/or enabling automated vehicle navigation.

Foremost of the vehicle-to-vehicle communication technology is Dedicated Short Range Communications (DSRC). It is a block of spectrum in the 5.850 to 5.925 GHz band allocated by US Federal Communication Commission to enhance the safety and the productivity of the transportation system. DSRC technology will provide secure, reliable communication links between vehicles and infrastructure safety subsystems that can increase highway safety. The promise of DRSC is to deliver a far greater data rate and range to wireless highway applications. “Compared with existing RFID toll applications, DRSC will deliver data rates of 25 Megabits per second, instead of 250 kilobits, and a range of up to 1 km, instead of 10 meters,” says Richard Schnacke, vice president of industry relations for TransCore.

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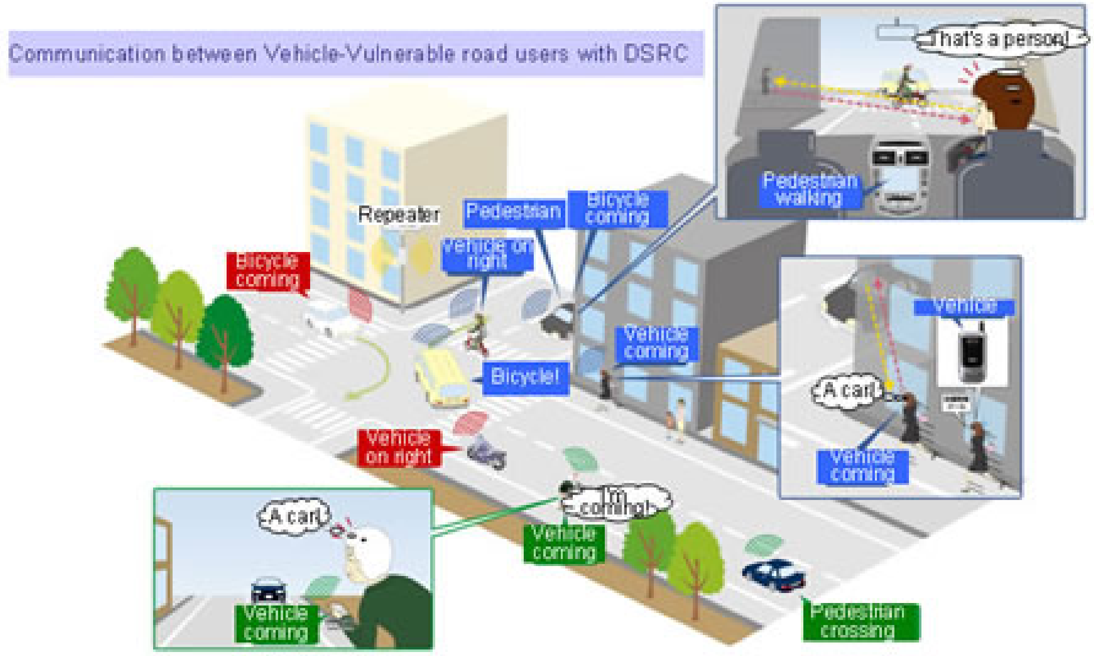
The DSRC system supports communication links up to the following parameter limits:

Vehicle speed (up to 120 mph), Communication range (up to 1000 meters for special vehicles; nominal is 300 meters), System Latency (< 50 ms), Data rate (default is 6 Mbps; up to 27 Mbps), Single transaction size (up to 20K bytes).



Source: http://www.fareastgizmos.com/2007/05/

DSRC should enable several transportation applications including Active safety systems communication on-board the vehicle, vehicle-vehicle and roadside-vehicle communications, roadside-vehicle wireless communications for Intersection Decision Support, cooperative Adaptive Cruise Control (CACC) system with potentially significant impact at highway merge junctions, Traffic Flow (Speed & Volume), Lane Occupancy, Priority Signal Preemption, Toll Collection, Freight Tracking, Roadway Conditions, Intersection collision avoidance, Approaching emergency vehicle warning, Vehicle safety inspection, Transit or emergency vehicle signal priority, Electronic parking payments, Commercial vehicle clearance and safety inspections, In-vehicle signing, Rollover warning, Probe data collection, Highway-rail intersection warning.

An emerging area of research that studies the science of vehicle-to-vehicle communication networks is **Vehicular Ad-Hoc Network**, or **VANET**. It is a form of Mobile ad-hoc network, to provide communications among nearby vehicles and between vehicles and nearby fixed equipment, usually described as roadside equipment. VANET is a technology that could significantly increase traffic productivity in the future. For safety purposes, police and fire vehicles are estimated to be instrumented first so that vehicles can communicate with each other. VANET related application can be categorized into safety and non-safety groups. Prototype system in research includes StreetSmart and TrafficView.

3.4 Computing and Internet technology

Computing and the Internet have revolutionized the global economy in the past decade. Advances continue to push the frontiers of their applications. In the *Extreme Futures* book, James Canton predicts five future trends of the Internet. These are *Smart, Media Rich, Always On, Wireless, Pervasive networks*. Every manufactured product will be online. E-mails are likely to be multimedia. "Telepresence" will become common. The Internet will be the medium through which more than 50% of the world population will be trading.

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To exploit the advances in communication and internet technologies, Computers will become ubiquitous and/or wearable devices; ultra-compact and ultra-powerful. Nano-storage devices will enable limitless data storage capabilities even on devices the size of a mobile phone.

These technologies could revolutionize people's travel. Activities that do not require physical presence will all be substituted by "telepresence". Further, the possibility of high-speed networks allows the use of 'idle' computers to come together and become a networked super computer. "There are roughly a billion PCs on the Internet, and they're 98 percent available for computing," says Larry Smarr, professor of computer science and engineering at the University of California, San Diego, and director of the California Institute for Telecommunications and Information Technology. "That's like having a billion-processor computer just sitting there, with nobody using it." The advances in computing will also enable highly sophisticated data mining and combinatorics allowing the use of advanced algorithms to improve the efficiency of complex transportation systems. Interactive computer graphics will be so lifelike that it will be hard to distinguish on screen between what is real and what is "virtual." Simulations will be accurate and cheap to reproduce thousands of scenarios allowing for improved decision making.

Collaboration software will allow individuals located remotely to interact seamlessly and *produce* jointly. *Augmented reality* which deals with the combination of real world and computer generated data will enhance our perception of the world around us and open new paradigms of social interactions. This is primarily achieved by augmenting human perception by adding to it information not normally detectable by the human senses. Already demonstrated simple examples include cell-phone alarms to indicate the presence of a friend who is passing near-by. Augmented Reality technology can provide for driving enhancement as well as driving performance testing under different scenarios, enable traffic tracking by combining data from a plurality of sensors.

Personal Awareness Assistant (Augmented Reality)
Source: http://www.learningcircuits.org/2004/dec2004/0412_trends.htm

Wearable computing will also act as a personal travel assistant which provides individuals, in vehicle and on foot, with location based information services. An example of this technology in application now is Verizon Wireless (>50 million users), Sprint-Nextel (>50 million users), and Alltel (>10 million users) that use GPS technology to provide E-911 services. Additional transportation applications include real-time information on traffic delays, personalized public transit information systems, advanced route guidance capabilities, and multi-modal information applications such as personalized multimodal trip planning, continuous on-trip information to multimodal travelers, information on transfers, tools to assist travelers in finding their way to the destination address once they get off at the last stop provided by public transport.

3.5 Transportation, Vehicular and Automotive technology

Advances in transportation, vehicular, and automotive technology are likely to have the most direct impact on future transportation. The technologies surveyed here include small wheeled transport including segways and electric scooters/skates, hybrid vehicles, personalized rapid transit, automated vehicles, and flying cars.

Small-wheeled transport is a category of Nonmotorized Transportation. Future implementations are likely to be electric with a range of options. Segway is a two-wheeled, self-balancing, electric transportation device. It is a versatile, agile, short-range device that utilizes the patented dynamic stabilization technology and advanced alternative-power systems. Small-wheeled transport impacts include modal shifts from automobile travel to alternative modes, improved access to public transit, faster and efficient movement of pedestrians, and easier mobility for people who are physically and economically disadvantaged.

A Segway

Personalized rapid transit (PRT) system includes fully automated vehicles capable of operation without human drivers over a reserved guideway. The vehicles are available on-demand, providing direct origin to destination service for an individual or a small group - typically 1 to 6 passengers. PRTs are a hybrid of personal vehicles and mass transit and therefore provide the advantages of both. However, PRT systems are capital intensive and are feasible in city centers only. Capital costs per mile are estimated at $5,458,013 while annual operating costs are $8,927,723. However, with increased need to move towards more sustainable transport, PRT may emerge as a major player in future.

Despite the improvements to mass transit and alternatives such as PRT, personal autos continue to be the most preferred transport mode in the US. Significant network throughput improvements may still be realized by improving the operations of road networks and personal vehicles. The intelligent vehicle-highway system (IVHS) initiative in the 1990s was a step in this regards. But IVHS required significant public investment on upgrading the infrastructure. The initiative lost steam in the late 90s. However, the private auto-makers have continued to develop technologies that automate vehicle navigation. Examples include adaptive cruise control, lane departure warning, and collision avoidance. The transportation implications include significant throughput improvement (reduced congestion) and safety improvements (no accidents). Adaptive cruise control would help prevent backward shockwave propagation. At an average speed of 67 miles per hour, if only one in five vehicles used adaptive cruise control, no traffic jams would form and traffic would generally flow freely.

Terragfugia's Transition – Flying Car

Flying cars have been tested since the 1950s but their widespread use is still not a reality. However advances in vehicle location and navigation technologies and suitable legislations could pave the way for flying cars over the next 25 years. Currently several companies are developing prototypes. Examples include Moller's Skycar (3) and Terrafugia's transition (4). NASA has been actively supporting the development of Personal Air Vehicles (PAVs). Flying cars could significantly reduce congestion; vehicles can travel through the three dimensional space and fly straight to destinations instead of having to follow flat guided pathways.

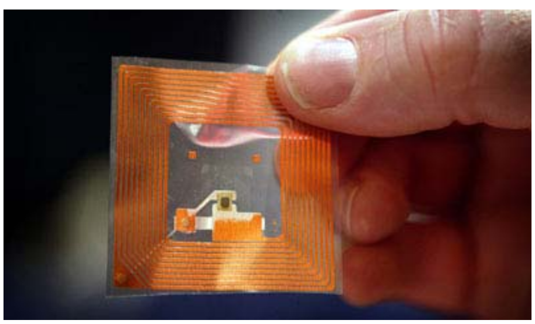
3.6 Sensors

As sensor technology advances towards miniaturization with communication capabilities, tiny smart sensors will increasingly be embedded in everyday objects and places, forming the basis for a ubiquitous sensory infrastructure. "Smart dust" sensors will perform complex tasks such as monitoring of health conditions to air quality. These sensors will also be linked together to form a massive, nano-scale sensor network. The sensors range from micro-scale (referred to as Micro-electrical mechanical systems, MEMS) to nano-scale (discussed earlier). Already several applications of sensors in transportation infrastructure have been explored.

MEMS can be used in Advanced Driver Assistance Systems, Crash Detection, Electronic Stability Control, LED Taillight Driver, both monitoring and testing of transportation infrastructure, and in transportation air-quality studies where MEMS "smart dust" has the potential to collect data for both analysis and forecasting the air-quality. The majority of the potential MEMS applications in transportation infrastructure will act as sensors. These include sensors used in monitoring temperature, crack measurements and monitoring, corrosion testing and monitoring, alkali-silica reaction (ASR) and other related reactions in concrete, and reliability of welding units in structural steel. MEMS thermal accelerometers in navigation systems with maps and global positioning satellite capabilities, MEMS-based display can overlay automobile diagnostics and repair instructions directly to the technician, and seat-based MEMS for passenger deduction.

Hewlett-Packard's Memory Spot wireless chip

More traditional sensors including GPS, RFID, smart cards, and biometric identification will be available with enhanced capabilities.



RFID Tag

Accuracy of GPS has been improving with enhancements (2). Targets include 5 -10 m resolution by 2009 and 1- 5 m resolution by 2013. Further the enhancements will improve reception near tall buildings, canyons, etc. It also will allow devices to reduce the amount of power they need to expend to receive a GPS signal. This will make putting accurate GPS receivers into mobile phones, watches, etc easier. Similarly, future RFID tags will shrink in size (example HP's memory spot 6, 7) to few millimeters, have greater storage capacity, faster transfer rates, and longer transfer range. Smart cards are likely to become common in wide range of transportation applications including secure identification (e-passport and e-license), security personnel identification at ports, and in transit and parking systems for fare payment. Yet another form of secure identification that will witness widespread use and acceptance is biometric identification.

3.7 Freight technology

The NYMTC Region is expected to have a 47% increase in volume (tonnage) through 2025. A majority of the region's freight is exchanged with the rest of the East Coast, and from manufacturing centers in the Midwest. The developments mentioned in the above technological domains are likely to impact freight transportation in addition to their impact on passenger transportation.

The focus of the technologies reviewed so far was on their impact on surface transportation. The freight mode split in NYMTC region indicates over 18% share for water based transportation. The ports and waterways in NYMTC region therefore handle a significant amount of freight transportation. Several technologies specific to water-based transportation exist.

The Waterbridge in Germany (21) connects two important German shipping canals by a giant kilometer-long concrete bathtub. The waterbridge will connect Berlin's inland harbor with the ports along the Rhine river. The project took six years to build and cost about half a billion Euros.

A technology that can improve material handling capabilities in ports is Automated Guided Vehicles (22). A more advanced concept is Automated Container Transport system between Inland POrt and Terminal (ACTIPOT) (23). ACTIPOT involves dedicated lanes between an Inland Port and terminals where trucks would go back and forth under full automatic control.

An equally important focus area is city logistics. With the growth of e-business and increasing material transactions, city logistics plays an important part in urban planning. The importance is furthered by the impacts on congestion and air quality of city logistics.

The Waterbridge in Germany

An emerging technological initiative for more efficient distribution of goods to the customers is pick-up centers. “Pick up points are local collection and distribution depots, or boxes, from which consumers can pick up goods they have ordered via home retail services” (20). The best known examples of pick up points in Europe today are the Kiala network in France and Benelux, and the Packstation network in Germany (20). Adopting similar freight technology should work well for densely populated regions such as New York City.

4 Technology Fact-Sheets

4.1 Nanotechnology

4.1.1 Nano-fuel

Technology	Nano-sized batteries (1) Nano Fuelsaver (2,3,6) Fuel-cell Catalyst (4,5,7)
Features	Nano-sized battery fuel cell measuring just 200 nanometers across that potentially can be integrated on-chip to supply power from a hydrogen reservoir for decades. Nano Fuelsaver uses revolutionary nano-technology to treat petrol or diesel entering the engine in order to enhance the combustion process, saving 10-20% fuel/diesel in cars, trucks, boats, motorbikes. Nano fuel-cell catalyst could lead to cheaper catalysts for making and using alternative fuels.
Timeline / Costs	"It will be 5 to 10 years before the technology (fuel cell catalyst) is ready to use in practical applications, according to the researchers." (5) Nano fuel-saver – already in commercial testing stage
Transportation Applications	Nano-batteries can be used to power remote sensors for its entire life time (CRM, SS) Fuel-cell catalysts could improve the efficiency of fuel-cells and bring down the costs making it inexpensive for use in vehicles (AQEM)
Challenges	Nano-sized batteries: commercialization is not feasible yet (1)

References:

1. http://www.fuelcellsworks.com/Supppage4589.html
2. http://www.nanovip.com/node/2359
3. http://www.newscientist.com/article/dn4271.html
4. http://www.technologyreview.com/Nanotech/18669/
5. http://www.trnmag.com/Stories/2005/050405/Nano_pyramids_boost_fuel_cells_Brief_050405.html
6. http://www.nanotechnology.net.nz/
7. http://www.iom3.org/materialsworld/feature-pdfs/jun05/Model%20behaviour.pdf

4.1.2 Nanosensors

Technology	To track bio-terror agents (1, 2) To track stress in materials (6) To detect polluting agents.
Features	Tiny detectors that could instantly screen for hundreds of toxins or pathogens Gaining increasing attention – special issue call for papers dedicated to the topic in IEEE journal of Sensors (3) The Golden Gate Bridge now has an experimental sensor network of approximately 200 small Motes, each with an accelerometer that measures movement such as traffic, wind, or seismic loads (5).
Timeline / Costs	"I work on a lot of things that I'll never see in my lifetime, this will happen in my lifetime." (1)
Transportation Applications	Nanosensors could be used in transportation to monitor pavement conditions, bridge conditions, pollution deduction, bio-terror agent detection, air quality monitor etc. The feasibility of "Cyberliths", or Smart Aggregates, as wireless sensors embedded in concrete or soil is being studied. (4) Researchers at Johns Hopkins University's Applied Physics Laboratory have developed a robust wireless embedded sensor, suitable for long term field monitoring of corrosion in rebar, particularly in bridge decks.
Challenges	Nanowire sensor devices have proven difficult to mass-produce, economic costs are high, regulatory hurdles, legal challenges (2)

References:

1. http://www.technologyreview.com/Nanotech/18127/
2. http://www.rpitechnology.com/files/article_nanosensors.pdf
3. http://ewh.ieee.org/tc/sensors/SJ/CallForPapers/NanosensorTechnologyCFP.pdf
4. http://concreteproducts.com/mag/concrete_fhwa_research_zeroes/
5. http://www.cs.berkeley.edu/~binetude/ggb/
6. http://www.ceam.ucsd.edu/papers/sensors.html

4.1.3 Nano-material

Technology	Carbon-based fibers Nanocoating of metallic surfaces Nanoparticle-reinforced materials Nanomaterials in pavements (2) Automatic healing materials (2)
Features	Carbon-based fibers are 100x stronger than steel and yet lighter Nanocoating of metallic surfaces help achieve super-hardening, low friction, and enhanced corrosion protection nanoparticle-reinforced materials that replace metallic components in cars Nanomaterials in pavements (2) Automatic healing of materials (2)
Timeline / Costs	The researchers surveyed predicted that many advances would arrive within five years (2011). (5)
Transportation Applications	Autonomic (spontaneous) healing research in structural polymers, could lead the way to guardrails that heal themselves, or concrete or asphalt that heal their own cracking. Coatings which mimic the surface of the lotus leaf — to which nothing adheres — likely will lead to signage and work zone barricades which shed dirt and grime and never need to be washed, enhancing safety and lowering labor costs. They can also be used on windshields to keep them clear of dirt and water. (4) Nanoparticle-reinforced materials can replace metallic components in cars Two nano-sized particles that stand out in their application to construction materials are titanium dioxide (TiO_2) and carbon nanotubes (CNT's). The former is being used for its ability to break down dirt or pollution and then allow it to be washed off by rain water on everything from concrete to glass and the latter is being used to strengthen and monitor concrete. (5)
Challenges	Cost and the relatively small number of practical applications, for now, hold back much of the prospects for nanotechnology. (5)

References:

1. http://tti.tamu.edu/documents/0-5239-1.pdf
2. T. Kuennen. "Small Science Will Bring Big Changes To Road." Better Roads, 2004, http://www.betterroads.com/
3. http://www.smt.sandvik.com/nanoflex
4. http://ieeexplore.ieee.org/iel5/7182/19339/00893798.pdf
5. http://www.innovationsgesellschaft.ch/images/fremde_publikationen/nov06_nanoforum.pdf

4.2 Energy

4.2.1 Hydrogen Fuel

Technology

Hydrogen is the simplest and most abundant element in the universe. At Earth surface temperatures and pressures, it is a colorless, odorless gas (H_2), but very little hydrogen gas is present in Earth's atmosphere. Instead, it is usually bonded with other elements. For example, Hydrogen is locked up in enormous quantities in water (H_2O), hydrocarbons (such as methane, CH_4), and other organic matter. (1)

Features/ benefits

1. Clean-burning;
2. High potential for domestic production;
3. A fuel with high efficiency. The energy in 2.2 lb (1 kg) of hydrogen gas is about the same as the energy in 1 gallon of gasoline. (1, 5)

Timeline / Costs

Hydrogen is currently very expensive, not because it is rare (it's the most common element in the universe!) but because it's difficult to generate, handle, and store. (7)

You can get average costs for hydrogen fuels through the Alternative Fuel Price Report. (8)

Transportation Applications

- Fuel cell vehicles, powered by Hydrogen, have the potential to revolutionize our transportation system. They are more efficient than conventional internal combustion engine vehicles and produce no harmful tailpipe exhaust—their only emission is water. Fuel.(2)
- BMW Hydrogen 7 powered by liquid hydrogen and gasoline bi-fuel vehicle is an industrial application case in USA. (3)
- Hydrogen Fuel Cell Bicycles developed in China. (4)
- Hydrogen is currently available only as an industrial or scientific chemical product, not as a bulk fuel. (7)

Challenges

1. Storage Technologies. Hydrogen has a low volumetric energy density. Therefore, to store the same amount of energy, hydrogen needs larger storage tank than gasoline. (1,5,6)
2. The primary challenge for hydrogen production is reducing the cost of production technologies to make the resulting hydrogen cost competitive with conventional transportation fuels. (1, 5)

Reference

1. http://www1.eere.energy.gov/hydrogenandfuelcells/production/basics.html
2. http://www.eere.energy.gov/afdc/vehicles/fuel_cell.html
3. http://www.hydrogencarsnow.com/blog/hydrogencars.html
4. http://www.alternative-energy-news.info/hydrogen-fuel-cell-bikes/
5. http://ec.europa.eu/research/energy/pdf/hlg_vision_report_en.pdf
6. http://www.sciencedaily.com/releases/2007/10/071003100601.htm
7. http://www.altfuels.org/backgrnd/altftype/hydrogen.html
8. http://www.eere.energy.gov/afdc/price_report.html

4.2.2 Biodiesel Fuel

Technology	**Biodiesel** is a liquid fuel made up of fatty acid alkyl esters, fatty acid methyl esters (FAME), or long-chain mono alkyl esters. It is produced from a variety of natural crops including rapeseed, soybean, mustard, flax, sunflower, canola, palm oil, hemp, jatropha and waste vegetable oils. (1, 2)
Features/ benefits	This fuel source is 1. Clean-burning; 2. Domestically produced, Renewable substitute for petroleum diesel; 3. Nontoxic and biodegradable; 4. Capable of reducing engine wear. (1, 2)
Timeline / Costs	The cost of Biodiesel is competitive with diesel. (7) You can get average costs for Biodiesel through the Alternative Fuel Price Report (5).
Transportation Applications	• At the production level, biodiesel fuel is a clean and affordable fuel for trucks, buses, farm equipment and other forms of heavy transportation. (4) • Biodiesel can be used in conventional diesel engines, directly substituting for or extending supplies of traditional petroleum diesel. (3) Modern diesel engine technology has taken the advantages of biofuel usage. Biodiesel is not currently widely available, even though there production-scale plants, such as NOPEC, do exist. (6)
Challenges	None

Reference:
1. http://www.eere.energy.gov/afdc/fuels/biodiesel.html
2. http://www.alternative-energy-news.info/technology/biofuels/biodiesel-fuel/
3. http://www.eere.energy.gov/afdc/vehicles/diesel.html
4. http://www.alternative-energy-news.info/advantages-biodiesel-fuel-transportation/
5. http://www.eere.energy.gov/afdc/price_report.html
6. http://www.altfuels.org/backgrnd/altftype/b20.html
7. http://www.biodiesel.com/theFuel.htm

4.2.3 Ethanol Fuel

Technology	Ethanol (CH_3CH_2OH) is a renewable transportation fuel primarily made from starch crops, such as corn. It is also made from sugar beets and cane or cellulosic materials, such as fast-growing trees and grasses. Nearly one-third of U.S. gasoline contains ethanol in a low-level blend to reduce air pollution. (1, 2)
Features/ benefits	1. Produced from domestic crops, increasing Energy Security. 2. Fueling the Economy. Ethanol production is a new industry that is creating jobs in rural areas where employment opportunities are strongly needed. 3. Reducing Greenhouse Gas
Timeline / Costs	E85 (85% ethanol, 15% gasoline) typically costs about the same or slightly less than gasoline on a gallon-for-gallon basis. (1)
Transportation Applications	E85 (85% ethanol, 15% gasoline) is considered an alternative fuel. It is used to fuel E85-capable flexible fuel vehicles (FFVs), which are available in a variety of models from U.S. and foreign automakers. (1) For more details about flexible fuel vehicles refer to (5).
Challenges	Requires more energy to produce than what it provides Can have negative social impacts since it increases the cost of food in places such as Mexico by re-directing corn produce for fuel production

Reference:

1. http://www.eere.energy.gov/afdc/fuels/ethanol_what_is.html
2. http://freeenergynews.com/Directory/Ethanol/
3. http://www.iastate.edu/~nscentral/news/2006/may/mold.shtml
4. http://www.newswise.com/articles/view/511547/?sc=dwhp
5. http://www.eere.energy.gov/afdc/vehicles/flexible_fuel.html

4.2.4 Methanol Fuel

Technology	Methanol (CH3OH), known as wood alcohol, is an alternative liquid engine fuel. Usually it is produced by natural gas, coal, or, woody biomass. (1)
Features/benefits	1. Methanol is domestically produced, sometimes from renewable resources. 2. Protecting Public Health and the Environment. When compared to reformulated gasoline, M85 emitted fewer (and less reactive) ozone forming pollutants, hydrocarbons, and potency-weighted toxics (including acetaldehyde, benzene, 1,3-butadiene.) However, it also emitted more NOx and formaldehyde.
Timeline / Costs	M85 is the least distinguishable from gasoline in how you buy and use. In California, M85 costs about the same per mile as mid-grade gasoline.(3)
Transportation Applications	• Methanol has been seen as a possible large volume motor fuel substitute at various times during gasoline shortages. (2) • Methanol can be used for mostly Heavy-duty buses.(1) • The flexible-fuel vehicles currently being manufactured by General Motors, Ford and Chrysler can run on any combination of ethanol, methanol and/or gasoline. (2)
Challenges	• Methanol is extremely toxic. Exposure can occur through inhalation of vapors or through skin contact. Special lubricants must be used as directed by the supplier and M-85-compatible replacement parts must be used. Therefore, Methanol remains a qualified alternative fuel as defined by EPAct, but it is not commonly used or easily available.(1) • Methanol's energy density is about half that of gasoline, reducing the range a vehicle can travel on an equivalent tank of fuel. (2) • The availability of 85 percent methanol is limited. (3)

Reference:
1. http://www.eere.energy.gov/afdc/fuels/ethanol_what_is.html
2. http://www.ethanol-gec.org/clean/cf05.htm
3. http://www.altfuels.org/backgrnd/altftype/m85.html

4.2.5 Natural gas

Technology	**Natural gas** is a mixture of hydrocarbons, predominantly methane (CH_4). As delivered through the pipeline system, it also contains hydrocarbons such as ethane and propane and other gases such as nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapor. (4,7) "Most natural gas is extracted from gas and oil wells. Much smaller amounts are derived from supplemental sources such as synthetic gas, landfill gas and other biogas resources, and coal-derived gas." (1,7)
Features/benefits	1. A domestically produced alternative fuel. (1) 2. A high octane rating and excellent properties for spark-ignited internal combustion engines. (1) It provides fueling convenience. (5) 3. It is safe, non-toxic, non-corrosive, and non-carcinogenic. It presents no threat to soil, surface water, or groundwater. (1,5) 4. Natural gas vehicles are cleaner than most fuels. (5)
Timeline / Costs	Compressed natural gas is the least expensive alternative fuel (except electricity) when you compare equal amounts of fuel energy. (2) You can get average costs for natural gas through the Alternative Fuel Price Report. (3)
Transportation Applications	Approximately 22 percent of the energy consumption of the U.S. comes from natural gas.(7) A direct natural gas application on transportation is the dedicated natural gas vehicles (NGVs). (6)
Challenges	Natural gas vehicles cost more (7) Fuel availability is an issue outside of California (7)

Reference:
1. http://www.eere.energy.gov/afdc/fuels/natural_gas.html
2. http://www.altfuels.org/backgrnd/altftype/cng.html
3. http://www.eere.energy.gov/afdc/price_report.html
4. http://www.socalgas.com/business/ngv/fleets.shtml
5. http://www.eere.energy.gov/afdc/vehicles/natural_gas_what_is.html
6. http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/naturalgas.html
7. http://www.nrel.gov/docs/fy07osti/41884.pdf

4.2.6 Propane

Technology	"**Propane**, also known as liquefied petroleum gas (LPG or LP-gas), or autogas in Europe, is a three-carbon alkane gas (C_3H_8). Stored under pressure inside a tank, propane turns into a colorless, odorless liquid. As pressure is released, the liquid propane vaporizes and turns into gas that is used for combustion. An odorant, ethyl mercaptan, is added for leak detection." Propane is produced as a by-product of natural gas processing and crude oil refining. (1)
Features/benefits	1. Enable excellent properties for spark-ignited internal combustion engines. (1) 2. An exceptionally safe fuel. Propane has the lowest flammability range of all alternative fuels. (1) 3. Non-toxic and presents no threat to soil, surface water, or groundwater. (1) 4. Compared with vehicles fueled by conventional diesel and gasoline, propane vehicles can produce significantly lower amounts of some harmful emissions and the greenhouse gas carbon dioxide. (3)
Timeline / Costs	Propane prices are subject to a number of influences, such as Crude Oil and Natural Gas Prices, Supply/Demand Balance. (7) The latest Alternative Fuel Price Report show the price of propane per gallon is less than regular gasoline. (6)
Transportation Applications	Propane is distributed nationwide. It is the most commonly used alternative transportation fuel and the third most used vehicle fuel, behind gasoline and diesel. Dedicated propane vehicles (2) have been used in delivery vehicles, school buses, utility vehicles, shuttle buses, and beverage vehicles. (4, 5)
Challenges	No information at this time.

Reference:
1. http://www.eere.energy.gov/afdc/fuels/propane_what_is.html
2. http://www.eere.energy.gov/afdc/vehicles/propane.html
3. http://www.propanecouncil.org/newsroom/press_releaseDetail.cfv?id=434
4. http://www.propaneshuttlebus.com/pressroom.htm
5. http://www.propaneshuttlebus.com/
6. http://www.eere.energy.gov/afdc/price_report.html
7. http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/propane_prices_brochure/propbro.html

4.2.7 Biogas Fuels

Technology	Biogas is the gaseous product of the anaerobic digestion (decomposition without oxygen) of organic matter. It is a mixture of methane, carbon dioxide, and traces of gases such as hydrogen, carbon monoxide, and nitrogen. (1, 4) For an overview of biogas and its uses, see the International Energy Agency's Biogas Production and Utilization. (2)
Features/benefits	1. Domestic, renewable resource. 2. Directly reduces greenhouse gas emissions by preventing methane release into the atmosphere. 3. Anaerobic digestion systems (non-landfill) treat waste naturally, require less land area than aerobic composting, reduce the amount of material that must be land filled, reduce waste odors, and produce sanitized compost and nutrient-rich liquid fertilizer.
Timeline / Costs	Emerging Fuels
Transportation Applications	Biogas-fueled vehicles: • A 2007 report estimated that 12,000 vehicles are being fueled with upgraded biogas worldwide, with 70,000 biogas-fueled vehicles predicted by 2010. Europe has most of these vehicles. United States only has a smaller scale of biogas vehicle.(2) • A biogas-fueled passenger train carriage, the world's first to run solely on biogas, was presented in Sweden, 2005. (3)
Challenges	Research and development are focusing on reducing the costs of biogas production and purification, producing higher-quality natural gas from biogas, and evaluating the performance of biogas-fueled vehicles. (1)

Reference:
1. http://www.eere.energy.gov/afdc/fuels/emerging_biogas_what_is.html
2. http://www.iea-biogas.net/Dokumente/Brochure%20final.pdf
3. http://findarticles.com/p/articles/mi_m0FZX/is_11_71/ai_n15892440
4. http://www.humboldt.edu/~serc/biogas.html

4.2.8 Biobutanol Fuels

Technology	Butanol is a 4-carbon alcohol. Biobutanol is butanol produced from biomass feedstock. Currently, butanol's primary use is as an industrial solvent in products such as lacquers and enamels." (1, 2)
Features/ benefits	1. It can be produced domestically from a variety of homegrown feedstock. 2. Greenhouse gas emissions are reduced. 3. It is easily blended with gasoline which is used in today's gasoline-powered vehicles. 4. Its energy density is only 10 to 20% lower than gasoline's. 5. It is compatible with the current gasoline distribution infrastructure so it does not need new facility for delivery and storage. 6. It can be produced using existing ethanol production facilities with relatively minor modifications.
Timeline / Costs	Emerging Fuels. Biobutanol research and development by government and industry groups is ongoing. (1)
Transportation Applications	Biobutanol proponents claim that today's vehicles can be fueled with high concentrations of biobutanol—up to 100%—with minor or no vehicle modifications, but tests for this claim are insufficient. (1)
Challenges	No infrastructure for fueling vehicles with biobutanol currently exists. However, biobutanol would be able to be distributed through the existing gasoline infrastructure, including pipeline transport since biobutanol does not cause corrosion or water contamination issues. (1)

Reference:
1. http://www.eere.energy.gov/afdc/fuels/emerging_biobutanol_what_is.html.
2. http://www.lightparty.com/Energy/Butanol.html

4.2.9 Hydrogenation-Derived Renewable Diesel

Technology	Hydrogenation-derived renewable diesel (HDRD), also called second-generation biodiesel, is the product of fats or vegetable oils—alone or blended with petroleum—that have been refined in an oil refinery.(1)
Features/Benefits	1. It can be produced domestically from a variety of homegrown feedstock. (1) 2. Greenhouse gas emissions are reduced. (1) 3. It should be compatible with the current diesel distribution infrastructure. (1) 4. It can be produced using existing oil refinery capacity and does not require extensive new production facilities. (1) 5. Its ultra-low sulfur content should enable use of advanced emission control devices.
Timeline / Costs	Emerging Fuels. Hydrogenation-derived renewable diesel (HDRD) is close to full commercialization. (1)
Transportation Applications	It should be able to be used directly in today's diesel-powered vehicles. Its fuel properties, especially its high octane number, suggest it will provide similar or better vehicle performance than conventional diesel. (1)

Reference:
1. http://www.eere.energy.gov/afdc/fuels/emerging_green_what_is.html.

4.2.10 P-Series

Technology	P-Series fuel is a blend of natural gas liquids (pentanes plus), ethanol, and the biomass-derived co-solvent methyltetrahydrofuran (MeTHF). (1)
Features/Benefits	1. Produced from domestic sources. (1) 2. More than 60% of energy contents is derived from renewable sources. (3) 3. Less greenhouse gas emissions.(1,3) 4. Reducing fossil fuel use. (3)
Timeline / Costs	Emerging Fuels. Currently, P-Series is not being produced in large quantities and is not widely used. (1, 2)
Transportation Applications	P-Series fuel can be used alone or freely mixed with gasoline in any proportion inside a flexible fuel vehicles fuel tank. (1, 2)
Challenges	No related information at this time.

Reference:
1. http://www.eere.energy.gov/afdc/fuels/emerging_pseries.html
2. http://www.iags.org/pseries.htm
3. http://books.google.com/books?id=U4TBoJB2zgsC&pg=PA680&lpg=PA680&dq=benefit+of+%22p+series%22+fuel&source=web&ots=MTSPRnPKom&sig=5kIHv9J7yDPwTGY4M57A3BGj3qc#PPA680,M1

4.2.11 Ultra-low sulfur diesel

Technology	Ultra-low sulfur diesel (ULSD) is diesel fuel with 15 parts per million (ppm) or lower sulfur content. (1, 3)
Features/Benefits	1. Ultra-low sulfur diesel enables use of advanced emission control technologies on light-duty and heavy-duty diesel vehicles.(1) 2. Diesel engines are 20-40% more efficient than comparable gasoline engines. (1) 3. Ultra-low sulfur diesel uses the existing fueling infrastructure, engine and vehicle technologies. (1)
Timeline / Costs	Emerging Fuels.
Transportation Applications	Ultra-low sulfur fuel (ULSD) is now nationwide available. It will be the primary highway diesel fuel produced, but EPA does not require service stations and truck stops to sell ULSD fuel. (2)
Challenges	Currently, the vast majority of ULSD is produced from petroleum. It cannot meet the demand requirement. However, biodiesel; biomass-to-liquids, coal-to-liquids, and gas-to-liquids diesel; and hydrogenation-derived renewable diesel are inherently ultra-low sulfur fuels and could help the insufficiency of ULSD in the future. Most ULSD fuels produced from non-petroleum and renewable sources are considered alternative fuels. (1, 3)

Reference:
1. http://www.eere.energy.gov/afdc/fuels/emerging_sulfur_diesel_what_is.html
2. http://www.clean-diesel.org/highway.html
3. http://www.dieselforum.org/meet-clean-diesel/what-is-clean-diesel/new-technologies/ultra-low-sulfur-diesel/

4.2.12 Electricity

Technology	"Electricity used to power vehicles is generally provided by the electricity grid and stored in the vehicle's batteries. Fuel cells are being explored as a way to use electricity generated on board the vehicle to power electric motors. Unlike batteries, fuel cells convert chemical energy from hydrogen into electricity." (4, 5)
Features/ Benefits	1. No tailpipe emissions. But the emissions can be generated in the electricity production process. 2. Easy to recharge.
Timeline / Costs	Electricity fueling costs for electric vehicles are reasonable compared to gasoline. $0.05 per mile for vehicles with direct current (DC) electric systems and $0.03 cents per mile for vehicles with alternating current (AC) systems.
Transportation Applications	Electricity can be used to power electric and plug-in hybrid electric vehicles directly from the power grid. (3) Hybrid Electric Vehicles (HEVs) are becoming widely available for a variety of applications. (1.2)
Challenges	Several barriers are preventing widespread commercialization of plug-in hybrid electric vehicles (PHEVs), including the following: 1. Hybrid component mass, volume, cost, reliability, and safety 2. Lack of domestic sources for batteries 3. Consumer behavior and expectations 4. Robust operation in range of environmental conditions.

Reference:

1. http://www.eere.energy.gov/afdc/vehicles/hybrid_electric.html
2. http://www.nrel.gov/vehiclesandfuels/hev/hevs.html
3. http://www.eere.energy.gov/afdc/vehicles/plugin_hybrids.html
4. http://www.eere.energy.gov/afdc/fuels/electricity_basics.html
5. http://www.altfuels.org/backgrnd/altftype/electricity.html

4.3 Communication

4.3.1 DSRC

Technology	Dedicated Short Range Communications (DSRC) is a block of spectrum in the 5.850 to 5.925 GHz band allocated by US FCC to enhance the safety and the productivity of the transportation system. (1) DSRC technology will provide secure, reliable communication links between vehicles and infrastructure safety subsystems that can increase highway safety. (5)
Features	DSRC applications now in use include electronic toll collection, and electronic credentialing and monitoring of commercial vehicle operations (CVO) (6) The promise of DRSC is to deliver a far greater data rate and range to wireless highway applications. “Compared with existing RFID toll applications, DRSC will deliver data rates of 25 Megabits per second, instead of 250 kilobits, and a range of up to 1 km, instead of 10 meters,” says Richard Schnacke, vice president of industry relations for TransCore (7) The DSRC system supports communication links in the following parameters (5): Vehicle speed (up to 120 mph), Communication range (up to 1000 meters for special vehicles; nominal is 300 meters), System Latency (< 50 ms), Data rate (default is 6 Mbps; up to 27 Mbps), Single transaction size (up to 20K bytes)
Timeline / Costs	Government and vehicle manufacturers plan to make a collaborative decision on deployment of DSRC in the year 2008 that could signal the beginning of the deployment process in the auto industry and public agencies. (9) DSRC is the technology for the 2010 decade and beyond. (5) No cost estimates are available, but they will clearly be a lot more expensive than today's standard toll tags, let alone the new sticker tags (9)
Transportation Applications	Active safety systems communication on-board the vehicle (2) Allows vehicle-vehicle and roadside-vehicle communications (1) Roadside-vehicle wireless communications for Intersection Decision Support (4) Cooperative Adaptive Cruise Control (CACC) system and its impact at highway merge junctions (3) Traffic Flow (Speed & Volume), Lane Occupancy, Priority Signal Preemption, Toll Collection, Freight Tracking, Roadway Conditions (5) Intersection collision avoidance, Approaching emergency vehicle warning, Vehicle safety inspection, Transit or emergency vehicle signal priority, Electronic parking payments, Commercial vehicle clearance and safety inspections, In-vehicle signing, Rollover warning, Probe data collection, Highway-rail intersection warning. (7)

References:

1. http://path.berkeley.edu/~dsrc/
2. Raja Sengupta and Qing Xu "DSRC for Safety Systems", Intellimotion Vol. 10 (4), p2-5, 2004
3. Qing Xu, Karl Hedrick, Raja Sengupta, Joel VanderWerf, "Effects of Vehicle-vehicle / roadside-vehicle Communication on Adaptive Cruise Controlled Highway Systems", IEEE VTC Fall 2002
4. http://path.berkeley.edu/~dsrc/reading/ids.pdf
5. http://www.itsa.org/itsa/files/pdf/DSRCICWhitePaper.pdf

6. http://www.standards.its.dot.gov/Documents/advisories/dsrc_advisory.htm
7. http://www.rfidjournal.com/article/articleview/866/1/1/
8. http://www.industrial-embedded.com/news/db/?1291
9. http://www.reason.org/surfacetransportation18.shtml

4.3.2 Wide area wireless communication

Technology	Wide area wireless communication includes WiMax, Mobile WiMax, Ultra Mobile Broadband (UMB) and UMTS.
Features	WiMAX provides large coverage distances of up to 50 kilometers under line of sight (LOS) conditions and typical cell radii of up to 5 miles/8 km under Non-LOS conditions. (2) Mobile WiMAX can provide tens of megabits per second of capacity. The high data throughput enables efficient data multiplexing and low data latency. Attributes essential to enable broadband data services including data, streaming video and VoIP with high quality of service (QoS). (1) Universal Mobile Telecommunications System (UMTS) is the European standard for 3G mobile communication systems which provide an enhanced range of multimedia services. UMTS supports up to 1920 kbit/s data transfer rates (5) "…known commercially as Ultra Mobile Broadband (UMB). Soon, people will be sending data through the air at speeds of up to 280 Mbps in a mobile environment." (6)
Timeline / Costs	Intel is bringing add-in cards in 2007 and embedded modules in 2008 for WiMax (3). Yankee Group Research Inc. has a somewhat conservative forecast for WiMax growth, predicting about 27 million subscribers in 2011, with about 7 million to 8 million in the U.S. (4)
Transportation Applications	In-vehicle communication, Inter-vehicle communication Anytime, anywhere connectivity allows for personalized real-time information dissemination. Encourages telecommuting and provides greater work flexibility. Allows for anytime, anywhere video conferencing.

References:

1. http://www.wimaxforum.org/technology/downloads/Mobile_WiMAX_Part1_Overview_and_Performance.pdf
2. http://www.wimaxforum.org/technology/downloads/WiMAXNLOSgeneral-versionaug04.pdf
3. http://www.intel.com/netcomms/technologies/wimax/index.htm
4. http://www.pcworld.com/article/id,137709-c,wirelesstechnologyservices/article.html
5. http://www.telecomspace.com/3g-umts.html
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4.3.3 Ultra high-speed Internet

Technology	Next generation optical networks, Dense Wave Division Multiplexing (DWDM) transmission technology
Features	Next generation optical networks will transfer data at the rate of 10 gigabits per second to 100 gbps (1-5)
Timeline / Costs	"the Internet2 community seeks to put these new technologies in the hands of businesses and consumers over the next 5 to 10 years." (4)
Transportation Applications	"…the network of the future will support a whole new set of applications -- immersive collaboration environments, resource-sharing, real-time computation-intensive simulations, HDTV-quality video on demand" (4) Advanced telecommuting options, advanced traveler information systems and traffic management, drastic changes in life-style affecting travel demand.

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4.3.4 VANETs

Technology	"A **Vehicular Ad-Hoc Network**, or **VANET**, is a form of Mobile ad-hoc network, to provide communications among nearby vehicles and between vehicles and nearby fixed equipment, usually described as roadside equipment." (1)
Features/ Benefits	Benefits: Infrastructure light. Fully take advantage of online traffic information. Reduce congestion. Improve traffic productivity. Improve traffic safety. (2)
Timeline / Costs	
Transportation Applications	VANET is a technology that could significantly increase traffic productivity in the future. For safety purposes, police and fire vehicles are estimated to be instrumented first so that vehicles can communicate with each other (2). VANET related application can be categorized into safety and non-safety groups. (6) Prototype system in research: StreetSmart (7), TrafficView (8).
Challenges	Application of VANET faces several research challenges as below: The high vehicular mobility makes VANET subject to frequent fragment and low connectivity. (4,6) The varying traffic flow characteristics in the transportation network could possibly lead to different VANET in a single trip. (5) The possibility of malicious messages and the accessibility of any traveler's origin-destination information can pose a serious security and privacy problem.(3) All nodes sharing the same medium access channel will lead to congestion in very dense networks. (3,4,5, 6)

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4.4 Computing and Internet Technology

4.4.1 Collaboration software

Technology	Software that enables coordinated remote work. Examples include Microsoft Office Groove (1), Adobe Acrobat Connect (2), Webex (3), OfficeScape (4), Documentum (5), IBM collaboration platform (6)
Features	Collaborative Management software provides audio, video, data, and desktop sharing features in a single package. There are more than 100 collaboration tools on the market, with about 25 geared to small businesses. (7)
Timeline / Costs	Already available in market.
Transportation Applications	Enables telecommuting

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4.4.2 Augmented Reality

Technology	"Augmented reality (AR) is a field of computer research which deals with the combination of real world and computer generated data." (1)
Features/ Benefits	Based on both software and hardware, it is a representation technique combing real world and computer generated data. The aim of this technique is to augment human perception by adding to it information not normally detectable by the human senses.
Timeline / Costs	Most of AR applications are under development and not in commercial use since for now, the technology is still too complicated and expensive for most companies. This situation will change as smaller and less expensive computer hardware is available. (5)
Transportation Applications	A main part of recent AR research focus on using live video imagery which is digitally processed and "augmented" by the addition of computer generated graphics. (1) AR technology is used in transportation simulation. It can offer a very realistic environment for driving enhancement as well as driving performance testing under different scenarios. (3) AR technology used in traffic tracking, for example "Augmented reality traffic control center" which combines data from a plurality of sensors to display real-time, information about traffic control objects, such as airplanes. (4)

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4.4.3 Personal travel assistant

Technology	Provides individuals, in vehicle and on foot, with location based information services.
Features	Brings together several features including navigation, traffic information, as well as utility and entertainment through stand-alone GPS or mobile phones. Initially, network-based location technologies from cellular service providers relied on triangulation using cell-tower signals to determine individual location; This method is increasingly giving way to leveraging built-in GPS chips in each handset, mostly because these chips have become dramatically more cost-effective and less power consumptive while improving location availability over the last several years. (6)
Timeline / Costs	Several models are available in the market including Garmin nuvi (1), TomTom (2) Of the $118 million in revenue that downloadable mobile applications such as location based services (LBS), weather applications, chat/community, and personal organization tools generated during Q2 2007, LBS represented 51 percent. (5) Today, Verizon Wireless (>50 million users), Sprint-Nextel (>50 million users), and Alltel (>10 million users) use GPS technology to provide E-911 services. (6)
Transportation Applications	Real-time information on traffic delays, enables personalized public transit information system, advanced route guidance capabilities Multi-modal information applications: Personalized multimodal trip planning, continuous on-trip information to multimodal travelers, information on transfers, assist travelers in finding their way to the destination address once they get off at the last stop provided by public transport. (3)
Challenges	While hardware technology is available, it is expensive and the corresponding software technology to provide real-time information content is lagging.

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4.4.4 HD video conferencing

Technology	Hi-def video conferencing service providers include: Cisco TelePresence (6), HP Halo Collaboration Studio (7), LifeSize (1), Polycom (10), Tandberg (4), UltraGrid (5), Teleris (8), Aethra (9), Sony (12)
Features	Also referred to as TelePresence, the system includes hi-definition cameras, monitors, bridges, and network equipment that allow two-way and multi-way video conferencing.
Timeline / Costs	LifeSize costs $8,000 to $12,000 (2, 3) The basic TelePresence 1000 model, designed for one-on-one meetings, is priced at $79,000 per station. TelePresence 3000, for larger meetings, is listed at $299,000 per station.
Transportation Applications	The main application industry is telemedicine. However with increasing availability, faster internet connections hi-def video conferencing will become more common. It can encourage telecommuting and offer alternate ways for individuals to socialize.
Challenges	High definition requires a large amount of bandwidth.

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4.4.5 Advanced route guidance systems

Technology	Examples include Mopar navigation (1)
Features	Advances in modeling route guidance (3,4) are enabling the implementation of next generation route guidance. With the introduction of European satellites for navigation – called GALILEO (2) - the accuracy in urban areas of GPS is likely to improve further.
Timeline / Costs	
Transportation Applications	Pre-trip coordination (3), En-route guidance, incorporate real-time information about dynamic tolls Real-time feedback route guidance can help alleviate and dissolve heavy non-recurrent traffic congestion, and establish dynamic user equilibrium (6)
Challenges	Personalization of route guidance by incorporating user preferences is one of the most desired features (to ensure consistency) (7).

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4.4.6 Adaptive ramp metering

Technology	Algorithms that ensure efficient traffic flow. Examples include: ALINEA (1), stratified zone-metering (2), and their combinations (3).
Features	Ramp metering algorithms are either local or coordinated. ALINEA is a local feedback-control algorithm. Several studies compare the different ramp metering strategies (3,4)
Timeline / Costs	Ramp metering have been implemented over the past 30 years in several states and countries. But the availability of new and improved algorithms coupled with more accurate deduction and communication technologies, have improved the benefits of adopting ramp metering algorithms.
Transportation Applications	Congestion reduction and management technique; better flow also helps realize air quality improvement objectives. Smoother traffic flow will result in lesser accidents.

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4.5 Transportation, Vehicular, and Automotive Technology

4.5.1 Small wheeled transport

Technology	Small-Wheeled Transport includes travel involving wheeled luggage, walkers, skates, skateboards, push scooter, motorized scooter, wheelchairs, Segway, handcarts and wagons. (1)
Features	They are a category of Nonmotorized Transportation. Future implementations are likely to be electric with a range of options (2, 3) Segway (4) is a two-wheeled, self-balancing, electric transportation device - versatile, agile, short-range devices that utilize the patented dynamic stabilization technology and advanced alternative-power systems.
Timeline / Costs	Several of these are available in the market but have seen only limited use.
Transportation Applications	Shifts automobile travel to alternative modes, Improves access to public transit, faster and efficient movement of pedestrians. Provides mobility for people who are physically and economically disadvantaged.
Challenges	Create conflicts when used on nonmotorized facilities. There are no clear policy measures outlined for the use of such devices. (5)

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4.5.2 Hybrid vehicles

Technology	Hybrid electric vehicles (HEV) comprising battery + ICE and plug-in hybrid electric vehicles (PHEV) Several (Toyota (1), Honda (2), Ford (3), General Motors (4)) commercially available Research efforts include DoE's FreedomCAR and Vehicle Technologies (FCVT) Program evaluating PHEV (5, 6), National Renewable Energy Laboratory's Advanced Vehicle and Fuels research program on HEV (7).
Features	Multiple technologies feed into developing hybrid vehicles including: Electric propulsion systems, Electrical energy storage systems (e.g., batteries, power capacitors), on-board data acquisition and control system. While several hybrid vehicles are available in passenger vehicle market, research is on-going to adopt hybrid technology for heavy-vehicles (8)
Timeline / Costs	The world hybrid-vehicle market, estimated at 384,000 vehicles in 2006, is projected to reach 1.1 million units in 2010 and 2 million units by 2015 (10) Despite rapid growth in hybrid-electric vehicle sales forecasted over the next few years, hybrid market share is expected to top out at 3 percent of the U.S. automotive market by 2010, according to the J.D. Power-LMC Automotive Forecasting Services Hybrid-Electric Vehicle Outlook (11) vehicle models utilizing a hybrid-electric powertrain still will remain a small portion of the market, growing from 1.3 percent of U.S. light-vehicle sales in 2005 to 4.2 percent market share by 2012. (12) Europe will see considerable growth in the number of HEVs with introduction of models such as Audi Q7, Porsche Cayene, Volkswagen Touran, BMW X3, Mercedes M&S Class in the years ahead, with volumes projected to be over 1.3 million vehicles in 2012. (1`3)
Challenges	Cost of battery, Energy storage density / vehicle range, Refueling facility (for pure electric vehicles) (9)

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4.5.3 Personalized rapid transit

Technology	Automated vehicles, reserved guideway, algorithms to control vehicle motions and match system capacity to demand
Features	PRT system includes fully automated vehicles capable of operation without human drivers over a reserved guideway. The vehicles are available on-demand, direct origin to destination service for an individual or a small group - typically 1 to 6 passengers. (1)
Timeline / Costs	Capital costs per mile are estimated at $5,458,013 while annual operating costs are $8,927,723. (3)
Challenges	Engineering and planning expertise, proprietary designs and vendor exclusivity, lack of standards are few of the challenges (2)

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4.5.4 Automated vehicles

Technology	Adaptive cruise control (5), lane departure warning, collision avoidance (7, 8) are all part of intelligent or automated vehicles (9, 11). Sensors to detect vehicles and obstacles, and intelligent algorithms (4) to enable these technologies.
Features	Automated vehicles were originally envisaged to be a part of automated highway systems (1, 2). However, lack of financial support as well as advances in vehicle-based technology led to automated vehicles not relying on highway-based technology. Vehicle based technology includes adaptive cruise control, lane departure warning, and collision warning devices. These have already been successfully demonstrated. Adaptive cruise control maintains a desired speed taking into account the vehicles in the front and back. Lane departure warning control vehicle's linear orientation and collision warning identifies and warns drivers of impending collision. These technologies together with advanced navigation systems will enable completely automated vehicle in the future.
Timeline / Costs	Technology has been demonstrated; May require more time before it becomes accepted and widely used.
Transportation Applications	Has significant impact on throughput (reduced congestion) and safety (no accidents). Adaptive cruise control breaks backward shockwave propagation. At an average speed of 67 miles per hour, if only one in five vehicles used adaptive cruise control, no traffic jams would form and traffic would generally flow freely. (6)
Challenges	Application of technology in mixed traffic where only a fraction of the vehicles have the technology (3); lacks wide spread tests in real situations. Understand human-factors in using the technology (10) When real-world factors such as inclement weather, difficult terrain, or limited visibility due to dust or nightfall are introduced, the problem of vehicle control at military-relevant speeds can quickly become intractable. (12)

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4.5.5 Flying cars

Technology	Hybrid of car and light aircraft; Examples include Moller's Skycar (3), Terrafugia's transition (4). NASA has been actively supporting the development of Personal Air Vehicles (PAVs) (6). What is making aircars a more imaginable possibility is information technology. Thanks to highly sophisticated and compact computers, GPS and other advanced navigational technologies, and aerial collision-avoidance systems, it is possible to build aircraft that, through a combination of on-board guidance systems and ground control, would fly themselves. (2)
Features	capabilities may include vertical-take-off-and-landing,
Timeline / Costs	Though several prototypes have been demonstrated, wide spread use of Flying cars may be 25 years or more away (5). Vehicles may become available in the market as early as 2009 (1). Initial costs range from $150000 (4) to $1 Million (2). But in the longer term costs could come down to $50000 (2).
Transportation Applications	Flying cars could significantly reduce congestion; vehicles can travel through the three dimensional space and fly straight to destinations instead of having to follow flat guided pathways.
Challenges	The greatest nontechnical challenge is meeting the regulatory requirements of both the FAA and the National Highway and Traffic Safety Administration (NHTSA). To satisfy FAA regulations for the category of light sports aircraft, the vehicle must have a maximum level speed of 138 miles per hour, a one- or two-person occupancy, and fixed landing gear, among other things. For the NHTSA, the Transition must be able to pass the same requirements that a regular car would. (1) Technical challenges include safety – how to ensure flying cars do not get in the way of each other, and how to deal with emergency issues.

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4.6 Sensor Technologies

4.6.1 GPS

Technology	Augmentations to GPS will enable more accurate location. These include (1): Nationwide Differential GPS System (NDGPS), Wide Area Augmentation System (WAAS), Continuously Operating Reference Station (CORS), Global Differential GPS (GDGPS), International GNSS Service (IGS).
Features	Accuracy of GPS has been improving with enhancements (2). Targets include 5 -10 m: by 2009 and 1- 5 m: by 2013. Further the enhancements will improve reception near tall buildings, canyons, etc. It also will allow devices to reduce the amount of power they need to expend to receive a GPS signal. This will make putting accurate GPS receivers into mobile phones, watches, etc easier. (3) Introduction of Galileo system will further enhance the capabilities of GPS receivers (4). GALILEO will be fully operable in 2008 .
Transportation Applications	More accurate GPS enables better navigation systems and the potential for use of these systems in flying cars. Mobile and wearable GPS allows for better personal navigation and quicker emergency response. GPS may also aid in collecting travel behavior data (7) that could be used in building models for planning and operations.
Challenges	Shared use of frequency bands between GPS and Galileo systems. The future for the navigation receiver user should be seen in the combined GPS / GALILEO receiver that will be capable of computing signals from both constellations (GPS + Galileo). This will provide for the best possible performance, accuracy and reliability. In the short-term the challenge is to develop GPS-denied location technologies. (5)

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4.6.2 Radio Frequency Identification (RFID)

Technology	Passive, active, or semi-passive transponder devices with memory for data storage, small battery, and antenna for capturing and transmitting radio signals. (1)
Features	An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification using radio waves. Passive tags have practical read distances ranging from about 10 cm (4 in.) up to a few meters. Active tags typically have much longer range (approximately 500 m/1500 feet) and larger memories than passive tags. Uses of RFID tags include in passports, tracking goods, animals, and people, automotive control etc. Future RFID tags will shrink in size (example HP's memory spot 6, 7) to few millimeters, have greater storage capacity, faster transfer rates, and longer transfer range.
Timeline / Costs	RFID market will swell from $2.8 billion in 2006 to $8.1 billion by 2010 (2) the price of RFID tags has fallen, from around $2 each in 1999 to around $0.10-0.15 today [2007] (2) SmartCode, an Israeli RFID systems provider, is offering UHF [RFID] inlays for 5 cents apiece in volumes of 100 million or more (3) the value of the market, including hardware, systems and services, is expected to be multiplied by 10 between 2006 and 2016. The number of tags delivered in 10 years will be over 450 times the number actually to be delivered this year. (4)
Transportation Applications	Business applications that use RFID, such as transport and logistics, access control, real time location, supply chain management, manufacturing and processing, agriculture, medicine and pharmaceuticals, should continue to grow strongly. But RFID devices will also pervade the Government sector (e.g. eGovernment, national defense and security) and the consumer field (e.g. personal safety, sports and leisure, smart homes and smart cities). (4) Public transport cards, the biometric passport, micro-payment systems, office ID tokens, customer loyalty cards, etcetera. (5) Applications range from e-payment that will enable pricing on road and transit systems to security – where RFID will be used for goods and possibly individual identification.
Challenges	Identity theft, fear of being overseen all the time. (5) Cost is still an issue for large scale implementations – active tags, the ones that are most likely to be used in Transportation still cost over a dollar each.

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4.6.3 MEMS sensors

Technology

Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology. (1)
MEMS technology have been applied to motion-based approach to navigation within and between pages in PDAs or MP3 players, in game controllers, MEMS sensors allow the player to play just moving the controller/pad (2)

Features

Sensors gather information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. The electronics then process the information derived from the sensors and through some decision making capability direct the actuators to respond by moving, positioning, regulating, pumping, and filtering, thereby controlling the environment for some desired outcome or purpose. (1)

Timeline / Costs

Air bag accelerometers that detects the beginning of the car's sudden impact by measuring the movement of an impossibly small (.10 microgram) "mass," which then causes the air bag to fire have been in use for about 10 years (4)

"The first step in development is to imagine a need and an application. The most obvious would be an application in which one would take a macro sensor or control system and miniaturize it. But one must also consider applications where no macro device has ever existed. Because of their size and low cost, MEMS could make measurement and control strategies that were not possible with macro or discrete devices now feasible. MEMS have the problem of a high initial development cost. But once developed, MEMS can be mass-produced for a relatively low per-unit cost: $5 to $50 each." (5)

Transportation Applications

MEMS can be used in Advanced Driver Assistance Systems, Crash Detection, Electronic Stability Control, LED Taillight Driver, Navigation (3)
MEMS can be used in both monitoring and testing of transportation infrastructure (5)
In transportation air-quality studies, MEMS "smart dust" has the potential to collect data for both analysis and forecasting the air-quality. (5)
The majority of the potential MEMS applications in transportation infrastructure will act as sensors. These include sensors used in monitoring temperature, crack measurements and monitoring, corrosion testing and monitoring, alkali-silica reaction (ASR) and other related reactions in concrete, and reliability of welding units in structural steel. (5)
MEMS thermal accelerometers in navigation systems with maps and global positioning satellite capabilities, MEMS-based display can overlay automobile diagnostics and repair instructions directly to the technician, seat-based MEMS for occupant deduction (6)

Challenges

To begin with, one drawback to extensive MEMS application is that MEMS products are application specific rather than generic. The vast majority of applications require solutions that necessitate the funding and completion of an evaluation or development program.
In addition, the environment in which the MEMS devices has to operate and the possible effect of the environment on the performance of the MEMS device has to be assessed. Protection of the MEMS device against damage from installation or construction procedures as well as from contact with materials is paramount. (5)

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4.6.4 Smart Cards

Technology	Smart cards are pocket sized cards with embedded integrated circuits which can process information. Examples in transportation: Oyster card in London, Octopus card in Hong Kong
Features	Use in public transit ticketing ensures: Reduce passenger/staff fraud levels, Reduce delays at entry gates, Improve cash handling procedures, Reduce staff handling costs and improve staff utilization, Flexibility in fare policies. (3)
Timeline / Costs	Typical costs range from $2.00 to $10.00.
Transportation Applications	Secure identification (e-passport) (4), security personnel identification at ports (11) In transit (10) and parking systems (5), can be coupled with other financial transactions (6)
Challenges	Smart card system security (1,2) A major impediment to the widespread use of smart cards has been interoperability (7, 8)

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4.6.5 Machine Vision

Technology	Machine vision involves the digitization, manipulation, and analysis of images, usually within a computer. (1)
Features	Machine vision has been applied in Industrial image processing for quality control, identify swimmers who are drowning (2), fire alert system (3), and many more (6)
Timeline / Costs	Most machine vision systems have already been tested and implemented. However it has been applied in only limited context in transportation
Transportation Applications	Machine vision has applications in traffic monitoring, navigation, and transport safety (4) Can deduct detecting lane markings, vehicles, pedestrians, road signs, traffic conditions, traffic incidents, and even driver drowsiness. (5) Road/Railroad Structure Analysis, Seaport Monitoring, vehicle License/Number Plate Analysis (6) Machine vision provides more accurate classification capabilities (7) compared to other sensor types.
Challenges	Challenges include making machine-vision systems less expensive, more compact, and more robust in various weather and traffic conditions. (5)

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4.6.6 Biometric Identification

Technology	Biometrics is the science of identifying people using physiological features. Biometric identification includes finger-print, face, DNA, hand geometry, voice, retina and Iris identification. (1)
Features	Important characteristics of a biometric identification technology are accuracy, ease of use, user acceptance, ease of implementation, and cost (1)
Transportation Applications	Security Fare-payment Access restriction
Challenges	Fingerprint and retina are highly accurate; while Iris and Face are not very accurate. In terms of ease of use, face and voice recognition are best suited; fingerprint and retina have low user acceptance; Iris recognition is expensive.

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5 PROJECT STATUS REPORT APPROVALS

Prepared by ________________________________
Principal Investigator

Approved by ________________________________
Project Manager

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