PreScouter

Smart Road Technologies Shaping the Future of Transportation

Research Support Service

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What smart road technologies are shaping the future of transportation?

Roadways are constantly in flux, either through repairs and construction or continual improvements. With recent developments in smart technologies, companies and research groups alike have been hard at work devising ways to make the roads safer and more driver-friendly, and enable the use of developments coming from the automotive sector.

This report discusses a wide variety of these technologies and how they will continue to be developed in the near future.

Executive Summary

Key Driving Trends:

Evolving technologies from a variety of industries are enabling smarter and safer roadways. These are the major driving factors for advancements included in this report:

1. Electrification Infrastructure Improvements
2. Safety and Improved User Experience
3. Renewable Energy Generation

Discussion:

With large pushes toward electrification across the automotive sector, smart roads are striving to accommodate and enable widespread adoption of electric vehicles. In previous years, this has been primarily the addition of more and more charging stations, which continues to date (The Ray, p. 32). The most recent advancements utilize electric fields and/or induction coil technology to create electric charging lanes that enable charging while vehicles are in motion (ElectReon p. 16, The Ray p. 32). These lanes would empower drivers of electric vehicles to drive longer without the need to stop and charge while also utilizing existing real estate without the need for added stations.

Executive Summary

Perhaps the most significant driving factor for smart road technologies is increasing driver and passenger safety while also improving the user experience. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications have yielded driver alerts and road monitoring technologies to aid in safe driving. For example, HP Lubricants and Leo Burnett India have developed "honking road" technology that alerts drivers coming into tight turns about oncoming traffic (p. 11). Additionally, weather, traffic, accidents, and other roadway information can be communicated both to vehicles on roads and to central processing hubs or emergency response teams (p. 23, 32, and 42).

Beyond these technologies, new technologies are also improving more rudimentary road issues. The Ray has incorporated a tire safety check that lets the driver know if their tires are properly inflated (p. 28). Additionally, to minimize construction and maintenance delays and prevent potential road-based vehicle damage, researchers have been developing self-healing concrete (p. 20).

Finally, a major advantage of roadways around the globe is the sheer amount of space they encompass and number of people they reach. If roads could be utilized for energy generation along with transport, it could bring renewable energy to vast portions of the world's population. In fact, this is a development goal for several companies and has already been piloted with *in situ* testing in progress (Wattway p. 34, The Ray p. 30), both on the roads themselves and on barriers along roadways.

The Smart Road Technologies Covered

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1. Roads that honk (SmartLife Pole for safer turns)

2. Electric charging lanes

3. Self-healing concrete roads

4. Road and weather traffic management

5. Ecosystem of smart road techs (WheelRight tire safety check) + solar barriers

6. Solar panel roadway

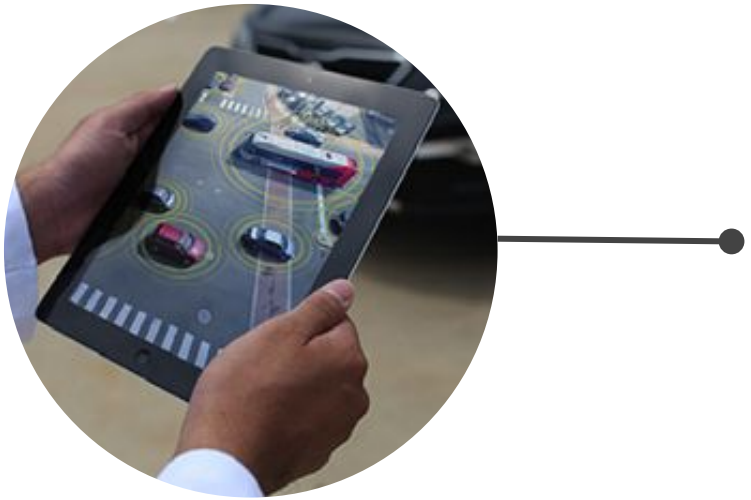
7. Temperature sensitive road paint

8. Smart pavement (concrete embedded with smart electronics)

An Introduction to Interactive Communication

Introduction

The past decade has been a game changer for the automotive industry with the rise in electric vehicles and their manufacturers. Now, smart city technology has opened up another possibility for connecting and communicating with vehicles on the road. Here are some of the top technologies in both autonomous driving and smart infrastructure that are opening the way to the future.



Introduction

Vehicle-to-vehicle (V2V) communication: V2V systems use dedicated short-range communications (DSRC), which are two-way wireless channels that enable V2V-equipped cars to communicate with each other at roughly 300 meters and whose broadcast updates ten times per second. DSRCs accrue and share basic safety messages (BSMs) about a vehicle's speed, direction, braking status, and position to determine whether an alert needs to be sent to the driver.

The two most prominent safety applications using V2V technologies are:

- Intersection movement assist (IMA), which warns drivers of unsafe intersections (i.e., a car runs a red light).
- Turn assist, which helps drivers avoid collisions by monitoring oncoming traffic. For example, in countries that drive on the right side, left-turn assist (LTA) helps a driver during an unprotected left turn across traffic.


Source: U.S.DOT

Introduction

Vehicle-to-Infrastructure (V2I) communication: This type of communication refers to the wireless exchange of knowledge between vehicles and road infrastructure. Enabled by a system of hardware, software, and computer code, V2I communication is often **wireless** and **bi-directional**, meaning that infrastructure elements like lane markings, road signs, and traffic lights can wirelessly provide information to the vehicle, and vice versa. With so much knowledge being captured and shared, rich, timely information can be used to enable a wide range of safety, mobility, and environmental benefits.

On top of reducing collisions with other vehicles, V2I communications will support safety applications, such as:

- Warning drivers about traffic jams, accidents, slippery patches of road, sharp turns, etc.
- Merging assist
- Intersection safety
- Alerting drivers if they veer too close to the road's edge

Vehicle-to-network (V2N) communication: V2N systems connect vehicles to the cellular infrastructure, and therefore the cloud, so drivers can take advantage of in-vehicle services like traffic updates and media streaming.

Smart Road Technologies

“Roads that Honk” System

In a quest to improve safety on highways, **HP Lubricants** and **Leo Burnett India** have come together to develop a system that involves roads that honk. The first prototype of the system is currently being tested in India on NH1, the highway connecting Jammu and Srinagar, which is known for being one of the most dangerous roads in the world.

Overview

The “Roads that Honk” system uses SmartLife poles just before sharp turns and hairpin bends. These poles wirelessly communicate with each other and exchange data on incoming traffic. They gauge the speed of the vehicles and alert the drivers of approaching traffic by sounding a horn, as shown in the figure aside. The product is called **SmartLife Pole.**

“Roads that Honk” System

Technology

India ranks high in the list of countries with the largest number of road fatalities. Driving conditions on mountain roads are especially risky, as there are few who follow traffic rules. According to reports published by the government, more than 140,000 people were killed in road accidents in 2015, and this risk is especially increased around hairpin bends.

This is where the SmartLife Pole technology comes into play. It monitors the incoming traffic on both sides of the hairpin bend, and if it sees that there is are vehicles approaching from both ends, the poles on both ends of the bend communicate with each other and send out sound signals in the form of a horn to alert both vehicles. Thus, alert signals are sent out to prevent a collision from happening.

SmartLife Pole

The Poles setup at two ends of the hair pin bend detecting incoming traffic

The Poles honking and alerting the incoming traffic to be careful around the bend

“Roads that Honk” System

Technology

RoadsThatHonk adopts SmartLife poles at sharp curves and hairpin bends, which employ advanced networked devices and combine wireless technology, radar systems, and an anti-collision warning system, all powered by solar PV modules. SmartLife Poles are placed on each side of key hairpin bends. The poles detect speeds of oncoming vehicles, then communicate with each other to caution approaching vehicles on either sides with a horn.

The functionality is achieved by transmitting an electromagnetic wave in the 24-GHz frequency range (K-band), and measuring the frequency shift of the reflected electromagnetic wave. The frequency shift is caused by the Doppler effect of the moving target on the electromagnetic wave. As the relative speed between the radar sensor and the target increases, the detected frequency shift also increases, thus enabling the radar sensor to precisely determine the target speed.

“Roads that Honk” System

Advantages

- The solar powered system is especially useful in hilly areas where this system is currently deployed.
- It is a simple and effective concept of alerting the drivers with sounds and honks that they are familiar with.
- This system is an innovative application of IoT to road safety to save lives.
- The use of K-band ensures that there is minimal interference and the best signal-to-noise ratio is ensured.

Limitations

- Currently, it is designed only for hairpin and other types of bends and not for head-on, close-call collisions.

“Roads that Honk” System

Commercial Testing / Implementation / Plans

SmartLife Poles are already being tested in India, and the first prototype is currently being tested on NH1, the Jammu-Srinagar highway, which is known as one of the most dangerous roads in the world. It is a unique device created specifically to reduce the risk of accidents in hilly areas.

The combination of communications infrastructure and technology provides a strong foundation and a way forward toward smarter and safer mobility. The technology adapted through RoadsThatHonk is a vision for long-term growth and the evolution of a host of capabilities and possibilities that will enable safer commutes across cities.

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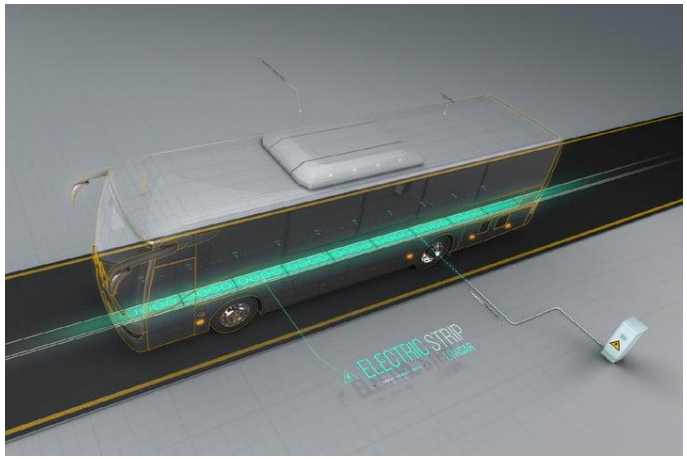
ElectReon's Electric Charging Lanes

ElectReon (previously ElectRoad) was founded in 2013 aiming to enable the large-scale adoption of pure electric buses, with the ultimate goal of eliminating oil dependence. Using specialized electromagnetic induction technology, ElectReon powers electric buses with renewable energy while in motion.

Overview

The system developed by ElectReon is called Dynamic Wireless Power Transfer (DWPT), and one of its advantages, in addition to direct wireless transmission, is the ability to exchange energy between all the vehicles that move along this road.



ElectReon’s Electric Charging Lanes

Technology

ElectReon's DWPT technology is based on an **induction coil** infrastructure installed below the surface of road lanes. The operating mode of these devices is optimized so that their magnetic field does not extend into the cab of vehicles, which makes this solution safe for humans.

Energy for the operating these systems is supplied by a network of **"smart" inverters**, which are converters that exchange information with each other in real time. The energy will be transmitted to electric vehicles traveling in the lane, thereby extending the vehicles' travel range, while also saving time spent on charging the vehicles. For traveling on roads that lack the company’s infrastructure, cars will be equipped with a small battery that can be charged while traveling on roads that do not have the coil infrastructure installed.

ElectReon's Electric Charging Lanes

ELECTREON
CHARGING THE WAY FORWARD

Advantages

- **Reduced vehicle cost and weight:** By supplying electricity to the vehicle wirelessly from the road, ElectReon removes the energy source from the vehicle, reducing the cost and weight of the vehicle.
- **High efficiency and safety:** DWPT is highly efficient, with more than 88% efficiency. No concerns regarding the safety of vehicles during the wireless power charging have been raised, making the charging lanes safe.
- **Energy sharing:** One of the advantages is the ability to exchange energy between all the vehicles that move along this road.

Limitations

- **Tearing up roads:** To lay the induction coils, tearing up sections of road is required, which is disruptive and expensive.
- **Cost intensive systems:** The systems themselves are expensive, requiring a continuous line of electromagnets for the length of the road, so it's unlikely that the infrastructure could be extended beyond a few high-traffic routes through a city. However, it may still work for the kinds of bus routes that ElectReon envisions, where less weight means more efficiency and routes are standardized.
- Vehicles would need to have a matching inverter installed.

ElectReon's Electric Charging Lanes

Commercial Testing / Implementation / Plans

- ElectReon plans to use its technology on buses traveling in designated lanes and later plans to use it in private vehicles.
- ElectReon reported success in a trial that began in March 2016 in cooperation with the municipality of Tel Aviv and Technion - Israel Institute of Technology. The trial was aimed at testing the durability of the coil infrastructure under real conditions in which buses and private cars travel on the road at all hours of the day, including testing whether the underground coils really do transmit energy to an external receiver above the road.
- ElectReon is presently completing construction of a test site north of Netanya, Israel. The company is planning demonstrations of its technology in the coming months with an electric vehicle with no battery as well as charging a small battery in a traveling electric car.
- ElectReon signed an agreement with Dan, a public transportation company, in which an initial public transportation route will be established that's powered by wireless energy charging.
- The company has also signed a memorandum of understanding with the French company Hutchinson to design and develop a mass-production line for the coil infrastructure developed by ElectReon to be installed beneath the road surface.

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Self-Healing Concrete Roads

BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

Researchers at Binghamton University in New York have been working on a new self-healing concept in which fungi are used fill concrete cracks. *Trichoderma reesei*, a fungus, was first isolated from a piece of cotton canvas in the Solomon Islands during World War II.

Overview

A new self-healing concept uses fungi as an agent for promoting calcium mineral precipitation to fill the cracks in concrete. *Trichoderma reesei* was found to be able to grow equally well with or without concrete and can promote the formation and precipitation of $CaCO_3$.

Self-Healing Concrete Roads

BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

Technology

Crumbling concrete begins with micro-cracks. Water and air can ooze into these barely visible cracks, expanding and eventually making the cracks grow deeper and longer. Researchers at Binghamton University, State University of New York have investigated a new concept of utilizing fungus as a self-healing agent to fill in the cracks in concrete.

The fungus *Trichoderma reesei* lays dormant in the concrete until cracks appear and it meets water and air, at which point the fungus will bloom and fill in the crack.

- The fungal spores, along with nutrients, will be added into the concrete matrix during the mixing process. When cracking occurs, water and oxygen will find their way in and the dormant fungal spores will germinate, grow, and precipitate calcium carbonate to heal the cracks.
- When the cracks are completely filled and no more water or oxygen can enter, the fungi will again form spores. As the environmental conditions become favorable in later stages, the spores could be wakened again.

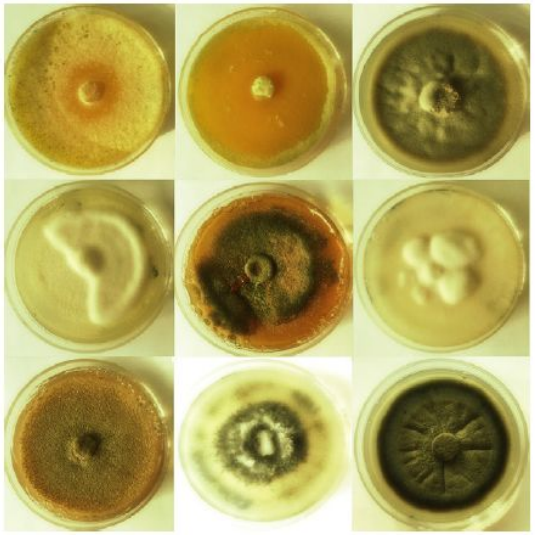

Figure: Graphical abstract from research paper showing the fungal growth of different species in a concrete environment.

Self-Healing Concrete Roads

BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

Advantages

- If it succeeds, this technology will provide a low-cost, pollution-free, and sustainable approach.

Limitations

- The biggest issue is the survivability of the fungus within the harsh environment of concrete.

Commercial Testing / Implementation / Plans

Further investigation into alternative microorganisms such as fungi and yeasts for the application of self-healing concrete is being conducted and still has a long way to go to bring an efficient self-healing product to the concrete market.

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HIKOB INSTANT: Road Weather and Traffic Management

HIKOB is a French IoT startup that provides wireless and scalable instrumentation systems that can capture real-time strategic data and information on physical resources and assets.

Overview

HIKOB INSTANT includes wireless magnetometers for vehicle detection and wireless road surface temperature sensors communicating real-time data. It also includes wireless routers to repeat and route the information and an advanced software system compatible with all types of web browsers.

Figure: The HIKOB WISECOW sensor

HIKOB INSTANT: Road Weather and Traffic Management

Technology

A) Road weather monitoring: HIKOB provides wireless data acquisition systems to collect road weather data and to create a powerful road weather information system (RWIS) system. The system includes wireless and low-power sensor nodes embedded within the road pavement to measure the road surface temperatures as well as the outside air temperature and humidity. The sensor nodes communicate real-time information through a wireless RF protocol to a gateway that is connected to an IP network (landline or cellular networks). Data can be accessed either by connecting remotely to the gateway or via the HIKOB cloud-computing infrastructure.

Figure: (Right) The HIKOB FROG, a low-power, wireless temperature, humidity, and air pressure smart sensor. (Left) The HIKOB WISECOW, a road temperature sensor that communicates in real time the measured road surface temperature for weather monitoring applications.

HIKOB INSTANT: Road Weather and Traffic Management

Technology

B) Traffic monitoring: The smart wireless and energy autonomous magnetometer sensors embedded in the road pavement detect vehicles, measure traffic flows, and help to better understand the road network. Applications include:

- Vehicle counting and traffic flow monitoring
- Vehicle classification (light vehicles and heavy goods vehicles)
- Speed and occupancy rate measurement
- Traffic jam length measurement

These road traffic counting and monitoring systems can easily integrate with existing IT systems.

➔ **Data collection and analysis:** The data collected by the installed IoT sensors is gathered in servers, where it is analyzed to provide real-time information about traffic and road conditions in IoT-equipped regions. The obtained data can be used for a number of purposes. For example, one application can be to predict and alert about possible hazards and accidents that may take place as a result of poor road and weather conditions.

HIKOB INSTANT: Road Weather and Traffic Management

Advantages

- Easy to install
- High accuracy of data collected by the RWIS system

Commercial Testing / Implementation / Plans

- Many French cities such as Marseilles, Grand Poitiers, and the City of Troyes introduced and successfully managed vehicle detection and traffic flow using the HIKOB INSTANT real-time wireless vehicle detection system.
- Wireless acquisition systems for weather data are deployed in nine locations spread across the Grand Lyon area in France. The locations have been selected due to their environmental and weather diversity. This technology helped to gather more accurate measurements about weather conditions and to better understand the local situations.

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“The Ray” - Ecosystem of Smart Road Technologies

“The Ray” is an ecosystem of smart road technologies. It is being built in memory of Ray C. Anderson, in a collaboration between the Ray C. Anderson Foundation, Interface, a multinational carpeting manufacturer, the Georgia Conservancy, and Georgia Tech’s School of Architecture. It is an 18-mile stretch of west Georgia’s I-85 highway.

Overview

The Ray was designed to be a proving ground for the evolving ideas and technologies transforming the infrastructure of future transportation. Partners of the project include the Georgia Department of Transportation (GDOT), Kia Motors Manufacturing Georgia (KMMG), Hannah Solar, the University of Georgia College of Environment and Design, Wattway, the Land Institute, Drawdown, Resilient Analytics, the Georgia Conservancy, the Chattahoochee Nature Center, and The Ray C. Anderson Foundation.

Figure: A rest stop at The Ray

“The Ray” - Ecosystem of Smart Road Technologies

Technology

The Ray is implementing new ideas and technologies to create a regenerative highway ecosystem on the 18-mile stretch of I-85, and several pilot projects are already underway. Some of the technologies involved are described here:

1. Tire Safety Check Station (WheelRight):

One of the technologies that The Ray employs is the WheelRight tire monitoring system. It measures the pressure and tread depth of the tires on vehicles traveling up to 10 miles per hour. The system has a monitor connected to an automatic number plate recognition system.

Figure: A car driving over the WheelRight tire safety system

“The Ray” - Ecosystem of Smart Road Technologies

Technology

The WheelRight system works as follows:

1. The customer drives over the WheelRight system and the camera connected to the monitor reads the plate number.
2. The driver then chooses the way in which he or she needs the information to be communicated to him or her via either a text message to their mobile phone or a direct printout.
3. Depending on the option entered, the system gives the necessary critical information about the tire status to the customer.

This system goes a long way toward passenger safety, especially regarding long distance travel on highways. Additionally, tire pressure is associated with the mileage you get from vehicles, so maintaining the optimum pressure is useful and important. The Ray is the only WheelRight station that offers this complete service.

They are also currently working on incorporating side wall damage analysis of tires into the algorithm.

“The Ray” - Ecosystem of Smart Road Technologies

Technology

2. Solar Noise Barriers: This technology falls under those that The Ray considers as futuristic or in the pipeline and not yet ready for implementation. One of the main existing challenges with solar panels is the huge amount of area it takes for the minimal amount of energy harvested. Solar barrier technology serves as a work-around for this problem by re-imagining how solar panels can be deployed.

Building solar noise barriers on the side of roads can help reduce much of the overhead cost that solar farms require, particularly the need for dedicated land. Aesthetics is another important factor when designing a noise barrier, while determining what solar technology to use presents a major challenge. Addressing these issues and innovating with them can help solar-powered noise barrier technology to be deployed in the following Visitor’s Center and other roadway scenarios as well:

- Energy storage water feature that eliminates the need for larger batteries or connecting to the grid
- Outdoor vending machines for refreshments and to automate equipment like sprinklers
- Work bar (for plugging in laptops, phone charging, WiFi hotspots, etc.)
- Road lighting

“The Ray” - Ecosystem of Smart Road Technologies

Technology

Table: A techno-economic comparison with conventional alternatives for a 270 m long, 3 m high E-W oriented barrier. The predictions assume 25 year life and 3% annual electricity price inflation.

Technology	Cost of barrier	Electricity Generated MWh/year	NPV of Electricity*	Residual cost of barrier
Basic concrete barrier (~$150/m2)	~$120,000	0	0	~$120,000
Architecturally designed barrier (~$1350/m2, estimate from Heijmans)	~$860,000	0	0	~$860,000
Concrete plus standard PV panels	~$180,000	146	$107,000	~$73,000
Bifacial PV with toughened glass	~$600,000	116	$86,000	~$514,000
Polysolar thin film noise barrier 40% transparency	~$300,000	60	$64,000	~$236,000

“The Ray” - Ecosystem of Smart Road Technologies

Other Ray Technologies

1. **Solar Powered Vehicle Charging:** Located along The Ray are several solar-powered Photovoltaic for Electric Vehicle (PV4EV) charging stations, which is a significant advancement in creating the infrastructure needed to support EVs.
2. **Solar Paved Highways:** The Ray is the testing ground for Wattway’s pilot project in the United States: A pavement that uses traditional solar cells, protected in a patented frame, that allows the road surface to generate clean energy. The 50-square-meter installation was installed in December, 2016, next to the Georgia Visitor Information Center on The Ray.
3. **Right-of-Way-Solar:** Renewable energy generation on the state-owned right-of-way, around the interstate where The Ray is currently being implemented.
4. **Smart Studs (Future Plan):** Solar-powered smart studs illuminate in different colors and patterns to communicate a variety of crucial alerts to drivers and passengers.
5. **EV Charging Lanes (Future Plan):** By wiring roads to create an electromagnetic field that transmits energy to a receiver that supplies the car’s battery, drivers could get the power they need while still in motion—no stopping required.

“The Ray” - Ecosystem of Smart Road Technologies

Commercial Testing / Implementation / Plans

The technologies under “The Ray Today” are actively getting tested and improved on I-85 in Georgia, as explained earlier. The future technology planned by The Ray will also be tested out on this section of the road

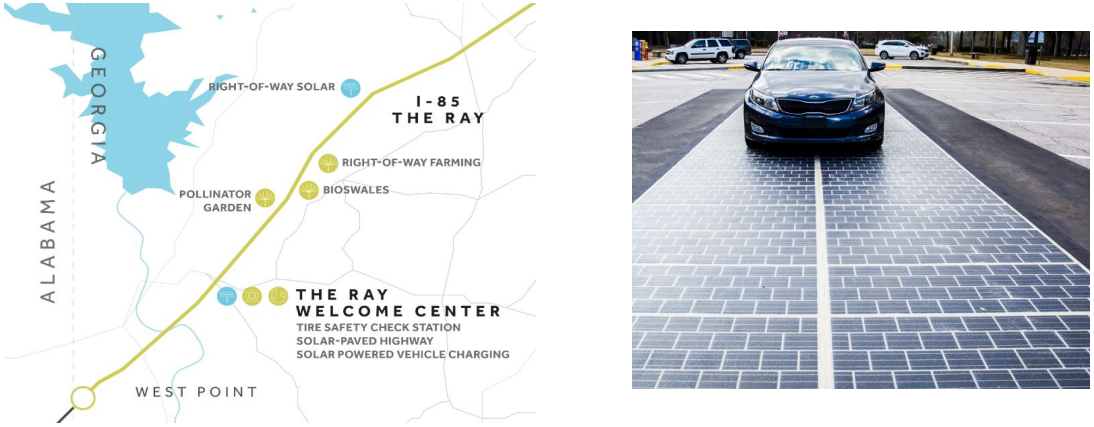

Figure: (Left) Map of I-85 where The Ray is getting implemented. (Right) A solar paved highway on The Ray

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Wattway's Solar Panel Roadway

wattway
by
COLAS
WE OPEN THE WAY

Wattway is a patented French innovation that was undertaken by Colas, a road materials and construction company, and the INES (French National Institute for Solar Energy).

Overview

Combining road construction and photovoltaic techniques, Wattway's pavement provides clean, renewable energy in the form of electricity. Twenty square meters of Wattway panels can supply the electricity requirements of a single home.

Wattway's Solar Panel Roadway

Technology

- Wattway's solar panels are composed of polycrystalline thin film cells. Each module is composed of 28 active cells with a production surface of 0.96 m^2. **Figure 1** shows an image of a polycrystalline thin film cell.
- The photovoltaic cells are embedded in resin and are thin enough that they won't peel off the road below during the expansion and contraction caused by heat and cold.
- In 2016, Colas trialed the world's first solar road in a small town in France, with a 1-kilometer (0.62-mile) stretch of solar pavement, producing enough power to light the village's street lamps and cater to its 3,400 residents.

Figure 1: Wattway's polycrystalline solar panel cell

Wattway's Solar Panel Roadway

Technology

Table 1: Technical data sheet for Wattway's solar panel roadway

Technical and mechanical settings	Specification (Reference 1)
Dimensions of a module	1398mm x 690mm **other dimensions possible*
Number of active cells	28
Nominal Power (Pnom)	115 Wc
Average Yield (module)	12%
Tolerance (module)	± 5%
Impact resistance	IK 07
Cells	Polycrystalline / mono-like
Road performance	1 million wheel passages (13T per axle)
Grip test	SRT – PFT, CFL, Wehner & Schulze

Wattway's Solar Panel Roadway

Advantages

- **High energy performance:** 20 m² of Wattway panels provide enough electricity to power a single home.
- Panels are composed of cells inserted into superposed layers that ensure **resistance** and **tire grip**.
- The composite material is just a few millimeters thick, making it possible to adapt to thermal dilation in the pavement, as well as vehicle loads, to provide **durability** and **safety**.
- Panels can be **installed directly** on the current pavement without the need for destroying the existing structure.
- The system is low maintenance, with a lifespan of 10-20 years, depending on the speed and level of traffic over it, and it has even been proven to handle snowplows.

Limitations

- **Cost intensive:** 30,000 square feet of solar panels cost around $5.2 million.
- **Questionable efficiency:** Wattway's photovoltaic efficiency is 15%, which is similar to rooftop solar panel efficiency. However, it doesn't take into account the fact that the solar panels are flat on the ground, rather than angled towards the sun's trajectory, significantly reducing efficiency at higher latitudes. Heavy traffic could also block sunlight; as could snow, mud, and perhaps standing water after rain.

Wattway's Solar Panel Roadway

Commercial Testing / Implementation / Plans

- The first major Wattway solar road project trial section, which is made up of some 2,880 photovoltaic panels, is located on Route RD5 in northern France.
  - The generated electricity by this solar road will be sent out to the France's Enedis electricity network.
- In the Netherlands, the State of Utrecht, Bam Infra, and Wattway inaugurated a new trial site of 48m² installed on the N401 roadway.
- More Wattway trial sites are being built in France, with the latest project involving a new demonstration section of 51 m² on Highway A63.
  - The generated electricity will be used to power the toll payment machine and gates at the Saugnacq-et-Muret toll station in southwestern France.
- A 68-m² Wattway trial site was installed at Savoie Technolac in Chambéry, France.
  - The generated electricity is designed to function as a local energy loop to power a hydrogen charging station and an electric vehicle charging station.

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Temperature-Sensitive Road Paint Projects

STUDIO ROOSEGAARDE

heijmans

VAN GOGH PATH is a light-emitting bicycle path that charges in the daytime and glows at night. The path is made of thousands of twinkling stones inspired by Vincent Van Gogh's *Starry Night* and is part of the SMART HIGHWAY project. Also associated with this project is the Glowing Lines project. Both are in coordination with the **Roosegarde Studio and Heijmans**.

Overview

Smart Highways are interactive and sustainable roads. Using new technologies and designs, designer Daan Roosegaarde and Heijmans Infrastructure are working to develop roads that are both sustainable and smart using light, energy, and signage that interact with traffic.

Figure: The VanGogh Path

Temperature-Sensitive Road Paint Projects

STUDIO ROOSEGAARDE

heijmans

Technology

The first **Glowing Lines** were realized after a 3-month trial period in the Netherlands and can glow for up to eight hours at night. It is part of the SMART HIGHWAY project which consists of the projects **Glowing Lines, Dynamic Paint, Interactive Light, Induction Priority Lane, and Road Printer.**

These lines collect energy during the day and give light during the night to increase visibility and safety. The bicycle path is 600 meters long and is part of the Van Gogh cycling route.

Figure: The VAN GOGH bicycle path

Figure: How the path looks at night when it is lit up

Temperature-Sensitive Road Paint Projects

STUDIO ROOSEGAARDE

heijmans

Commercial Testing / Implementation / Plans

Product development and field testing of two of the technologies, Glowing Lines and Dynamic Paint, is now underway through the collaboration between Heijmans and Studio Roosegarde. Material testing is carried out in the Heijmans labs, and two working prototypes have been deployed.

The bicycle path is a novel joint venture between the municipality of Eindhoven, Van Gogh Brabant, Vrijetijdshuis Brabant, Eindhoven 365, and Routebureau Brabant. The core technology is developed by Heijmans and Studio Roosegarde, with the other partners facilitating the implementation.

References

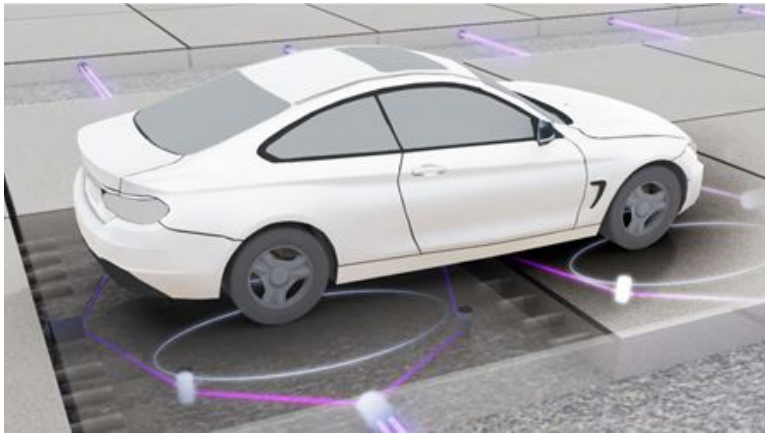
1. https://www.studioroosegaarde.net/project/glowing-lines
2. https://www.studioroosegaarde.net/data/files/2018/08/323/glowinglinesfactsheetroosegaarde.pdf
3. https://www.studioroosegaarde.net/project/van-gogh-path

Smart Pavement Technologies

Integrated Roadways is a Kansas City technology startup that is developing a technology called **Smart Pavement** that would not only help increase roadway safety but also serve as the Wi-Fi platform for cars and other future mobility services.

Overview

The Smart Pavement road system uses high-resolution fiber optic sensors and other technologies inside the pavement to detect vehicle positions in real time as well as roadway conditions. Beyond roadway conditions, sensors can also detect accidents and notify emergency responders automatically.

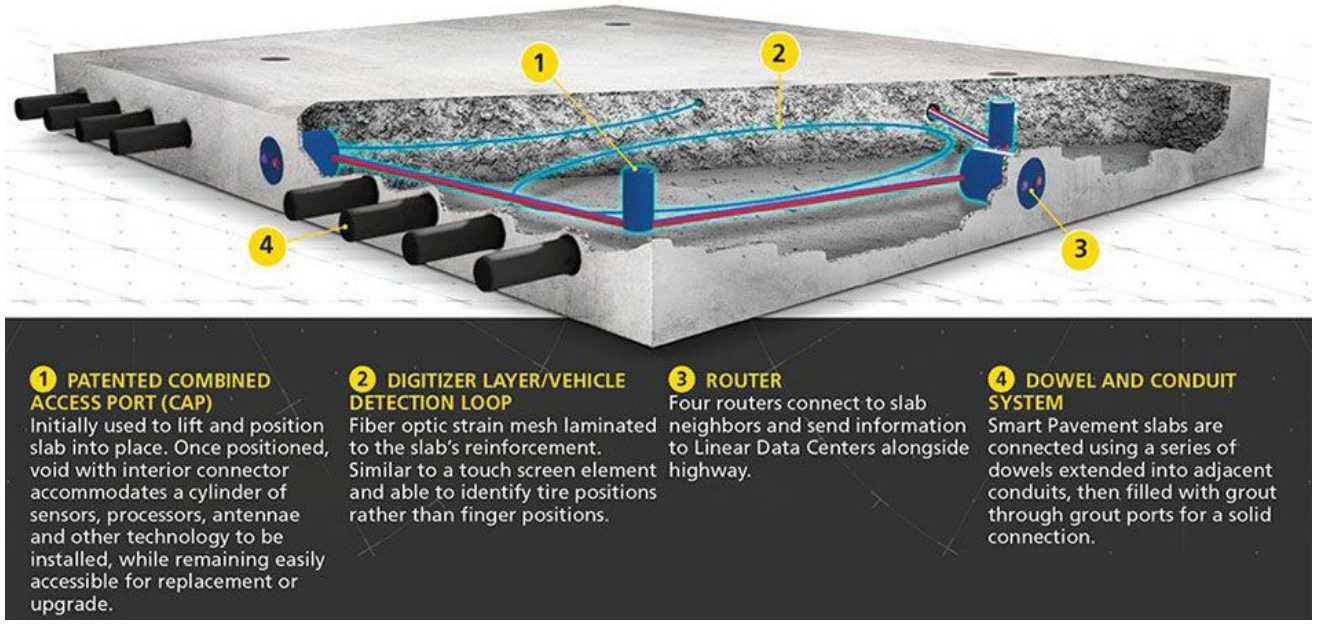


Smart Pavement Technologies

INTEGRATED ROADWAYS

Technology

The main components of this smart pavement, which is made up of precast concrete embedded with smart electronics, are shown in the figure below:



Smart Pavement Technologies

INTEGRATED ROADWAYS

Advantages

- **Modular, upgradable, and removable:** The technology in the Smart Pavement modular system is upgradable, making it easy to add new features. And each slab can be removed easily for repair or to access underlying utilities for service.
- **Strong and cost-effective:** Smart Pavement lasts four times longer than traditional asphalt construction and is 95% less costly to install versus traditional highway construction.
- **Sustainable:** The roads pay for themselves in the sense that the pavement and construction costs can be recovered through leasing agreements with private sector service providers - for example, providers looking to set up 5G networks.

Limitations

- Acceptance by the governance for widespread deployment might be a challenge.
- It requires the development of an ecosystem for precast concrete blocks that are the basis for this technology.

As more features get added, this forms an ecosystem technology; but it also brings along management and governance challenges relating to the pitfalls of a monopoly, which needs to be dealt with through suitable policy interventions. Thus, more players need to enter and competition needs to be democratized.

Smart Pavement Technologies

Commercial Testing / Implementation / Plans

A pilot project to test the Smart Pavement technology is underway:

- The Colorado Department of Transportation awarded a $2.75 million contract to the company for a 5-year smart pavement project on U.S. 285 near Fairplay, Colo.
- The pilot project is a quasi-public/private partnership between Integrated Roadways and RoadX, a Colorado Department of Transportation Program.
- A half mile of smart pavement will be built to collect data on run-off-the-road crashes as well as to automatically alert authorities about the crashes.

References

1. http://integratedroadways.com/#hero-continue
2. https://www.nbmcw.com/tech-articles/roads-and-pavements/38369-precast-concrete-smart-pavement-the-future-of-road-building.html
3. https://www.thedenverchannel.com/news/local-news/company-releases-details-on-smart-pavement-to-be-installed-along-major-highway
4. https://www.roadsbridges.com/kansas-city-start-developing-smart-pavement-technology

Next Steps

Topic	Question	Report
Smart Roads	What smart road technologies are shaping the future of transportation?	Intelligence Brief 1
Automotive Manufacturers	How are automotive manufacturers utilizing new infrastructures to forward their development? What automotive technologies are in the mid-term of development related to improvements?	Intelligence Brief 2
Allied Industries	Which other industries are in development with similar infrastructure developments? Examples: aviation, aerospace, manufacturing, construction, etc.	Intelligence Brief 3

About the Authors

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PreScouter

Professional Summary:

Paula is a Senior Project Architect and is the head of the Transportation Segment. She has worked on a wide variety of projects in her tenure, including topics like coatings and materials research, process optimization in many industries, comparative intelligence, and more.

Paula earned her BS in Chemistry from DePaul University before continuing on to her PhD in Physical Chemistry at the University of Pittsburgh. There, her research focused on the characterization of organic semiconducting thin films for use in electronic devices. That is also where she started with the PreScouter Global Scholars program in August, 2014. After working as a researcher for a few months, she became a Team Leader, before eventually taking a full-time role with PreScouter.

About the Authors

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Anil is a PhD candidate in Bioengineering at the Indian Institute of Science, Bangalore, India. He has a demonstrated history of working in VLSI, embedded, and the research industry in general. He is skilled in Field-Programmable Gate Arrays (FPGA), Java, System on a Chip (SoC), and Application-Specific Integrated Circuits (ASIC), and lately for his research shifted his focus and field of interest to MEMS fabrication for developing low-cost point-of-care medical diagnostic devices for cancer care by pursuing his PhD in the field of bioengineering. He wishes to apply his cross-disciplinary knowledge from his professional and academic experiences in the area of public policy.

About PreScouter

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