PIARC Italy 2023 National Competition
"The Roads of the Future – Imagine Your Road"
Truck's lane ERS ZE-Feed
Cost-effective ERS using a Conductive, Protected Low Voltage Slotted Pavement Cable
Fast lane ERS2.0 ZE-Drive/ZE-Freight
Secured Light Load Highly Automated Electro Mobility for People and Goods for the 2020's

ABSTRACT

The **ZE-F**eed slotted cable aims to provide a Cost-effective Electric Road for Highway's Truck's lane to achieve a substantial CO^2 emission reduction by permitting accelerated conversion of Truck's fleets from ICE to Electric Powertrain.

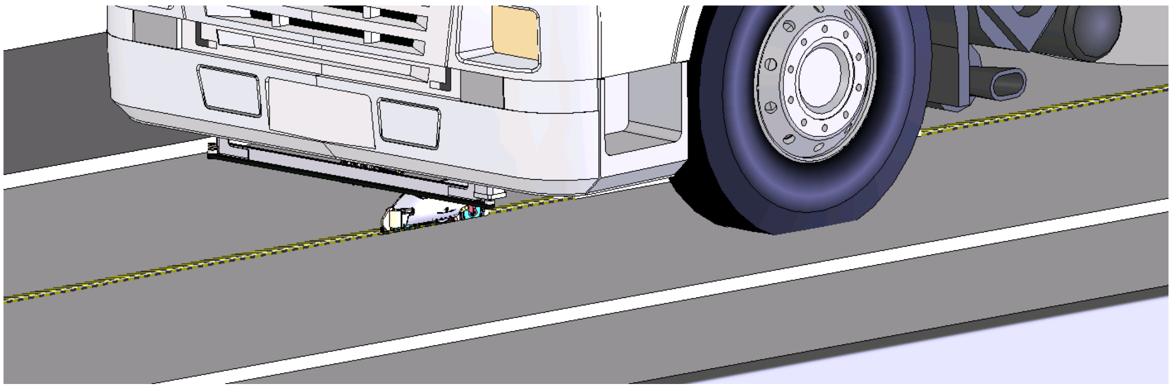

Figure 1: Truck connected to ZE-Feed pavement power supply cable

Conductive low voltage third rail capture is a technique proven for over 100 years in railways, and **ZE-F**eed slotted cable improves on this technology by adding the missing standard electric protection to allow deployment on open road.

Then **ZE-F**eed offers the simplicity and energy efficiency of overhead catenary without its drawbacks which are:

- the restriction to only high height vehicles (Truck/Buses) cars/vans being excluded;
- the high cost and impact on road safety with the posts,
- and not the least the controversial visual impact and emergency crane/helicopter access restrictions.

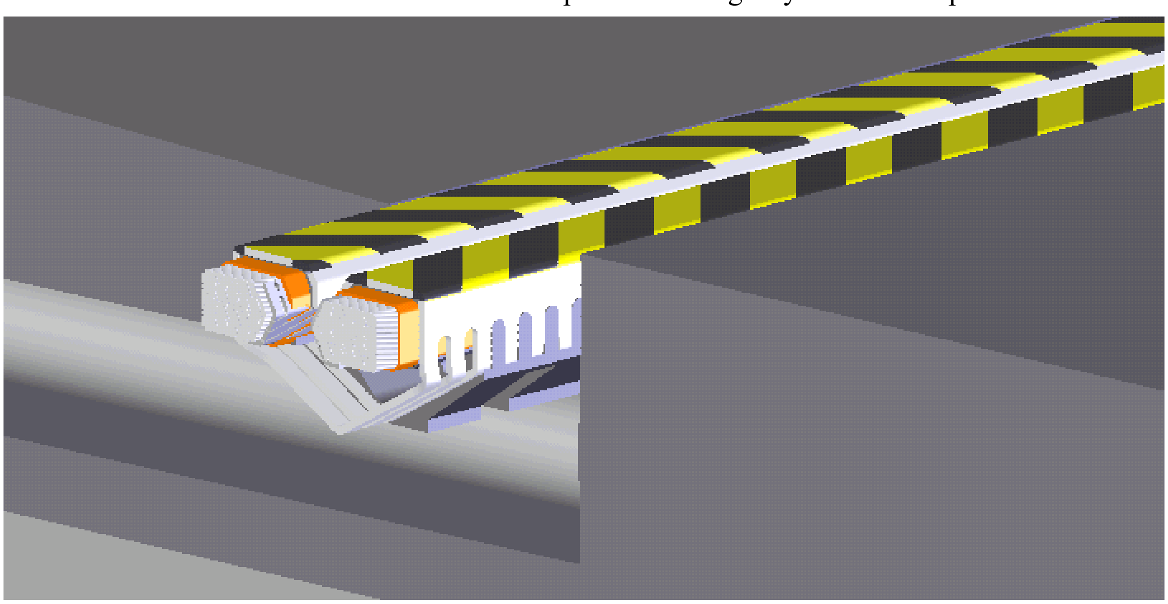

Figure 2: ZE-Feed in pavement and detail of power supply cable

ZE-Drive is based on the **TEMPO ßeta** concept *(1)* which originates from the participation in the Intelligent Vehicle/Highway System (IVHS) committee established by the **U.S. Intermodal Surface Transportation Efficiency Act of 1991** *(2)*.

Since then **electro mobility** and **autonomous driving** have come a long way and gained appeal with drivers.

Building on some of the foundations set up by **TEMPO ßeta** and taking into account the recent **UN Regulation** which substantially restricts the use of Automated Lane Keeping Systems (**ALKS**) for passenger cars, **ZE-Drive/ZE-Freight** technology **(Figure 1)** re-engineered the **TEMPO ßeta** concept to disruptively respond to the four following challenges facing road traffic today thanks to the introduction, amongst other things, of (i) an innovative **Powerful (2G) Emergency Braking System** (not affected by weather conditions); (ii) a **ELV 120 V DC Direct Power** for safe Electrified Road System; (iii) a **New Class of Electric Light Truck** for Automated Goods Transportation and (iv) the sharing of the left lane between conventional and **ZE-Drive Autonomous Traffic**:

Challenge 1: Safe, affordable, cyber secured **Level 3/4 Autonomous Driving** at high speed (up to130 km/h - 80 mph) with **ELKS** (Emergency Lane Keeping System) for secured platooning;

Challenge 2: **Extended range EVs** without the need for multiple charging stops and/or weight/battery capacity expansion;

Challenge 3: **Rush Hour Mitigation** without road expansion; and

Challenge 4: **Efficient and cyber secured transportation of palletized goods,** which today accounts for over 50% by weight of road freight.

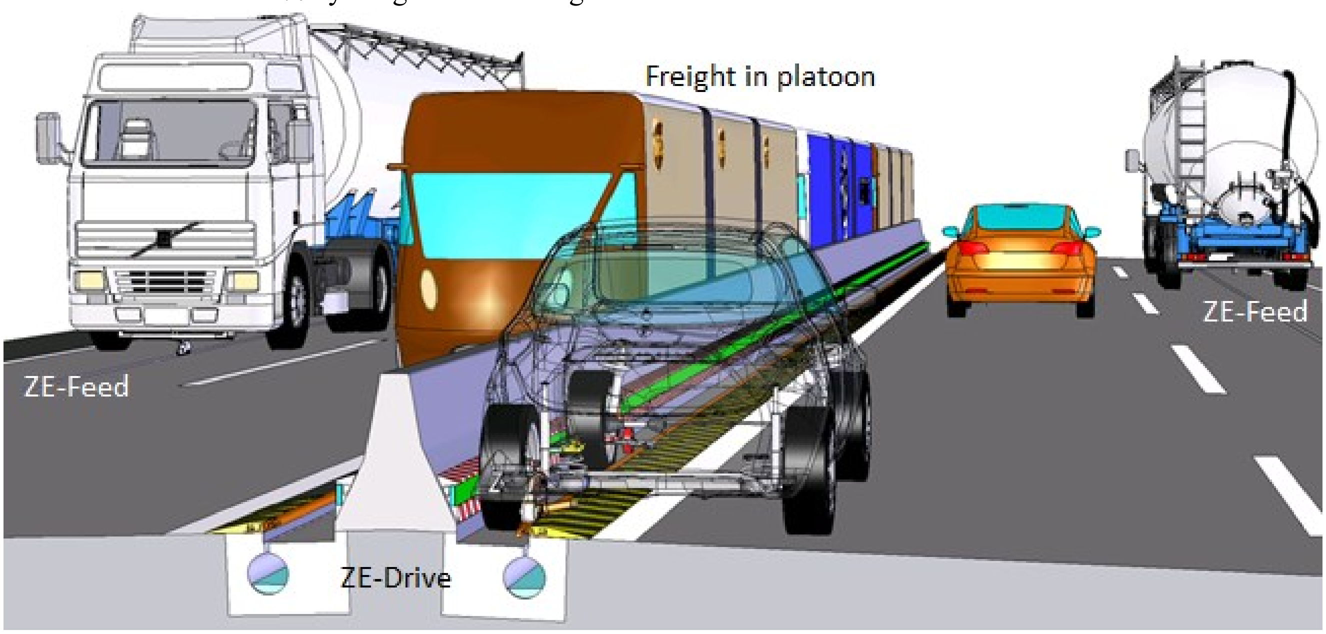

Figure 3: ZE-Feed & ZE-Drive equipped Freeway showing a "phantom" car on ZE-Drive sharing the left lane with conventional traffic and 3 platooned ZE-Freight light trucks cruising along on the other direction.

INTRODUCTION

The **TEMPO ßeta** concept raised the interest of Californian players in the 90's as illustrated in the unpublished attached document untitled ***"92-93 TEMPO Beta US",*** however due to electro mobility being in its infancy the **vision** was far ahead of its time.

ZE-Feed's Description

Succeeding to ZE-Drive, a highly automated mode of circulation for electric vehicles, proposed a power supply in ELSV (Extra-low Voltage) limited to 120 volts in DC, but this configuration generates amperages that are too high to supply Trucks/Buses in ERS and/or Fast Charge, in particular for Urban Buses/Tram at stops.

ZE-Feed slotted cable provides a solution for supplying high power (up to 1.2Mw) low voltage to vehicles, up to 1,000 volts AC and 1,500 volts DC, from a fixed power supply source. This is done by means of a roadway pavement slotted cable, allowing dynamic conductive connections, having on its upper face a slot with a width less than the safety standard preventing the penetration of a finger in the slot. This safety width is currently set at 12 mm in Europe (IEC 60529).

The **ZE-F**eed slotted cable, bendable on the slit plane, permits fast installation on the right lane of road's infrastructure. A small groove, W: 100mm x H: 65 mm, is grinded into the pavement in the centerline of the lane. The **ZE-F**eed slotted cable is unwound from the reel and straightened by the bending unit and a roller guide assembly aligns it with the groove in which the **ZE-F**eed slotted cable is lowered and secured.

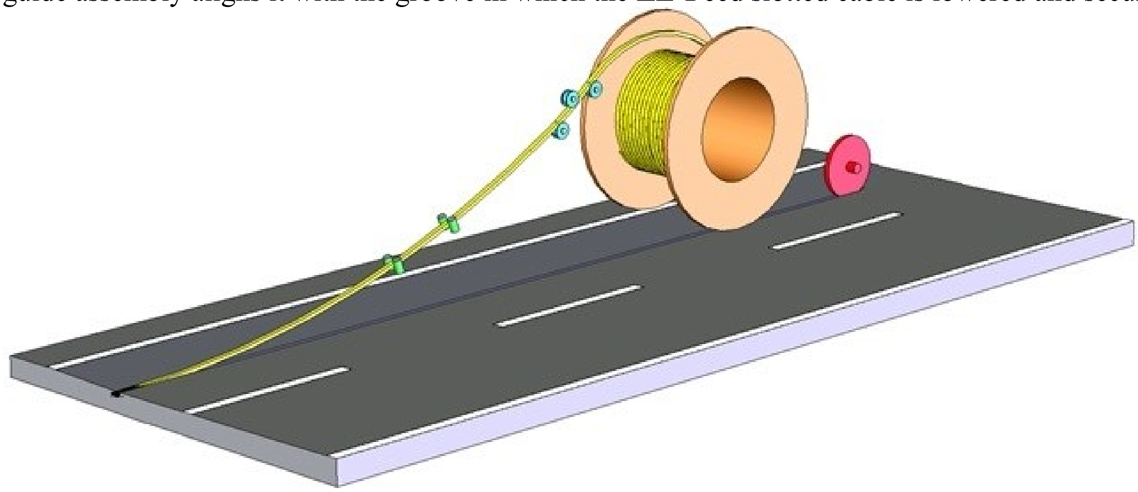

Figure 4: ZE-Feed on spool installed on grinded pavement groove

The **ZE-F**eed pavement slotted rigid cable (entirely recyclable) is torn off at each resurfacing of the asphalt, event which occurs approximately every 10 years on motorways. This specificity is very well received by road infrastructure operators because it minimizes their initial investment to cover a maximum of roads quickly.

Figure 5 illustrates the Collector sliding sideways on a transversal rail installed on the bottom of the Front Bumper.

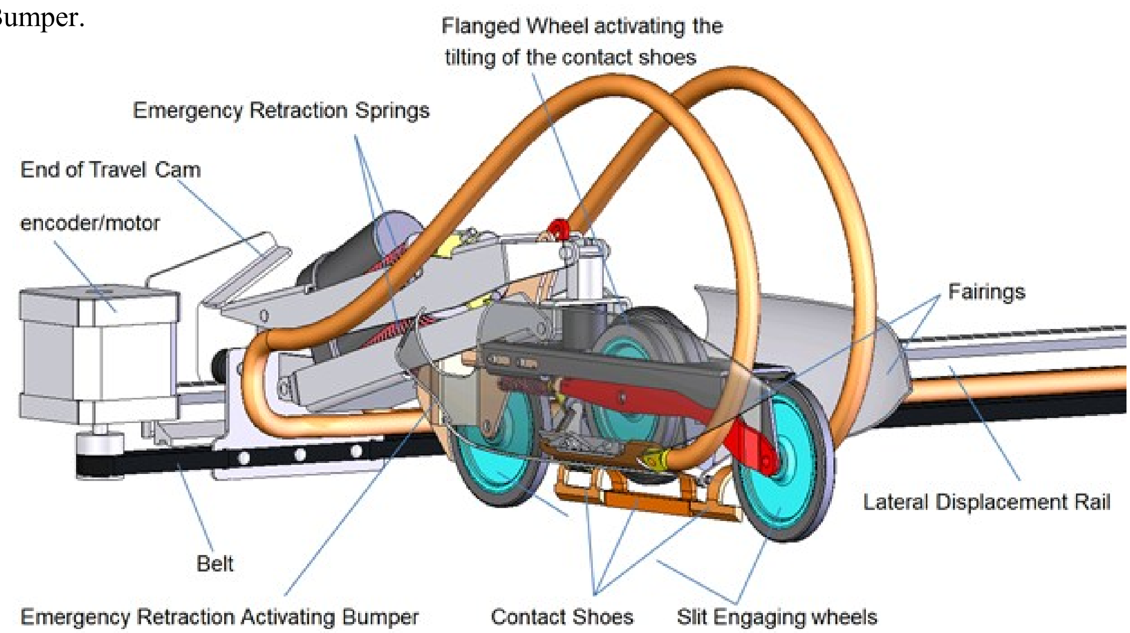

Figure 5: ZE-Feed retracted collector

Figure 6 illustrates the collector lowered in the approach phase upon engagement in the slot where the slit engaging wheels, in contact with the roadway, support the force applied on the collector which moves laterally on the arm support sliding on the transversal rail. This displacement, while driving, is obtained by the action of the motor/encoder acting on the belt connected to the sliding arm support. In the event that the truck changes lane, the front part of the arm comes into contact with the inclined stops fixed on the transversal rail, mechanically retracting the collector.

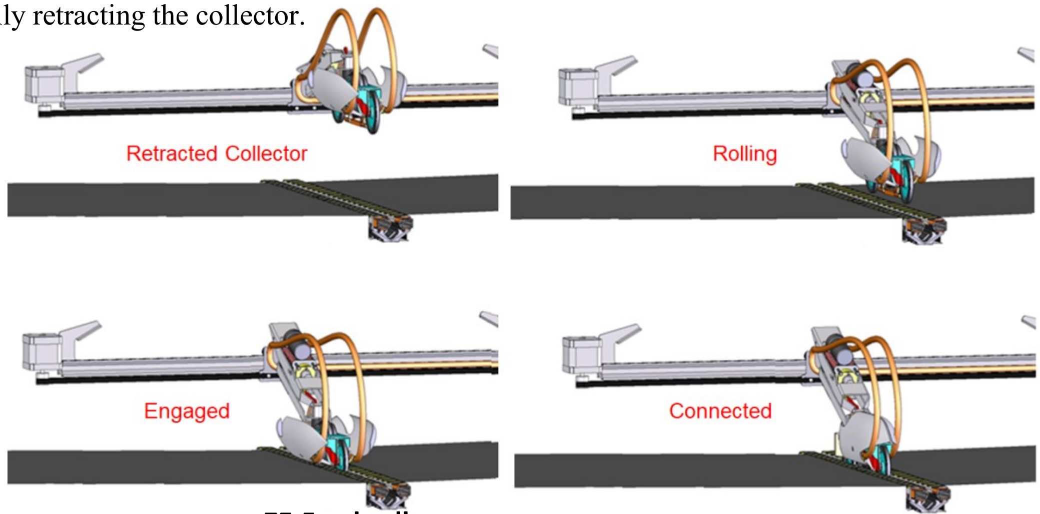

Figure 6: Sequence engagement ZE-Feed collector

Testing and Qualification

The Grenoble's 13 meters 40 tons testing wheel will be used to assess wear and particle emission as well as running endurance tests on 2 slotted 40meters long ZE-Feed cables.

Several collectors from different designs will be tested on the ZE-Feed cables, with numerous cycles of engagement-connection-disconnection under Low Voltage transmission up to 500 Amp.

See attached note *(3)* on reliability and life tests *TACV Lab _ GC_màj - Mars 2023*

ERS 2.0 TRANSPORTATION ARCHITECTURE AND DESIGN

ZE-Drive technology addresses the four above listed challenges with the introduction of the following components:

- a **secured level 4/5 Autonomous Driving Mode** at cruising speed (110/130 km/h – 70/80 mph) which is cost effective, thanks to a **mechanical back-up guidance**: as the left wheels are captured in a curbed path forming an Emergency Lane Keeping System (ELKS);
- an **Electrified Road System** for electric and hybrid vehicles with **Extra-Low Safety Voltage (ELV 120 Volts DC)** and medium power ~30 kW, which will (i) resolve the original impediment of electro mobility (i.e. limitation in range) and (ii) reduce in the long term the size and weight of the batteries used in all-electric vehicles;
- a **"Platooned" Traffic Mode** *(4)* which increases traffic capacity without having to widen the road featuring the back-up inertia braking actuation as pioneered in **TEMPO ßeta** on the **Powerful (2g) Emergency Braking System**.

The **ZE-Drive** technology is comprised of a dedicated tread for the left wheels of vehicles, located on the central skid strip of existing motorways and expressways (160,000 km in the USA and 100,000 km in Europe).

The concept of **ZE-Freight** (which takes advantage of the **ZE-Drive** infrastructure) introduces a new generation of monocoque frameless electric lorry of "light truck" class (max. 5,000 lbs. per axle) with a capacity varying between 5 to 36 tons, illustrated above by a 17-meter long, 18-wheeled, double-articulated 18-tons version, capable both of moving goods between hubs on the **ZE-Drive** infrastructure (between 10 pm and 6 am for example) in level 5 autonomous driverless mode: thanks to the dedicated feeders, and ensuring local distribution of palletized loads during the day.

Since over 50% by weight of goods transported by road are palletized, the full size truck based on sea container dimensions is not anymore required besides not being an efficient solution.

The autonomous contactless normal operative mode of **ZE-Drive**, which is not based on image recognition which means it is **"weather proof"**, when allied to a back-up mechanical guidance system provides an effective mitigation of the "manufacturer" liability risk which is one of the major stumbling blocks for a widespread deployment of level 4/5 autonomous driving for personal cars. The recent **UN Regulation** dated **24 June 2020**, which limits to 60 km/h the speed on separate lanes for the use of level 4/5 autonomous vehicles, is an acknowledgment of the current limitations of existing autonomous driving technology based exclusively on the capability of the combination of sophisticated sensors, lidar and radar and artificial intelligence process to enhance crash avoidance.

The uses of **ZE-Drive** technology can increase road safety, thanks to its **powerful 2G braking system**. Furthermore, the democratization of electro mobility which will ensue from a widespread adoption of **ZE-Drive** technology will promote, air cleanliness and reduce noise pollution. Ultimately, **ZE-Drive** technology will increase road fluidity during rush hours, and reduce weight/drag by **platooning traffic** as well as provide a **continuous dynamic power supply** to electric and hybrid vehicles, yielding productivity gains in private and business transportations of people and goods.

ERS2.0 ZE-Drive's Description

The infrastructure required to deploy **ZE-Drive** technology is minimalist and concentrated on the central separating strip of freeways, made of a Jersey Wall and slotted spillway gutters **(Figure 2)**, and does not interfere with the conventional traffic lanes.

A 24 kg/m (16 lbs. /ft.) **steel rail** (in orange above) is anchored to the spillway gutters. **Sloping ramp** sections (striped yellow-black above) connect the pavement to the upper surface of the rail while the **"third rail"** (in green above) provides the ELV 120 Volts DC supply.

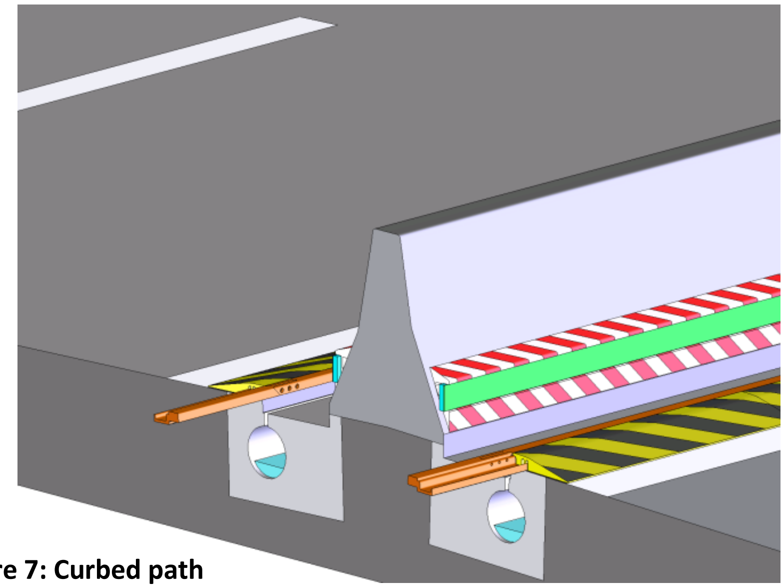

Figure 7: Curbed path

Cars in **ZE-Drive** mode travel astride the left white line **(Figure 3)** with left wheels running on a dedicated curbed path bordered internally by the steel rail.

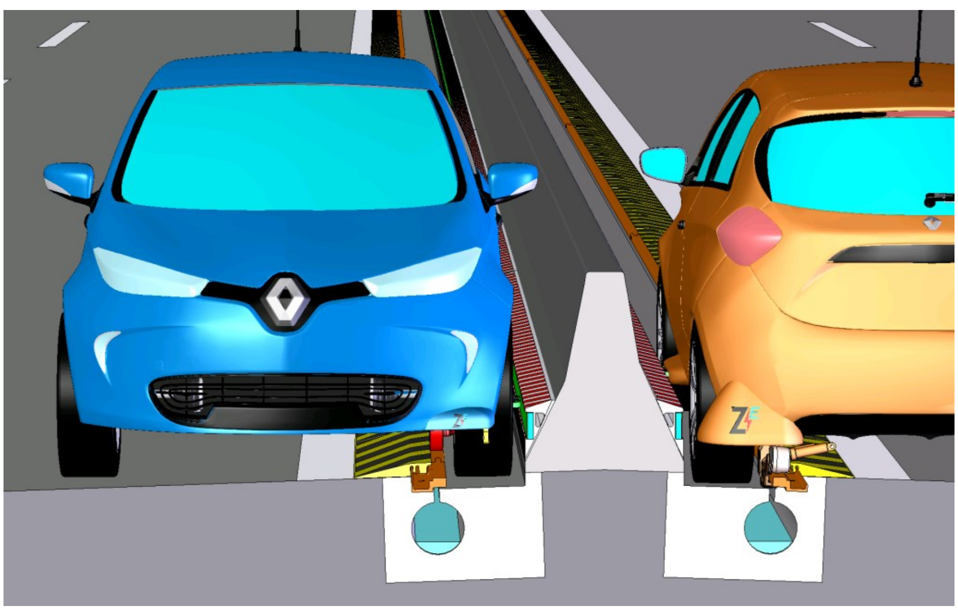

Figure 8: ZE-Drive Traffic

Ahead of the left front wheel **(Figure 6)** a **multi-sensor device** continuously senses the lateral distance of the vehicle from the Jersey Wall and in **ZE-Drive** mode steers the car autonomously in all weather conditions as it keeps the left wheels at the center of the curbed track in a contactless fashion.

The rail also provides electric ground return (similar to an electric railroad) of the **Safe ELV DC power** supply captured by a **retractable slider** (in green above and below) located at the bottom of the driver's door.

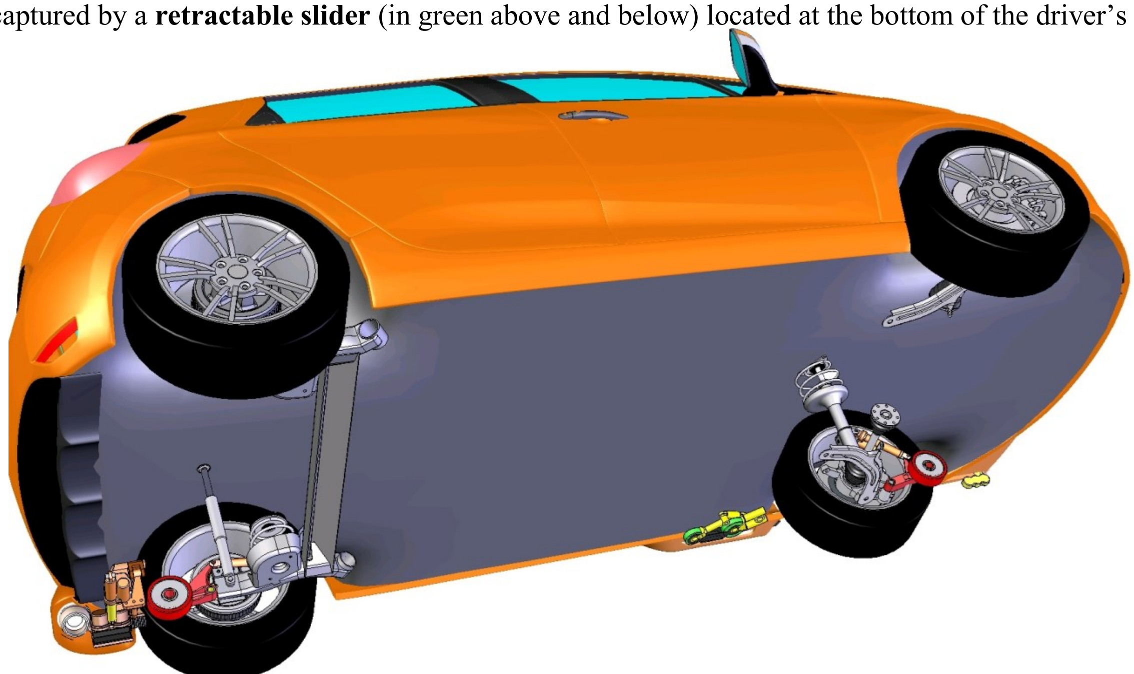

Figure 9: ZE-Drive Car Underneath

On the inside of the stub axles of the two left wheels **two retractable rollers** (in red above) are attached to take over the load of the left wheels when laterally crossing the rail. The rollers bear temporarily on the rail and smoothly land (or extract) said wheels to and/from the dedicated curbed track. As an option the suspensions, on the left side, could be of variable height to allow mitigation of the body roll induced from crossing the rail.

Behind the left rear wheel a **swinging brake caliper** (in brown above) attached to the car's body enables the steel rail to be gripped in order to exert a strong deceleration (~2g) independently of the tire/road grip limitations due to weather conditions (rain, snow, ice…).

As a side note, the required safety distance is 72 m (240 feet) for a speed of 130 km/h (80 mph) (based on 2 seconds of car travel) however the 2g emergency braking capacity allows a stop in 33 m (110 feet) which will enable sufficient time for computer analysis of the situation to avoid any false emergency braking.

With the 2G emergency braking system groups of 2 to 8 cars can be formed "bumper-to-bumper" as demonstrated in 1997 on HOV-Lane between Los Angeles and San Diego *(4)* doubling and even quadrupling, in the long term, the capacity of a road lane.

An automatic sequence system (similar to **"park-assist")** will assist the driver in entering and exiting the **ZE-Drive** track laterally at cruising speed.

All the technologies forming the **ZE-Drive** system, both in road infrastructure and cars, are mature and can immediately deliver cost-effective reliable level 4/5 autonomous driving.

Efficiency and Deployment

In terms of overall energy efficiency (i.e. taking into account not only the energy used to drive the car, but also the extraction and transformation of raw materials for the manufacturing of the car and the production of the battery pack), **ZE-Drive** technology makes it possible to substantially reduce the capacity and consequently the weight of the battery pack. This further limits the quantity of CO^2 generated by the production and the transportation by the car of the extra battery weight, which is no longer needed. A **Renault ZOE** curb weight could be reduced by 300 kg (650 lbs.) and a **Tesla S** by 540 kg (1,200 lbs.) if the reduction of structure and component weights is taken into account.

Joint Industry Project

A **Joint Industry Project** will be proposed to bring together road, infrastructure and car industry players to validate through **JIP** demonstrations the viability and potential of the **ZE-Drive** technology.

The **Phase 1 "PoC"** of the **ZE-Drive Joint Industry Project** would aim to demonstrate the ease of lateral entry/exit at a **Transportation Research Center**.

Phase 2 would test the deployment of the **powerful 2g emergency braking system** and will demonstrate the **platooning capability** and the viability of **ELV 120 Volts DC power dynamic feed.**

Phase 3 will entail an **open road pilot installation** to collect usage data and show case the technology to users and industry players.

We expect that a consensual **international standard** for the **ZE-Drive** gutter track should emerge from the **JIP**.

CONCLUSION

ZE-Feed offers a rugged cost-effective universal dynamic DC connection to build cost effective ERS, comprising features not offered by any competitive ground conductive feeds:

1- a dynamic connection with ground (3 conductors)
2- an IES 60529 standard compliance avoiding the need of separate capture conductors and vehicle detection ;
3- no slippery surface on pavement.

Its inherent low cost (up to 5 times cheaper than competition) and easy maintenance will permit to install long section on country highways and urban motorways to provide fast charging for local traffic without overrunning surface of cities for fast charging stations.

Its robust design and ease of installation made it suitable for installation in emerging countries accelerating the worldwide de-carbonation of surface transports.

For the **ERS2.0 ZE-D**rive, the emergence in the current decade of a fleet of electric private vehicles, vans (commercial, RVs, etc.), up to the "light truck" size capable of carrying out a substantial portion of transportations done today by full size rig (bus, tractor, semitrailer, etc.) with axle load reduced from 18/20,000 lbs. down to 5,000 lbs. which are **"ZE-Drive equipped"** will enhance the safety record of road transportation and open up prospects for **dedicated, lighter road infrastructures** capable of running along large spans for **economical overhead crossings** or **reduced diameters for underground expressways (Figure 10)**.

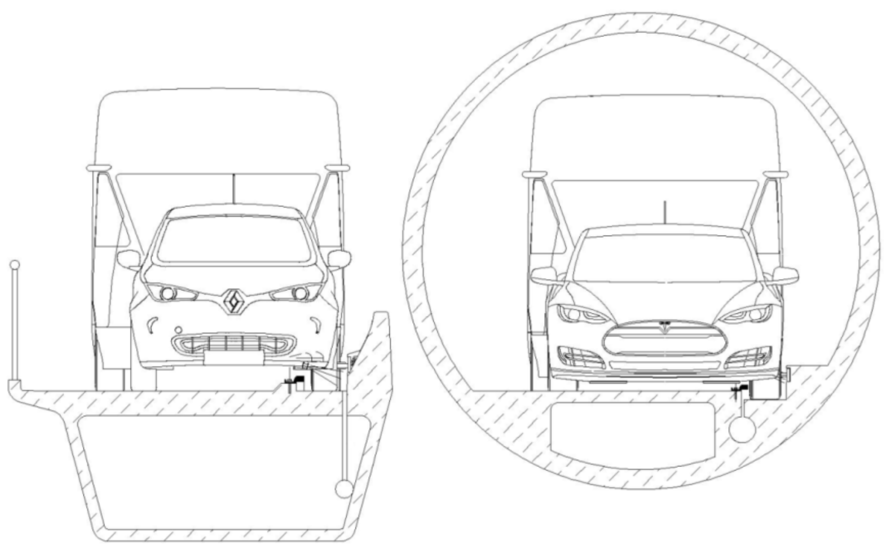

Figure 10: Light Load & Reduced Dimension Infrastructure

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1. 92-93 TEMPO Beta US
2. Intelligent vehicle highway system: advanced public transportation systems PD Heermann, DL Caskey - Mathematical and computer modeling, 1995 – Elsevier
3. 5-2013 Platooning Safety and Capacity in Automated Electric Transportation - James Fishelson Utah State University
4. Wear and tear of the collector's interface for the electric power supply of trucks ERS. Note on reliability and life tests TACV Lab _ GC_màj - March 2023

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