Cristina Olaverri

e-Mobility Laboratory (EML) at KAIST

1. Mission

KAIST (Korea Advanced Institute of Science and Technology) focuses on innovative future technologies of various fields, including transportation. KAIST was established in 1971 as a research-focused university to foster the highest quality human resources in Science and Technology field with global competitiveness, fully sponsored by the Korean government, having 800 full-time faculties and 10,000 students of which 60% are in graduate programs. KAIST ranked 60th globally and 12th in Asia in the OS World University Rankings in 2013/14. Moreover, it was placed 24th by QS of the same year in the field of Engineering and Technology. Per THE (Times Higher Education), KAIST's reputation rank was at 51–60 in 2014.

The e-Mobility Laboratory (EML) in KAIST's Engineering School focuses on innovative vehicle- and infrastructure-cooperative innovative transportation technology coping with global issues on the energy and sustainability. The key emphasis of EML is on:

- Research and development on eco-friendly vehicle technologies, such as electric, hybrid, fuel cell vehicles and their charging or energy supply technologies
- Research and development on innovative vehicle technologies toward automated and autonomous driving
- Contribute to strategic planning on safe and efficient future transportation system on smart grid and smart mobility.

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2. Research Programs

Research programs of EML are classified into three categories, such as environmentally-friendly vehicle technologies, vehicle and infrastructure integrated safety and throughputs enhancement technologies, and charging infrastructure strategy for electric vehicles and related global technical standard.

Foldable Micro Electric Vehicle as a Means of Public Attractiveness

Micro mobility can provide good opportunity as a future mobility solution for urban applications responding to personalized mobility demand and city traffic issues. While governmental policy and regulatory actions are important, technologies for enhancing public acceptance and attractiveness has also been a challenge.

A completely innovative body-folding design, the prototype vehicle, named as Armadillo-T, drew strong attention from major on-line communities and public broadcastings in 2013, such as Wall Street Journal, NHK World, Popular Science, and ABC News, etc. With four in-wheel direct drive, integrated vehicle stability control by independent torque vectoring and steering assistance, incorporating nomadic device interfaced vehicle operation, this prototype has been successful in promoting user's acceptance and public attractiveness of micro electric vehicle as a new mobility solution in general, in addition to the innovative foldable body design (Fig 1). About $28 million research grant from two consortia of central and local government, and industry together has been allocated for a three-year project to bring the micro mobility on the road, supported by the Korean government and national congress in 2014. EML is proud to bring the micro mobility test-bed project, and eventually the new vehicle segment and its market here.

Public Transit Bus with Dynamic Wireless Charging

Wireless charging applying magnetic induction or resonance phenomena for the electric vehicle, has been one of innovative technical challenges recently (Fig 2).

As a leading member of dynamic wireless charging R&D group (called OLEV) from 2009, Professor

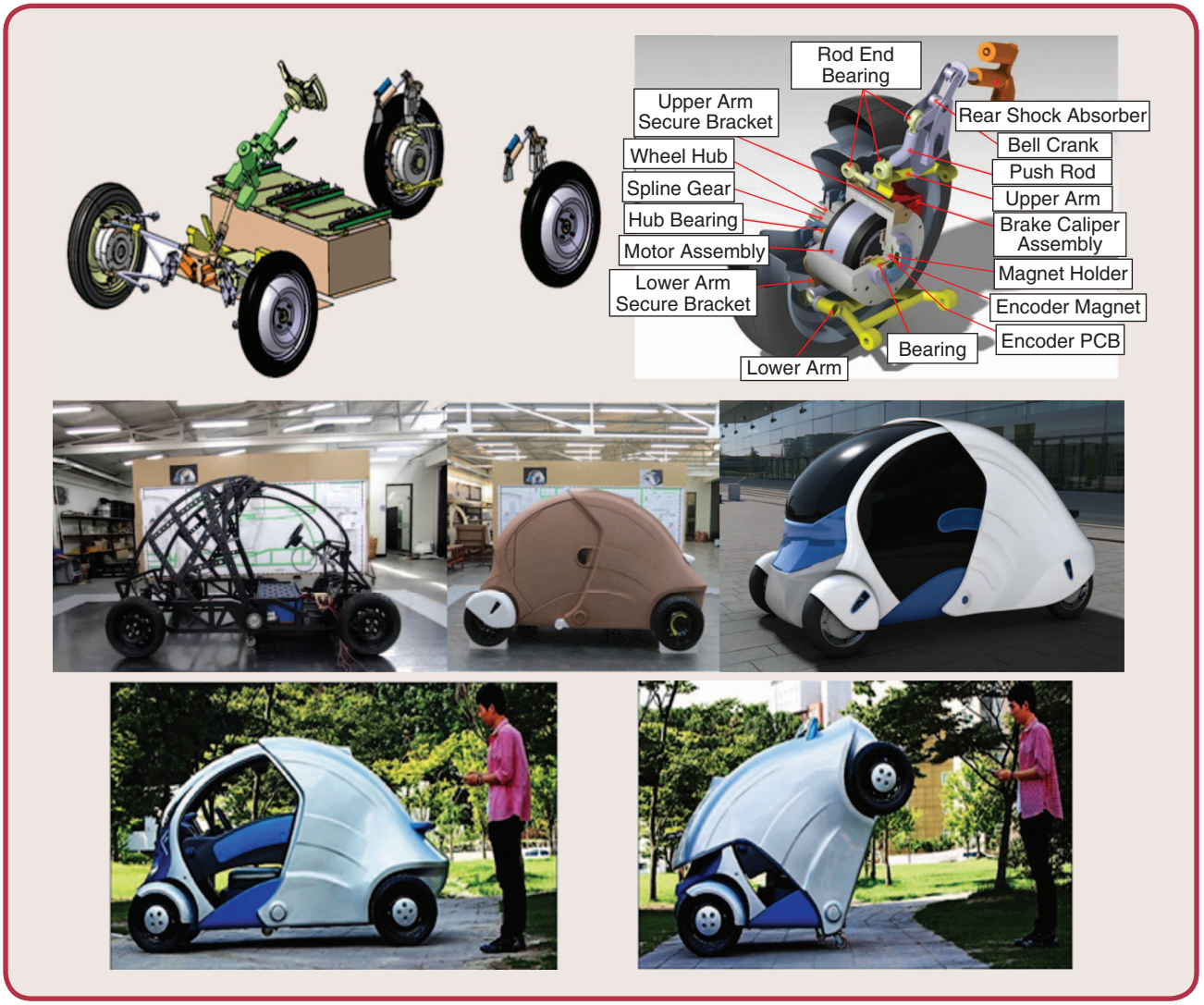

FIG 1 Creation of the Armadillo-T, a foldable micro electric vehicle.

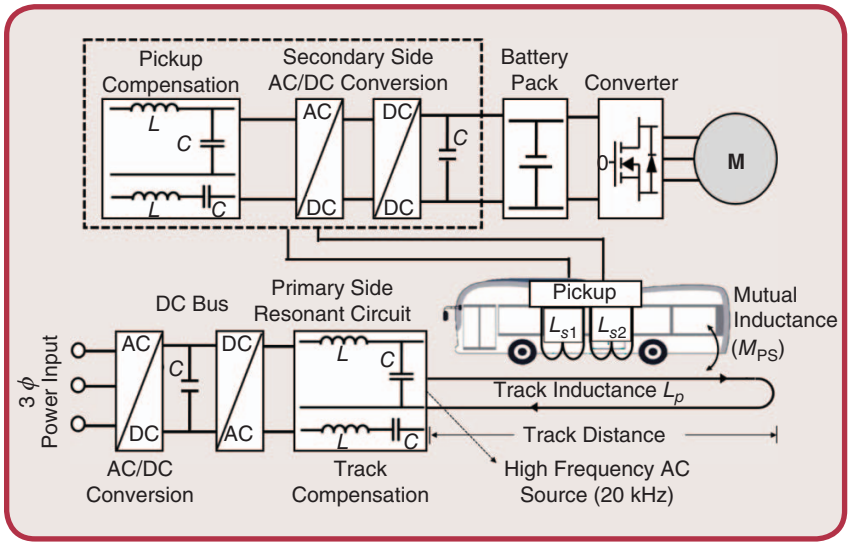

FIG 2 System architecture of dynamic wireless charging of electric vehicles.

Suh has led the vehicle integration and in-vehicle power management of whole OLEV project until 2011. He also led the first public launch of OLEV Tram in Seoul Grand Park as a chief engineer (Fig 3). The technology has been successful from laboratory-based research to public transit application in less than 4 years, acknowledged "50 Best Innovations of 2010" by Time Magazine and "Top 10 Emerging technologies for 2013" by World Economic Forum.

The wireless power transmission efficiency of 85% of static charging and 60% of dynamic charging has been a high record with dynamic wireless charging technology whilst reducing the on-board battery's

FIG 3 From lab-based research to daily transit application within 4 years with dynamic wireless charging technology.

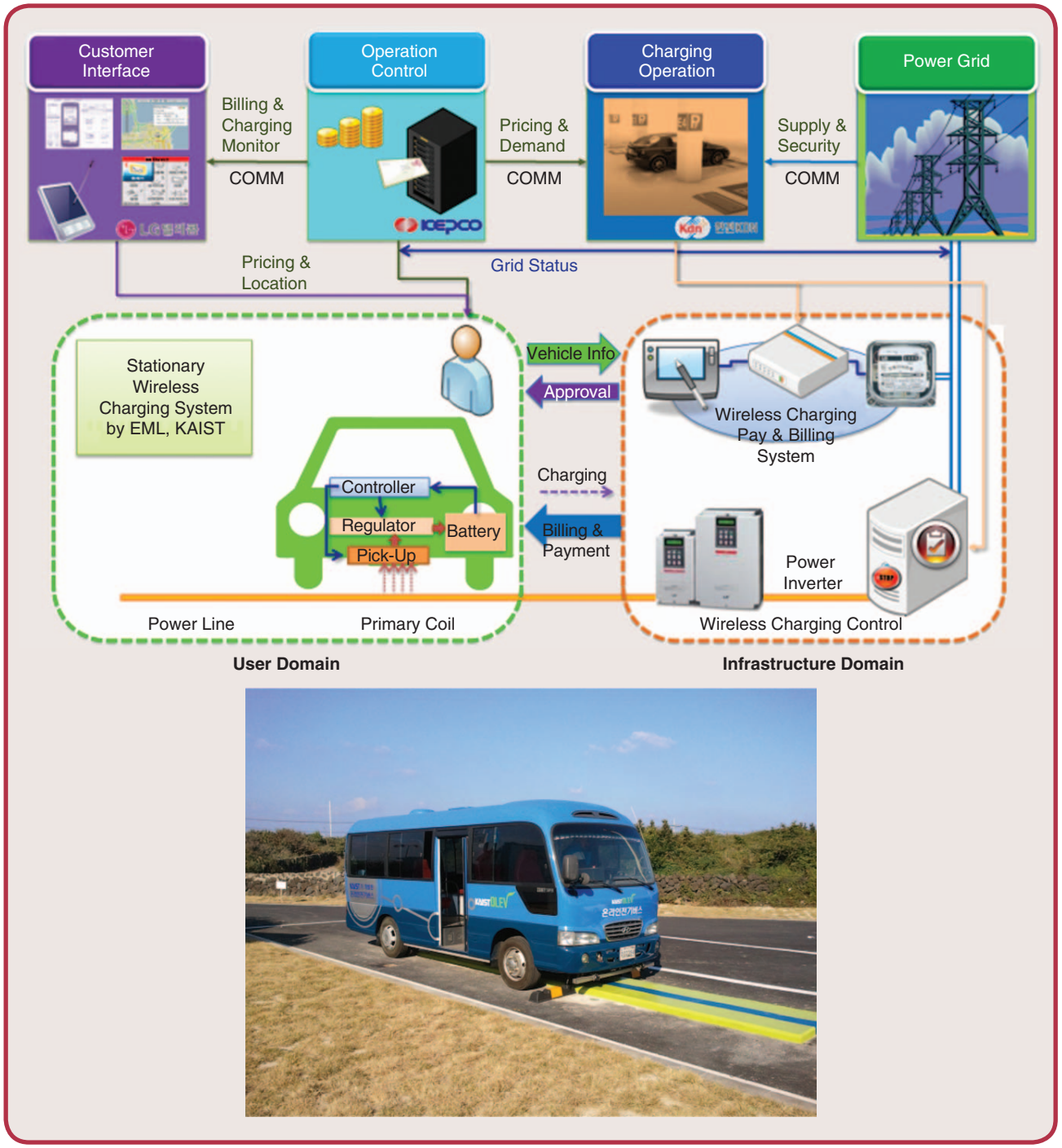

FIG 4 Demonstration of a complete wireless charging control network with user interface of billing and payment system.

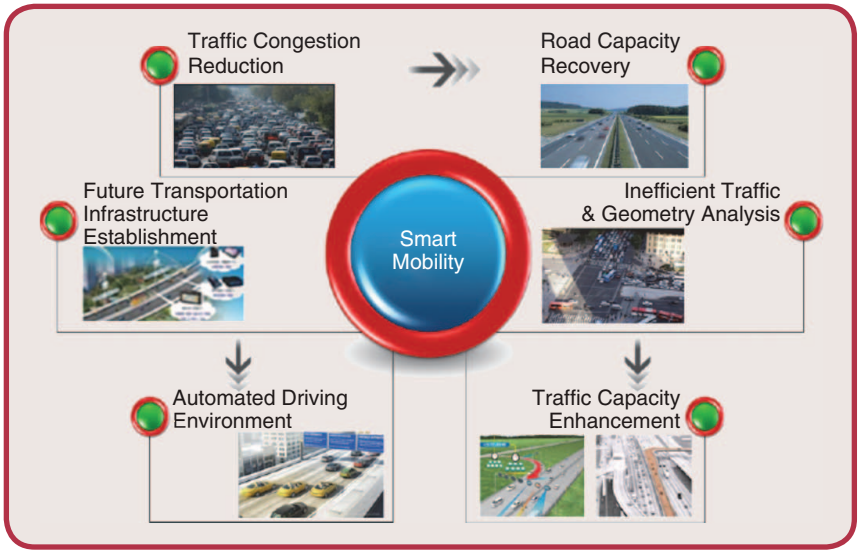

FIG 5 Concept of smart mobility as a tuture transportation strategy.

energy storage capacity to 1/3 of typical pure electric vehicles.

Stationary Wireless Charging for Electric Vehicles in the Smart Grid Project with Connectivity

As a member of 30-industry consortium on Smart Grid Testbed Project, led by KEPCO (Korea Electric Power Corporation), EML demonstrated a complete system of stationary wireless charging of 25 kW of power capacity, with 92% of the wireless power transfer system efficiency at 6 cm of a ground height (Fig 4). Combined with ICT integration, the complete process of in-vehicle power flow management, charging operation control, billing and payment system, and other user interface are demonstrated.

Strategic Planning of Smart Mobility Toward 2025

Smart mobility is a strategic technology planning for establishing future transportation, including foundation technology developments and implementation toward 2025. Five national research institutes and four universities in Korea including KAIST EML are participating. The main objectives are to eliminate traffic congestion occurred on the highways and urban roads, and to enhance safety and throughputs without additional road construction by adopting ITS (Intelligent Transportation System) technologies (Fig 5).

Key technology modules are a network-based integrated congestion-free management system on highways, a smart traffic signal management system in urban areas, a vehicle-ICT convergence based traffic flow analysis and simulation platform development, a high-speed vehicle platooning support system, an on-demand real-time reserved lane system, a seamless real-time vehicle positioning system, and a cooperative ITS environment-based vehicle stability evaluation platform, etc.

International Technology Standard Activities

Establishing global technical standards in emerging technological fields are very important in expediting the technology acceptance into the society. In the field of ITS and wireless charging electric vehicles, the international standard activities are currently very strong and active. EML is involved in electrical safety and inter-operability fields of electric vehicle and wireless charging, such as SAE J2954-Wireless Charging of Plug-In Electric Vehicles and Positioning Communication, IEC/TC69/JPT61980-Electric Vehicles Wireless Power Transfer Systems, ISO/TC22/SC21/19363-Electrically Propelled Road Vehicles-Inductive Charging, and EMF/EMC field such as IEC/TC69/CISPR B/D, IEC/TC105/62764-1

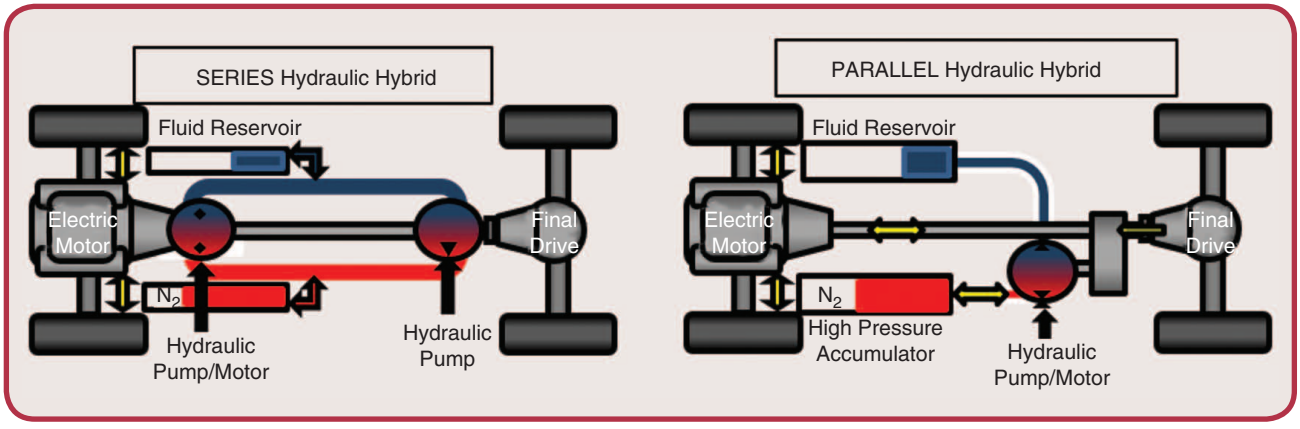

FIG 6 Electric-hydraulic hybrid vehicle feasibility.

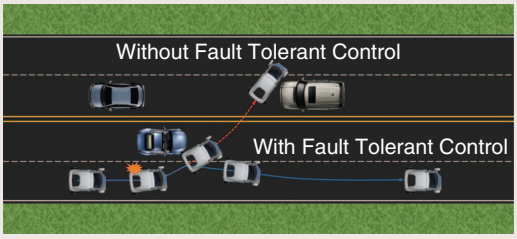

FIG 7 Four-wheel electric vehicle fault tolerant control applying vehicle dynamic stability and torque vectoring.

and ISO/TC22, etc. It is closely working with Koreas Society of Automotive Engineers (KSAE) and Korean Agency for Technology and Standards (KATS).

Innovative Vehicle Technology

For the sustainable future transportation system, the vehicular technology integrated with road infrastructure is necessary, yet challenging. Alternative power sources, such as electric-battery hybrid and electric-hydraulic hybrid can potentially be an efficient and eco-friendly vehicular technology (Fig 6).

About the four in-wheel independent motor drive system, relating to the foldable micro electric vehicle, the fault-tolerant algorithm is also important in the view of road safety (Fig 7). Applying real-time instantaneous dynamic stability control with proper torque vectoring of four wheel independent control, the vehicle can maintain minimal required maneuverability under possible faulty conditions of the electric power drive system.

As discussed in the above, e-Mobility Laboratory at KAIST is working on the future transportation technology from a fundamental to the application research, coping with global future energy and environmental issues. The new innovative future transportation technology always has barriers from early-stage laboratory research to proof-of-concept prototype and on to full-scale commercialization. Bridging the gaps between new technologies and market, known as "technology valley of death" of the early-stage and the later-stage of "commercialization valley of death," requires technological advancement in efficiency and speed, which EML cherishes this basic ground-rule of research and development.

ITS

Related Information

Website: http://e-mobility.kaist.ac.kr/
Related Conferences:
- International IEEE Conference on Intelligent Transportation Systems
- IEEE Intelligent Vehicles Symposium
- IEEE International Electric Machines & Drives Conference

Related Journals:
- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Power Electronics
- IEEE Transactions on Vehicular Technology
- IEEE Transactions on Intelligent Transportation System

Quick Facts

Director: In-Soo Suh

Lab name: e-Mobility Laboratory
Affiliation: Korea Advanced Institute of Science and Technology (KAIST), Korea
Website: http://e-mobility.kaist.ac.kr
Research Focus: Future Mobility and Transportation, Electric Vehicles, Charging Infrastructure Strategy, Vehicle Dynamics, Integrated Vehicle Control, HMI, and ITS.

In-Soo Suh and is currently serving as an associate professor in the ChoChunShik Graduate School for Green Transportation, KAIST. His expertise and research fields are electric mobility, intelligent transportation system, automated driving, and charging infrastructure strategy and technology. Dr. Suh holds a Ph.D. degree from Massachusetts Institute of Technology, Cambridge, MA, USA, in Mechanical Engineering, and BS and MS degrees from Seoul National University, Korea.

Contact Info:
Address: N7-5, RM 304,
KAIST 291 Daehak-ro, Yuseong-gu,
Daejeon 305–701, Korea
Tel: (+82)-42-350-1261
E-mail: insoo.suh@kaist.ac.kr