Presenting Results of Initiatives Toward the Realization of the Smart Mobility Society that Toyota Envisions — Overview of Toyota Exhibits at the 26th ITS World Congress 2019 in Singapore —

Toyota believes that everyone deserves freedom of movement, the freedom to enjoy their lives, and the freedom to move from place to place safely and comfortably. Toyota strives toward this vision of a smart mobility society, minus barriers of any kind, a society where “Mobility for All” is a reality.

To realize such a society, we have been active in the field of ITS*1 for a long time, and have participated in this world congress since its first edition. We will be presenting exhibits at this year’s 26th ITS World Congress 2019 in Singapore (organizers: the Singapore Land Transport Authority and ITS Singapore).

Echoing this year’s theme of “Smart Mobility, Empowering Cities”, Toyota will be presenting its vision of the future mobility society, and the outcomes of specific connected and MaaS*2 technology initiatives aimed at making it a reality. At the same time, we hope to accelerate research to realize that society through the exchange of policies and technology, sessions, and other events involving other participating companies and organizations.

*1 Abbreviation of Intelligent Transport Systems. They seek to provide safe, comfortable and smooth traffic by relying on cutting-edge information and communication technology to unify people, roads, and vehicles.

*2 This term is derived from Mobility as a Service and refers to services that provide seamless means of moving around by combining mass transit systems, rental cars, taxis, rental bicycles, and other means of transportation.

Organizer theme: “Smart Mobility, Empowering Cities”
Dates: Monday, October 21 to Friday, October 25.
Venue: Suntec Singapore Convention and Exhibition Centre
Organizers: Singapore Land Transport Authority and ITS Singapore
1. Overall Theme: Attachment 1
   The smart mobility society envisioned by Toyota under the theme “Mobility for All”.

2. Vehicle-to-Everything (V2X): Attachment 2
   Initiatives to propagate cooperative ITS to realize a society with zero accidents.
   Technical differences between DSRC and cellular networks, approach taken by Toyota, and more…

3. Initiatives for the Global Expansion of MaaS: Attachment 3
   The Toyota MaaS strategy and plans for the development of dedicated vehicles, MaaS partnerships around the world, and more…

4. The Technologies that Support Mobility for All: Attachment 4
   Approaches to the development of automated driving technologies that will make ultimate safety and mobility for all a reality, and the development of the ICT platform that will support upcoming connected cars and automated driving.

5. Coordination with the Toyota Group: Attachment 5
   Presenting the group company initiatives under the banner of “The Next Innovation by the Toyota Group for the Future Mobility Society”, our shared message.

6. Sessions and Technical Paper Presentations
   Toyota group members will take the podium in executive, special interest, and technical session.

Logo and official website

http://itsworldcongress2019.com/
Envisioning Smart Mobility Society in the Connected Future

By connecting vehicles, people, and communities, Toyota aims to create a safe and exciting society where people can move freely.

Connected with vehicles and roads

**SAFETY**

By linking connected and automated driving technology, Toyota hopes for a society where everyone can move safely, efficiently, and freely, based on the ultimate goal "zero traffic fatalities".

**FOT for Automated Driving**

*2020 Yearly Demonstration Test*

**TRI’s trial Automated Vehicle**

*Guardian* Vehicles are able to safely change lanes and navigate around obstacles without a human driver.

*Chauffeur* Automated driving system operating in parallel to a human driver to support driving and protect passengers.

Connected with society and the community

**ECO & CONVENIENCE**

Create new appealing value for vehicles that benefit people's lives, and contribute to a mobility society that is friendly to the environment and where everyone can move freely and comfortably.

**e-Palette Concept**

Create new exclusive services for the car by providing MaaS vehicles and releasing software functions to service business operators.

Connected with People

**COMFORT**

By advancing Toyota’s Agent, the car will become an irreplaceable partner as it grows in concert with the driver.

**Toyota MyAgent**

Through daily communication, The Agent will come to understand the feelings and preferences of the driver and exist as way to further enrich the mobility life of each person.
Commercialized V2X in Japan
ITS Connect

Practical Application of Cooperative ITS

Approx. 40% of traffic accidents in Japan occur near intersections.

ITS Connect commercially launched in Oct. 2015.
The system uses the dedicated 760 MHz ITS frequency to provide drivers with information such as the color of traffic signals or the presence of pedestrians or other vehicles in blind spots not covered by on-board sensors.

V2I

1. Right-turn Collision Caution
2. Red Light Caution
3. Signal Change Advisory
4. Public Transportation Priority System (PTPS)

V2V

4. Communicating Radar Cruise Control (C-ACC)
5. Emergency Vehicle Notification
6. Crossing Collision Prevention
7. Right-turn Collision Caution

Evaluation of satisfaction with the service (Internet survey results)
Respondent: Customers who used the systems

<table>
<thead>
<tr>
<th>Functions</th>
<th>Infrastructure</th>
<th>Expectations for the future</th>
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<tbody>
<tr>
<td>There are many blind spots when turning right. Receiving the warnings is helpful.</td>
<td>I would like to experience these services at many more intersections.</td>
<td>ITS is important technology for automated driving. I hope it will become more common and offer more advanced functionality.</td>
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</table>

Deployment

- Infrastructure: 8 prefectures, 86 intersections (as of Sep. 2019)
- ITS Connect sales data: Approx. 170,000 vehicles in total (as of Sep. 2019) → Gradually installed in more models

Passenger car

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<td>LS</td>
<td>ES</td>
<td>CROWN</td>
<td>NOAH</td>
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<td>RX</td>
<td>UX</td>
<td>PRUIS</td>
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<tr>
<td>UX</td>
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Public Transportation

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<th>Standard [1 model]</th>
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<td>SORA</td>
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Evolution Utilizing V2X

Aiming to create more advanced automated driving through coordination between autonomous and cooperative systems.

Reference: U.S.DOT Automation Program by U.S.DOT

Utilization of predictive information (V2X)

Connected and Cooperative ITS

Automated Driving System

Expands the functions of the increasingly common ITS Connect and ETC 2.0 services, and applies them in automated driving.

Automated driving field test in the Tokyo waterfront area

- Automated driving field test begun in Tokyo in 2019 as part of a SIP* initiative.
- Toyota is planning to demonstrate level 4 automated driving in accordance with the 2020 Tokyo Olympics and Paralympics.

Automated Driving Scenarios Using V2X

**ITS Connect expansion**

**Going through a signalized intersection (Waterfront Subcenter)**

- Reliable signal recognition with V2I and an autonomous camera.
- Recognizes traffic signal color.
- Receives traffic signal information.
- Ascertainment of signal change timing via V2I to stop smoothly when a signal changes to red.
- 1) Acquires future signal information.
- 2) Decelerates and stops smoothly.

**ETC2.0 expansion**

**Merging support (Tokyo Expressway)**

- Ascertainment of main lane traffic conditions via V2I and adjusts speed accordingly in the access lane.
- Transmits detected information.

**Public transport signal priority control (Haneda)**

- A bus approaching an intersection uses V2I to request signal priority control.
- Requests green light extension to pass through the intersection.
TOYOTA supports interoperable, fully-validated and government-supported V2X technologies.

### V2X Short Range Environment

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<thead>
<tr>
<th>Japan</th>
<th>USA</th>
<th>Europe</th>
<th>China</th>
<th>Australia</th>
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<tbody>
<tr>
<td>V2X Technology</td>
<td>DSRC (ITS Connect)</td>
<td>DSRC</td>
<td>DSRC (ITS-G5)</td>
<td>LTE-V2X</td>
</tr>
<tr>
<td>Frequency</td>
<td>760 MHz</td>
<td>5.9 GHz</td>
<td>5.9 GHz</td>
<td>5.9 GHz</td>
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<tr>
<td>755-765 MHz</td>
<td>5,850-5,925 GHz</td>
<td>5,855-5,925 GHz</td>
<td>5,905-5,925 GHz</td>
<td>5,905-5,925 GHz</td>
</tr>
<tr>
<td>Deployment Status</td>
<td>Commercial</td>
<td>Operational</td>
<td>Announcement</td>
<td>Pilot</td>
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### V2X Hybrid Communication

Vehicle-to-everything (V2X) connectivity is achieved with a combination of Short-range direct communication (DSRC for Safety) and Long-range network communication (Cellular-V2N) — “Hybrid Communication”.

#### V2X Requirement

**Short Range (V2X) Direct**
- Low Latency / Safety Critical / Proximity (-300m)

**Long Range (V2N)**
- Non Low Latency / Large Data

#### Base Technology

- **DSRC**
  - IEEE 802.11p / ETSI ITS-G5
  - SAE J2735
  - SAE J2945, ETSI TS102 687

- **Cellular (LTE/5G NR)**
  - PCS
  - Uu (5G Cellular Network)

- **Infotainment**
  - Cellular Base Station
  - Cloud

- **Pilot Trials LTE-V2X**
  - Congestion Control Problems
  - Half Duplex Problem
  - Near-Far Problem
  - Transmit Collision Problem etc.

- **3GPP Release 14**
  - SAE J1611 (under development)

### Technology Evolution

<table>
<thead>
<tr>
<th>Now</th>
<th>Future</th>
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<tr>
<td>DSRC IEEE802.11p</td>
<td>DSRC and/or NGV IEEE802.11bd</td>
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### V2X Evolution from DSRC to NGV

#### Key Factors: Interoperability, Coexistence, Backward Compatibility

- NGV (IEEE 802.11bd) is an evolutionary technology of DSRC V2X (IEEE 802.11p) while retaining full interoperability with the current IEEE 802.11p PHY.
- An NGV device will:
  1. Use DSRC for communication with DSRC devices
  2. Use NGV when only NGV devices are in the communication range

A Rel-16 V2X device with LTE-V2X module can:
  1. Listen to Rel-14/15 LTE-V2X devices
MaaS Strategy

Contributing to a mobility society where everyone can enjoy freedom of travel, through creating new appeal and value for cars, expanding the value chains as Mobility Service Platformer.

Connected Strategy

1. **Build a Mobility Service Platform (MSPF)**
   for use with vehicles that will all be connected

2. **Accelerate business innovation within Toyota**
   by promoting the utilization of big data,
   benefiting customers and society

3. **Create new mobility services**
   via tie-ups with various companies

**Mobility Service Platform (MSPF)**

- MSPF is the contact point with car and external companies (MaaS operators) and collects vehicle data. Toyota manages responsibly in safe and secure manner.
- Ride/car-sharing operators, insurance companies and others can provide services for Toyota and Lexus cars via MSPF.
**Autono-MaaS**

**MaaS-dedicated Vehicle**

Needs for MaaS vehicles are increasingly in demand. Development planned for multi-purpose vehicles to cater for MaaS (e.g. storage, accessibility, ease of maintenance).

<table>
<thead>
<tr>
<th>Purpose</th>
<th>e-Palette</th>
<th>MaaS Sienna</th>
<th>MaaS BEV</th>
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</thead>
<tbody>
<tr>
<td>Multi-task short distance transportation (people/cargo)</td>
<td>Medium-to-long distance ridesharing</td>
<td>Short-to-medium distance ridesharing</td>
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<tr>
<td>Launch</td>
<td>2020 Tokyo Olympic Games</td>
<td>2021</td>
<td>—</td>
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<tr>
<td>Power</td>
<td>BEV</td>
<td>HEV</td>
<td>BEV</td>
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<tr>
<td>Size</td>
<td>Large</td>
<td>Medium</td>
<td>Small</td>
</tr>
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</table>

TOYOTA believes MaaS vehicles will lead to future mobility services. Development in progress to realize ultimate just-in-time service. Big data at MSPF will predict person, things, and services, enabling cars to be where customer requests are made.

**Automated Driving MaaS Vehicles**

Automated Driving System (ADS) developed by 3rd parties and TOYOTA Guardian (advanced driver assistance) System being equipped, being connected to MSPF. Enhancing vehicle’s overall safety level through ADS and TOYOTA Guardian monitoring the surrounding in real time.

**Opening control interface to allow partner companies to install their own Automated Driving System**

- Converting to Level 4 MaaS vehicles by installing ADS to Level 2-3 mass produced vehicles.
- Standardizing Vehicle Control Interface (VCI) and targeting to cope with various ADSs.
Collaboration with MaaS players in the world

China
- DiDi
  Establishment of a joint venture, offering a rental car to ride-sharing drivers.

Japan-Tokyo
- JapanTaxi
  Proof of concept for AI-based taxi dispatch system.

Japan-Tokyo
- MONET
  "Just-in-time" vehicle dispatch service, together with local authorities and companies.

Southeast Asia
- Grab
  Total Care Service provision to enable safe and secure service through Grab.

Japan-Fukuoka
- myroute
  Conducting proof of concept for a multimodal mobility service together with railway operators.

North America
- Uber
  Collaboration on automated MaaS vehicles.

North America
- getaround
  Car-sharing business operation utilizing SNB.

Please touch the spot
"Total-care Service" Designed for Ride-hailing Companies

- Toyota developed "Total Care Service", tailored for ride-hailing vehicles, including fleet management, insurance, and maintenance.
- Highly efficient maintenance based on Toyota Production System.
Establishing a joint venture for vehicle-related services for ride-hailing drivers

- Expanding connected services provided by MSPF for value chain, including fleet management, maintenance, insurance, and finance.
- Aiming to introduce Electric Vehicles (EVs) suitable for China's future mobility services.

**Business model**

- **DiDi**
  - Vehicle leasing
  - Joint venture
- **GTMC**
  - Vehicle provision, exclusive maintenance packs, guidance on improvements based on TPS
- **Dealers**
  - Vehicle sales and maintenance
  - Vehicle price and service fee
- **Driver**
  - Lease
  - Pay lease fee
Establishing a car-sharing business in North America utilizing Smart Key Box (SKB) and off-lease vehicles

- Co-launching a pilot program with Getaround, utilizing TOYOTA vehicles installing TOYOTA proprietary SKB.
- Start a new TFS leasing program where the owner is able to use the income generated from car-sharing to pay for leasing fee.
- Piloting optimal vehicle allocation, with MSPF analyzing the operation result of TOYOTA owned vehicles and POIs.

Collaboration scheme with Getaround
Extending collaboration to develop and expand automated ridesharing services

- Developing automated driving vehicles for ridesharing.
- Jointly designing and developing next-generation automated driving system, aiming for mass production of automated driving vehicles and its service implementation.
Piloting Taxi dispatch support system, applying artificial intelligence

• Developed "Taxi dispatch support system," predicting demand and distributing taxis based on data collected from taxi, demographic and weather forecasts.
• By using this system, helped to improve the sales efficiency and increased the taxi driver's average sales by 11%.

Overview of taxi dispatch support system

Established : 1977
Base of operations : Tokyo (Japan)

Taxi-hailing with 900+ taxi dispatch operators throughout Japan

Attachment 3
Established Monet Technologies Inc.

- Provide services such as on-demand transportation through regional partnerships and corporate shuttles to local municipalities and private companies.
- Deploy Autono-MaaS businesses with the e-Palette, which can fulfill various purposes including transportation, logistics, and product sales.

Target Launch Timing of e-Palette: 2023

Expansion of services:
- People: 2018 On-demand Bus
- Thing: 2019 Logistics, etc.
- Service: 2019 Mobile shops, etc.

Expansion of areas:
- 17 Cities
- 100 Cities
- ...

A joint venture to operate new mobility services with Softbank
Aiming to contribute to the support of smooth movement and creation a bustling city

• “my route” provides shop and event information while enabling users to search, book, and pay for transport, offering a single mobility-focused application with integrated functions.
• Toyota aim to verify the viability of multi-modal mobility services, understand areas for improvement, and provide most convenient services for residents and tourists.

1) Multi-modal route search
2) Reservations and payments
3) Spot information

- Combining various modes of transport and enabling to search.
- Ex) Taxi/Train/Bike sharing route
- Displays real-time location of route buses and parking lot availability
- A my route app-exclusive Nishitetsu-Bus digital Fukuoka City One-day / new Six-hour Pass
- Plenty of information on must-visit shop and event!
e-Palette (Tokyo 2020 version)

Toyota's first BEV developed specifically for Autono-MaaS*, the Tokyo 2020 e-Palette will support transportation needs of staff and athletes, with a dozen or more running on a continuous loop within the Olympic and Paralympic Village.

*Combination of "autonomous" and "mobility as a service" describing Toyota's mobility services using automated driving vehicles.
Automated Driving and Active Safety

**Toyota’s Goals**
- Safety
- Freedom
- Efficiency

**Our Approach**
- **Guardian**
  - Safety
  - The Ultimate ADAS
  - Enjoy driving safely, as systems watch over you
- **Chauffeur**
  - Freedom
  - Fully automated mobility
  - System takes care of the driving, while you enjoy your freedom

**Structure of Automated Driving**
- **System takes control of the driving process of a human driver**
  - **Driving process of a human driver**
    - Recognition
    - Decision making
    - Control
  - **Automated Driving System**
    - Sensors
    - Maps
    - Ego-Vehicle Location
    - Path Planning
    - System Control

**Three Intelligences for Automated Driving**
- **“Connected” Intelligence**
  - Cloud
  - Roads and vehicles’ data are collected, wirelessly sending and receiving data for maps and software to be up-to-date at all times; can even be programmed over the air.

- **“Driving” Intelligence**
  - The Driving Intelligent system accumulates knowledge and experience, then uses self-learning technology to build up on its own experience to handle new situations.

- **“Interactive” Intelligence**
  - Driver and system have a mutual understanding to meet the shifting demands of the roads. The system is always able to notify the driver effectively when required.
We take two approaches towards Full automation: Step-by-step for POV, whereas MaaS aims to be fully automated from the outset. For POV, we will start with Highways, and will then deploy new technologies to surface roads, eventually. For MaaS, we aim showcase a demonstration at the Tokyo Olympic and Paralympic Games in 2020, then we will pursue to deploy technologies in various areas for everyday MaaS.

Automated Driving System for POV

- **PERCEPTIVE**
  Cutting-edge 360-degree surround multi-modal sensor configuration

- **INTELLIGENT**
  "A Powerful Supercomputer on Wheels"
  - The first Lexus / Toyota with the Deep Learning

- **INTERACTIVE**
  HMI that promises a trusting relationship between driver and vehicle

- **UPGRADEABLE**
  Can provide improvements and new capabilities via Over-the-air (OTA) software updates

Automated Driving System for MaaS

**Characteristics**

- Limited Operating Conditions
- Favorable System Cost
- Flexible sensor installation
- Easier to Maintain

**Toyota e-Palette concept**

- EV platform of next generation designed for MaaS
- Support transportation needs within the 2020 Tokyo Olympic and Paralympic Village

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**“TRI-P4” : Cutting-edge Test vehicle for MaaS Automated Driving**

- Highly advanced sensing and redundancy
  360 degree sensing system capable of extremely precise perception delivers a highly reliable performance

- Super computing components
  Software can respond to ever changing complex traffic environments in real-time
Based on the Lexus LS, the TRI-P4 is the latest automated driving test vehicle from Toyota. With its cameras, radars and high resolution LIDAR smartly integrated into the vehicle design, the Lexus style is maintained. The vehicle’s 360 degree sensing system capable of extremely precise perception delivers a highly reliable automated driving experience. The P4’s onboard automated driving software can respond to changing complex traffic environments in real-time, and its cutting-edge liquid cooled computer is discreetly tucked away in the trunk space. With these technologies, Toyota aims to realize the society where everyone can enjoy their freedom to be anywhere they want, at anytime in any condition.
ICT Platform Development to Support Connected & Automated Driving Vehicles

Our Motivation

Increases of data types to be acquired (CAN, GPS, Images and Sensor data)

![Graph showing cumulative data amount and installed vehicles]

Create new values and businesses as vehicles are becoming sensors for mobility society.

Our Challenge

Development of ICT platform optimized for vehicles is necessary.

- Large volume data collection anticipated for tens of millions of vehicles

What We Do

- Established a development organization with the world top players and evaluated the processing performance limits in the latest technologies.
- Based on the results, built a series of testbed linking vehicles to data centers and started a field survey.

Our Partners

- NTT
- KDDI

Outcome

1. Real-time Processing

- Obstacle Detection
  - Data Center Analysis
  - Notify in tens of seconds
- Notification to surrounding vehicles
  - Notification to neighboring vehicles following obstacle detection would be possible within tens of seconds

2. HD Map Generation

- Data Center
  - Travelling car Image collection
  - Manipulate
  - Analyze
  - Object detection
  - Map creation
- Update

3. Effective Data Storage for Millions of Vehicles (Several EB)

- Images
- CAN/GPS
- xmillions of vehicles

- Of the results acquired, requirements and solution methods are submitted to AECC (Automotive Edge Computing Consortium).
- Working on acquisition of processing platform technologies for big data.
- Conduct research and development openly with the aim of global-oriented platform.
### TOYOTA Group Exhibits

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<td><strong>TOYOTA</strong></td>
<td>Commercialized V2X in Japan ITS Connect</td>
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<td>V2X for Cooperative Transportation</td>
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<td><strong>AIRLSTEEL</strong></td>
<td>MPS (Magnetic Positioning System)</td>
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<td><strong>JTEKT</strong></td>
<td>Precise Docking Control System for Next Generation Transport</td>
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<td>ADAS Compliance Steering system for Bus and Truck</td>
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<td><strong>AISIN GROUP</strong></td>
<td>Risk Prediction Technology that Considers Changes in Surrounding Environment</td>
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<td>Road Surface Detection for Road Maintenance Using Accumulated Vehicle Data</td>
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<td><strong>DENSO</strong></td>
<td>Intersection Traffic Safety Assistance</td>
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<td>On-demand View</td>
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<td>Cybersecurity</td>
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<td>V2X Communication</td>
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<td><strong>TOYOTA</strong></td>
<td>MaaS Strategy</td>
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<td>Autono-MaaS</td>
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<td>Collaboration with MaaS players in the world (Grab, Didi, Getaround, Uber, Japan Taxi, MONET, my route)</td>
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<td>ICT Platform Development to Support Connected &amp; Automated Driving Vehicles</td>
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<tr>
<td><strong>TOYOTA TRUSHD</strong></td>
<td>Fleet Management System</td>
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<td>Truck Platooning System</td>
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<td>Mathematical Optimization</td>
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<td>Micromobility Service</td>
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<td>High Accuracy Positioning</td>
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<td><strong>AISIN GROUP</strong></td>
<td>Logistics Support Service (Transport Management)</td>
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<td>Personal Mobility Vehicle : ILY-AI</td>
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<td>Sponsored On-demand Transport System : “ChaiSoko”</td>
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<td><strong>DENSO</strong></td>
<td>Blockchain</td>
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<td>LifeScience</td>
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The Next Innovation by the Toyota Group for the Future Mobility Society

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