Design and land-use of road space in the automated driving society

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Approaches to Level 5

SAE* driving automation level

- Level 5
  - Achievement of logistics / transport services

- Level 4
  - Measures for depopulated areas
  - Resolving the driver shortage
  - Freedom of movement

- Level 3
  - Unmanned transport vehicles in factories

- Level 2
  - Golf carts

- Level 1
  - Autonomous Emergency Braking

Physical Distribution / transport services

Private owned vehicles

- Reduction in traffic accidents
- Alleviation of traffic congestion
- Increased vehicle valu

Resolution of social issue

Expansion from expressways to ordinary roads

- International cooperation
- Economic development

Limited Unlimited

* SAE: Society of Automotive Engineers (U. S.)
<table>
<thead>
<tr>
<th>Types of roads</th>
<th>Categories</th>
<th>Government Goals</th>
<th>Rationales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expressways</td>
<td>Truck platooning</td>
<td>- Commercialization of driverless platooning by 2022</td>
<td>Lack of truck drivers due to aging</td>
</tr>
<tr>
<td></td>
<td>Owner cars</td>
<td>- Level 3 by 2020&lt;br&gt;- Level 4 by 2025</td>
<td>Heavily relies on private firms efforts</td>
</tr>
<tr>
<td>General Highways</td>
<td>Public transportations in the designated routes</td>
<td>- Implementation Level 4 in society by 2020;&lt;br&gt;- Disperse of Level 4 by 2025 (around 100 site all over Japan)</td>
<td>Lack of transportation ways due to an decease in population in rural areas</td>
</tr>
</tbody>
</table>
Amendments of two acts for automated vehicle society

Vehicle standards
Road Transport Vehicle Act

Imposed new regulations for “automated driving equipment”
- Added to items that are subject to safety standards;
- When used under conditions imposed by the Minister of Land, Infrastructure, Transport and Tourism; and,
- Equipment that contains apparatuses with functions to take over all capabilities relating to recognition, prediction, judgment and operation pertaining to steering of the vehicle by a human being, and an apparatus to record data

Traffic rules
Road Traffic Act

A portion of the regulations that must be observed when operating a vehicle using automatic driving equipment have been relaxed (assuming Level 3).

Conditions for use
- Use conditions imposed by the Minister of Land, Infrastructure, Transport and Tourism
- Must be able to reliably operate the vehicle even when use conditions are not fulfilled or equipment failure has occurred

Content that has been relaxed
- Use of mobile phones and screen viewing

ODD (Operational Design Domain) combination of the following conditions
- Road conditions (expressway or ordinary road, vehicle-only road or mixed traffic environment, number of lanes, presence of lanes etc.)
- Geographical conditions (urban area or depopulated area, etc.)
- Environmental conditions (weather, daytime or nighttime etc.), and others
A variety of FOTs implemented all over Japan

Self-driving vehicle mobility services in regional areas (MLIT / Cabinet Office SIP)
- December 2018 – February 2019
  - Kamikomi Village, Akita Pref.
  - 前川のうた
- January – March 2019
  - Ashikita-machi, Kumamoto Pref.
- 道の駅「芦北でこぽん」
- May – June 2019
  - Taiki-cho, Hokkaido
- 道の駅「コスモール大樹」
- November 2018
  - Ina City, Nagano Pref.
- 道の駅「南アルプス長谷」
- November – December 2018
  - Miyama City, Fukuoka Pref.
- みやま市役所 山川支所
- June – July 2019
  - Hitachi City, Ibaraki Pref.
- 道の駅「ひたちおおた」及び高倉交流センター

Cross-ministerial Strategic Innovation Promotion Program (SIP), etc. (Cabinet Office)
- October 2017 – ongoing
  - Expressways in Kanto Region, etc. and ordinary roads in vicinity of Tokyo Waterfront Area
- 国内外の自動車メーカー、自動車部品メーカー、大学等
- February – March 2019
  - Okinawa Pref.
  - Naha Airport – Michi-no-Eki Toyozaki
  - JTECT等

Automated driving in airport restricted areas (MLIT)
- December 2018
  - Sendai Airport
  - 豊田通商
- December 2018 – January 2019
  - Narita International Airport
  - 鴻池運輸、ZMP、丸紅
- January – February 2019
  - Tokyo International Airport
  - 愛知製鋼、NIPPO、日本電気、SBドライブ、先進モビリティ

Truck platooning (MLIT & METI)
- November 2018 – February 2019
  - Shin-Tomei Expressway
  - 豊田通商、国内トラックメーカー等

Last One Mile automated driving (METI & MLIT)
- October 2018
  - Hitachi City, Ibaraki Pref.
  - 日立市、産総研、SBドライブ等
- February 2019
  - Wajima City, Ishikawa Pref.
  - 輪島市、輪島商工会議所、産総研、ヤマハ発動機等
- October – November 2018
  - Eiheiji-cho, Fukui Pref.
  - 永平寺町、福井県、産総研、ヤマハ発動機等
- January – February 2019
  - Chatan-cho, Okinawa Pref.
  - 北谷町、産総研、ヤマハ発動機等

Locally governments, private sector and universities (* indicates major FOT)
- December 2018 – February 2019
  - Kamikomi Village, Akita Pref.
  - 道の駅「かみこあに」
- January – March 2019
  - Ashikita-machi, Kumamoto Pref.
  - 道の駅「てんかすべ」
- May – June 2019
  - Taiki-cho, Hokkaido
  - 道の駅「コスモール大樹」
- November 2018
  - Ina City, Nagano Pref.
  - 道の駅「南アルプス長谷」
- November – December 2018
  - Miyama City, Fukuoka Pref.
- みやま市役所 山川支所
- June – July 2019
  - Hitachi City, Ibaraki Pref.
- 道の駅「ひたちおおた」及び高倉交流センター

Cross-ministerial Strategic Innovation Promotion Program (SIP), etc. (Cabinet Office)
- February 2019
  - Tama City, Tokyo
  - 日本総研、京王電鉄バス
- February 2019
  - Miki City, Hyogo Pref.
  - 日本工営、大和ハウス
- February 2019 – March 2019
  - Okinawa Pref.
  - Naha Airport – Michi-no-Eki Toyozaki
  - JTECT等

Automated driving in airport restricted areas (MLIT)
- December 2018 – February 2019
  - Shin-Tomei Expressway
  - 豊田通商、国内トラックメーカー等

Self-driving vehicle mobility services in regional areas (MLIT / Cabinet Office SIP)
- April 2018
  - Fujisawa City, Kanagawa Pref.
  - やまと運輸、DeNA
- April 2018
  - Akawa City, Oita Pref.
  - SBIドライブ、宇野自動車
- April 2018
  - Fukushima Daiichi Nuclear Power Plant
  - 東京電力、SBIドライブ
- August 2018
  - Chiyoda Ward, Tokyo
  - 東京都、日の丸交通、ZMP
- August 2018 – ongoing
  - Kobe City, Hyogo Pref.
  - 神戸市、日本総研、関電、電通、NTTデータ、群馬大、沖電気等
- September 2018
  - Fujisawa City, Kanagawa Pref.
  - 神奈川県、小田急、SBIドライブ
- November 2018
  - Maebashi City, Gunma Pref.
  - 前橋市、NTTデータ、日本中央バス、群馬大
- November 2018
  - Iida City, Nagano Pref.
  - 飯田市、KDDI、アイサンテクノロジー
- November 2018
  - Ofunato City, Iwate Pref.
  - JR東日本、先進モビリティ、愛知鉄鋼、京セラ、ソフトバンク、日本信号、日本電気
- December 2018
  - Miyakejima, Tokyo
  - 東京都、アイサンテクノロジー、群馬大
- January 2019
  - Fukuroi City, Shizuoka Pref.
  - 静岡県、袋井市、名古屋大
- February 2019
  - Ichinomiya City, Aichi Pref.
  - 愛知県、KDDI総研、アイサンテクノロジー、ティアフォー、名古屋大、岡谷鋼機、損保ジャパン日本興亜
- February 2019 – ongoing
  - Central Japan International Airport
  - アイサンテクノロジー、ダイナミックマップ基盤、丸紅、ZMP

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- April 2018
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Thirteen FOTs in hilly and mountainous areas

**Technology verification**

- Measures for securing dedicated driving spaces

**Verification of V2I technologies**

**Business feasibility**

- Transport of agricultural products, etc.

Automated service route

- Kosawada area
- Dedicated space One-way, approx. 1.0km
- Assembly site
- Dogawa area

Simple traffic signal installed to prevent entry by ordinary vehicles while automated vehicle is driving

Total distance approx. 4 km (one way)

- Automated driving service route
  - Dedicated autonomous vehicle-only section
  - Ordinary vehicle mixed traffic section
  - Stop

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Results in 13 FOTs in hilly and mountainous areas

Incidence of manual intervention by cause and road structure (FY 2017 FOT: driving distance 2,200km)

- Avoidance of vehicles parked on (N=183 incidences)
- Avoidance of bicycles/pedestrians (N=68 incidences)
- Passing oncoming (N=75 incidences)
- Passing by following vehicles (N=23 incidences)
- GPS, etc., vehicle position identification failure
- Sensor detection of plowed snow on
- Detection of weeds, etc.
- Right turn waiting and ceding at
- Intersection (5%)
- Other (34%)
- Michi-no-Eki parking spaces, etc.
Results in terms of driving spaces

**Vehicles parked on road**

- Areas with houses (169 incidents / 183 incidents): 1.8
- Mountainous areas (9 incidents / 183 incidents): 0.2
- Farmland (5 incidents / 183 incidents): 0.2

▲ Avoidance of vehicles parked on road

**Pedestrians / bicycles**

- Road with sidewalk (0 incident / 68 incidents): 0
- Road with shoulder (17 incidents / 68 incidents): 0.5
- Road with no shoulder (28 incidents / 68 incidents): 0.6

▲ Incidence of pedestrian / bicycle avoidance by cause

▼ Manual intervention due to vehicles parked on road

▼ Manual intervention to avoid pedestrians on road

Direction of movement
Results in terms of road maintenance

Vegetation along road / snow piled on road

- Vegetation detected as obstacle, causing vehicle to stop
- Manual intervention due to narrowing of road caused by piled-up snow

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>One lane</th>
<th>Two lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>(46/49)</td>
<td>0.6</td>
<td>0.03</td>
</tr>
<tr>
<td>Piled-up snow</td>
<td>One lane</td>
<td>Two lane</td>
</tr>
<tr>
<td>(41/55)</td>
<td>0.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

(unit: incidents)

Direction of movement
As one solution to the truck driver shortage, there are high hopes for the achievement of truck platooning in which only the lead vehicle is manned and the following vehicles are unmanned.

FOTs have been conducted primarily on the Shin-Tomei Expressway.
A number of points requiring solutions were listed up in the FOT conducted in the previous fiscal year.

**Large vehicle merging interference**

**Reduced GPS localization accuracy**

<table>
<thead>
<tr>
<th>Truck No.2 &amp; 3</th>
<th>Average (m)</th>
<th>Maximum (m)</th>
<th>( \sigma ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main roadway</td>
<td>0.17</td>
<td>0.53</td>
<td>0.08</td>
</tr>
<tr>
<td>Main roadway, strong winds</td>
<td>0.08</td>
<td>0.31</td>
<td>0.07</td>
</tr>
<tr>
<td>Lane change</td>
<td>0.20</td>
<td>0.44</td>
<td>0.06</td>
</tr>
<tr>
<td>Left/right turn</td>
<td>0.05</td>
<td>0.37</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Pedestrian congestion in service areas / parking areas**

**Delays in communication between vehicles**

<table>
<thead>
<tr>
<th></th>
<th>Average delay (msec)</th>
<th>Maximum (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical transmission</td>
<td>14</td>
<td>168</td>
</tr>
<tr>
<td>760MHz</td>
<td>268</td>
<td>688</td>
</tr>
<tr>
<td>LTE</td>
<td>141</td>
<td>5590</td>
</tr>
</tbody>
</table>

*In FOTs using 5G on public roads, the transmission delay when transmitting via base stations was roughly 1/10 that of transmission using LTE.*
Requests from automobile societies

【Preparing HD maps and maintaining map accuracy】

- Dynamic information (< 1sec)
  - ITS advance warning information (surrounding vehicles, pedestrian information, traffic signal information)
- Semi-dynamic information (< 1min)
  - Accident information, traffic congestion information, local weather information, etc.
- Semi-static information (< 1hour)
  - Traffic restriction information, road construction information, regional weather information, etc.
- Static information (< 1month)
  - Road surface information, lane information, 3D structures, etc.

Excerpted from JAMA materials

【Ensuring the detectability of lane markings】

- Information on main roadway conditions is provided to merging vehicles.
- Merging vehicle speed and timing are controlled automatically to enable the vehicle to merge safely and smoothly.

- Road indication (non-statutory indications, etc.)

1. Optical dots: speed control

2. Triple line: speed control/caution

3. Deceleration mark indications in lane

4. Colored pavement: Cautions regarding sharp curves, etc.

- Information on branching and merging, etc.

- Providing merging vehicles with information, such as driving speeds on main-lane vehicles
- Generating information to be provided to merging ADVs
- Road-to-vehicle communication
- Roadside processing unit
- Vehicle detection sensor
- Sensing speeds and lengths other and so on of main-lane vehicles
Examples of design for road spaces

Independent dedicated space
- Separate facility structure to prevent entry to dedicated space from other lanes
- Dedicated ramp structure linked directly to logistics center

Road structures to prevent drop in GPS positioning accuracy, etc.
- Structure with magnetic markers and other facilities provided at tunnels, bridges and other locations where GPS positioning accuracy drops
- Structures and specifications for facilities to provide location data from the infrastructure

Space for platoon coupling / decoupling
- Specifications for scale and placement of facilities needed to prevent congestion and ensure safety

Road facilities needed for self-position correcting during automated driving and when stopping or parking
- Structure of electromagnetic guide lines, magnetic markers and other facilities to support AVs

Markings in driving spaces
- Standardized markings in driving spaces for self-driving vehicles

Dedicated spaces
- Separate facility, etc. structure to prevent entry to dedicated spaces from other lanes, based on the needs of the local community

Markings on pavement to indicate driving space for self-driving vehicles

Facility for separation from other roads to prevent merging, etc. from ordinary vehicle lanes (Hitachi City test)
Can AVs provide reliable public transportation?

FOTs have focused on the use of AVs in hilly and mountainous areas, in order to address social issues caused by the aging of local society;

The results of FOTs can be summarized as follows;

1. **Passenger acceptance**
   - Experience of AVs travel increases their acceptability of local residents.

2. **Labor cost saving**
   - Labor costs can be reduced by substituting semi-paid volunteers for professional drivers without a loss of efficiency.

3. **Integration into regular bus route service**
   - Even low-speed AVs can efficiently connect local homes with regular bus stops.

4. **Business feasibility**
   - Welfare authorities can provide adequate AV service subsidies without burdening local authority transportation budget.