

# 해외출장복명서

기 간: 2022. 11. 01. ~ 2022. 11. 06.

출장지: 미국 워싱턴 D.C.

출장자: 윤태관 부연구위원

## I. 출장개요

1. 출 장 지 : 미국 워싱턴 D.C.
2. 출장기간 : 2022. 11. 01(화) ~ 2022. 11. 06(일) (4박 6일, 기내 1박)
3. 출 장 자 : 총 1명

소속	직위	성명
국토연구원 국토인프라연구본부	부연구위원	윤태관

### 4. 출장 목적

- IRF(International Road Federation) R2T 컨퍼런스 참석에 참석하여 현재 수행중인 기술개발사업(R&D) 2차년도 성과에 대한 발표 및 공유

### 5. 주요 수행 내용

- R&D 2차년도 성과 관련 논문 발표
  - 논문 발표주제: Figuring out the optimized autonomous vehicle scenarios based on conjoint analysis
- IRF(International Road Federation) R2T 컨퍼런스 기술 전시회 참석 및 국제 기술동향 조사
- 자율주행 안전 및 디지털 도로 관련 세션 참석
- 자율주행 데이터 관련 회의를 통한 국제 연구동향 파악

## II. 출장 일정

일시	내용	비고
11.01(화)	10:15 인천 출발, 10:50 미국 워싱턴 D.C. 도착	인천 -워싱턴D.C.
오전 오후	- 출장지 이동 - 학회 등록 및 세션 참석 (16:00~17:30) ES6. Digitalization of road & transport projects	
11.02(수)	논문 발표 및 학회 참석	워싱턴D.C.
오전 오후	- (11:00~12:30) TS 5.1. Preparing the road for CAVs & traffic engineering (발표논문: Figuring out the optimized autonomous vehicle scenarios based on conjoint analysis) - (14:00~15:30) ES10: AI for traffic safety - (16:00~17:30) ES13: Advances in roadside safety	
11.03(목)	학회 참석 및 기술전시회 참관	워싱턴D.C.
오전 오후	- (11:00~12:30) ES15: AI for predictive maintenance - Exhibition 참관	
11.04(금)	자율주행 데이터 관련 회의 및 D.C. 교통수단 견학	워싱턴D.C.
오전 오후	- 자율주행 데이터 관련 회의 참석 - 워싱턴 D.C. 교통수단 관련 현장견학	
11.05(토)	12:50 미국 워싱턴 D.C. 출발	워싱턴D.C.
11.06(일)	17:35 인천 도착	- 인천

### III. 수행사항

#### 1. R&D 2차년도 성과 발표

■ 일정 및 장소: 2022년 11월 2일 11:00~, 워싱턴 D.C. Mayflower Hotel, Georgia Room. (세션: TS 5.1. Preparing the road for CAVs & traffic engineering)

■ 참석자: 출장자 및 교통분야 전문가

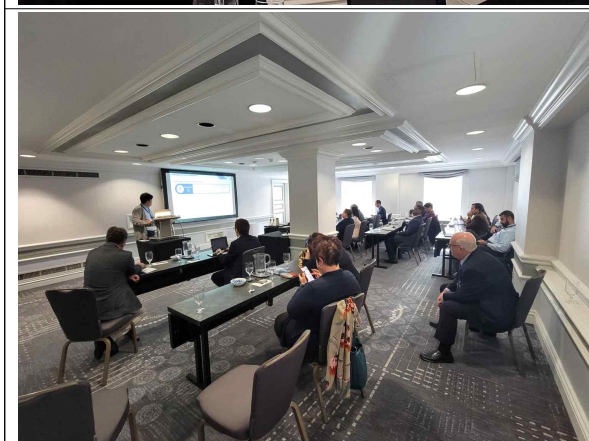
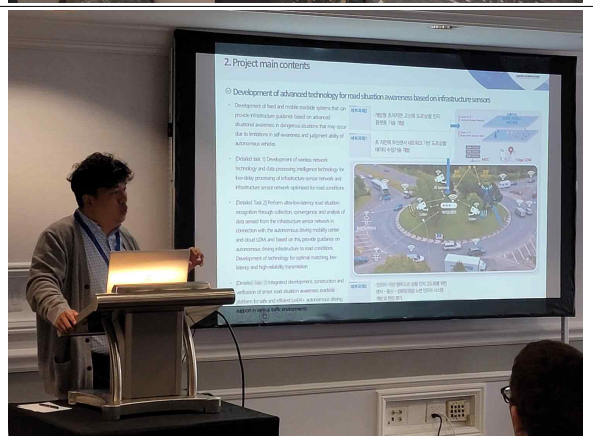
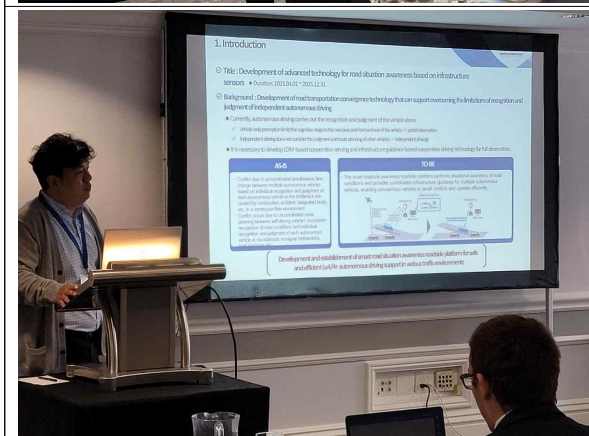
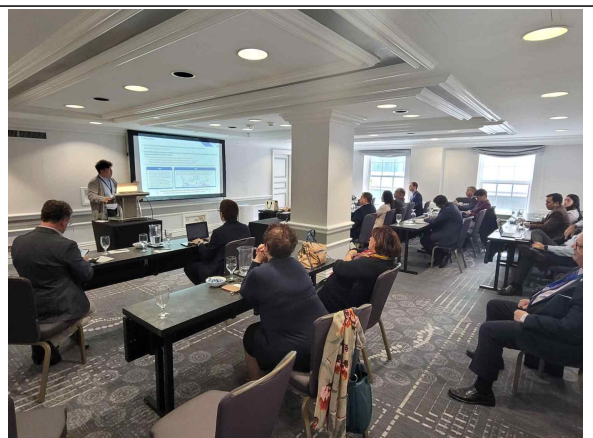
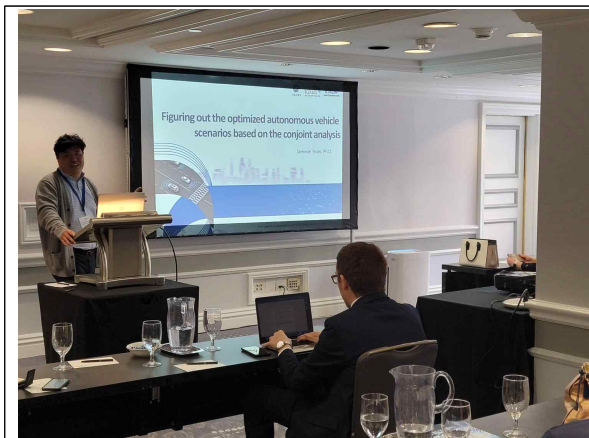
■ 주요내용

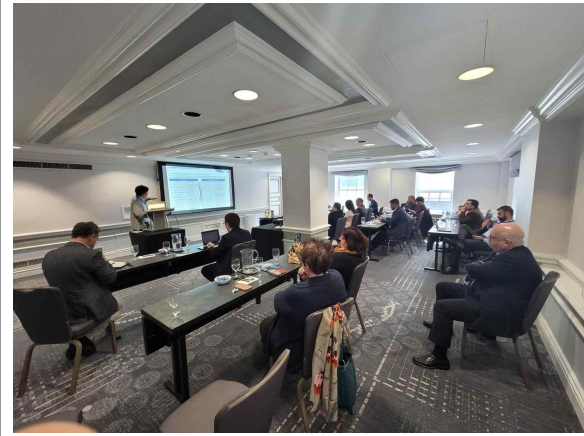
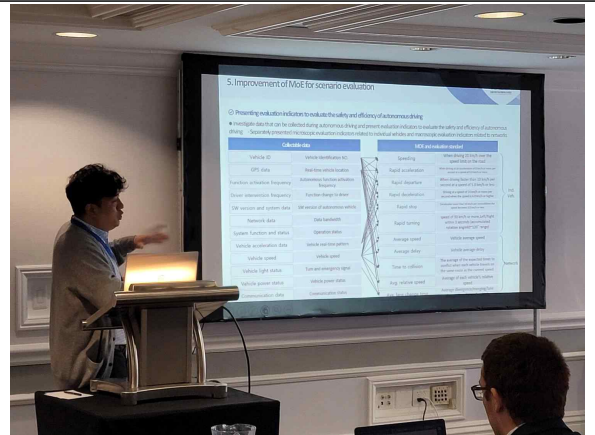
● R&D 2차년도 성과 발표

- R&D 전반적인 사업 개요 및 목적
- 2차년도 사업 개요 및 연구 목표/진행상황 공유
- 인프라 센서 장비 설치 현황
- SILS/HILS 시나리오 구성
- 시나리오 압축을 위한 컨조인트 분석 결과 제시
- 향후 연구과제 공유

● 기타

- 논문 발표 후, 질의응답 시간에 본 연구방법론인 컨조인트 분석, 직교배열법에 대한 타 분야 적용 사례에 대해, 설문조사 기법 등에서 본 연구방법론 활용시 통계적으로 유의한 경우의 수를 도출하여 다양한 시나리오 조합을 테스트 할 수 있음을 공유
- 한국 자율주행 서비스에 대한 소개 및 현재 진행상황, 정부의 1조 3천억원을 다부처 기술개발 사업에 투자한 현황 등을 타 기관에 공유





2차년도 성과 논문발표 및 질의응답



## 2. IRF R2T 컨퍼런스 세션 참석

■ 일정 및 장소: 2022년 11월 1일~3일, 워싱턴 D.C. Mayflower Hotel

■ 참석자: 출장자 1인

■ 주요내용

● ES6. Digitalization of road & transport projects

- 데이터 수집 및 가공을 통한 디지털 기술 융합으로 도로 디지털화를 위한 연구주제 2개에 대한 발표
- Infotech와 Parsons 업체 근무자 2인이 현재 해당 업체에서 개발 또는 구축 중인 디지털도로 기술에 대해 제시하고, 특히 그 중 Parsons에서는 디지털트윈을 활용하는 방안에 대해 발표함

● TS 5.1. Preparing the road for CAVs & traffic engineering

- Benjamin Stabler는 머신러닝 기술을 활용한 교통관리에 대해 데이터를 활용한 사례를 발표하였고, Fahdad Alrukaibi는 도심부 교통 네트워크의 통행 시간 산정을 위해 머신러닝을 적용했고, 그 정확도가 다른 방법을 활용한 것 에 비해 더 높게 나타나서 머신러닝의 적용을 향후 교통정보 생성에 유용하게 활용할 수 있을 것으로 발표함
- Sara는 현재 Maryland에서 공부중인 학생으로, 대기행렬 길이를 예측하는 알고리즘을 개발하여 실제와 비교분석하였고, 개발한 모형의 정확도가 높게 나타난 것으로 분석됨. Matthew는 자율주행의 한 서비스인 로봇택시에 대해 간단한 소개와 전략을 제시함

● ES10: AI for traffic safety

- 논문발표가 아닌 Tony Geara 좌장의 토론세션으로 AI 알고리즘을 통해 인간의 시각을 대신할 수 있는지에 대한 활발한 토론이 벌어짐. 특히, 인간의 인지반응시간에 비해 AI 알고리즘과 축적된 빅데이터를 활용한 데이터 가공이 얼마나 더 정확할 수 있는지에 대해 D.C.의 Department of Transportation, DensysGatso, DERQ, Inrix, MobilityVision, Parsons와 같이 도로를 운영하는 정부 기관과 센서 등 자율주행 산업체가 함께 참석하여 서로의 의견을 공유하며, 앞으로 나아갈 길과 전략에 대해 제시함

● ES13: Advances in roadside safety

- 자율주행 시대에 인간인 운전자의 실수를 줄여서 안전성이 향상될 것이라는 의견이 지배적인 가운데, 각 나라의 자율주행 시대에 대한 안전에 대한 시각, 자율주행 시대 도로 활용 방안 등에 대해 각 분야 전문가들이 토론

● ES15: AI for predictive maintenance

- 기존 도로관리를 위해 고속도로 순찰대, 시민의 불편신고 등에 의존하였지만, 도로가 디지털화 됨에 따라 축적된 빅데이터와 AI를 통해 예지정비가 가능해졌다. 이는 도로의 효율성 향상 뿐만 아니라 도로유지비용 절감 등의 효과를 거둘 수 있을 것으로 기대됨



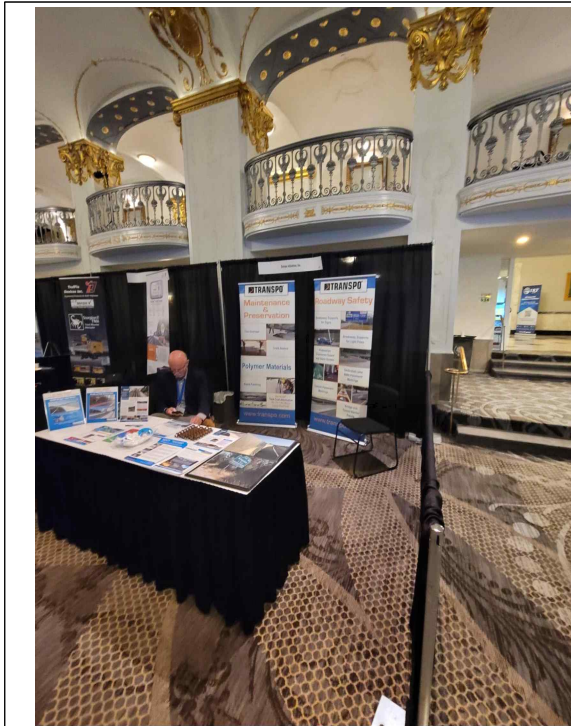




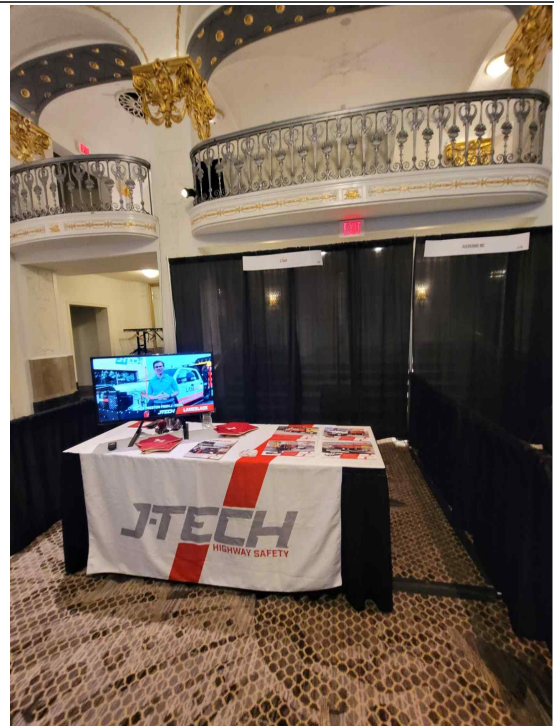
IRF R2T 컨퍼런스 세션 참석

### 3. 기술전시회 참관

- ❑ 일정 및 장소: 2022년 11월 3일 오후, 워싱턴 D.C. Mayflower Hotel
- ❑ 참석자: 출장자 1인
- ❑ 주요사진



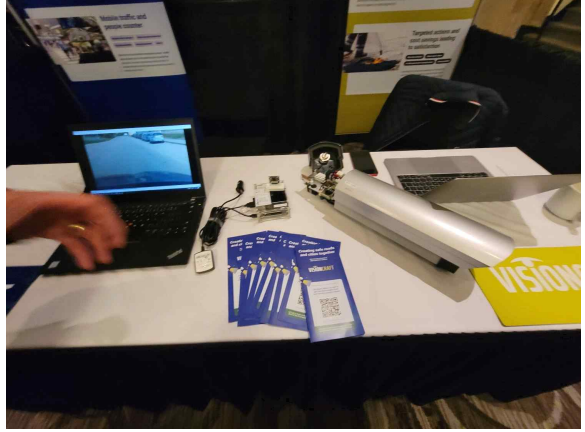
Transpo 도로유지관리 및 안전



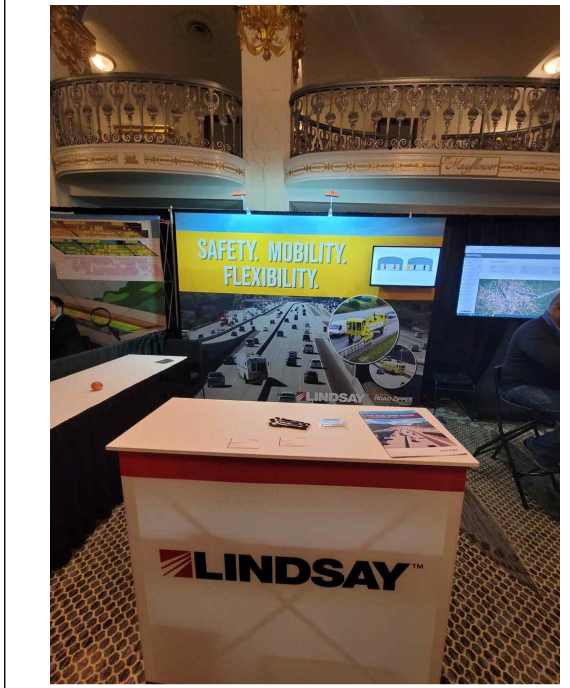
J-Tech 도로 안전



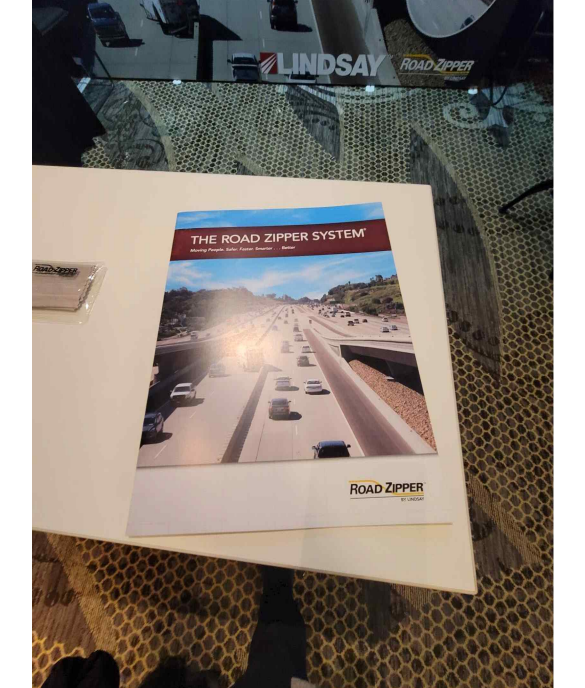
Xenomatrix 자율주행 센서(라이다)



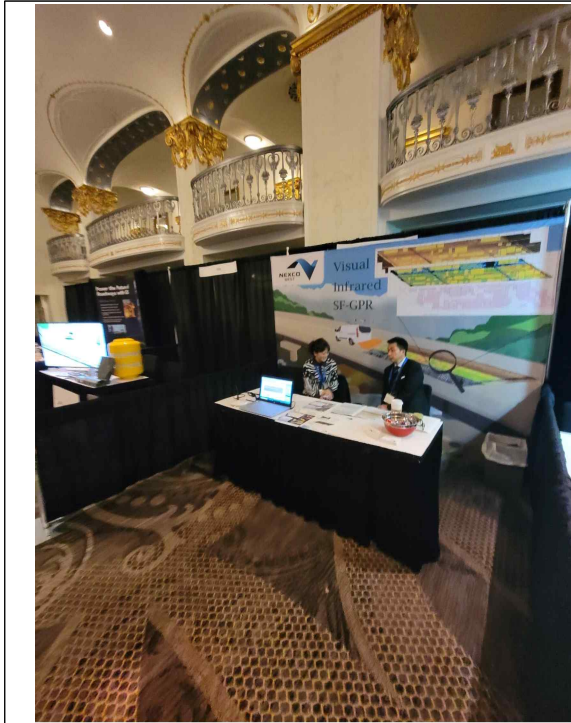
Visioncraft, 센싱 카메라



Lindsay 안전, 모빌리티 관련







Nexco 인프라센서



Esri

기술전시회 참관

## 4. 자율주행 데이터 관련 회의

■ 일정 및 장소: 2022년 11월 4일 오전, 워싱턴 D.C. 시내

■ 참석자: 출장자 1인, VDOT 담당자

■ 주요내용

### ● 버지니아주의 자율주행 비전

- 버지니아는 현재 자율주행 기술을 도입하여 안전과 이동성 향상을 목표로 하고 있음
- 뿐만 아니고 도로를 활용한 화물 운송에도 효율화를 추진중

### ● 버지니아주의 자율주행 데이터

- 소프트웨어와 데이터 관리 기술은 향후 자율주행 기술 도입 시 가장 중요할 것으로 예상됨
- 이를 위해, 데이터를 효율적으로 저장, 공유, 분석할 수 있는 엣지컴퓨팅 기능을 도입하여 활용
- 또한, 고속도로 유지관리 시스템(HMMS, Highway Maintenance Management System)과 연계를 통해 자율주행차량으로부터 실시간 도로정비 관련 정보를 수집하고 있음
- 데이터 관리에서 가장 중요한 부분이 사이버보안인데, 이 부분은 Security Operations Center라는 곳에서 담당하고 있으며, 네트워크 업데이트 등을 수행하여 보안에 각별히 신경쓰고 있음
- 현재 버지니아주에는 ITS 장비가 많이 구축되어 운영중인데, 이 모든 데이터가 광통신을 통해 센터로 전송되고 있으며, RSU 통신인프라 또한 많이 구축되어 있음
- 이러한 기존 설치 장비 등을 활용하여 자율주행 통신 및 데이터 연계, 융합에 정확도 및 안정성을 높일 것으로 기대됨



# 부록 1. 2차년도 성과 논문 발표자료



## Figuring out the optimized autonomous vehicle scenarios based on the conjoint analysis

Taekwan Yoon, Ph.D.



This research is supported by the KADIF under MOUIT, 21AMDP-C160501-01

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### 1. Introduction

◎ Title : Development of advanced technology for road situation awareness based on infrastructure sensors ● Duration:2021.04.01~2025.12.31

◎ Background : Development of road transportation convergence technology that can support overcoming the limitations of recognition and judgment of independent autonomous driving

- Currently, autonomous driving carries out the recognition and judgment of the vehicle alone.
  - Vehicle-only perception limits the cognitive range to the next lane and front and rear of the vehicle → partial observation
  - Independent driving does not consider the judgment and route planning of other vehicles → independent driving
- It is necessary to develop LDM-based cooperative sensing and infrastructure guidance-based cooperative driving technology for full observation.

AS-IS

• Conflict due to uncoordinated simultaneous lane change between multiple autonomous vehicles based on individual recognition and judgment of each autonomous vehicle at the bottleneck site caused by construction, accident, disrupted loads, etc., in a continuous flow environment

• Conflict occurs due to uncoordinated route planning between self-driving vehicles' incomplete recognition of road conditions and individual recognition and judgment of each autonomous vehicle at roundabouts, no-signal intersections, road junctions, etc.

TO-BE

• The smart roadside awareness roadside platform performs situational awareness of road conditions and provides coordinated infrastructure guidance for multiple autonomous vehicles, enabling autonomous vehicles to avoid conflicts and operate efficiently.



Development and establishment of smart road situation awareness roadside platform for safe and efficient L4/4+ autonomous driving support in various traffic environments

### 2. Project main contents

◎ Development of advanced technology for road situation awareness based on infrastructure sensors

- Development of fixed and mobile roadside systems that can provide infrastructure guidance based on advanced situational awareness in dangerous situations that may occur due to limitations in self-awareness and judgmentability of autonomous vehicles
- [Detailed task 1] Development of wireless network technology and data processing intelligence technology for low-delay processing of infrastructure sensor network and infrastructure sensor network optimized for road conditions
- [Detailed task 2] Perform ultra-low latency road situation recognition through collection, convergence, and analysis of data sensed from the infrastructure sensor network in connection with the autonomous driving mobility center and cloud LDM, and based on this provide guidance on autonomous driving infrastructure to road conditions. Development of technology for optimal matching low-latency and high-reliability transmission
- [Detailed task 3] Integrated development, construction and verification of smart road situation awareness roadside platform for safe and efficient L4/4+ autonomous driving support in various traffic environments



세부과제1: 개발형 송수신기 고신뢰 도로상황 인지 플랫폼 기술 개발  
 세부과제2: 초 저연의 무선랜서 (네트워크) 기반 도로상황 데이터 수집 기술 개발  
 세부과제3: 인공위성 기반 도로 상황 인지 고신뢰성 유선/무선 융합 - 협력형 플랫폼 기반 인프라 시스템 개발 및 운영 평가

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### 3. Detailed scope of the project

◎ Purpose and detailed plans

Research Purpose	Detailed Plans
<ul style="list-style-type: none"> <li>Cognitive Development infrastructure system OOD definition and operation scenario analysis</li> <li>Completion and Development of evaluation indicators and standards through analysis of evaluation results for each operation scenario</li> </ul>	<ul style="list-style-type: none"> <li>Advising and verifying external experts for the Development of previously developed scenarios</li> <li>Algorithm evaluation by operation scenario through evaluation index measurement and result analysis</li> <li>Development of evaluation indicators through mutual feedback</li> </ul>

◎ Progress against the plan

No.	Detailed Plans	Planned	Actual
Total	Completion rate/Development of Evaluation Indicators and Standards by Analysis of Evaluation Results by Operational Scenario	30.48%	38.02%
1	Algorithm evaluation by operation scenario through evaluation index measurement and result analysis	58%	58%
2	Development of evaluation indicators through mutual feedback	0%	0%
3	Selection of standardization core targets and development of standard requirements/Standard safety requirements	48%	49%

### 4. Simulation & Scenario Development



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### 4. Simulation & Scenario Development

**SILS development**

➤ SILS: The SW that performs the recognition and judgment of the cognitive advanced roadside system through SILS is tested. In other words, the performance of the cognitive enhancement and guidance generation SW implemented inside the MEC can be evaluated based on the scenario in the virtual environment.

➤ Developed SILS that generates infrastructure camera images for traffic conditions in various evaluation scenarios in a virtual environment in various road environments, extracts and classifies objects, and generates tracking results.



가상환경 시뮬레이션

### 4. Simulation & Scenario Development



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### 4. Simulation & Scenario Development

Vehicle ID	Speed	Length	Width	Coordinate (x, y, z)	Orientation angle
1	20	4.5	1.8	100, 100, 1.2	90
2	15	3.5	1.5	110, 110, 1.2	45
3	25	5.0	2.0	120, 120, 1.2	135
4	18	4.0	1.6	130, 130, 1.2	0
5	22	4.8	1.9	140, 140, 1.2	90
6	16	3.8	1.6	150, 150, 1.2	45
7	24	4.9	1.9	160, 160, 1.2	135
8	19	4.1	1.7	170, 170, 1.2	0
9	21	4.6	1.8	180, 180, 1.2	90
10	17	3.9	1.6	190, 190, 1.2	45
11	23	4.7	1.8	200, 200, 1.2	135
12	18	4.0	1.6	210, 210, 1.2	0
13	22	4.6	1.8	220, 220, 1.2	90
14	16	3.8	1.6	230, 230, 1.2	45
15	24	4.9	1.9	240, 240, 1.2	135
16	19	4.1	1.7	250, 250, 1.2	0
17	21	4.6	1.8	260, 260, 1.2	90
18	17	3.9	1.6	270, 270, 1.2	45
19	23	4.7	1.8	280, 280, 1.2	135
20	18	4.0	1.6	290, 290, 1.2	0

### 4. Simulation & Scenario Development

#### SILS development

► SILS design for performance analysis of MEC

- If you create a Traffic Scenario in the environment modeled in VISSIM and create a BoundingBox in MATLAB for vehicle image information, information that can be analyzed for performance is collected.

```

    graph TD
      TS[Traffic Scenario] --> VISSIM[VISSIM]
      VISSIM --> VI[Vehicle information]
      VI --> BA[BoundingBox]
      BA --> PA[Performance Analysis]
      VISSIM --> MAT[MATLAB]
      MAT --> BA
  
```

### 4. Simulation & Scenario Development

#### SILS development

##### ► Road and edge AI camera modeling

- The road modeling in the virtual environment is designed as shown in the table below based on the road capacity manual and roundabout design guidelines.
- In order to calculate the amount of traffic that can minimize delay, it was selected based on 500 vehicles/hour, which was found to reduce delay time when switching from a signal intersection to a roundabout.
- Set up 4 FOV 110° cameras to the camera sensing range for 360° sensing of the roundabout from the horizontal side

	Standard	Select
Design speed	20-30km/h	20km/h
Circle diameter	22-25m	25m
Traffic island diameter	13-17m	16.5m
Width of entrance	3.5m	3.5m
Width of turning	4.0-4.5m	4.3m
Traffic volume	Max. daily 3,400veh/h	500veh/h

Roundabout Design Criteria and Selection

Height of the pole	FOV
12m	110°

Edge AI camera modeling

### 4. Simulation & Scenario Development

#### SILS development

##### ► Data creation

- Shows the results of deep learning processing on vehicle data and infrastructure camera images obtained from VISSIM
- Currently working on syncing real coordinates and image BoundingBox coordinates

Collected vehicle data from VISSIM

Deep learning processing results for infrastructure camera images

### 4. Simulation & Scenario Development

#### Scenario composition according to the ratio of autonomous vehicles in the communication virtual environment

AV ratio (A)

- Scenario composition by year according to the proportion of autonomous vehicles
- Refer to the Autonomous Driving Prospect Report, Traffic flow composition according to CAV (autonomous driving vehicle LV3 or higher) ratio and presence/absence of bicycle/emergency vehicle

Year	Brid (2018)	CATAPUL (2017)	Utman (2015)	Mosquet (2013)	Frost/Sulivan (2018)	Average
2020	6%	-	2%	-	8%	5%
2025	25%	11%	-	13%	27%	19%
2030	62%	37%	20%	20%	55%	39%
2035	-	85%	-	25%	-	55%

### 4. Simulation & Scenario Development

#### Scenario composition according to the transportation environments

Transportation Env. (B)

- Scenario construction by reflecting not only road traffic internal factors such as road intersection type, signal operation type, and road structure type, but also external factors such as unexpected situations and weather conditions
- Combining the preceding traffic flow scenarios and environmental factors to build a full scenario

Internal factors	External factors
<b>Intersection &amp; No Lanes</b> <ul style="list-style-type: none"> <li>Signalized Intersection (2)</li> <li>4-legged, 3-legged</li> <li>Unsignalized (3)</li> <li>4-legged, 3-legged, roundabout</li> <li>No Lanes (2)</li> <li>Single, Multi</li> </ul>	<b>Weather &amp; Time</b> <ul style="list-style-type: none"> <li>Weather (4)</li> <li>Good, Rain, Snow, Fog</li> <li>Time (2)</li> <li>Day, Night</li> </ul>
<b>Geometric &amp; Pavement</b> <ul style="list-style-type: none"> <li>Geometric (4)</li> <li>Straight, Curved, Uphill, Downhill</li> <li>Pavement (2)</li> <li>Paved, Non-paved</li> </ul>	<b>Unexpected Situations</b> <ul style="list-style-type: none"> <li>Effected No Lanes(3)</li> <li>- 1, 2, All Lanes</li> <li>Unexpected Situation Duration(5)</li> <li>- Less than 15 mins</li> <li>- 15-30, 30-45, 45-60, More than 60 mins</li> </ul>

### 4. Simulation & Scenario Development

Scenario Combinations

**Total Scenario (AXB)**

- Summarize the appropriate number of scenarios to realistically analyze the combined total number of scenarios.
- Since the orthogonal array method cannot perform all experiments when there are many factors, it is used for the purpose of finding many effects with a small number of experiments (expected to collectively reduce the total number of scenarios).

**AV ratio(A)**  
4X3X2X2=48

- Traffic volume survey results by total lanes(4)
- Autonomous vehicle penetration rate: Conservative, average, optimistic (3)
- Bike With/Without (2)
- Emergency vehicle presence/non-existence (2)

**Transportation Env (B)**  
10X8x15x8=9,600

- Intersection and number of lanes (5x2)
- Road geometry and structural pavement (4x2)
- Unexpected situations such as construction sections (3x5)
- Weather and road environment (4x2)

AXB = 460,800 cases

### 4. Simulation & Scenario Development

Compression of scenarios through the conjoint analysis in R

**Statistically Significant Scenarios**

- Impossible to validate all hundreds of thousands of scenarios in HLS/SLS
- Summarize/compress the number of cases to the smallest statistically significant number through conjoint analysis
- 460,800 → 32 scenarios

### 5. Improvement of MoE for scenario evaluation

Presenting evaluation indicators to evaluate the safety and efficiency of autonomous driving

- Investigate data that can be collected during autonomous driving and present evaluation indicators to evaluate the safety and efficiency of autonomous driving
- Separately presented microscopic evaluation indicators related to individual vehicles and macroscopic evaluation indicators related to networks

Collectable data		MOE and evaluation standard	
Vehicle ID	Vehicle identification NO.	Speeding	When driving 20 km/h over the speed limit on the road
GPS data	Real-time vehicle location	Rapid acceleration	When driving at an acceleration of 8 m/s <sup>2</sup> or more per second at a speed of 50 km/h or more
Function activation frequency	Autonomous function activation frequency	Rapid departure	When driving faster than 1.0 km/h per second at a speed of 5.0 km/h or less
Driver intervention frequency	Function change to driver	Rapid deceleration	Driving at a speed of 5 km/h or more per second when the speed is 5.0 km/h or higher
SW version and system data	SW version of autonomous vehicle	Rapid stop	Exceeding the stop distance per second (from speed before 1.0 km/h or less)
Network data	Data bandwidth	Rapid turning	speed of 50 km/h or more Left/Right within 5 seconds (at controlled rotation angle 60°-135° range)
System function and status	Operation status	Average speed	Vehicle average speed
Vehicle acceleration data	Vehicle real-time pattern	Average delay	Vehicle average delay
Vehicle speed	Vehicle speed	Time to collision	The average of the expected times to conflict when each vehicle travels on the same route as the current speed
Vehicle light status	Turn and emergency signal	Avg. relative speed	Average of each vehicle's relative speed
Vehicle power status	Vehicle power status	Ave. lane change time	Average divergence/merging/lane change time for each vehicle
Communication data	Communication status		

Ind. Veh. (Individual Vehicle) and Network indicators are shown on the right side of the table.

### 5. Improvement of MoE for scenario evaluation

Evaluation index (MOE) for scenario evaluation (improvement and verification of safety aspects)

- It is determined that safety-related indicators can be calculated using location data, steering data, and speed data that can be collected from autonomous vehicles.
- The risk level of each scenario is judged by the following indicators calculated through acceleration, acceleration (jerk), and angular velocity (yaw)

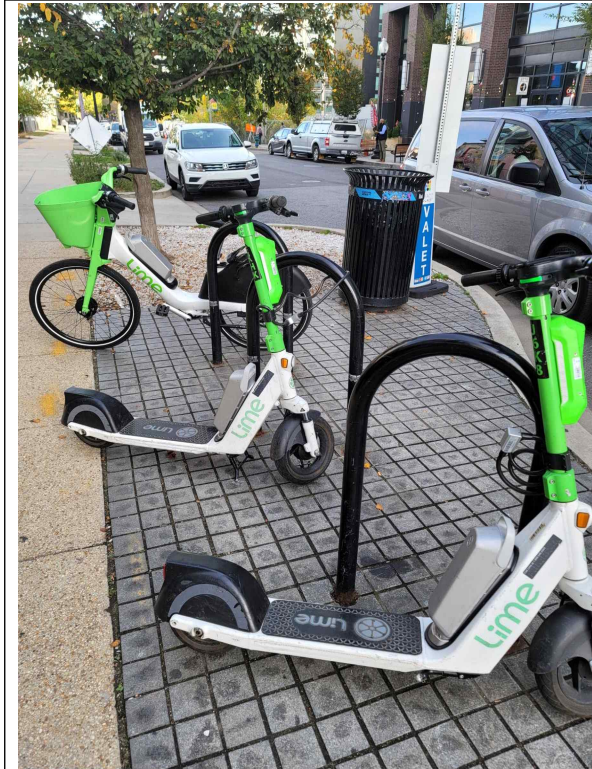
Indicator	Details
1. Dangerous Driving Event	Overspeed + Rapid Acceleration + Rapid Deceleration + Rapid Stop + Rapid Left/Right Turn
2. EDI(Eratic driving index)	The sum of the areas of variables (speed, acceleration, jerk, yaw) exceeding the threshold value during the analysis time divided by the driving time
3. SRI(Safety reliable index)	Proportion of variables (velocity, acceleration, jerk, yaw) exceeding the threshold during analysis time
4. Peak to peak jerk	difference between max and min in jerk
5. RDE(Rapid deceleration events)	Rate of deceleration exceeding 7.35m/s <sup>2</sup>
6. LNI(Large negative jerk), LPI(Large positive jerk)	The change in Jerk value exceeds or falls below the threshold [ 1.5m/s <sup>3</sup> , 2m/s <sup>3</sup> , 3m/s <sup>3</sup> ]
7. Peak to peak rate	Ratio when the peak-to-peak jerk value exceeds the threshold (14.7m/s <sup>3</sup> )

## 부록 2. 학회 등록 관련 자료

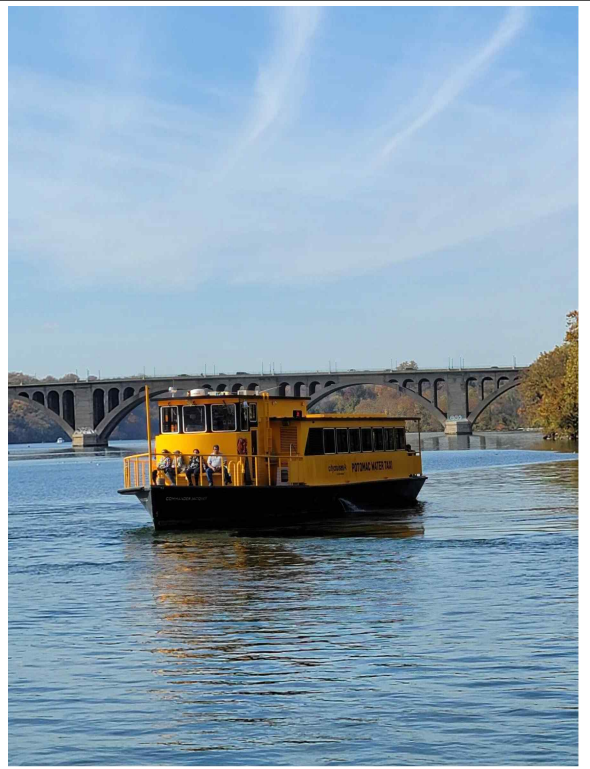




### 부록 3. 워싱턴 D.C. 교통수단 관련 사진



공유 자전거 및 퍼스널 모빌리티(PM)



수상 버스