Cross-ministerial Strategic Innovation Promotion Program (SIP)/ Automated Driving for Universal Services/ Update of High-precision Three-dimensional Map with Vehicle Probe Data

Progress Report

March 2020
Dynamic Map Platform Co., Ltd.

DMP-PD-OC-088

DYNAMIC MAP PLATFORM

1 Background and objectives

- Updating high-precision three-dimensional(3D) maps imposes substantial costs
- Detection of change points is the most upstream process of all update processes, and is the most important process
- Updating maps requires diverse change data. Existing administrator data alone is insufficient.
- Different ways of detecting changes are currently being explored. One of those ways is the use of probe data.

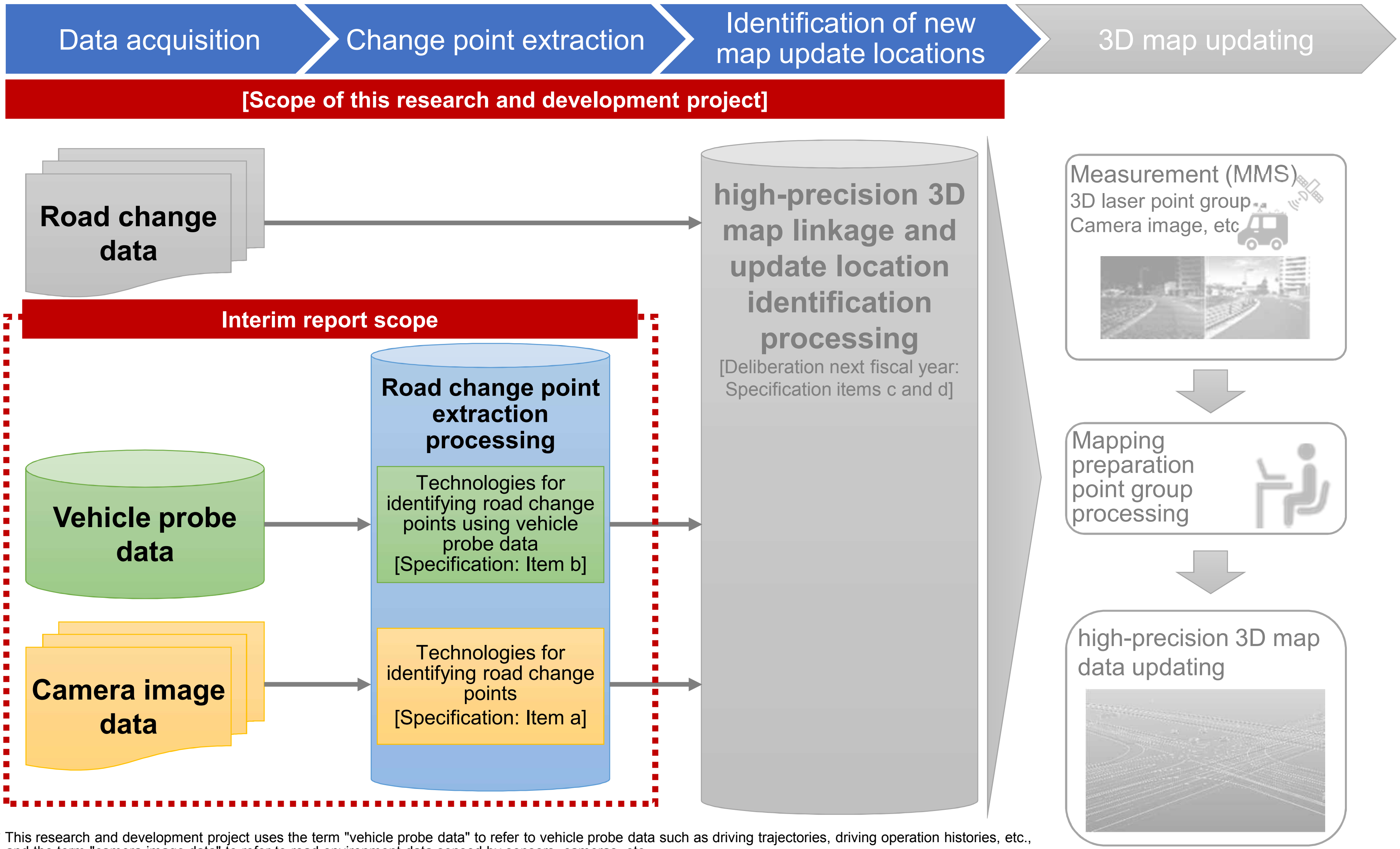
- **In addition to using administrator data, it is also essential to develop technologies for identifying road changes based on probe data**
- **We aim to use the results of this verification work to reduce costs and lead times, to deploy systems globally, and to extend systems to ordinary roads.**

	Change data necessary for updating high precision maps	Detection possible?
Related to road structure changes	New road construction	○
	Road extension	○
	Cruising line shape changes	○
	Increase/decrease in number of lanes	○
	Lane widening	○
	Interchange construction, decommissioning, relocation	○
	Service Area/Parking Area construction, decommissioning, relocation	○
	Junction construction, decommissioning, relocation	○
	Toll booth construction, decommissioning, relocation	○
	Divergence/merging position changes	○
Not related to road structure changes	Increase/decrease in number of lanes	△
	Lane widening	△
	Divergence/merging position changes	△
	Physical structure construction, decommissioning, relocation	×
	Zebra crossing zone creation, removal, changes	×
	Carriageway marking solid line/dashed line/color changes	×
	Emergency parking area creation, removal, changes	×
	Carriageway marking repainting	×
	Road sign installation, removal, changes	×
	Road marking creation, removal, changes	×
	Traffic signal installation, removal, changes	×

Change data to be identified in this verification project

DMP-PD-OC-088

2 Activities conducted this fiscal year / 2.1 Deliberation process

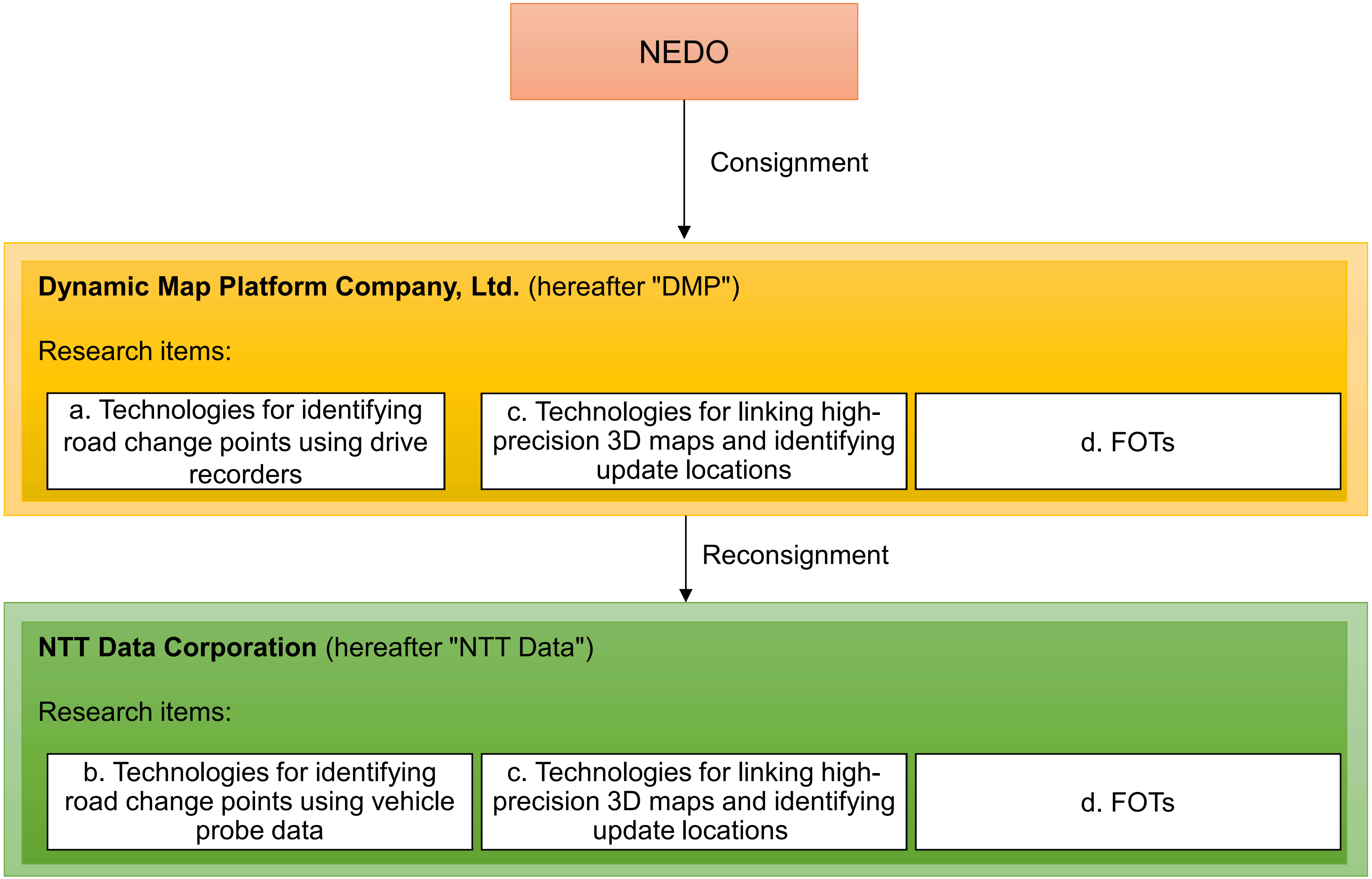


* This research and development project uses the term "vehicle probe data" to refer to vehicle probe data such as driving trajectories, driving operation histories, etc., and the term "camera image data" to refer to road environment data sensed by sensors, cameras, etc.

* Figures and photographs reproduced from publicly disclosed materials released by the Ministry of Land, Infrastructure, Transport and Tourism and NEXCO companies, or taken during the course of this project.

DMP-PD-OC-088

2 Activities conducted this fiscal year / 2.2 Implementation structure



DMP-PD-OC-088

2 Activities conducted this fiscal year / 2.3 Initial schedule and current progress status

- In 2019, we decided to conduct technology investigations regarding "technologies for identifying road change points using drive recorders (a.)" and "technologies for identifying road change points using vehicle probe data (b.)." We also decided to investigate "technologies for identifying high precision 3D map update locations" using road change point data obtained using these two technologies and road change data obtained from separately issued public information. Progress on this project has proceeded roughly as scheduled (see the following page for the results of our investigations).

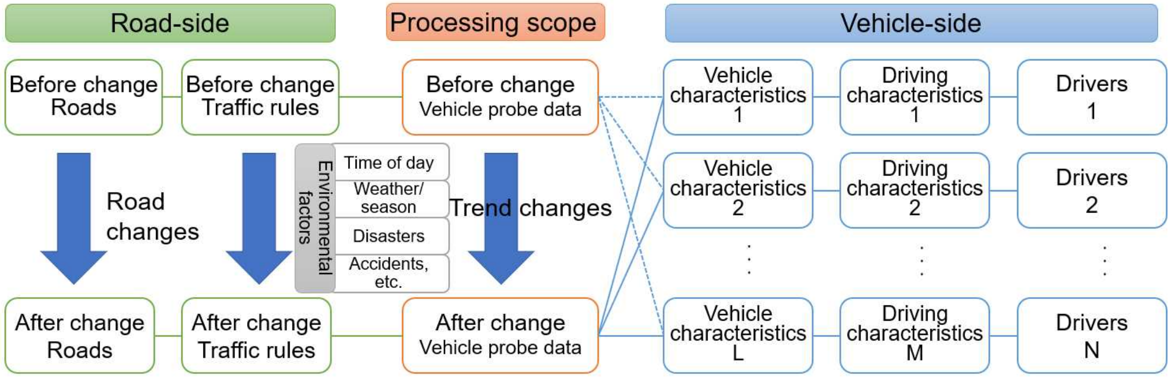
- With regard to the initial issue of coordination with OEMs, we formulated specifications for data provision, taking into consideration the perspectives of whether they would place undue burdens on the OEMs with regard to OEM-side pre-processing and whether sufficient regard was given to data which required anonymity, such as the behavior of individual vehicles. We had OEMs begin by providing data for specific locations. We are now analyzing the submitted data and reviewing and revising the amount of data that is required and the data provision specifications.

Project item		2018	2019				2020			
		4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
a. Technologies for identifying road change points using drive recorders	a-1. Selection of image data to be used	Data acquisition (a-1-1)	FS implementation (a-1-2)		Interim evaluation					
	a-2. Establishment of technologies for extracting road change points using image data, etc.				Technology investigation and deployment					
b. Technologies for identifying road change points using vehicle probe data	b-1. Selection of data to be used for road change point extraction	Theoretical study (b-1-1)	FS implementation (b-1-2)	Coordination with OEMs (b-1-3)						
	b-2. Establishment of technologies for extracting map change points by overlapping vehicle probe data				Technology investigation and deployment					
c. Technologies for linking high-precision 3D maps and identifying update locations	c-1. Technologies for identifying high precision 3D map update locations				Technology investigation and deployment					
	c-2. Technologies for linking with high-precision 3D maps						Technology investigation and deployment			
d. FOTs								Testing and verification		Summary

: Phase 1 : Phase2

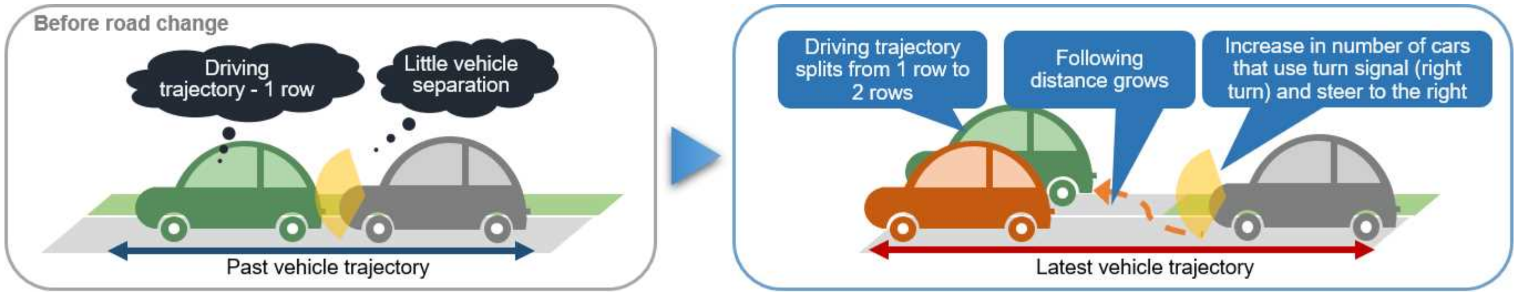
b Technologies for identifying road change points using vehicle probe data (Selection of data to be used for road change point extraction)

- Vehicle probe data is generated result data that is affected by various factors, such as the vehicles driving on roads, the characteristics of vehicle drivers, time of day, and weather. We attempted to extract road change points by reducing the impact of environmental factors and vehicle-side characteristics on vehicle probe data trend changes.



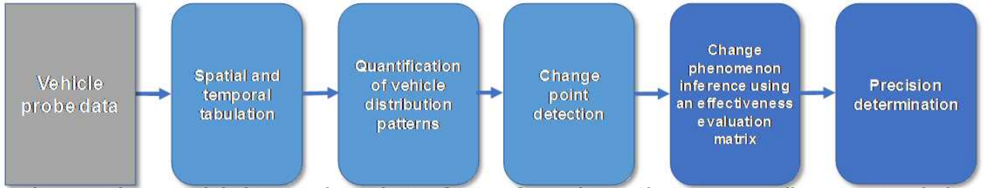
- Based on public materials, we investigated what data was effective in detecting driver behavior and change in the event of increases/decreases in the number of lanes, lane widening, or divergence/merging position change that were not related to road structure changes. We then verified this information by conducting a feasibility study. Our verification found that, based on turn signal operation, steering, and brake usage (data), drivers generally behaved as hypothesized when encountering changes, and that this data could be assessed from vehicle probe data.

- However, we also determined that there was a need for investigation that takes into consideration factors that occur in actual society, such as other moving vehicles, and to perform verification that leverages actual data. We coordinated with OEMs and formulated data provision specifications.



b Technologies for identifying road change points using vehicle probe data (technologies for extracting map change points by overlapping vehicle probe data)

- Vehicle probe data from four locations where there were actual road changes, obtained from OEMs, was used in a detailed process based on the conceptual image shown on the previous page in an attempt to extract road change points. In order to determine if the change point detection was correct or not, we obtained probe data from before and after the change points from the OEM and used this data to determine the detection precision.



- As the result of our verification using vehicle probe data from four locations, we discovered that the following two factors had a significant impact on change point detection: 1) parallel and intersecting ordinary roads which produce noise in expressway vehicle probe data 2) the state of roads and nearby structures that have an impact on vehicle measurement precision.
- In order to achieve practical implementation, further deliberation is required regarding the methods used to identify areas with high detection potential (areas with environments conducive to measurement and with few ordinary roads), the automation of threshold value setting based on more widespread case verification, and the reduction of detection errors through the use of secondary information.

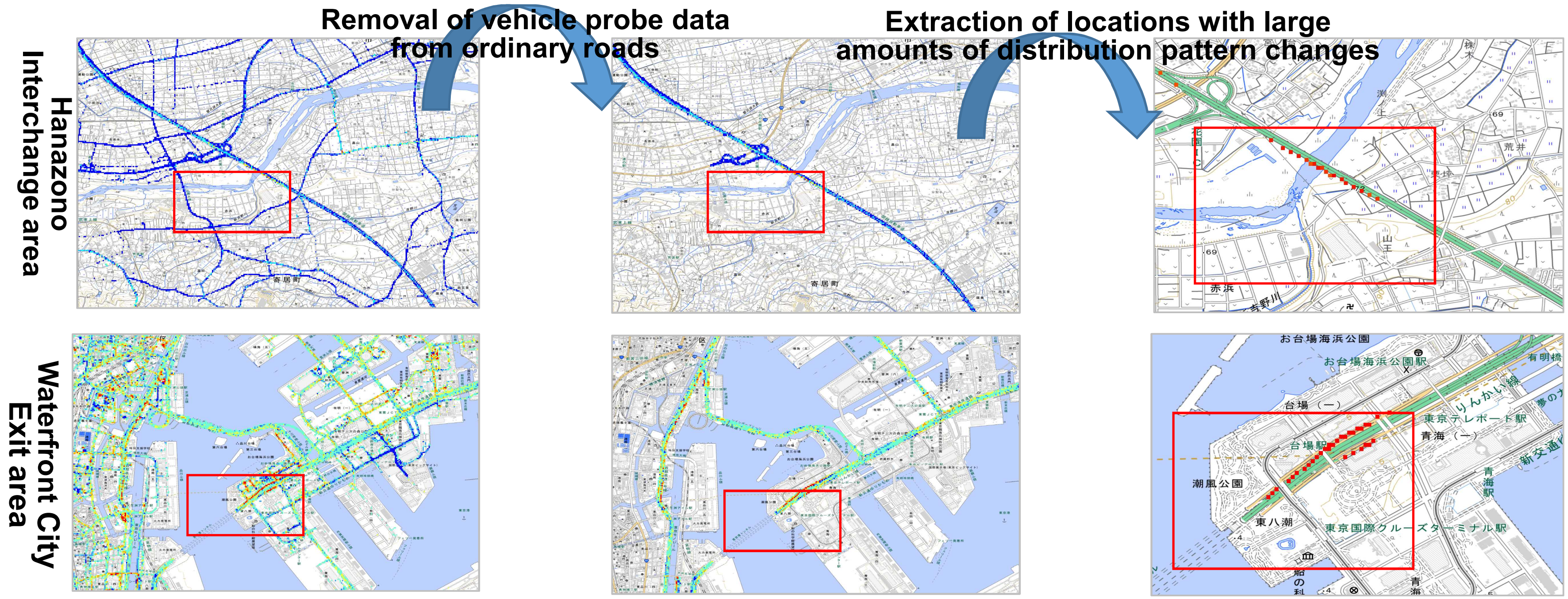
#	Area	Content of road changes	Verification results	Result findings
1	Horikiri/Kosuge Junction	Lane widening (3 lanes => 4 lanes)	**Not detectable from distribution pattern** Consideration must be given to improvements to vehicle probe data pre-processing, etc.	• The expressway is a two-level expressway, making the environment a difficult one for measurement. • An ordinary road runs below the expressway, making it difficult to separate vehicle probe data.
2	Itabashi/Kumano Junction	Lane widening (3 lanes => 4 lanes)	**Not detectable from distribution pattern** Consideration must be given to improvements to vehicle probe data pre-processing, etc.	• The expressway is a two-level expressway, making the environment a difficult one for measurement. • An ordinary road runs below the expressway, and there are many crossing ordinary roads, making it difficult to separate vehicle probe data.
3	Waterfront City Exit	Exit movement	Detectable from distribution pattern (see next page) Consideration must be given to threshold determination processing based on a larger number of samples	• The expressway is completely separated from ordinary roads and it has good visibility over the surrounding area, so its measurement environment is a comparatively good one.
4	Hanazono Interchange	Lane widening (2 lanes => 3 lanes)	Detectable from distribution pattern (see next page) Consideration must be given to threshold determination processing based on a larger number of samples	• The expressway is a suburban expressway, completely separated from ordinary roads, with good visibility over the surrounding area, so its measurement environment is a comparatively good one. • The number of nearby ordinary roads and the traffic volume are limited, so it is easy to separate vehicle probe data.

2 Activities conducted this fiscal year / 2.4 Implementation results

b Technologies for extracting road change points using vehicle probe data (technologies for extracting map change points by overlapping vehicle probe data)

■ **Procedure used by road change point extraction technology**

- Data from ordinary roads, which is noise when performing change point extraction, was eliminated. Quantified vehicle distribution patterns were used to extract locations with large amounts of changes as potential change points.
- Verification found that vehicle distribution patterns could be effectively used to identify road change points in locations with ideal environments -- environments in which there is a sufficient amount of vehicle probe data, in which there are few nearby ordinary roads with high traffic volumes that produce noise in the data, and in which there are few measurement situation disparities.



Vehicle probe data before and after road changes was quantified as distribution patterns and used to generate pre/post-change differential data

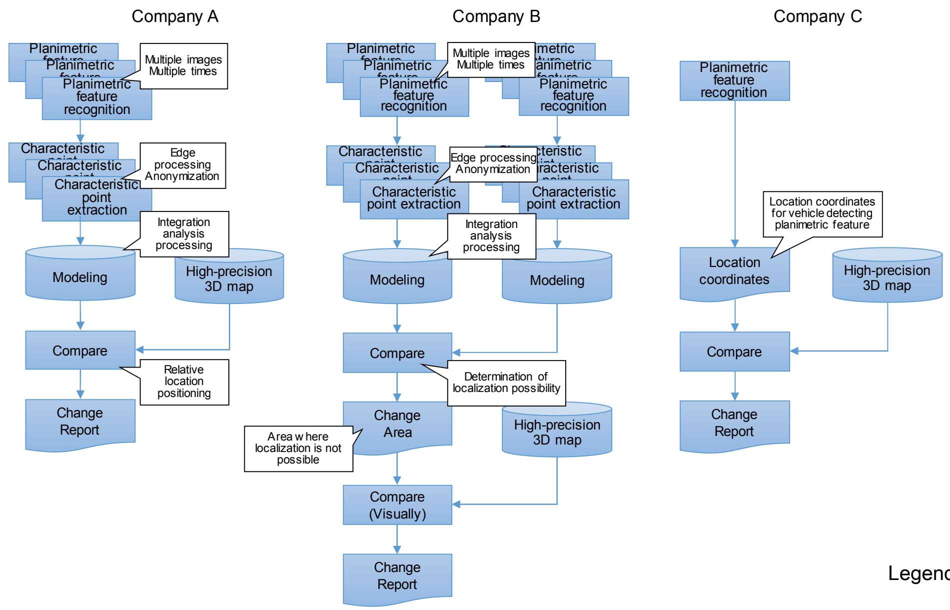
Data for expressway areas, the target areas for road change point extraction, was extracted

Locations with large amounts of distribution pattern changes were extracted as potential road change points

Source) Created based on Geospatial Information Authority of Japan maps
https://maps.gsi.go.jp/

a Technologies for identifying road change points using drive recorders (Selection of image data to be used)

- Technologies for using drive recorders are still in the research and development phase. We performed the following to acquire data for planimetric features stipulated in high precision 3D map design specifications and planimetric features that are appropriately detected from camera image data (carriageway markings, road markings (restriction markings, instruction markings), road signs (information signs, warning signs), etc.), and investigated whether change data could be obtained for these planimetric features.
  - Vehicles were driven on expressways that had many "carriageway marking solid line/dashed line/color changes," "road sign installation or removal," or the like not related to road structure changes (such as the Tomei Expressway between the Fuji Interchange and the Shimizu Ihara Interchange), and camera image data was acquired using drive recorders, etc.
  - The acquired camera image data was processed using the technologies of companies A through C (as shown in the diagram at left" and road change point data was extracted
- The results of the extraction are shown in the table at right. We confirmed that all three of the technologies we verified were able to identify carriageway marking, road marking, and road sign addition and removal.



Category	Subcategory	Company A	Company B	Company C
Carriageway lines	Addition/removal	●	▲	▲
	Shape changes	●	▲	
	Line type changes	●	▲	●
	Installed structure changes	●	△	
Shoulder edge	Shape changes	○	△	
	Installed structure changes	○	△	
Road markings	Addition/removal	●	▲	●
	Shape (text) changes	●	△	
Road signs	Addition/removal	●	▲	●
	Shape (text) changes	○	△	
Traffic signal	Addition	○	△	
	Removal	○	△	

Legend ○: Detectable planimetric features, △: Conditionally detectable planimetric features
●: Detectable planimetric features (planimetric features confirmed through feasibility study)
▲: Conditionally detectable planimetric features (planimetric features confirmed through feasibility study)

* As the conceptual processing image at left shows, Company B's technology could identify areas with changes automatically on the system side, but the identification of changed planimetric features was performed visually, so the evaluation of each item is △ or ▲.

DMP-PD-OC-088

a Technologies for extracting road change points (Establishment of technologies for extracting road change points using image data, etc.)

- The results on the previous page were for individual companies' technologies (road change point data), and could differ from actual road conditions. We therefore compared the road change point data from each company against accurate data from DMP and identified and organized the features of actually detected changes, etc., by road sign (speed limit), road marking (instruction marking), and carriageway marking.

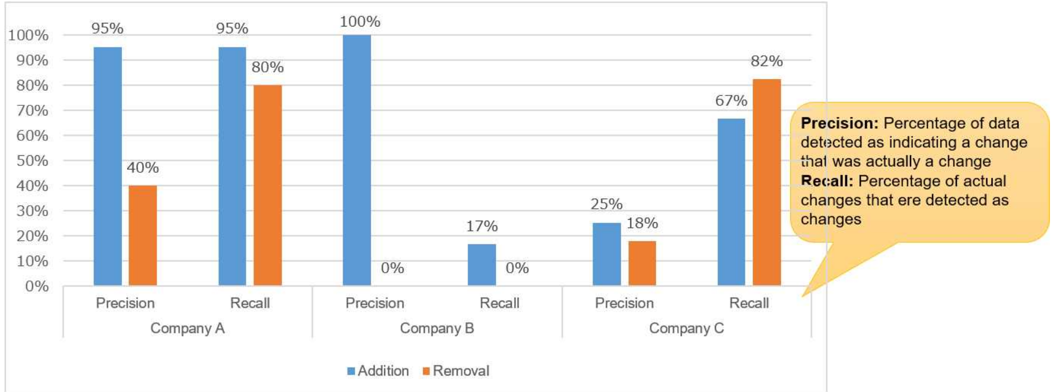
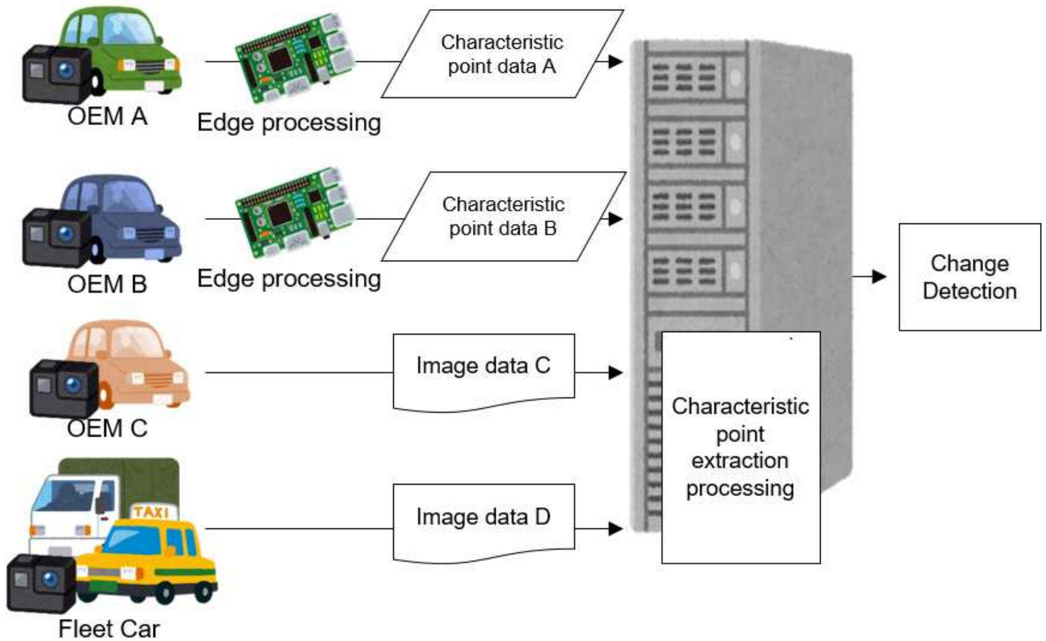


Figure Road marking (instruction marking) results

- Based on the results of this organization, we determined technical characteristics and the situations in which precision and recall fell.
  - Company A's technology (identifying planimetric features from camera image data, extracting characteristic point groups, performing integration analysis processing (modeling), and comparing the results against DMP's high precision 3D map) had higher recall and precision rates than the technologies of Company B or Company C.
  - Systems that were highly dependent on GNSS location precision had high likelihoods of misdetection due to the influence of photographic environment
  - System-side factors (insufficient learning, planimetric features being outside the detection scope) resulted in cases in which planimetric features that were within the scope were not detected.
  - At locations with multiple different planimetric features, when modeling was performed, there were cases in which individual planimetric features could not be detected.
- In addition to the above, the following were assessed using the road change point extraction processing procedure on the previous page.
  - When camera image data taken with drive recorders by Company A or Company B were sent to the server, characteristic points were extracted, data transmission loads were reduced, and anonymization processing was performed to prevent the determination of individuals from the data.

a Technologies for extracting road change points (Establishment of technologies for extracting road change points using image data, etc.)

- Based on the issues considered in the previous pages, **we organized the requirements of technologies for extracting road change points, as shown below**.
  - They must be able to identify planimetric features from camera image data
  - They must be able to extract and accurately model characteristic points from camera image data
  - It must be possible to use the modeled data to compare high-precision 3D maps and individual planimetric features
- Furthermore, when sending the data acquired using the road change point extraction process shown on page 8 to the server, we found that there are two possible patterns: 1) performing edge processing and then sending the data to the server, and 2) sending the acquired camera image data itself to the server. Support for the following envisioned operation scheme must be taken into consideration when considering requirements, etc.
  - Collecting data for which edge (vehicle) processing has been performed
  - Collecting actual images taken using drive recorders, smartphones, etc.



Summary

Through our deliberations in 2018 and 2019, we determined the following.

- When detecting planimetric feature changes that are not related to road structure changes, due to the respective characteristics of vehicle probe data and camera image data, their roles will be separated, as shown below.
  - Vehicle probe data : Increase/decrease in number of lanes, etc.
  - Camera image data : Changes to road signs, road markings, etc.

- Vehicle probe data
  - In our investigation using vehicle probe data, analysis mainly based on locations determined from the vehicle probe data also found that in ideal environments, vehicle probe data could be used to identify road changes.
  - The necessary vehicle probe specifications and analysis setting values must be considered. In parallel with this, ongoing investigation must be carried out, encompassing a greater amount of variety.
    - Deliberation regarding optimal values in specifications for the data required for change detection
    - Investigation of change locations with different conditions

- Camera image data
  - Camera image data is essential to detecting changes in planimetric features on high precision 3D maps that are not related to road structure changes.
  - To detect change points from camera image data, not only do the planimetric features need to be identified from the camera image data, but characteristic points must be identified and modeled.
  - Through our verification, we found that none of the three technologies we verified were systems that collected images processed on the vehicle side and could appropriately detect change points in high precision 3D map.