Cross-ministerial Strategic Innovation Promotion Program (SIP)/
Automated Driving for Universal Services /

Research and Study of Common Reference Point (CRP) in High Definition Map (FY2019-FY2020)

FY2019 Annual Report
Summary version

Mitsubishi Research Institute, Inc.

March 31, 2020

Outline

Introduction

1. Analysis and review of basic data related to CRP
   - 1.1. Items to be defined as CRP
   - 1.2. Definition of CRP at road sites of particular attention
2. Analysis and review of basic data concerning the expression method using CRP for the location of objects, etc.
   - 2.1. Review of the mechanism of Pre-coded location references
   - 2.2. Review of location expression method using CRP
3. Analysis and review of basic data concerning the alignment with existing linked maps, etc.
4. Review Meeting
5. Future plans

* The period of this Research and Study is from August 19, 2019 to February 28, 2020.
  This Report shows the summary of this Research and Study's Intermediate result on FY2019.

Introduction

Introduction

Background

- On automated driving systems, it is necessary for different entities to exchange location information.
- As specifications of High Definition maps (HD maps) are currently determined independently by map makers, how to exchange information among different maps and how to express the locations of objects are not unified.

Purpose

- The purpose of this investigation is to make a proposal of the following items, in order to unify the methods in Japan and to make a proposal of international standard:
  - ① Definition and maintenance of Common Reference Point (CRP)
  - ② Expression method using CRP for the location of objects, etc.
  - ③ Alignment with existing linked maps, etc.

* The sections on this FY2019 Annual Report (Summary version) (1., 2., and 3.) corresponds to the numbers ①, ②, and ③ above. Verification of the topics above and examination of the content of the international standard proposal will be carried out in FY2020.

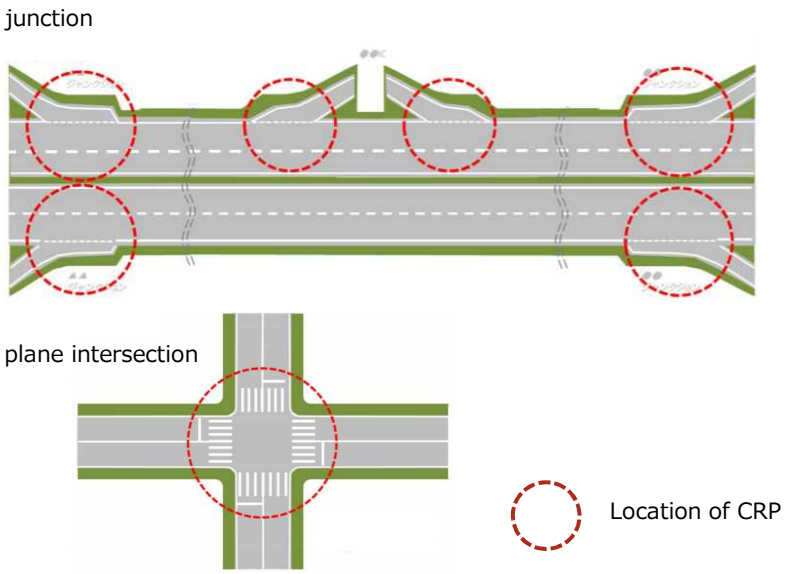
1. Analysis and review of basic data related to CRP

1.1. Items to be defined as CRP

Location of CRP

- In light of the two location reference methods (‘Differential measurement from a reference point’ (Type 1) , ‘Lane number count’ (Type 2)) in “ISO 17572 -4: Precise Relative Location Referencing for Geographic Databases", the following are possible candidates for the location of CRP *.
  - Motorway: Junctions (Lamps, etc.)
  - General road: Junctions (Side roads, etc.) and a plane intersections
- On actual HD maps, it is conceivable to define plane intersections and junctions with reference to nodes of road network data (e.g. DRM Database).

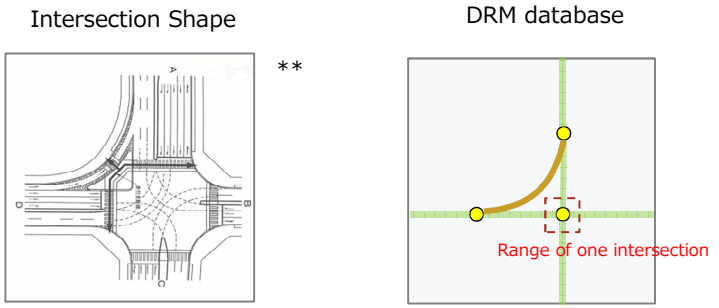
Fig. Location of CRP (Draft)



Source: Created by Mitsubishi Research Institute

*The necessity and method of CRP installation at locations other than junctions and plane intersections (tolls, etc.)will be discussed as necessary in the future.

Fig. Identify intersections from the DRM Database (Draft)



CRPs are set at intersections where nodes of road network data is set.

* CRP is not set at the introduction route of the intersection, because it is near the adjacent cross intersection.

: Main link (Link Type Code 1.2)

: Path Link (Link Type Code 3.5)

intersection node

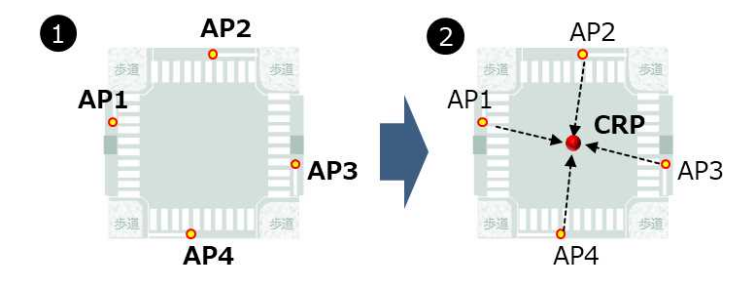
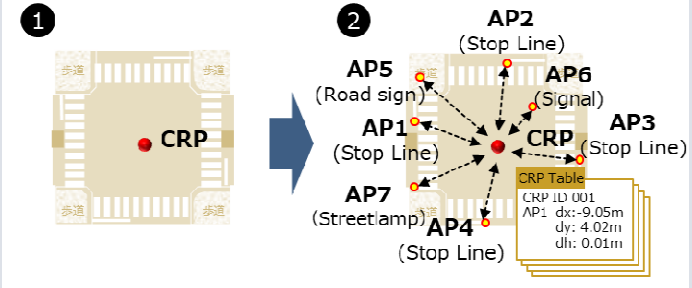
Source:
** Japan Society of Traffic Engineering "2007 Plan and Design of Plane Intersections - Applications -", 2007, Maruzen Publishing
Other figures are created by Mitsubishi Research Institute

1.1. Items to be defined as CRP

Method for setting CRP

Two methods can be considered:
(1) <Be determined by the AP> and (2) <Be determined by the CRP>

Table: Method for setting CRP (Draft)

	Method (1) <Be determined by the AP>	Method (2) <Be determined by the CRP>
Summary	1. Define the rule for specifying AP. *Example: AP is at the right edge of a stop line 2. Define the rule for determining the location of CRP from the location of APs. *Example: CRP is set at the geometric centroids of all Aps →Each HD map maker sets CRPs based on the rules. 	1. Initial maintenance personnel determines the location of CRP in some way. *Example: CRP is center of the intersection. 2. Make the CRP table** which shows the relative distance between APs and CRP. →Each HD map maker sets CRPs with CRP tables. 
Advantage / Disadvantage	○ Low cost ○ Even if the location of the object to identify the AP is moved, the operation method of updating the location of the CRP is simple. × As the location of the object to identify the AP is moved, so does the location of the CRP. × Necessary to set the rule of the location of AP which can be applied to any level intersection or junction where CRP is required.	○ Flexible choice of AP for each map ○ Even if the location of the object to identify the AP is moved, the location of CRP is difficult to move. ○ LO *** is more likely to be an AP × Requires initial maintenance personnel × High Cost (Initial maintenance and updating of tables) × The CRP table needs to be updated when an object to identify AP is moved.

*AP (Anchorage Point): a point identified from an object on a HD map for the purpose of locating CRP on the HD map
** The CRP table can be generated for CRP located using method (1).
*** LO (Localization Object): A geographic object recognized by an on-board camera or the like, for the purpose of identifying the location of the vehicle on a HD map by an autonomous vehicle
Source: Created by Mitsubishi Research Institute

1.1. Items to be defined as CRP

Specifying AP

- The candidates of the object for specifying the AP can be narrowed down, by evaluating objects around junctions and plane intersections based on the requirements for AP as follows.

#	Requirements for AP
1	Managed by a public institution
2	Installed thoroughly around junctions and plane intersections
3	Not easily moved (in principle)
4	Easy to measure
5	Single point can be identified uniquely

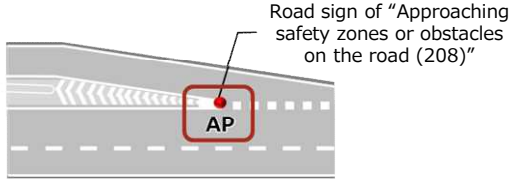
Select objects that meet requirements 1 ~ 5 as an AP

Method (1)
<Be determined by the AP>

Candidates for objects to specify the AP

junction

"Approaching safety zones or obstacles on the road (208)" *, etc.

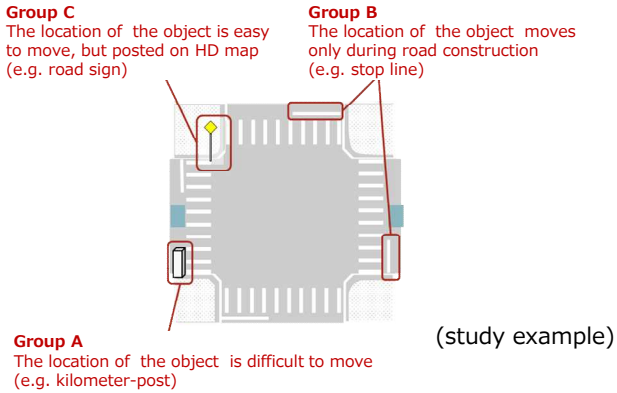


plane intersection

"Stop line (203)", roadway boundaries, "Roadway outside lines (103)", etc.

Method (2)
<Be determined by the CRP>

Select multiple objects with different characteristics (How to meet the requirements) as APs, and create a CRP table showing the relative distance to CRP.



(study example)

*Number "208" Indicates the number specified in "Orders Concerning Road Signs, Lot Lines and Road Markings" (Ordinance of the Prime Minister's Office and the Ministry of Construction No. 3 of December 17, 1960).

1.1. Items to be defined as CRP

Items in the CRP table

- The following items may be included in the CRP table (in Method (2)) .

Table: Items of CRP table (Draft)

Item name			Definition	Required/ Optional	Description (Draft)
(1)CRP ID			Unique ID allocated per CRP	Required	Describe ID of the CRP
(2)Location (latitude longitude altitude)			location of CRP (latitude longitude altitude)	Optional	Lat/Long*: 4 decimal places Elevation*: 1 decimal place [m]
(3)Note of specified location			Note on where CRP was obtained (Text)	Optional	Describe location in text data
(4) Road information	1)Type and name		Types and names of roads	Optional	Describe in text data or code
	2)ID of other network data		ID of the road an existing network (Data DRM, interval ID, etc.)	Optional	Describe ID as an identifier
	3)ID of the neighboring CRP		ID of the neighboring CRP	Optional	Describe CRP-ID as an identifier
(5) Relationship with APs	1) Number of APs		Number of geographic objects used to locate CRP	Required	Describe in number
	Iterate same times as the number of APs	2) Type of AP	Type of AP	Required	Describe in text data or code
		3)From CRP to AP relative distance	(Per AP) Relative distance from CRP to AP (Δx, Δy, Δh)	Required	Δx, Δy, Δh: two decimal places [m] *The north of the grid is the positive x-axis direction, and the intersecting direction is the y-axis direction.
		4) The location of the AP (latitude longitude altitude)	(Per AP) location of the object itself (latitude longitude altitude)	Required	Lat/Long*: 4 decimal places Elevation*: 1 decimal place [m]
		5)Note of location	(Per AP) Notes concerning specified locations of Geographical Objects (Text)	Optional	Describe location in text data
		6)image	(Per AP) Images for Facilitating Recognition of Geographical Objects	Optional	Describe in image data, for the purpose of precise specification of the object for AP and the specified location

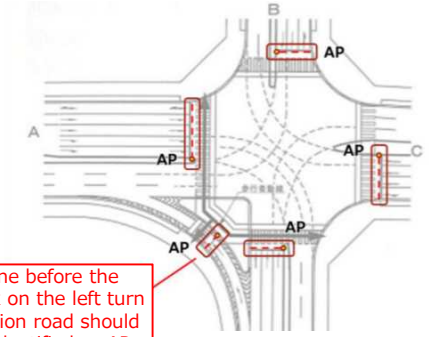
*The unit of lat/long is the decimal degree, and the unit of altitude is the meter. The number of digits is the minimum number of digits required to represent the approximate position.
Source: Created by Mitsubishi Research Institute

1.2. Definition of CRP at road sites of particular attention

Study for complicated intersections

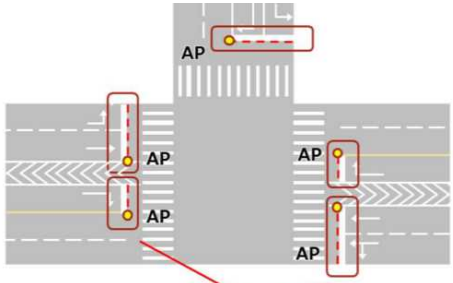
- It is necessary to arrange how to specify APs at complicated intersections.
- In case of APs are specified from stop lines, attention should be paid to selection of the object to identify AP, especially for the complicated intersections shown below.

Stop line before the crosswalk on the left turn introduction road

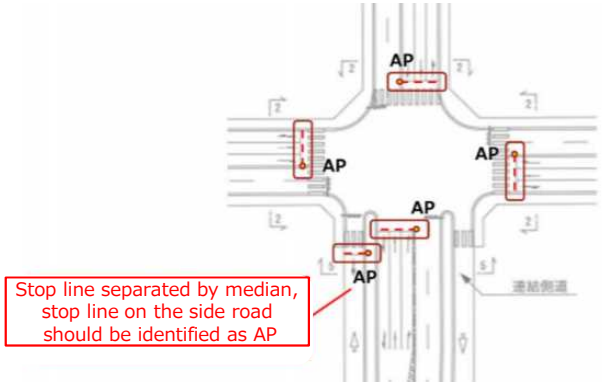


*

Stop line separated by zebra zones or median

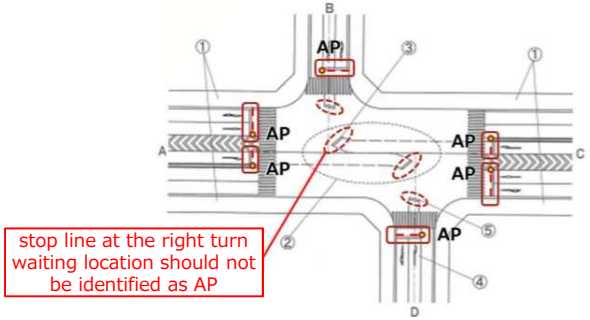


Stop line separated by median stop line on the side road



*

Stop line at the right turn waiting location



*

Source:
* Japan Society of Traffic Engineering "2007 Plan and Design of Plane Intersections - Applications -", 2007, Maruzen Publishing(Red lines and letters were added by Mitsubishi Research Institute.)
Other figures are created by Mitsubishi Research Institute

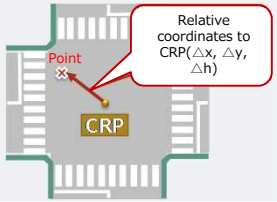
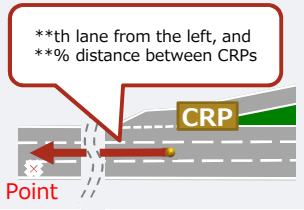
Fig. Specify AP at complicated intersections (Draft)

2. Analysis and review of basic data concerning the expression method using CRP for the location of objects, etc.

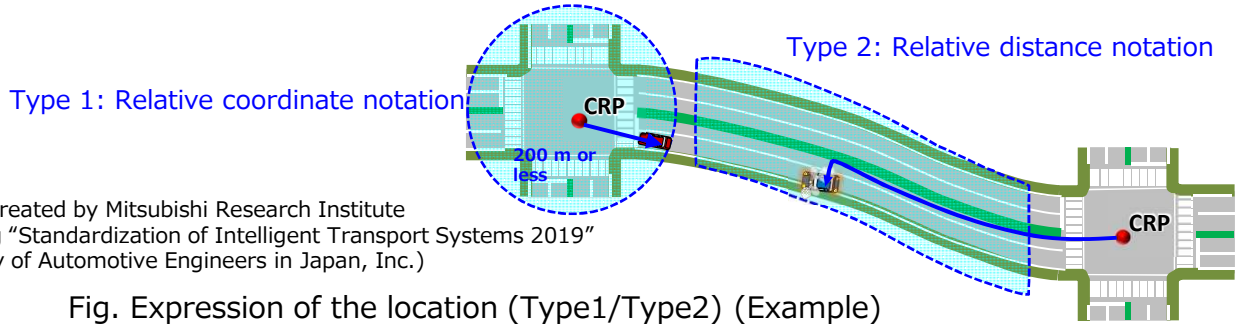
2.1. Review of the mechanism of Pre-coded location references

- ISO 17572-4 has been internationally standardized as a referencing method assuming common pre-coded location tables (Pre-Code location references) to exchange information. The outline of two methods of expressing locations in the standard are as follows.

Table Method of expressing the location specified in ISO 17572-4 and the content specified in this study (Draft)

	Type 1: Relative coordinate notation (Differential measurement from reference point)	Type 2: Relative distance notation (Lane number count)
Expression of the location	● Relative coordinate to CRP	• Relative distance to CRP
Diagram		
Scope of use specified in international standards	● Limited to use within 200 m radius of CRP	-
Scope of use (Draft)	● Area surrounding the intersection, junction, and tollgate, and within a radius of 200 m of CRP ➢ Lane boundaries do not exist around intersections, junctions and tollbooths, and it is difficult to link them with lanes.	● Areas other than those listed on the left ➢ The lane boundaries are clear, and it is easy to express the location linked to the lane
Use cases assumed in this study (Draft)	● Exchange of location information in inter-vehicle and roadside-to-vehicle communication at the junction	● Transmission of ahead lane regulation location

Source: Created by Mitsubishi Research Institute



Source: Created by Mitsubishi Research Institute
(Referring "Standardization of Intelligent Transport Systems 2019" by Society of Automotive Engineers in Japan, Inc.)

Fig. Expression of the location (Type1/Type2) (Example)

2.2. Review of location expression method using CRP

Type 1: Relative coordinate notation (Information item)

- In ISO 17572-4, the location is expressed by the distance from the reference point (displacement). As the standards of x, y, and height directions are not specified in ISO, they were specified in this study. Descriptions of the information items considered are shown in the table below.

Table : Description of location Expression Items in Type 1 (Draft)

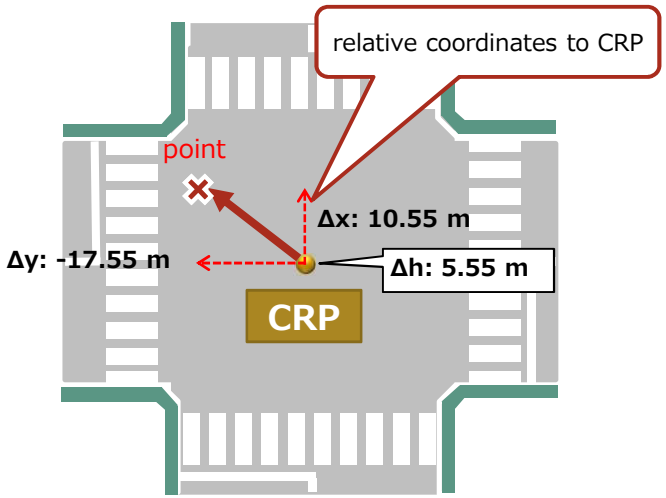
Classification	Items	Required / Optional	Type	Definition	Description (Draft)
CRP information	Reference CRP ID	Required	Text	Identify baseline CRP	-
Relative coordinates	Displacement Δx	Required	Numeric	Displacement in x-direction (North and South) relative to CRP	・ The distance from the reference point when the grid north is the x-axis direction. ・ Positive north and negative south from the reference point ・ [m] (two decimal places)
	Displacement Δy	Required	Numeric	Displacement in y-direction (east and west) relative to CRP	・ The distance from the reference point when the grid east is the y-axis direction. ・ Positive east and negative west from the reference point ・ [m] (two decimal places)
	Displacement Δh	Optional	Numeric	Displacement in z-direction (Height) relative to CRP	・ The top direction of the reference point is positive and the bottom direction is negative. ・ [m] (two decimal places) ・ This item is an optional item.

Source: Created by Mitsubishi Research Institute

2.2. Review of location expression method using CRP

Type 1: Relative coordinate notation (description example)

- The following figure shows an example of description when the point of the plane intersection is shown. The ID of CRP and the horizontal and vertical displacement from CRP to the point concerned should be described.



Type	Classification	Items	Description example
Type 1	CRP information	Reference CRP ID	544001000001
	Relative coordinates	Displacement Δx	10.55 m
		Displacement Δy	-17.55 m
		Displacement Δh	5.55 m

Source: Created by Mitsubishi Research Institute

Left Fig. Expression based on Type1 (Draft) / Right Table: Description example based Type1 (Draft)

2.2. Review of location expression method using CRP

Type 2: Relative distance notation (Information item 1/2)

- In ISO 17572-4, the location is expressed by both “the relative distance between two CRP points on a line segment” and “the lane number.” Since the method of expressing the location on the line and the method of counting the lane location are not specified, they were specified in this study. Descriptions of the information items considered are shown in the table below.

Table : Description of location expression items in Type 2 (Draft) 1/2

Classification	Items	Required / Optional	Type	Definition	Description (Draft)
CRP information	CRP ID of the origin	Required	Text	CRP at the origin of the reference line of the distance expression	Describe the ID of the CRP at the origin
	End CRP ID	Required	Text	CRP at the end of the reference line for the distance representation	Describe the ID of the terminating CRP
Longitudinal location	Reference line to measure distance ratio	Required *1	Text	Reference line for measuring distance ratio	The following are described: Roadway center line, roadway outside line, lane boundary line, roadway link, lane link, etc. The interpolation method of the section where the reference line does not exist is also described.
	Ratio of distance from origin side	Required *2	Numeric	location on reference line from start point expressed as a percentage (percentage)	[%] The number of digits should be determined so as to represent the location of the content with metric unit.
	Distance ratio from end	Required *2	Numeric	location on reference line from end expressed as a percentage (percentage)	

*1 Metadata or the like can be applied to describe as long as they are not different for each information and are the same for each data unit.

*2 Either “Ratio of distance from origin side” or “Distance ratio from end” is required.

Source: Created by Mitsubishi Research Institute

2.2. Review of location expression method using CRP

Type 2: Relative distance notation (Information item 2/2)

Table Description of location expression items in Type 2 (Draft) 2/2

Classification	Items	Required / Optional	Type	Definition	Description (Draft)
Lane information	Direction	Required	Code	Indicate the direction in which the content resides	The direction of CRP from the base point to the end point is defined as "positive" and described as "positive" and "opposite".
	Total number of lanes	Optional	Numeric	Total number of lanes where the content resides	Number of lanes in the road travel direction
	Content-based lane location	Required	Numeric	Lane number where the content resides	Lane number counted from the left when looking from the road direction
	Lane type	Optional	Code	Lane type where the content resides	Code from the following options BUS Lane, HOV Lane, Bicycle Lane, Pedestrian Lane, Reversible Lane, Auxiliary Lane, Overtaking Lane, Driving Lane, Other
Lateral location	Reference line indicating a horizontal location	Optional *3	Code	Reference line indicating horizontal location	Describes the reference line from which the horizontal location is indicated.
	Direction of the reference line	Optional *3	Code	Offset direction from reference line	To describe whether the reference line is left or right in view of information to be expressed.
	Horizontal location	Optional *3	Numeric	Distance from reference line	Distance in offset direction from reference line [m] (two decimal places)

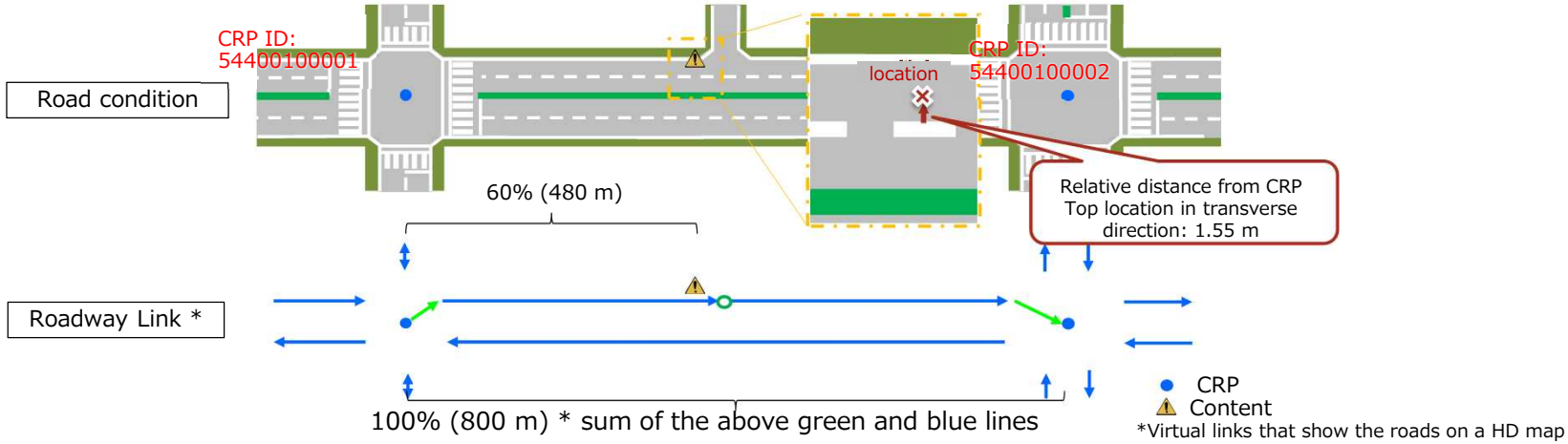
*3: When the location in the lane is indicated, three items are also described.

Source: Created by Mitsubishi Research Institute

2.2. Review of location expression method using CRP

Type 2: Relative distance notation (description example)

- The following figure shows an description example of indicating a point of a single route (Roads between plane intersections). CRP information, longitudinal (road direction) location, lane information, and lateral location should be described.



Classification	Items	Description example
CRP information	ID of CRP as the origin point	54400100001
	ID of CRP as the end point	54400100002
Longitudinal location	Reference line to measure distance ratio	The roadway link is used as the reference line
	Ratio of distance from the origin point	60.00%
	Distance ratio from end point	40.00%
Lane information	Direction	Correct
	Total number of lanes	2
	Content-based lane location	1
	Lane type	driving lane
Lateral location	Reference line indicating a horizontal location	lane boundary
	Direction of the reference line	Right
	Horizontal location	1.55 m

Source: Created by Mitsubishi Research Institute

Upper Fig. Expression based on Type2 (Draft) / Lower Table: Description example based Type2 (Draft)

3. Analysis and review of basic data concerning the alignment with existing linked maps, etc.

Areas where consistency is considered to be difficult

- The method for expressing road network, the range of “intersection(s)”, and the location of points were arranged among existing location expression methods and CRP.
- The results are as shown in the table below. In some cases, it would be difficult to achieve consistency of the range of intersections and the locations of points (e.g. roads where the difference in locations increases, **Bold underlined parts**).

Table: Alignment with existing location expression

	Existing location expression method		Location expression method using CRP (Current draft*)
	DRM Database (DRM-DB)	Road Section ID table	
Method for expressing road network	・On a road with a median, links are set up for each of up and down lines / On a road without a median, a single link is set up. ・At an intersection where links are set up for each of the up and down lines, plural nodes are set up / At an intersection where all of the incoming roads have a single link, a single node is set up.	・Each road has a section for both up and down lines. ・There is one reference point at each intersection.	・On a road with a median, CRPs are set up for both up and down lines. Although CRP itself is not the object to express road network, connected CRPs are able to describe a road network which distinguishes up and down lines. ・On a road without a median, a single CRP is set up at the intersection. Connected CRPs describe a road network which does not distinguish up and down lines.
Definition of intersection	・On motorways, every junction and merging is considered to be a single “intersection”. ・On ordinary roads, every plane intersection is considered to be a single “intersection”.	・On motorways, **a couple of branching and merging are considered together to be a single “intersection”**. ・On ordinary roads, the rule is the same as DRM-DB, but in some cases**, several nearby intersections are considered a single “intersection”.**	・On motorway, **every junction and merging is considered to be a single “intersection”**. ・On ordinary roads, **every plane intersection is considered to be a single “intersection”.**
Location of nodes at intersection	・DRM-DB is based on **city planning map (Map Information Level 2500) and topographical maps (Map Information Level 25000).** ・Since a link roughly indicates the center of the road and the node indicating the plane intersection is the intersection of the links, it is located inside the intersection. ・**The resolution of the data is about a m-order.**	・Road Section ID Table is a table in which an intersection is defined as a “reference point”, a section between the intersections is defined as “a section”, and IDs are assigned thereto. Road Section ID Table does not indicate location information. ・The approximate location of “reference point” is stored as reference information to specify the location. **Since the information is created from DRM-DB,** the resolution of the data is same as DRM-DB.	・CRP is specified at a distance (locational relation) from actual objects, and is located inside the intersection. ・**The resolution is about a cm-order,** depending on the map used.

* The current draft are based on “definition of CRP” and “expression method using CRP” discussed above (as of FY2019).

Source: Created by Mitsubishi Research Institute

Items to verify consistency

- A way of specifying “intersection” where CRP is to be located is different from existing location expression methods. Therefore, it may be difficult to achieve consistency of the location expression method of CRP with the other methods (e.g. a place where there are several nearby intersections).
- It is conceivable to verify the alignment of the range of “intersections” and the location of the reference point at several junctions and/or plane intersections. The following table shows the items to be verified, the viewpoints of verification, and the points to be verified.

Table: Items to verify consistency (Draft)

Validation Item #	Viewpoint of Verification	Point of Verification
1: Differences in specifying intersections	Consistency with the number of CRP installations	Places where there are several nearby junctions/plane intersections
	Consistency with the order of CRP placement	Places where there are several nearby junctions
2: Differences in locations of reference point	Differences in CRP location	Places where there are several nearby junctions/plane intersections

Source: Created by Mitsubishi Research Institute

4. Review Meeting

4. Review Meeting

- A review meeting was set up for a discussion among location reference experts, information providers and users expected to be involved in future content distribution. The dates and agenda of the meetings are shown in the table below.

Table: Summary of review meeting

#	Date	Agenda
1	October 17, 2019	1. Establishment of the Study Group 2. Scope and Process of this Research and Study 3. Explanation on the status of international standardization and the content of proposed standards 4. Explanation of examples of CRP utilization in SIP-adus large-scale demonstration experiment 5. Review of the CRP Definition Method 6. Review of CRP Expression Methods
2	January 6, 2020	1. Definition of CRP (draft) 2. expression using CRP (draft)
3	March 4, 2020 (Conducted at a web conference)	1. Definition of CRP (draft) - How to install CRP (How to install with AP) - Location of CRP (What kind of intersection to install) - Definition of AP (What is the local product of AP)

Source: Created by Mitsubishi Research Institute

5. Future plans

5. Future plans

- In FY 2019, the following is carried out:
  - In ”1. Analysis and review of basic data related to CRP”, items to be defined as CRP and methods for specifying AP are shown.
  - In “2. Analysis and review of basic data concerning the expression method using CRP for the location of objects, etc.”, location expression method using CRP are reviewed with reference to ISO 17572-4.
  - In “3. Analysis and review of basic data concerning the alignment with existing linked maps, etc.”, items to verify consistency between existing location expression methods and the location expression method of CRP are shown.
- The following will be carried out after FY2019: examination of the maintenance and operation method of CRP, verification of the topics above, and examination of the content of the international standard proposal.
- Based on the verification, etc., the topics 1.~3. (examined in FY 2019) shall be reviewed as appropriate.