STUDY OF PREPARATION SPECIFICATIONS FOR 3-DIMENSIONAL TOPOGRAPHICAL MAP DATA FOR ROAD DESIGN IN JAPAN

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ABSTRACT: 3-dimensional CAD is known to be an effective and convenient method of designing roads. But road design in Japan makes little use of 3-dimensional CAD. This is due to the fact that Japanese topographical surveys provide 2-dimensional topographical map data, and height data have to be newly input at the road design phase. The reason for this phenomenon is that results of the survey phase and uses at the downstream phases are not linked. This study is intended to create a procedure for providing topographical map data including height data needed for 3-dimensional road design from the survey phase to the design phase. This paper reports on the achievements of the study of "3-dimensional topographical map data preparation specifications". Considering the topographical survey work load, height data will be provided to the new regulations, is desirable to minimize. Therefore, these preparation specifications describe the type of height data required by road design and priority of acquisition. In addition, we performed a survey of the needs of road designers and a fact-finding survey of topographical map data in Japan. Based on the results of these studies, these preparation specifications are organized. Additionally, we used case studies to verify the data reproducibility.

***Keyword**: The Design by 3-dimensional CAD, 3-dimensional Topographical Map Data, Road Design*

1. INTRODUCTION

The life cycle of public works projects in Japan consists of four phases. These are the survey, design, construction, and maintenance phases. The Ministry of Land, Infrastructure, Transport and Tourism (below called, "MLIT")has created the CALS/EC (Continuous Acquisition and Life cycle Support/Electronic Commerce) environment for the life cycle of public works projects. CALS/EC provides an environment for using a network to exchange, link, and share information in electronic form throughout the life cycle of a public works project. This is an initiative intended to improve productivity and reduce costs of public works projects [1].

To realize CALS/EC, the MLIT has created a data format for electronic products at each phase. Delivery of electronic products in compliance with this regulation is called electronic delivery. Among electronic products, drawings are reused at different phases.

The goal at the survey phase is to prepare electronic maps rather than drawings. To do so, the drawing data format applied is "Expanded DM (Digital Mapping) [2-3]". At the design phase and construction phase, the goal is to prepare drawings based on CAD (Computer Aided Design). To do so, the drawing formats applied are "SXF (Scadec [Standard for CAD Date Exchange in Japanese Construction Field] Exchange Format)" based on ISO 10303 STEP (Standard for the exchange of product model data)/AP202 [4-5]. In this way, in public works projects in Japan, the data format of drawings differs at each phase according to purpose. And all are 2-dimensional drawings.

And in Japan on the other hand, 3-dimensional CAD is known to be an effective and convenient method of designing roads. But road design in Japan makes little use of 3-dimensional CAD. The reason is that in the electronic topographical map data prepared at the survey phase in Japan (below called, “topographical map”), height data are not attached to most topography and features other than contour. So height data have to be newly manually input in the road design. In brief, results at the survey phase and uses at the downstream phases are not linked. This is a factor obstructing efforts to improve efficiency by applying 3-dimensional CAD.

This study is intended to create a procedure for providing topographical maps including height data needed for 3-dimensional road design from the survey phase to the design phase (Fig. 1).

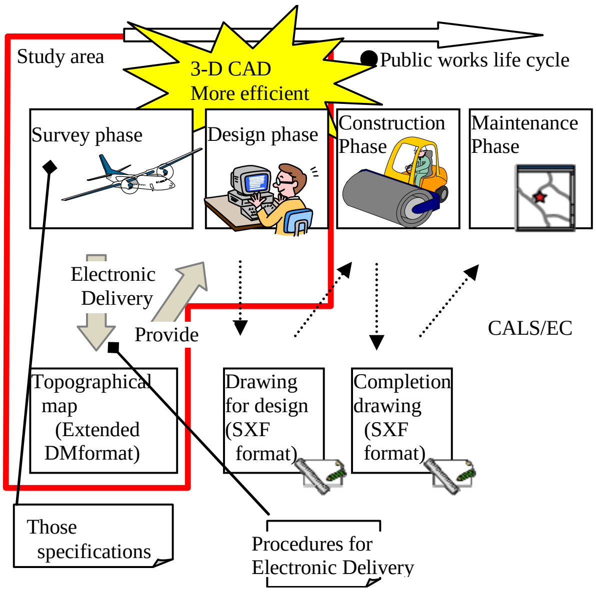


Fig. 1 Basic concept

This paper reports on the achievements of the following initiatives to create such a mechanism.

- Performing a survey of the needs of road designers and a fact-finding survey of topographical maps in Japan.
- Outlining 3-dimensional topographical map data preparation specifications prepared based on survey results.
- Verification of data reproducibility in compliance with preparation specifications.

2. Needs and fact-finding survey

2.1 Contents of the surveys

In order that 3-dimensional topographical maps are handed down from upstream phases at the design phase, the premise is that road designers use 3-dimensional topographical maps for road design. This study surveyed the needs for 3-dimensional topographical map in road design. And the types of height data needed for 3-dimensional road design were surveyed. The survey method was a questionnaire survey directed at 11 companies (12 people) of 15 companies which are members of the Japan Civil Engineering Construction Association.

To study these preparation specifications, it was necessary to clarify the actual state of topographical maps. This study analyzed topographical maps delivered to regional development bureaus of the MLIT in order to survey the types of topography or features for which height data have been acquired. This study analyzed 16 files.

2.2 Survey results

Figure 2 shows the survey results for question: “What kinds of work efficiently use 3-dimensional road design?” 100% of the respondents answered, “It is effective in designing the alignment of a road.” And 60% of the respondents answered, “It is effective in preparing design drawings (longitudinal drawings, lateral drawings, and plane drawings).” This result shows that designers think that 3-dimensional road design is an effective method.

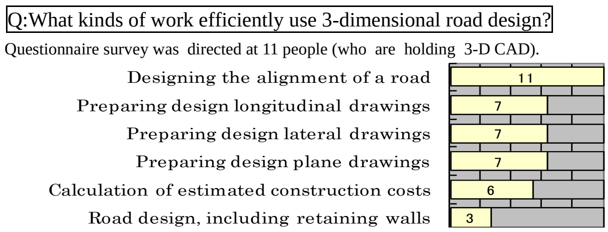


Fig. 2 Survey results of effective work

Figure 3 shows the survey results for the question, “Are there any problems with 3-dimensional road design?” More than 65% of the respondents answered, “It is a lot of work to prepare and to process the topographical data.” More than 55% of the respondents answered, "There is not enough topographical information." The survey results indicate that the problem is that the topographical maps used by the designers at this stage are not suitable for design use."

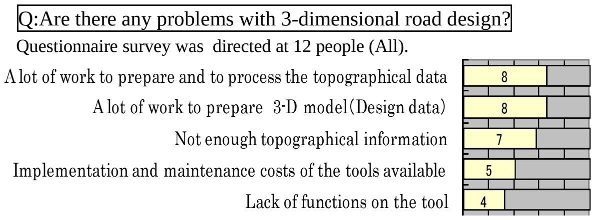


Fig.3 Survey results of problems with 3-D road design

Figure 4 shows the results for the question, "What kinds of height data are needed to perform 3-dimensional road design?" More than 90% of the respondents answered, "In addition to contour and elevation points, height data of a slope, road, sidewalk, railroad, bridge, and water areas." This survey result shows the types of height data which are specified in the specifications prepared.

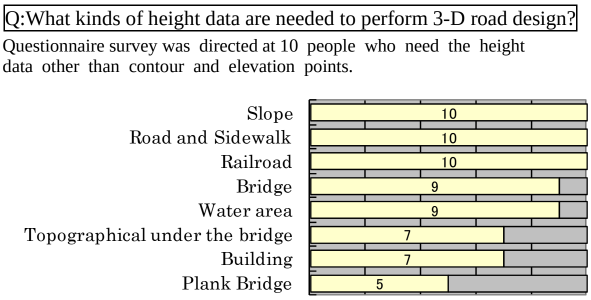


Fig.4 Survey results of kinds of height data

Figure 5 shows the results for the question, "What merits would it provide other than letting you perform 3-dimensional design more efficiently?" More than 80% of the respondents answered, "It would help me prepare explanatory documents which are easier to understand by doing 3-dimensional drawing." This survey result shows that they need to use 3-dimensional topographical maps not only for road design, but to prepare CG (Computer Graphics) and VR (Virtual Reality) to be used to explain projects to residents.

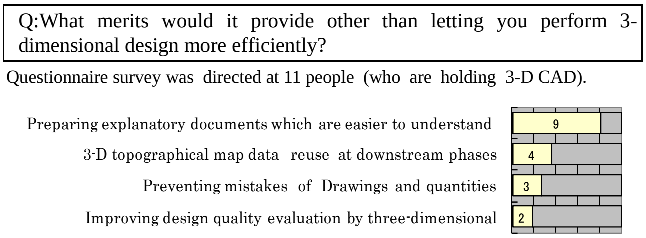


Fig.5 Survey results of merits in other than design

Table 1 shows the results of the analysis of topographical maps in 8 files at the survey phase. It reveals that, regardless of the category of survey results, problems with the types of topography and features for which height data were acquired include the fact that they are partially inconsistent and incomplete topographical maps (including cases of errors).

Table 1 Results of the analysis of topographical maps

	topographical survey classification	The types of topography or features for which height data was acquired (above remarks)
1	Digital Mapping	Elevation points, Contour
2	Total Station	All (other than numerical and symbols)
3	Total Station	Elevation points, Contour, Stake
4	Total Station	N/A (incomplete)
5	Digital Mapping	Elevation points, Contour, stake
6	Total Station	Contour(This data has not been filled for the type of Geographic element Classification)
7	Total Station	N/A (Only title panel)
8	Digital Mapping	Elevation points, Contour

2.3 Considerations

The survey results in Figure 2 or Figure 5 show that 3-dimensional road design is an effective method, and that road designers will use 3-dimensional topographical maps to design the alignments of roads, to prepare design drawings, and to prepare CG or VR. It is also thought that the problem that the topographical maps abstracted from the results of the survey in Figure 3 are unsuitable for road design use, and the challenge that the types of topography or features for which height data were acquired in topographical maps abstracted from the survey results on Table 1 are inconsistent and include errors, can both be overcome by enacting and complying with topographical map preparation specifications suited for design use.

3. Outline of the preparation specifications

This study considered 3-dimensional topographical map data preparation specifications based on survey results. “Expanded DM” was adopted as the data format for the survey phase. This data format can retain height data. Thus, as the 3-dimensional topographical map data format, “Expanded DM” was adopted as it was for 2-dimensional topographical map data. For this reason, in this specification, a data format is not newly stipulated.

And the priority of acquiring height data was categorized according to use at the design phase (Table 2). It is possible to minimize the quantity of survey work by stipulating the types of height data which should be acquired according to use. Level 1 stipulates the types of height data deemed necessary for 3-dimensional road design. Based on the survey results in Figure 2, it is stipulated that its uses be, not only alignment design, but preparing design drawings (longitudinal drawings, lateral drawings, etc.) and calculating the quantity of earthwork. And based on the survey results in Figure 5, it is stipulated that it be used to prepare CG or VR to explain projects to residents.

Table 2 The priority of acquiring height data

acquisition level	Use at the design phase
Level 1	3-dimensional road design ・ Alignment design, ・ preparing design longitudinal drawings, lateral drawings and plane drawings ・ Calculating the quantity of earthwork. Preparing CG or VR (To explain projects to residents.)
Level 2	Preparing CG or VR (Shape representation of the building in addition to level 1)
Level 3	Preparing CG or VR (Shape representation of all topography and features.)

The more topography and features for which height data are acquired, the more feasible CG or VR become. But an increase of the number of topography and features for which height data are acquired also increases survey work. So at level 1, height data required for road design are also used to prepare CG or VR of roads and topography considering the quantity of survey work. At level 2, only height data for buildings which stand along roadsides in large numbers were acquired in addition to level 1, considering the feasibility of CG or VR and the quantity of survey work. At level 3, height data for all topography and features which can be acquired are acquired considering feasibility without accounting for the quantity of survey work.

Table 3 shows types of height data for each acquisition level required by this preparation specification. These preparation specifications stipulate the types of height data which should be acquired for the types of topography and features which are acquired in 2 dimensions considering the survey work load. The aerial surveying in the survey phase is 3-dimensional (X, Y, Z) measurement. Thus the coordinates X and Y are measured as in the past and included in topographical maps. In addition, height data which have been measured but not been used (Z coordinate) is included in topographical maps according to the table. Thus, the quantity of survey work does not rise. Under “Road edge (category code: 2101)” at level 1 for example, in accordance with Reference [2], the plotting system performs 3-dimensional measurement of road width based on lines as before. In the past, it was included in topographical maps as 2-dimensional alignments. But in conformity with this preparation specification, height data are retained and included in topographical maps as 3-dimensional lines.

5. Verification of reproducibility of data

5.1 Contents of the verification

A 3-dimensional topographical map is used to prepare design drawings (longitudinal drawings, lateral drawings, etc.) or to prepare CG and VR. So the reproducibility of 3-dimensional CAD was verified. Specifically, it was verified that 3-dimensional CAD can represent the shapes of land forms such as roads and man-made structures such as buildings as anticipated. This verification was done using existing 3-dimensional CAD.

Table 3 Types of height data for each acquisition level (Abridgment)

Specifications of "Extended DM (Digital Mapping)" format						This study's specifications		
Geographic element Classification				shape acquisition	shape Class	Heigaht data 「○」 is Essential 「Op」 is Option		
large	small	code	item			Level 1	Level 2	Level 3
Traffic facilities	Road	2101	Road edge	Edge line	Line	○	○	○
		2102	Light car road	Centerline	Line	○	○	○
		2103	Foot path	Centerline	Line	○	○	○
	Road facilities	2203	Road Bridge	Edge line	Line	○	○	○
				Bridge railing	Surface	Op	Op	○
				Bridge pier	Line	Op	Op	○
		2205	Foot bridge	Centerline	Line	Op	Op	○
		2206	Plank Bridge	Edge line	Line	○	○	○
				Bridge pier	Line	Op	Op	○
		2211	Pedestrian crossing bridge	Circumference	Surface	Op	Op	○
		2213	Sidewalk	Boundary with road	Line	Op	Op	○
		2219	Road tunnel	Shape Symbol	Surface・Line Direction	Op	Op	○
		2221	Bus Stop	Point	point	Op	Op	○
		2222	Traffic Island	Circumference	Surface	Op	Op	○
		2226	Divider Strip	Circumference	Surface	Op	Op	○
		2227	Concrete block	Edge line	Line	Op	Op	○
		2231	Non-operculated U Gutter border	Edge line	Line	Op	Op	○
		2233	L Gutter border	Edge line	Line	Op	Op	○
		2235	Street inlet	Circumference	Surface	Op	Op	○
		2236	Tree inlet	Circumference	Surface	Op	Op	○
		2239	Tree Planting	Point	Point	Op	Op	○
		2242	Traffic sign (information)	Point and direction	Direction	Op	Op	○
		2246	Signal Lamp Pole	Point and direction	Direction	Op	Op	○
		2253	Curve Mirror	Point	Point	Op	Op	○
		2255	Distance（km）	Point	Point	Op	Op	○
		2256	Distance（m）	Point	Point	Op	Op	○
	Railroad	2301	common railroad	Rail	Line	○	○	○
		2303	Street car	Rail	Line	○	○	○
		2304	Monorail	Circumference	Line	○	○	○
		2309	Railroad under construction	Circumference	Surface	Op	Op	○
	Railroad facilities	2401	Rail road Bridge（raised）	Edge line	Line	○	○	○
				Bridge pier	Line	Op	Op	○
		2411	bridge over railroad	Circumference	Surface	Op	Op	○
		2412	UndergroundPassage	Edge line	Surface	Op	Op	○
		2419	Railroad tunnel	Shape symbol	Surface・Line Direction	Op	Op	○
		2421	Stop(Street car)	Circumference・point	Surface・Point	Op	Op	○
		2424	Platform	Circumference	Surface	Op	Op	○
Building and all that jazz	building	3001	Common building	Circumference	Surface	Op	○	○
				Court	Surface	Op	Op	○
				Ridge line	Line	Op	Op	○
				Floor Line	Line	Op	Op	○
				Outside stairs	Surface	Op	Op	○
				Step line	Line	Op	Op	○
				Canopy top	Surface	Op	Op	○
Small object	Small Object (other)	4201	Gravestone	Circumference・point	Surface・Point	Op	Op	○
		4211	PublicPrivate picket	Point	Point	Op	Op	○
		4215	Fire hydrant	Point	Point	Op	Op	○
		4236	Electric tower	Circumference・point	Surface・Point	Op	Op	○
		4237	Illuminating light	Point	Point	Op	Op	○
		4265	Power line	Centerline	Line	Op	Op	○
Water area	Water	5106	Shore line	Watershed line	Line	○	○	○
	Structure	5202	Steel Concrete Pier	Circumference	Line	Op	Op	○
		5211	Breakwater	Vertical covering	Line	Op	Op	○
				Top edge line	Line	Op	Op	○
				Bottom edge line	Line	Op	Op	○
		5212	Revetment Covering	Vertical covering	Line	○	○	○
				Top edge line	Line	○	○	○
				Bottom edge line	Line	○	○	○
		5228	Water Gate	Circumference・point	Surface・Point	Op	Op	○
		5255	Distance	Point	Point	Op	Op	○
		5256	Water gauge	Point	Point	Op	Op	○
Land-use and all that jazz	Slope	6101	Artificial Slope	top edge line	Line	○	○	○
				bottom edge line	Line	○	○	○
		6102	Bank	top edge line	Line	○	○	○
				bottom edge line	Line	○	○	○
		6121	slope protection mesh	Circumference	Surface	○	○	○
	Enclosure	6130	Fence	Centerline	Line	Op	Op	○
		6132	Protective fence	Guardrail	Line	Op	Op	○
				Post	Line	Op	Op	○
	Vegetable	6301	Border vegetable	Center	Line	Op	Op	○
		6302	Cultivated land	Center	Line	Op	Op	○
Geography and all that jazz	Contour	7101	Contour (Index)	Contour	Line	○	○	○
		7102	Contour (Inter)	Contour	Line	○	○	○
	DeformedLand	7201	Soil cliff	Top edge line	Line	○	○	○
				Bottom edge line	Line	○	○	○
		7203	Steep slope	Top edge line	Line	○	○	○
				Bottom edge line	Line	○	○	○
		7304	Public control points （triangulation point）	Point	Point	○	○	○
		7305	Public control points （benchmark Point）	Point	Point	○	○	○

The trial data used for the verification was prepared based on the results of aerial photographic surveying delivered to the regional development bureaus of the MLIT. The precision of the original data is 1/500 scale. The trial data was prepared by adding height data to the original data. (Fig. 6)

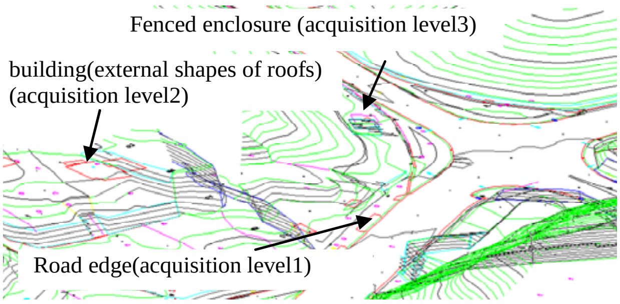


Fig.6 Trial data

5.2 Results of the verification

Table 4 shows the results of the verification. As shown in the table, A and B type 3-dimensional CAD can represent accurate shapes as was anticipated based on the trial data. A and B type 3-dimensional CAD can represent shapes distinguishing contours and road edges. Thus, road edges impact the representation of shapes. On the other hand, C type 3-dimensional CAD cannot distinguish road edges from contours. Thus it is not different from conventional data.

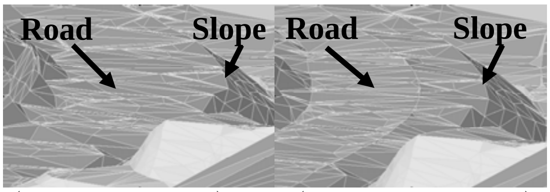
And A and C type 3-dimensional CAD can prepare TIN (Triangulated Irregular Network). But it does not distinguish between topographical height data and man-made structure height data. For this reason, height data about man-made structures were represented as part of topography. And B type 3-dimensional CAD cannot represent man-made structures in 3-dimensions. Thus, it could not be confirmed that buildings and other man-made structures can be effectively represented by all types of 3-dimensional CAD.

Figure 7 shows representation of 3-dimensional shapes of conventional data and of trial data. The left is conventional 3-dimensional shape representation, while the right is 3-dimensional shape representation by trial data. Height data of conventional data include contour and control points.

The trial data add height data to road edges. The figures were prepared using type A 3-dimensional CAD. The figure shows that the trial data can represent shapes more accurately than conventional data.

Table 4 Results of verification of reproducibility

Verification item / Using 3-D CAD	Represent accurate Shapes of roads (acquisition level1)	Shape representation of buildings (acquisition level2,3)
A	【effective】 3-D CAD can represent accurate shapes By road edges.	【Not be confirmed】 It does not distinguish between topographical height data and man-made structure height data.
B		【Not be confirmed】 3-D CAD cannot represent man-made structures in 3-dimensions.
C	【Not be confirmed】 3-D CAD cannot distinguish road edges from contours.	【Not be confirmed】 It does not distinguish between topographical height data and man-made structure height data.



（Contour and Control points）　（Adds height data to road edges）

Fig. 7 Representation of 3-dimensional shapes

5.3 Considerations

The verification results in Table 4 show that data which conforms with this preparation specification can accurately represent topography such as present roads etc, revealing that it is possible to effectively use 3-dimensional CAD. Buildings and other man-made structures could not be confirmed by effectively using 3-dimensional CAD. This can be resolved by the ability to distinguish height data of topography and of man-made structures. The data format in this preparation specification is “Expanded DM”, and “Expanded DM” categorizes each kind of data such as 2-dimensional coordinate data or annotation data, as “actual data categorization” in “numerical topographical map data file specifications”. So this was resolved by supplementing the actual data category codes with “3-dimensional coordinate codes (acquisition by measuring height of surfaces of topography)” and “3-dimensional coordinate records (acquisition by measuring height of other than surfaces of topography, such as man-made structures etc.)” This means it is now possible to distinguish between data which can be used to represent topographical shape data and data which cannot be used to represent topographical shape data.

8. Conclusions

This study was undertaken to create a mechanism to provide information needed for 3-dimensional road design from the survey phase to the design phase. This paper reports on 3-dimensional topographical map data preparation specifications: specifically, on a survey of the needs of road designers and a fact-finding survey of topographical maps in Japan. It also reports on preparation specifications based on the results of these surveys, and the verification of the reproducibility of data according to the preparation specifications. Preparing topographical maps according to this preparation specification will reduce the work of entering height data for 3-dimensional road design. This means that the work of 3-dimensional road design will be performed with increasing efficiency. And providing road designers with 3-dimensional topographical maps is counted on to effectively improve quality by, for example, preventing posting errors, maintaining posting precision, and permitting the representation of topography too difficult to represent 2-dimensionally.

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