STEEL BRIDGE INFORMATION DELIVERY MODEL FOR EARNED VALUE MANAGEMENT (EVM)

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Agenda

1. INTRODUCTION AND EXISTING STUDIES
2. IDM AND IDE
   - Acts, Guidelines and Standards
   - Information Delivery Manual (IDM) for Steel Bridge Project
   - Information Delivery Elements (IDE)
3. SB-IDM AND EVM
   - Quantity Survey and Cost Estimation
   - Earned Value Management (EVM)
4. CONCLUSIONS

1. INTRODUCTION AND EXISTING STUDIES

- Building Information Modeling (BIM) has been widely adopted in the building industry, and its established methods and technologies show enormous potential in benefiting the civil engineering industry.

- Through the rapid growth of BIM in the civil engineering industry, mandatory use in government procurements, and utilization for improving productivity, the importance of 3D product models in the civil engineering industry is becoming increasingly prominent.

- For government procurements in Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) launched a trial project called Construction Information Modeling/Management (CIM) in 2014.

1. INTRODUCTION AND EXISTING STUDIES

The purpose of this paper is to propose for government organizations to implement Earned Value Management (EVM) using 3D product models.

- Firstly, the government contract process in line with the acts, guidelines and standards are mapped using an Information Delivery Manual (IDM).
- Next, in order to implement EVM using 3D product models, it is necessary to organize the relationship between the Work Package (WP), the minimum units of the Work Breakdown Structure (WBS), and the government contract units. For this reason, 3D product models with government contract units are defined as Information Delivery Elements (IDE).
- Finally, by using the Steel Bridge Information Delivery Model (SB-IDM), which has been integrated with the IDE of the steel bridge structure, the usability of EVM is evaluated.

1. INTRODUCTION AND EXISTING STUDIES

EVM

- The American National Standards Institute/Electronic Industries Alliance (ANSI/EIA) approved the Earned Value Management Systems (EVMS) standard in June 1998.

- EVMS is a project management system that helps project managers measure, analyze, and manage performance-related factors for projects such as costs and schedules through a comparison and analysis of the Planned Value (PV), Earned Value (EV), and actual costs (Fleming and Koppelman, 2010).

1. INTRODUCTION AND EXISTING STUDIES

EVM with BIM

- Studies on EVM in the civil engineering industry involving 3D product models include a study by Yabuki et al. (2004) on the development of construction management systems for cut and fill earthworks based on 4D-CAD and EVM.
- The study aims to streamline and improve construction management and implement progress payment methods. In addition, a study by Mohamed et al. (2014) implementing an EVM concept on BrIM, which is a method for the 3D product modeling of bridges developed by the Federal Highway Administration (FHWA, 2016), and which investigates a system for controlling costs and scheduling construction works.

However, there are no existing studies focusing on the relationship between 3D product models and government contract units/project management.

2. IDM AND IDE

Acts, Guidelines and Standards

- The MLIT performs a quantity survey prior to procuring a project using the “ceiling price,” which is set in accordance with the “Laws and regulations on the procedure for determining the contract amount.”

- The government contract unit standardization is a system tree diagram which subdivides diverse construction items in a standardized manner and consists of seven hierarchical layers (levels). units.

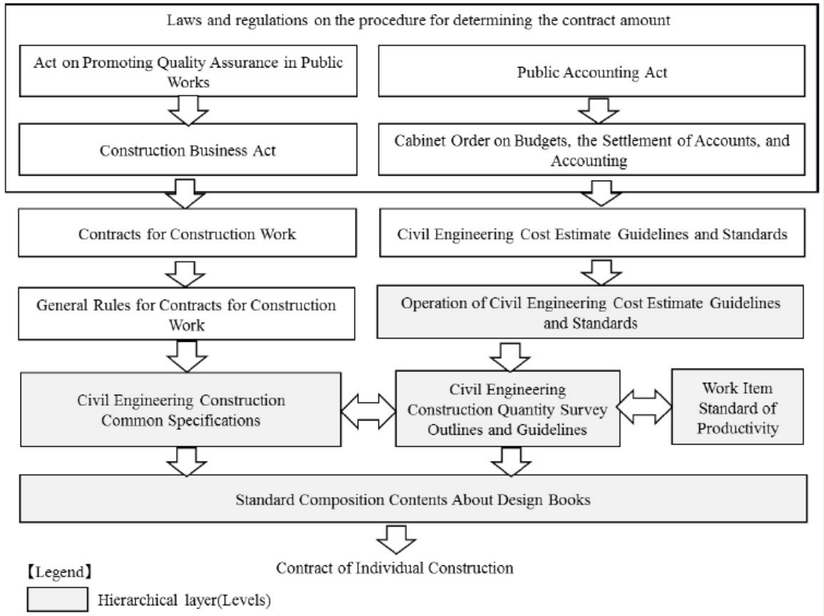

Figure 1. Acts, Guidelines and Standards regarding government contracts in Japan

Table 1. Hierarchical layers (levels) for government contract units

Level	Identifier	Content
Level 0	Business Classification	Classification based on budgeting system and business operations.
Level 1	Construction Classification	Level 0 divided to address work order lot and client
Level 2	Work Item	General term for a series of operations required to construct certain structural elements (part of Level 1 elements).
Level 3	Class	Level classification to connect Levels 2 and 4 to clarify the overall standardization system.
Level 4	Subdivision	Level to indicate units and contract units that are basic derivative units or temporary structure units of the relevant construction work.
Level 5	Specification	Objective information on materials, standards, and contract-specified conditions for Level 4 configuration components.
Level 6	Quantity Survey Element	Level 4 cost calculation components generally not disclosed in contracts.

2. IDM AND IDE

IDM for Steel Bridge Project

- The IDM aims to provide an integrated reference for process and data required by BIM.
- The IDM comprises “Process Maps” and “Exchange Requirements,” which can be described as layers within the architecture.
- Figure 2 shows IDM for the design, quantity survey, and cost estimation stages of a steel bridge project.

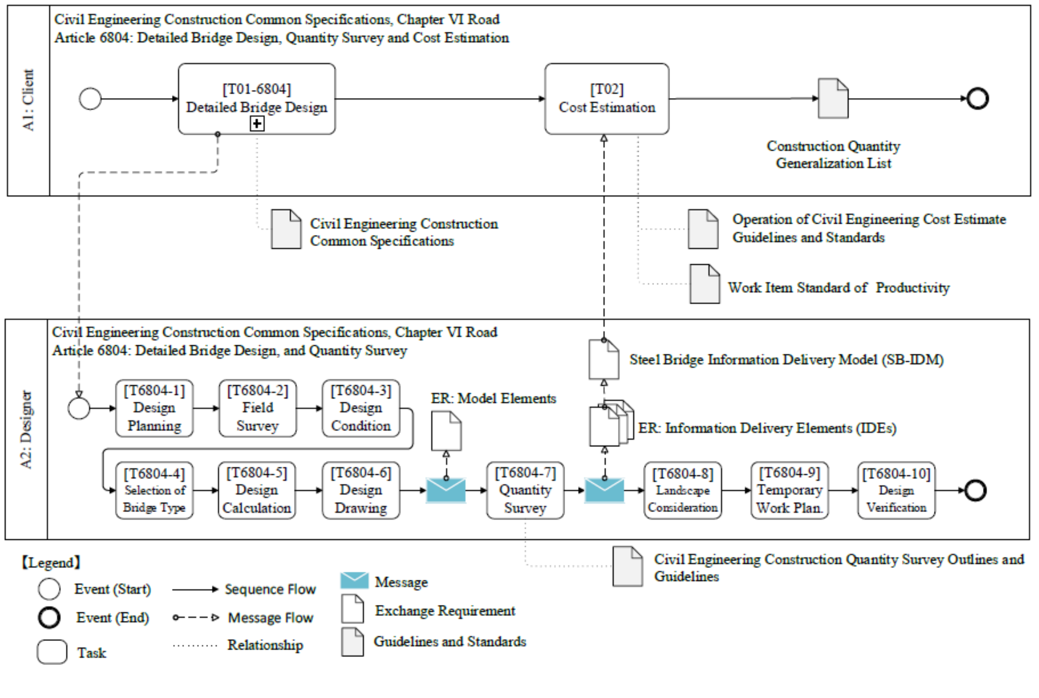

Figure 2. IDM for the design, quantity survey, and cost estimation stages of a steel bridge project

2. IDM AND IDE

IDE

- In order to implement EVM using 3D product models, it is necessary to organize the relationship between the WP, the minimum units of the WBS, and the government contract units.

  - The government contract units standardized in Japan define;
  - Level 4 defines indicate units.
  - Level 5 defines materials and specifications and conditions disclosed in contracts.
  - Level 6 defines component elements for cost calculations.

2. IDM AND IDE

IDE

- IDE of the steel bridge as an exchange requirement are shown in Figure 3.

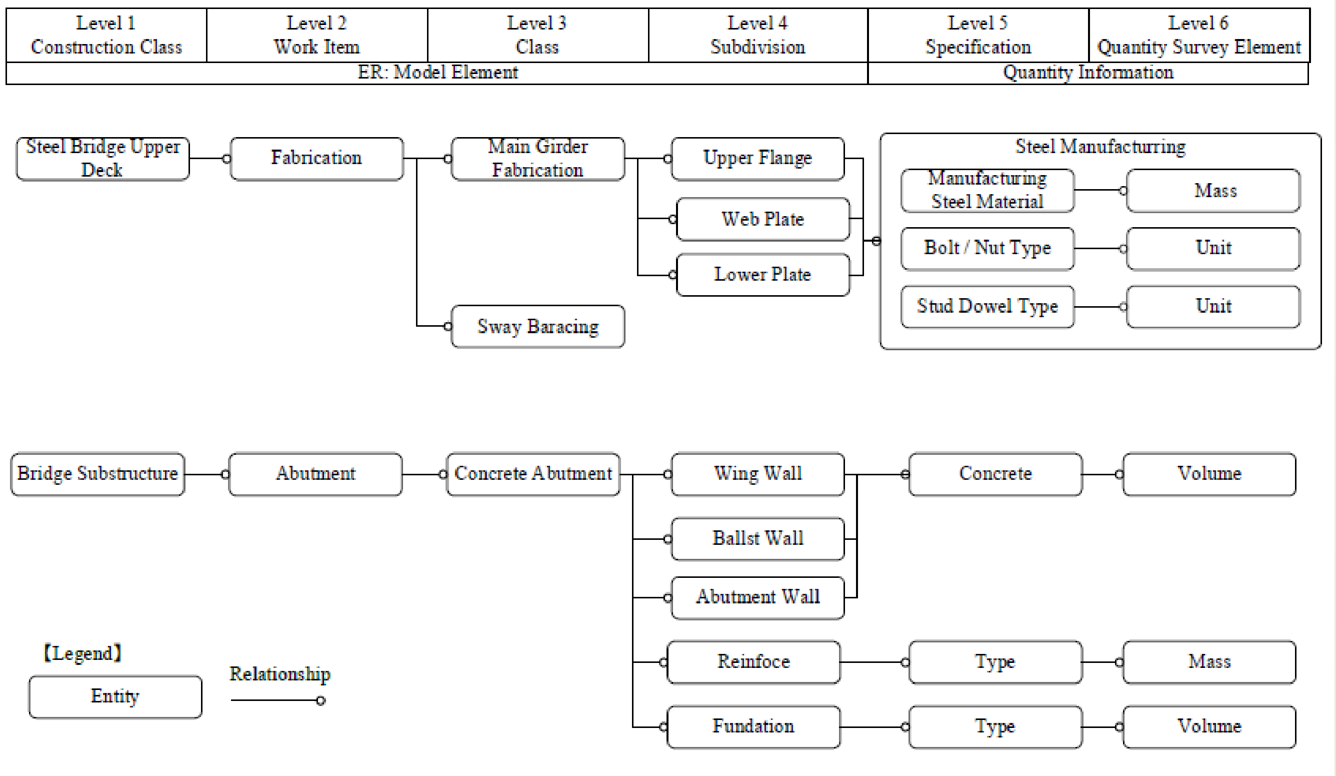

Figure 3. IDE for a steel bridge

2. IDM AND IDE

IDE

- IDE equipped with Level 4 and Level 5 information can be used to quantify work items in accordance with the Quantity Survey Items and Classification Conditions .
- Figure 4 shows a class diagram for the IDE linked with the EVM.

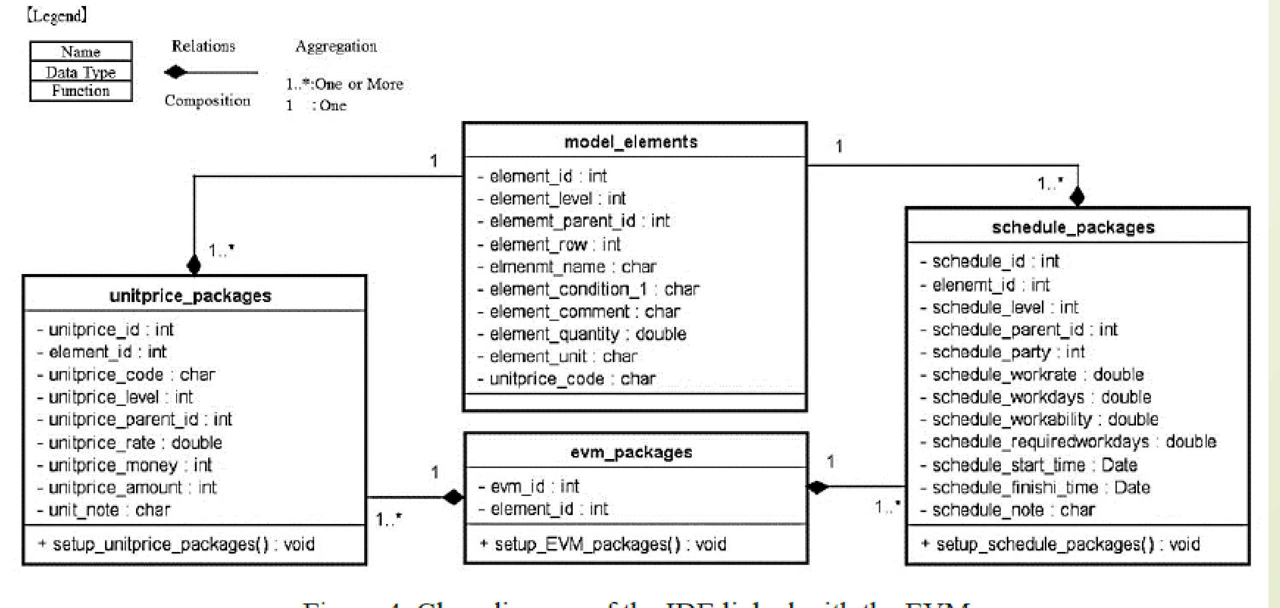

Figure 4. Class diagram of the IDE linked with the EVM

3. SB-IDM AND EVM

- The potential of EVM coordination was evaluated by outputting the government quantity survey data obtained from the SB-IDM, which has integrated the IDE of the steel bridge structure generated in accordance with the newly defined data structure.
- The newly defined SB-IDM was developed using Autodesk Revit 2018.
- Table 2 shows design conditions of the steel bridge upper deck used for this evaluation.

Table 2. Design conditions

Format	Unit	Simple Plate Girder
Bridge Length	m	122.20
Girder Length	m	40.60@3
Skew Angle	Degree	0°
Live Load		B Live Load
Large Vehicle Traffic Volume	Number of Vehicles / Day / Direction	2000 or greater
Slab Thickness	mm	250
Design Lateral Seismic Coefficient		Kh = 0.25

3. SB-IDM AND EVM

- Figure 5 shows components of the main girder and connection materials.
- Using this information, work items can be quantified at a per-material basis. In quantity surveys by government organizations, the manufacturing and material costs, as well as the assembly time, welding time, and temporary assembly time, are calculated based on the weight of the steel plates per material type after quantifying the work items.

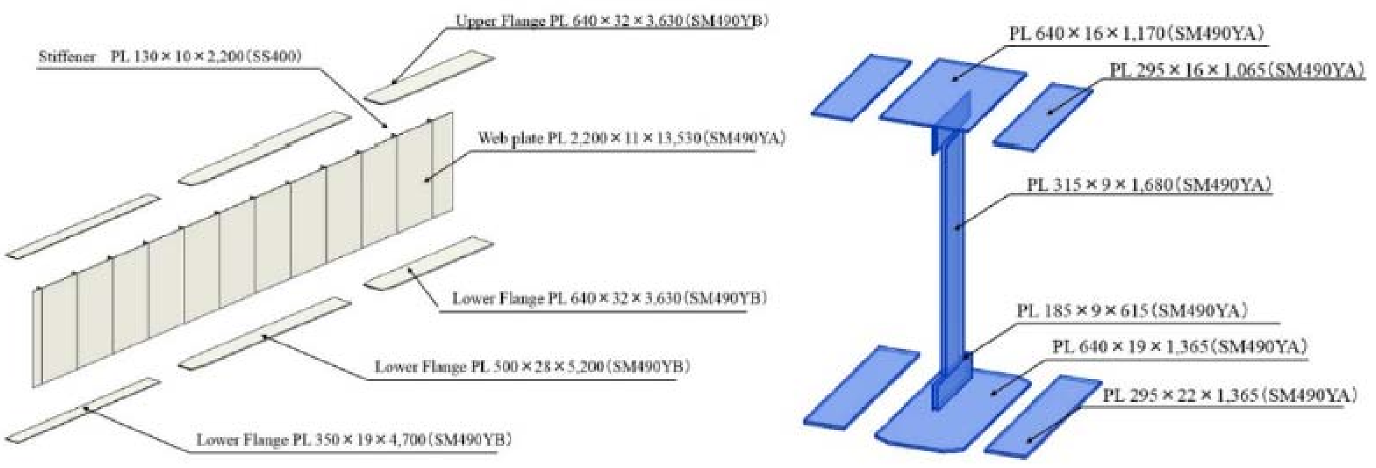

Figure 5. Main girder components and connection member components

3. SB-IDM AND EVM

- When performing this process, the assembly time shall be calculated using a block length of the component materials. The total length of welding required in quantity surveys by government organizations can be calculated by predefining the welding edges of each component material.
- Figures 6 show the SB-IDM with IDE components in place.

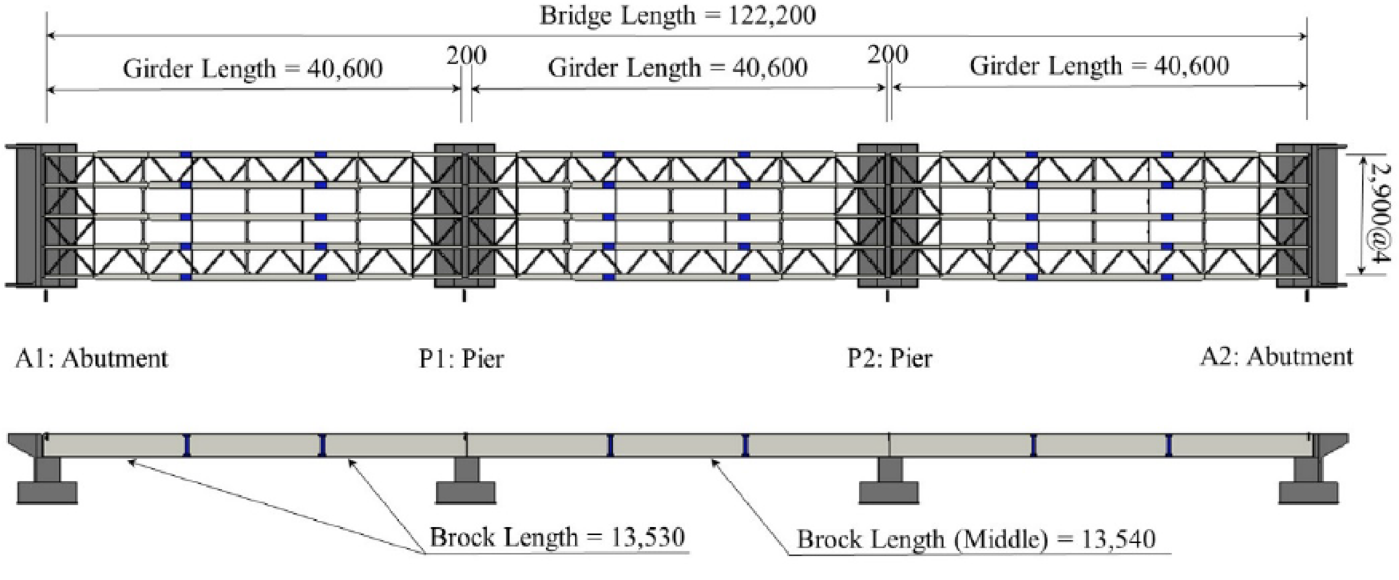

Figure 6. SB-IDM

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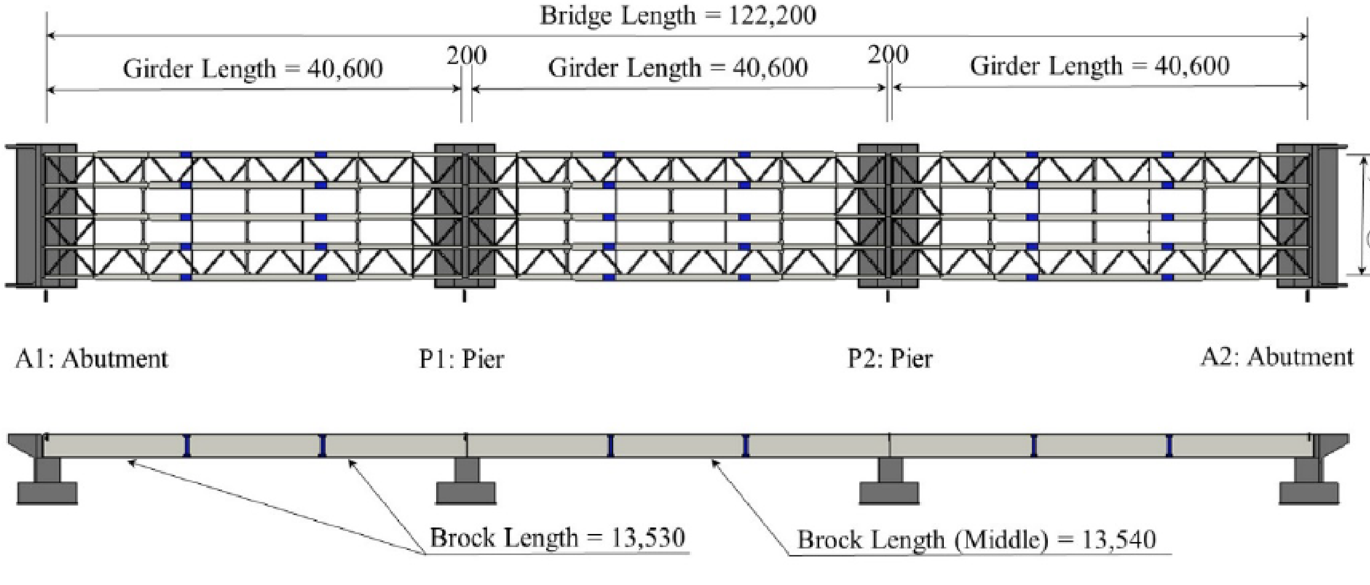

Figure 6. SB-IDM

3. SB-IDM AND EVM

Quantity Survey and Cost Estimation

- A quantity and cost estimation summary (Table 3) was generated using the quantification obtained from the SB-IDM.

- For the quantity and cost estimation summary, quantity and cost information from the IDE produced in Revit were exported to a CSV file.

Table 3. Quantity and Cost Estimation Summary

(Japanese yen)

		Specification	Unit	Price	Quantity	Amount
(1) Material costs						
	Steel	SM490YB	t	131.0	62.8	8,227,000
		SS400	t	113.3	13.4	1,518,000
	Bearing	A1, A2	Piece	2400.0	4.0	9,600,000
		P1, P2	Piece	2300.0	4.0	9,200,000
	H. T. B.	S10T	t	220.0	1.4	308,000
	Sub total					28,853,000
(2) Manufacturing costs			Person	26.1	1458.0	38,054,000
(A) Direct cost		(A)=(1)+(2)				66,907,000
(B) Indirect cost		(B)=(A)×38.0%				14,460,000
(C) Sub total		(C)=A+B				81,367,000
(D) Management cost (factory)		(D)=C-(2)				52,514,000
(E) Manufacturing total cost		(E)=C+D				133,882,000
	Transportation cost	30km (Tokyo)	t	7.0	76.2	533,000
	Temporay work cost	Mobile crane	t	56.0	76.2	4,267,000
	(F) Sub total	(F)				4,801,000
(G) Temporary work cost		(G)=F×17.00%				816,000
(H) Expenses rate		(H)=F×14.34%				688,000
(I) Construction cost		(I)				6,305,000
(J) Management cost (site)		(J)=I×30.98%				1,953,000
(K) Sub total		(K)=I+J				8,258,000
(L) General management cost		(L)=K×9.54%				788,000
Total		E+K+L				142,928,000

3. SB-IDM AND EVM

EVM

- The construction procedure was to simultaneously construct the A1 and A2 abutments during the steel bridge manufacturing period and to construct the P1 and P2 piers sequentially after completion.
- The steel bridge will be constructed from the A1 side, and the construction period is set to 9 months, avoiding the flood period. In addition, the workable days of each month are unified on the 20th.
- Table 4 shows the results of the calculation of various EVM parameters by inputting data for 5 months for verification.

Table 4. Results of calculation of various EVM parameters

Work Item	Direct cost	Work days	Sep.	Oct.	Nov.	Dec.	Jan.	Notes
Manufacturing steel bridge	66,907	132	10,137	10,137	10,137	10,137	10,137	Table 3. (A)
Temporary work cost	4,801	30						Table 3. (F)
A1: Abutment	4,659	51	1,827	1,827	1,005			
P1: Pier	4,311	48				1,796	1,796	
P2: Pier	4,311	48						
A2: Abutment	4,659	51	1,827	1,827	1,005			
Planned Value (PV) [Month]			13,792	13,792	12,147	11,934	11,934	
Planned Value (PV) [Accumulation]			13,792	27,583	39,730	51,664	63,598	
Earned Value (EV)			13,200	27,100	39,800	52,500	64,900	
Actual Cost (AC)			14,400	28,600	40,500	50,800	59,700	
Schedule Performance Index (SPI)			0.96	0.98	1.00	1.02	1.02	
Cost Performance Index (CPI)			0.92	0.95	0.98	1.03	1.09	
Estimate at Completion		(EAC1)	97,798	94,610	91,225	86,745	82,465	SPI≧1
		(EAC2)	101,535	95,787	91,136	86,173	82,008	SPI<1
Time Estimate Completion		(Tec1)	373	364	360	357	358	SPI≧1
		(Tec2)	390	366	359	354	349	SPI<1

3. SB-IDM AND EVM

EVM

- Figure 7 shows a graph of the vertical axis with the SPI and the horizontal axis with the CPI to evaluate the work progress by EVM.
- In the case of the data for verification, the start month indicates the area of low cost/slow process in the lower left where the EV falls below the PV through the confirmation of site construction conditions and preparation of materials and equipment.
- The predicted completion period (Tec 2) will be 390 days, which can be expected to be extended by 30 days from the initial construction period.

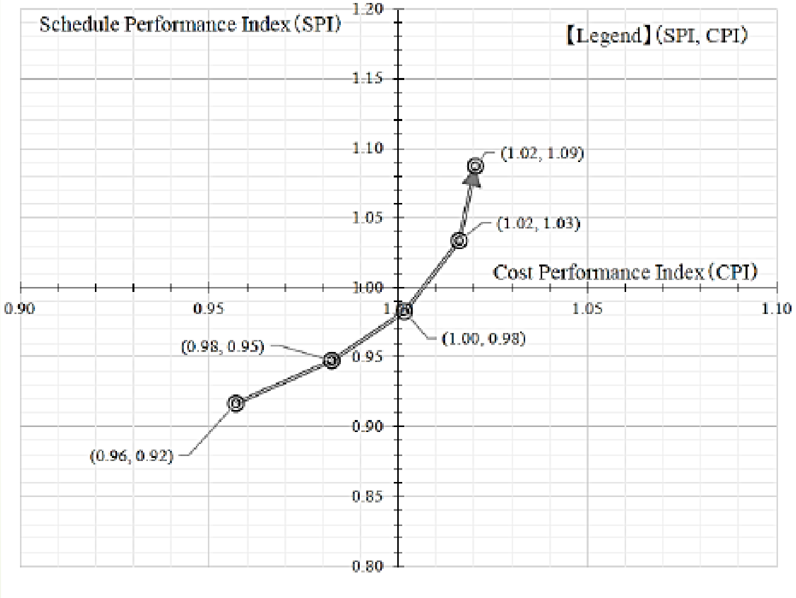

Figure 7. SPI and CPI

4. CONCLUSIONS

The research presented in this paper has purpose for EVM using 3D product models. The key benefits of the SB-IDM that have been developed include:

- Organized in IDM include the acts, guidelines and standards that must be followed in order to use 3D product models in the civil engineering industry;
- The SB-IDM which are integrated the IDE are defined to use 3D product models with government contract unit.
- EVM based on the government procurement quantity can confirm the progress of construction objectively and quantitatively;

However, the government procurement system in japan, in principle, it is a design-bid-build. When applying the method proposed in this report at the time of construction, it is need to be checked the SB-IDM according to the temporary equipment of the construction method and the construction by the contractor.