Application of Building Information Modeling in the Construction of the Parakan Lima Bridge in Purwakarta Regency

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ABSTRACT

Parakan Lima Bridge was built by the Purwakarta Regency Government to improve transportation access. In this study, BIM was applied to the construction of the Parakan Lima Bridge by creating the bridge 3D model using Tekla Structures software, which can automatically generate the Quantity Take-Off of the project. The Quantity Take Off resulted from model were used as the basis for calculating the Cost Estimation Plan and project scheduling. The Cost Estimation Plan calculation was carried out by compiling the AHSP in Microsoft Excel, and the scheduling is created using Microsoft Project and Microsoft Excel software. The results of the 3D modeling, scheduling, and Cost Estimation Plan are then simulated in 4D and 5D using Navisworks software. To support the preparation of implementation methods and visualization during presentations, bridge animations are created using Sketchup and Lumion software, as well as Augmented Reality displays using Augin software. The result of this study shows that the cost estimate for the construction of the Parakan Lima Bridge was Rp 13,619,902,175 with an estimated project duration of 223 days, starting on May 23, 2022, and ended on December 31, 2022.

Keyword: BIM, Cost Estimation Plan, Project Scheduling, AHSP

1. INTRODUCTION

The Parakan Lima Bridge is a construction project in the form of a bridge located in Parakan Lima Village, Jatiluhur District, Purwakarta Regency, West Java, which plays a role in facilitating community transportation access [1]. Transportation itself is one of the pillars of national development [2]. This Warren-type bridge has a span of 60 meters and a width of 7 meters. Figure 1 is an image of the Parakan Lima Bridge obtained from field documentation.

Figure 1 Parakan Lima Bridge

Every construction project requires management or administration that regulates the planning, implementation, and control of the resources used to produce a project that meets expectations [3]. To support the achievement of maximum project objectives, a technology has been developed in the field of construction based on the concept of Building Information Modeling (BIM). BIM is a digital representation of construction that can be created to visualize the actual form of a building, containing information about planned building elements in 3D to 7D variations [4]. The implementation of BIM (maturity level) in a project organization is currently divided into four levels, namely level 0, level 1, level 2, and level 3 [5]. In completing this research, BIM was applied up to level 5D in the implementation of the Parakan Lima Bridge project, which aimed to facilitate the reading of construction information, three-dimensional model integration, scheduling, and cost estimation. Work information can be visualized more comprehensively and easily understood by all project parties [6].

2. METHODS

The methods used to complete this research can be seen in the flowchart in Figure 2. The stages carried out in this study included collecting data in the form of shop drawings, special specifications for bridges, as well as the Parakan Lima Bridge Cost Estimation

Plan and Weekly Schedule. The data was obtained through the Purwakarta Regency Public Works and Spatial Planning Agency (DPUTR) to be used as a reference for the stages of completing the research.

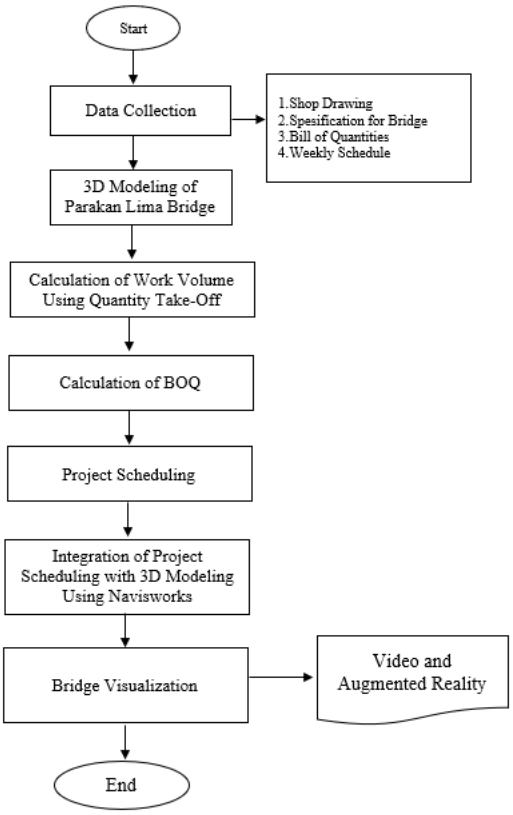

Figure 2 Research Flowchart

2.1 3D Modeling of the Parakan Lima Bridge

The three-dimensional modeling created includes the bridge structure and accessories using Tekla Structures software. The 3D modeling was carried out by modeling the grid, objects or structural elements and bridge accessories, and was also equipped with reinforcement and connection details. After the modeling was completed, the shop drawings and special specifications were checked again. The 3D modeling results can also produce 2D drawings, so there is no need to redraw to get good results.

2.2 Calculation of Work Volume with Quantity Take-Off

The results of bridge modeling and detailing can then be used to calculate the volume of work using the Quantity Take-Off feature in Tekla Structures software to automatically calculate the volume of work according to the material specifications for each part of the bridge. The results of this Quantity Take-Off can be presented in more detail for each part in the form of a Quantity Take-Off Report.

2.3 Calculation of the Bill of Quantities

The Cost Estimation Plan is the product of the Unit Price of Work (HSP) and the volume of work. The volume of work has been successfully obtained. Next, a Work Breakdown Structure (WBS) for the bridge project is created. After the WBS is created, each work item is broken down into a Work Method Statement (WMS) and animated using Sketchup and Lumion software, resulting in a clearer description of the bridge implementation method.

The next step is to determine the HSP based on the Unit Price Analysis (AHSP) compiled using Microsoft Excel software. In compiling the AHSP, it is necessary to determine the unit price for each labor, material, and equipment used. In this case, the 2021 Bekasi City Activity Unit Price is used as a reference. After the unit prices are determined, the AHSP can be compiled by referring to the Appendix to Permen PUPR No. 1 of 2022: Part III of the Road Construction Sector. The AHSP calculation and Cost Estimation Plan calculation are carried out using Microsoft Excel software.

2.4 Project Scheduling

The project scheduling flow can be carried out based on the calculation of the volume of work, WBS and WMS, work coefficients, and the number of workers, which are then used to calculate the duration of the work. The results are then used as input for scheduling using Microsoft Project software, which produces a Bar Chart and S Curve schedule.

2.5 4D and 5D Simulation

In the next stage, the scheduling and Cost Estimation Plan results are integrated with 3D modeling by inputting them into Navisworks software. The final result is a 4D and 5D simulation of the project from start to finish.

2.6 Bridge Visualization

Visualizations for bridges are created in two forms: video animations and augmented reality. Animations are used to illustrate bridge construction methods, facilitating the process of preparing cost estimates, as well as to depict the condition of bridges after construction. These animations are created using Sketchup and Lumion software. For augmented reality, the final modeling results are used as input for AR processing using Augin software.

3. RESULTS AND DISCUSSION

Using the research method in Figure 2, the output results were obtained in accordance with the objectives and background of this study. The data in the form of 2D shop drawings were modeled into 3D. The bridge structure is divided into the lower structure, namely the pile foundation, abutment pier, and abutment (wall and wingwall). The upper structure is divided into the bridge steel frame, vehicle floor, bearing, and expansion joint, as well as bridge accessories such as sidewalks, drainage pipes, railings, and parapet walls. These bridge parts were modeled using Tekla Structures software. With the available tools, the modeling was made in accordance with the shape and dimensions found in the shop drawing. Concrete elements were created using the "Concrete" option, while steel elements used the "Steel" option. For details, such as reinforcement, the "Rebar" option was used. Other commands were utilized as needed to produce a 3D model of the Parakan Lima Bridge in .IFC format, which can be seen in Figure 3. By modeling the bridge structure and components in 3D, 2D drawings can also be generated using the same software, Tekla Structures. An example of the 2D drawing produced is shown in Figure 4.

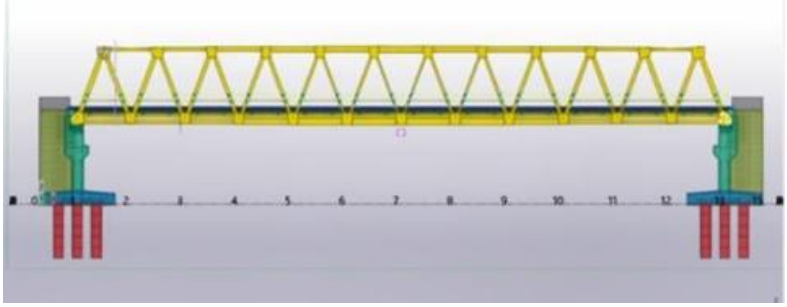

Figure 3 Example of the Parakan Lima Bridge 3D Modeling Results

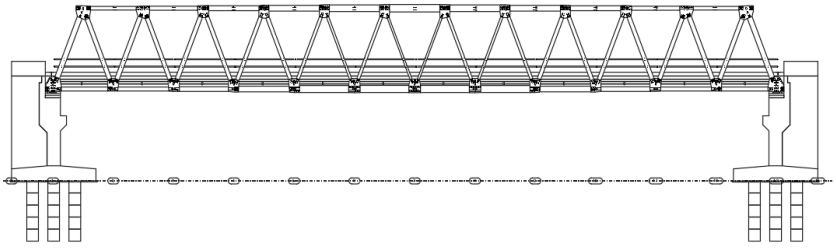

Figure 4 Example of 2D Drawing Output from 3D Modeling Results

Based on the modeling results, the volume of each part can be generated using the Quantity Take-Off feature in Tekla Structures software. The volume units generated vary according to the type of material used. The Quantity Take-Off output is in the form of a table containing information such as part name, material type, position, height, length, width, weight, and volume. Calculating the volume of each part of the work is necessary for calculating the budget plan. In addition to volume information, planning the Cost Estimation Plan also requires planning the construction method. Each work item is arranged hierarchically by creating a WBS that refers to the Appendix to Permen PUPR No. 1 of 2022. Based on these guidelines, bridge work is divided into 10 divisions [6]. In

this study, the implementation of the Parakan Lima Bridge is generally classified into four divisions, namely Division 1 General, Division 2 Construction Safety Management System (SMKK), Division 4 Earthworks and Geosynthetics, Division 8 Structures, and Division 9 Bridge Rehabilitation.

Each work item that has been grouped in the WBS is then described in more detail in the WMS. At this stage, the equipment, materials, and human resources (HR) required for each work item are described. The selection of heavy equipment is adjusted to the work method determined according to field conditions. By determining the equipment and HR, work productivity can be calculated. The visualization of the Parakan Lima Bridge construction method was created in the form of an animation using Sketchup and Lumion software, as seen on Figure 5.

Figure 5 Examples of Animations of the Parakan Lima Bridge Implementation Method

By calculating work productivity, the coefficients for materials, human resources, and tools needed to prepare the Cost Estimation Plan can be determined. The coefficient values obtained can be used to calculate the Unit Price of Work (HSP) by multiplying the coefficient values by the unit price. The unit prices used are sourced from Bekasi Mayor Decree No. 913/Kep.32-Bang/I/2021 concerning the Basic Unit Prices (HSPK) of the Bekasi City Government for the 2021 Fiscal Year [7]. This is due to the limited information available on the latest Unit Price List (DHS) for Purwakarta Regency, so the DHS for the area adjacent to Purwakarta Regency was selected.

One of the work items calculated is the steel bridge frame. This work includes the supply, fabrication, transportation, installation, galvanization, and painting of the steel structure [8]. The installation of the Parakan Lima Bridge steel frame uses the semi-cantilever method with the help of PD 8 shoring. The number of shoring required for each segment is determined based on the load calculation that can be withstood by the shoring tower. One set of PD8 shoring towers can withstand a load of 62 kN or 6.32 tons [9]. The weight of one steel profile segment based on the Quantity Take Off is known to be 10 tons. To withstand this load, more than one shoring tower is required, as the weight of one segment exceeds the load that can be withstood. Therefore, three sets of shoring towers are required to withstand a load of more than 18 tons. In addition to this reason, three sets of shoring towers placed at three parallel points can be more balanced in withstanding the load of each segment. One set of shoring towers can consist of frames, cross hand spindles, quick jack nuts, base plates, pin joints, cotter pins [10], and other materials such as swivel couplers and RO pipes. Figure 6 shows an illustration of the load of the steel frame profile segment and the shoring that supports it. Furthermore, a calculation example of material, equipment, and human resource coefficients for the installation of steel bridge frames can be seen in Table 1.

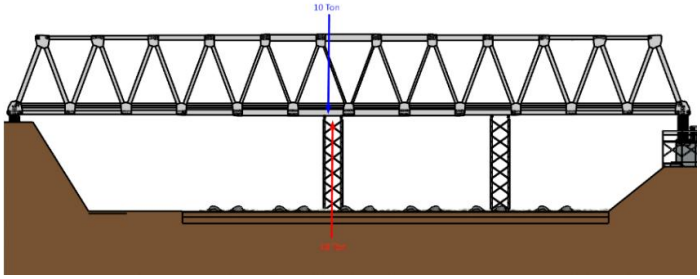

Figure 6 Illustration of Steel Frame Profile Segment Load and Shoring

Table 1 Calculation of Bridge Steel Frame Installation Coefficients

NO	Item	Code	Coef	Unit
I.	**Asumption**			
1	Purchasing Structural Steel Components from the Factory (pre-coated)			
2	Work Location : Bridge			
3	Average Distance from Base Camp to Project Site	Lp	0.04	KM
4	Effective Working Hours per Day	Tk	7.00	hour
5	Distance from Factory to Project Site	Ld2	30.00	KM
II.	**Work Sequence**			
1	Materials are already available at the work site			
2	Semi-cantilever method is applied			
3	PD 8 shoring is used.			
III.	**Utilization of Materials, Equipment, and Manpower**			
1.	**Tools**			
1.a.	*Crawler Crane* 50 T	(E07)		
	Capacity	V	6	Ton
	Equipment Efficiency Factor	Fa	0.83	-
	Time Cycle			
	- Mobilization Time	T1	60	
	- Loading Time	T2	60	minute
	- Swinging, Shifting, and Lowering Time	T3	125	minute
		Ts	**90.00**	minute
	Production Capacity per Hour = V x Fa x 60 x 1000 / Ts2	Q1	**1219,57**	Kg
	Equipment Coefficient per kg = 1 : Q1	(E07)	**0.00082**	hour
1.b.	SUPPORTING TOOLS			
	Minor auxiliary equipment is required			
	- Tools and Accessories			Lumpsum
	- Lifting tackles, ropes, slings, and other tools			
	- Hydraulic Lifting Jack			
2.	**POWER**			
	Steel Frame Output (Dependent on Crane Production)	Qt	8537,143	kg
	Requirement for Additional Workers at the Site:			
	- Foreman	M	1.00	worker
	- Worker	P	26.00	worker
	- Operator	O	1.00	worker
	Manpower Coefficient per Hour			
	Foreman = (M x Tk) : Qt	(L03)	**0.00082**	hour
	Worker = (P x Tk) : Qt	(L01)	**0.0214**	hour
	Operator = (O x Tk) : Qt	(L05)	**0.00082**	hour

Based on the calculation of work productivity and the coefficients of materials, equipment, human resources, the duration of the work can be calculated by dividing the total volume of work by the product of the number of tools, tool productivity, and effective working hours. For the example above, it takes 24 days to complete the installation of the bridge steel frame. The Unit Price Analysis (AHSP) for this work is calculated based on daily requirements with payment for one bridge frame in total. Table 2 is an example of AHSP for bridge steel frame installation. Furthermore, the Cost Estimation Plan calculation is carried out after the volume and unit

price of each work are determined, by multiplying the two components. The results of the Cost Estimation Plan calculation recapitulation can be seen in Table 3.

Table 2 AHSP for Bridge Steel Frame Installation

NO	ITEM	CODE	UNIT	QTY	Unit Price	Total Price
A	**POWER**					
1	Worker	(L01)	OH	26 x 24 = 624	125,000.00	78,000,000.00
2	Foreman	(L03)	OH	1 x 24 = 24	170,000.00	4,080,000.00
3	Operator	(L04)	OH	1 x 24 = 24	185,000.00	4,440,000.00
					TOTAL	86,520,000.00
B.	**MATERIAL**					
					TOTAL	0.00
C	**TOOLS**					
1.	*Crawler Crane* 50 T	(E07)	Rental per Day	24	9,843,750.00	236,250,000.00
					TOTAL	71,662,500.00
D	Total Price of Labor, Materials, and Equipment (A+B+C)					322,770,000.00
E	Overheard and Profit		10.0 % X D			32,277,000.00
F	Unit Price of Work (D + E)					355,047,000.00

Table 3 Recapitulation of Cost Estimation Plan for Parakan Lima Bridge

Divisi	Description of Work	Cost
1	General	Rp 50,000,000
2	Construction Safety Management System (CSMS)	Rp 9,000,000
4	Soil and Geosynthetic Works	Rp 4,115,627,643
8	Structure	Rp 7,594,895,252
9	Bridge Rehabilitation	Rp 612,206,355
Total Cost of Work, including General Expenses and Profit (A)		Rp 12,381,729,250
Value Added Tax (B) = 10% x (A)		Rp 1,238,172,925
Total Cost of Work = (A) + (B)		**Rp 13,619,902,175**

With the data obtained, the duration for each work item can be calculated. In creating the schedule, the relationship between tasks or predecessors is also considered. After the work description, duration, price, and predecessor data are entered into Microsoft Project software, the start and end dates of the project can be set. In addition, effective working hours are set at 7 hours with working days from Monday to Sunday. Based on this schedule, the planned duration is 223 days, starting on March 23, 2022, and ending on December 31, 2022.

The next BIM application output is in the form of 4D and 5D simulations. The software used is Autodesk Naviswork. With Autodesk Naviswork, the modeling results from Tekla Structures software, scheduling designs, and Cost Estimation Plan can be integrated into a 4D simulation in the form of modeling parts that correspond to the schedule and in the form of a 5D simulation in the form of cost estimates in line with the progress of the project. Figure 7 illustrates Autodesk Navisworks software displaying 4D and 5D simulations.

To support visualization needs, an animation of the bridge's condition after the project was created. The software used was Sketchup and Lumion. The 3D model used was the result of modeling in Tekla Structures software in IFC format. In SketchUp software, several elements related to the implementation method were added, such as materials, workers, and heavy equipment. Changes made in Lumion software included the addition of elements that enhance the realistic effect during rendering, such as natural conditions, vehicles, people, and lighting settings. To produce videos with different points of view (POV), scenes can be created and arranged in Lumion software. The resulting scenes can then be rendered into MP4 format videos. Figure 8 shows a screenshot of the animation.

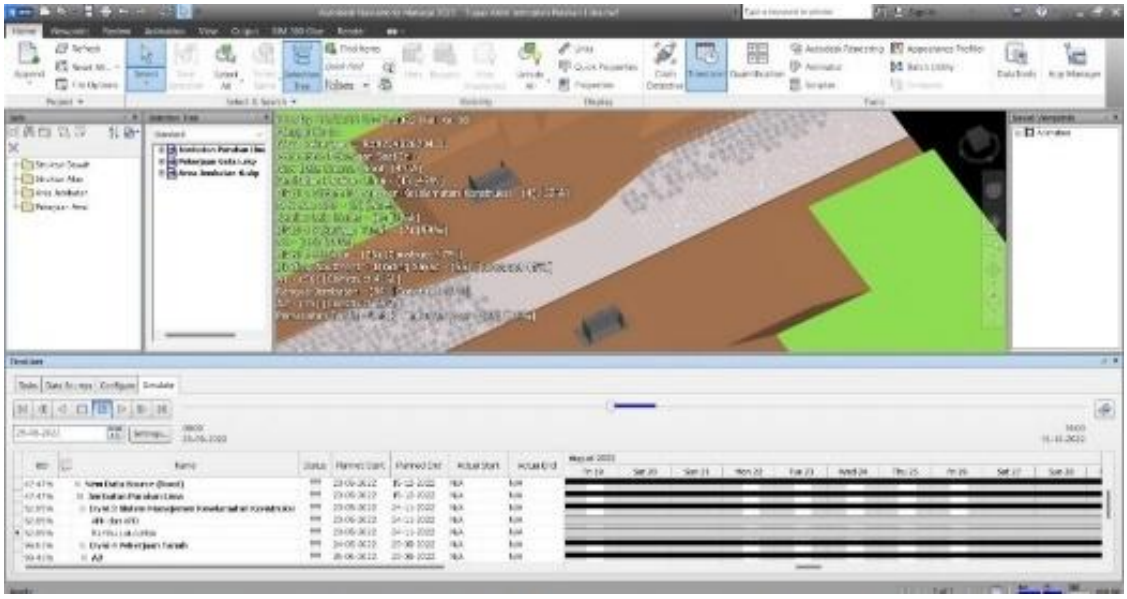

Figure 7 4D and 5D Simulation Display with Autodesk Navisworks

Figure 8 Image of the Parakan Lima Bridge Animation After Project

In addition to animations in video form as shown above, another output in the form of Augmented Reality was also created. The modeling results in .IFC format were uploaded to the Augin software installed on a smartphone. The way it works is by launching the Augin application, then allowing camera access and selecting the model to be displayed. Figure 9 shows the AR display on a smartphone using Augin software.

Figure 9 Augin Usage for Augmented Reality

4. CONCLUSION

The application of BIM can yield several benefits, including the creation of a 3D model of the Parakan Lima Bridge using Tekla Structures software, which then generates output in the form of a quantity take-off and 2D drawings. Based on the work volume output and the description of the implementation method, the Parakan Lima Bridge Cost Estimate (Cost Estimation Plan) is Rp 13,619,902,175 (including 10% VAT). The project is scheduled using Microsoft Project software with a duration of 223 days, starting on May 23, 2022, and ending on December 31, 2022. For visualization, animations are produced in the form of videos of the Parakan Lima Bridge implementation method, the condition of the bridge and the surrounding environment after the project, as well as 4D and 5D project simulations and Augmented Reality using .IFC format modeling files.

REFERENCES

[1] Supiandi, Asep. Jembatan Rp 15 Miliar Jadi Pembuka Akses Parakan Lima – Ciherang, SINDONews (2019). Available: https://daerah.sindonews.com/artikel/jabar/11934/jembatan-rp15-miliar-jadi-pembuka-akses-parakanlimaciherang,

[2] Transportasi sebagai Pendukung Sasaran Pembangunan Nasional, Kementerian Perhubungan Republik Indonesia (2017). Available: http://dephub.go.id/post/read/transportasi-sebagai-pendukung-sasaran-pembangunan-nasional

[3] Siswanto, Agus B. M. Afif Salim, Manajemen Proyek, CV. Pilar Nusantara (2019). Available: https://ftp.idu.ac.id/wpcontent/uploads/ebook/ip/BUKU%20MANAJEMEN%20PROYEK/ManajemenProyek.pdf

[4] Badan Pengembangan Sumber Daya Manusia Pusat Pendidikan dan Pelatihan Sumber Daya Air dan Konstruksi, Modul 3 Prinsip Dasar Sistem Teknologi BIM dan Implementasinya di Indonesia, Kementerian Pekerjaan Umum dan Perumahan Rakyat (2018). Available: https://bpsdm.pu.go.id/center/pelatihan/uploads/edok/2019/02/8b2aa_MODUL_3-PRINSIP_DASAR_SISTEM_TEKNOLOGI_BIM.pdf

[5] Tim BIM PUPR. Panduan Adopsi BIM dalam Organisasi, Pusat Litbang Kebijakan dan Penerapan Teknologi (2018). Available: http://bim.pu.go.id/assets/files/Panduan_Adopsi_BIM.pdf

[6] Sabil, D., & Erizal. (2023). *Penerapan Building Information Modeling (BIM) 5D pada Proyek Gedung Simpang Temu Dukuh Atas, Jakarta Pusat*. Jurnal Teknik Sipil dan Lingkungan, 8(02), 95-104. https://doi.org/10.29244/jsil.8.02.95-104

[7] Peraturan Menteri PUPR No. 1 Tahun 2022, Kementerian Pekerjaan Umum dan Perumahan Rakyat (2022). Available:

[8] Keputusan Wali Kota Bekasi Nomor 913/Kep. 32-Bang/I/2021 Tentang Harga Satuan Pokok Kegiatan Pemerintah Kota Bekasi Tahun Anggaran 2021, Jaringan Dokumentasi dan Informasi Hukum (JDIH) (2021). Available: https://jdih.bekasikota.go.id/jdih/web/uploads/kepwal_21-05-10%2003:13:03_.pdf

[9] Spesifikasi Umum Bina Marga 2018 Revisi Final, Kementerian Pekerjaan Umum dan Perumahan Rakyat (2019). Available: https://keselamatanjalan.wordpress.com/2020/11/18/spesifikasi-umum-bina-marga-2018-revisi-2/

[10] PD 8 *Table System*, PERI (2022). Available: https://www.peri.id/products/scaffolding/shoring/pd8-shoring-system.html

[11] Ramadhan, Alfahmi Gustav, Fauziah Hasanah Lukman. Perencanaan Anggaran Biaya dan Penjadwalan Pekerjaan Flyover pada Ruas Jalan Dr. Djunjunan Kota Bandung. Tugas Akhir Program Diploma Empat Politeknik Negeri Bandung (2020). Available: http://digilib.polban.ac.id/files/disk1/248/jbptppolban-gdl-alfahmigus-12356-1-kelengka-3.pdf