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Comparison of Erection Pierhead Segmental Method With Beam Lifter and Crawler Crane From of Time and Cost (JAPEK Elevated 2 Toll Project)

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Abstract

Jalan Toll Jakarta - Cikampek Elevated 2 is an elevated toll road built to connect the JABODETABEK area and its surroundings. One of the important jobs in the construction of the JAPEK Elevated 2 toll road is the segmental pierhead erection. This final project aims to determine the comparison of the time and cost aspects of the segmental pierhead erection method using beam lifters and crawler cranes, as well as to determine what factors influence the segmental pierhead erection method. Primary and secondary data were collected, then a comparative analysis of time and costs was carried out on the beam liftter and crawler crane methods by calculating the cycle time and the performance index of the tools. Furthermore, researchers used quantitative research by distributing questionnaires to respondents, namely all employees involved in the segmental pierhead erection process in the JAPEK Elevated 2 Toll project. The results of this study indicate that the segmental pierhead erection method using a crawler crane is faster but slightly more expensive than beam lifters. Then it is known the results of the analysis using SPSS software from the beam lifter tool, there are 17 independent variables that correlate to the dependent variable and the percentage of influence of the two variables is 53.8%. Meanwhile, from the crawler crane, there are 26 independent variables which correlate with the dependent variable and the percentage of influence of the two variables is 55.5%.

Keywords
Beam Lifter , Crawler Crane ,Segmental Erection Pierhead, ,SPSS

1. Preliminary

Construction development has increased very rapidly in terms of technology used, such as the development of technology in the construction of bridge structures and viaducts. The types of viaduct structures have developed in line with the history of human civilization, from simple types to complex types, with simple materials to modern ones. One of the developments in the construction of the current viaduct structure is the Jakarta - Cikampek Elevated Toll project 2. The application of technology to the relatively new viaduct structure is applied to the Jakarta - Cikampek Elevated Toll project 2. The Jakarta - Cikampek Elevated 2 toll road project along 36.4 KM stretches from Cikunir (KM 9 + 500) to West Karawang (KM 47 + 500). In the Jakarta - Cikampek Elevated 2 Toll project all structures are elevated consisting of borepile, pilecap, consisting of borepile, pilecap, column, pierhead, slab and asphalt and there are 2 main contractors working on the project, namely PT Waskita Karya Tbk from KM 9+ 500 to 28 + 000 and PT Acset Indonusa Tbk from KM 28 + 780 to 38 + 525. According to Dwi Laga (2019), one of the components of the viaduct structure is Pierhead, Pierhead is the Upper Structure holder which functions to distribute the load from the structure above to the Pier to the Borepile. The pierhead used in the Jakarta - Cikampek 2 Elevated toll road project, especially in the PT Acset Indonusa Tbk area, is a segmental pierhead which is divided into 3 segments. The segmental pierhead erection uses a beam liftter, one of the newest erection methods. However, from the segmental pierhead erection method there is another erection method that we can use in the Jakarta - Cikampek Elevated 2 Toll project, namely the segmental pierhead erection method using a crawler crane. Because the Jakarta - Cikampek Elevated 2 Toll project is one of the national strategic projects and is one of the acceleration projects, therefore in the PT Acset Indonusa Tbk area, 2 segmental pierhead erection methods were used using beam lifters and crawler cranes simultaneously to speed up time. completion of the project.

In this research, a main problem can be taken as follows:

1. How does the segmental pierhead erection method compare using beam lifters and crawler cranes in terms of time and cost?
2. What factors affect the time and cost of the segmental pierhead erection method using beam lifters and crawler cranes?

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2. Research Methodology

In the process of working on this final project, the writer needs theoretical foundations that support the problems to be studied. Through literature studies, it is hoped that the author can increase knowledge and learn the basic theory that will be used as a reference.

Data collection is done by collecting data related to the problem being reviewed. Data collection was carried out on predetermined samples. These data are in the form of:

1. Secondary data: work images and project internal data
2. Primary data: direct field observations, interviews and documentation.

3. Method of Analysis

3.1.Time Analysis

The duration of work on the project is carried out by calculating the cycle time, which is the time needed to complete the production of one unit from start to finish. Furthermore, calculating productivity, namely the comparison between the results achieved (output) with all resources used (input).

Average / pierhead =(Total cycle time)/(Jumlah pierhead)
Tool productivity formula:
Tool Productivity Formula:
Productivity =60/(RATA-RATA PERPIERHEAD) X EFISIEnsi
Information:
Q = tool capacity
Cycle Time = cycle time (minutes)
Efficiency = efficiency tool

To determine the efficiency of the tool, if the working day is 8 hours while the effective working time is 6 hours, the efficiency of the tool is 6/8 or 0.75. After knowing the productivity of the tool, we can calculate the maximum number of girders to be lifted in one working day, which is 8 hours.

$$Durasi = produktivitas\ alat \times jam\ kerja\ perhari$$

3.2. Cost Analysis

The cost comparison of segmental pierhead erection will be done using the performance index of each tool.

$$\text{Index} = \frac{Total\ jam\ kerja}{Jam\ kerja\ normal} x \frac{Jml\ tenaga\ kerja/jml\ \ alat\ berat}{Jml\ komponen\ yang\ terpasang}$$

After knowing the index on each difference from the cost of work on each tool. The goal is to find out what heavy equipment is right for use in terms of cost.

$$Persentase\ Selisih,\% = \text{x } 100\frac{total\ biaya\ tertinggi}{total\ biaya\ terendah}$$

3.3. Validity test

The conditions that must be met by the validity test are, if the correlation coefficient> r table then the item is declared valid.

3.4. Reliability Test

Reliability test is used to find out how far the measurement results remain consistent when two or more measurements are made using the same measuring instrument. To see the reliability of each instrument used, th Cronbach's Alpha coefficient is used, namely

Table 1 Interpretation of R Value

No.	Ket	Score	Category
1	Alpha Value	0.00 - 0.20	Less reliable
2	Alpha Value	0.21 - 0.40	Rather reliable
3	Alpha Value	0.41 - 0.60	Fairly reliable
4	Alpha Value	0.61 - 0.80	Reliable
5	Alpha Value	0.81 - 1	Very Reliable

3.5. Correlation Test

Correlation test is used to determine the relationship between independent variables and the dependent variable or vice versa. Decision making can be seen from the significance value that must be achieved if the variables are correlated, namely the Sig. <0.05.

3.6. Regression Test

Linear regression test is useful for knowing the direction of the relationship between the independent variable and the dependent variable, whether each independent variable has a positive or negative relationship, and to predict the value of the dependent variable if the value of the independent variable has increased or decreased. The linear regression equation is:

$Y = a + bX$ ..... (1.1)

X = Independent variable
Y = Dependent variable
a = Constant
b = Regression coefficient

3.7. Determination Coefficient Test (R^2)

The coefficient of determination test is a tool to measure the ability of the model to explain the variation in the dependent variable. The value of the coefficient of determination is between 0 and 1. A small R^2 value means that the ability of the independent variable to explain the variation of the dependent variable is very limited, and vice versa (Achmad and Witiastuti, 2018).

4. Results and Discussion

The comparative aspects of segmental pierhead erection work in this study consist of time and cost aspects. Where the aspect of time is viewed from cycle time (cycle time) and calculates the productivity of the tool during segmental pierhead erection work using beam lifters or crawler cranes. While the cost aspect is carried out by calculating the performance index of each heavy equipment used in the segmental pierhead erection work on the Jakarta - Cikampek Elevated 2 toll road project (Mirnayani, 2016).

4.1. Job Time Segmental Pierhead Erection with Beam Lifter

The calculation of work duration and productivity of segmental pierhead erection with beam lifters is done by direct observation in the field. The number of pierhads to be observed is 5 or 5 spans.

Table 2. Key Cycle Time Cycle Erection Pierhead Segmental Work with Beam Lifter

Kode Waktu	Keterangan
t1	Pengaturan posisi *crawler crane* untuk *erection segment* 1
t2	*Checklist* kondisi *crawler crane*
t3	Pengangkatan *segment* 1 sampai atas *pier*
t4	Cek elevasi setelah itu install strand looping
t5	Stressing looping tendon
t6	Perakitan alat beam lifter sekaligus checklist kondisi beam lifter
t7	Pengangkatan beam lifter menggunakan crane ke atas segment 1
t8	Pengangkatan segment 2 (kanan & kiri)
t9	Install dan stressing strand segment 2 (kanan & kiri)
t10	Pengangkatan segment 3 (kanan & kiri)
t11	Install dan stressing strand segment 3 (kanan & kiri)
t12	t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11

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The results of recording the cycle time of segmental pierhead erection work using a beam lifter can be seen in the following table:

Table 3. Cycle Time of Segmental Pierhead Erection Pek with Beam Lifter at Span 1

Time Code	Cycle Time (Minutes) Span 1
t1	18.46
t2	7.29
t3	28.32
t4	8.53
t5	42.3
t6	28.43
t7	48.36
t8	41.36
t9	42.38
t10	38.09
t11	55.59
t12	359.11

Source: Researcher Processed Data

Table 4. Cycle Time of Segmental Pierhead Erection Pack with Beam Lifter on Span 2

Time Code	Cycle Time (Minutes) Span 2
t1	19.46
t2	7.29
t3	30.35
t4	7.53
t5	42.1
t6	26.15
t7	46.23
t8	43.05
t9	42.2
t10	40.06
t11	52.03
t12	356.45

Source: Researcher Processed Data

Table 5. Cycle Time of Segmental Pierhead Erection Pack with Beam Lifter at Span 3

Time Code	Cycle Time (Minutes) Span 3
t1	16.58
t2	6.52
t3	29.44
t4	8.38
t5	40.08
t6	27.16
t7	46.45
t8	43.12
t9	46.38
t10	41.53
t11	51.39
t12	357.03

Source: Researcher Processed Data

Table 6. Cycle Time of Segmental Pierhead Erection Pack with Beam Lifter at Span 4

Time Code	Cycle Time (Minutes) Span 4
t1	18.39
t2	8.57
t3	28.48
t4	7.23
t5	43.45
t6	27.37
t7	47.31
t8	42.55
t9	44.17
t10	39.06
t11	52.11
t12	358.69

Source: Researcher Processed Data

Table 7. Cycle Time of Segmental Pierhead Erection Pack with Beam Lifter at Span 5

Time Code	Cycle Time (Minutes) Span 5
t1	19.32
t2	7.49
t3	28.1
t4	7.4
t5	41.55
t6	28.14
t7	47.21
t8	41.44
t9	47.32
t10	38.58
t11	54.39
t12	360.94

Source: Researcher Processed Data

The next step is to calculate the productivity of the beam lifter as a lifting tool for the span 1-5. Here are the steps for calculating the productivity of the beam lifter:

Total cycle time = Total t12 total (5 segmental pierheads)
= t12 pierhead 1 + t12 pierhead 2 + t12 pierhead 3 + t12 pierhead 4 + t12 pierhead 5
= 359.11 + 356.45 + 357.03 + 358.69 + 360.94 = 1792.22 minutes

Average / pierhead $= \frac{Total\ cycle\ time}{jml\ pierhead}$

$= \frac{1792,22}{5}$

$= 358,444\ menit/pierhead$

Productivity = qx $\frac{60}{rata-rata\ perpierhead} x\ efisiensi$

= 1 x $\frac{60}{358,444} x\ 0,75$

= 0.125 pierhead / hour

Productivity / hour = 0.125 pierheads / hour

Productivity / day = 0.125 x 8 hours

= 1,004 ≈ 1 pierhead / day

4.2. Time of Segmental Pierhead Erection Work with Crawler Crane

The calculation of the work duration and productivity of segmental pierhead erection with a crawler crane is done by direct observation in the field. The number of pierhads to be observed is 5 or 5 spans.

Table 8. Time Code Cycle of Erection Pierhead Segmental Work with Crawler Crane

Kode Waktu	Keterangan
t1	Pengaturan posisi *crawler crane* untuk *erection segment* 1
t2	*Checklist* kondisi *crawler crane*
t3	Pengangkatan *segment* 1 sampai atas *pier*
t4	Cek elevasi setelah itu install strand looping
t5	Stressing looping tendon
t6	Pengaturan posisi *crawler crane* dan pemasangan tambang pada *segment* 2 (kanan & kiri)
t7	Pengangkatan segment 2 (kanan & kiri)
t8	Install dan stressing strand segment 2 (kanan & kiri)
t9	Pengaturan posisi *crawler crane* dan pemasangan tambang pada *segment* 3 (kanan & kiri)
t10	Pengangkatan segment 3 (kanan & kiri)
t11	Install dan stressing strand segment 3 (kanan & kiri)
t12	t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11

The results of recording the cycle time of segmental pierhead erection work using a beam lifter can be seen in the following table:

Table 9. Cycle Time of Segmental Pierhead Erection Cycle with Crawler Crane at Span 1

Time Code	Cycle Time (Minutes) Span 1
t1	17.5
t2	8,12
t3	28.33
t4	7.58
t5	44.46
t6	25.47
t7	32.28
t8	42.13
t9	27.19
t10	34.21
t11	49.09
t12	316.36

Source: Researcher Processed Data

Table 10. Cycle Time of Segmental Pierhead Erection Cycle with Crawler Crane at Span 2

Time Code	Cycle Time (Minutes) Span 2
t1	18.32
t2	7.21
t3	27.28
t4	8.15
t5	43.56
t6	26.37
t7	33.16
t8	41.58
t9	28.47
t10	35.49
t11	52.08
t12	321.67

Source: Researcher Processed Data

Table 11. Cycle Time of Segmental Pierhead Erection Cycle with Crawler Crane at Span 3

Time Code	Cycle Time (Minutes)
	Span 3
t1	17.42
t2	8.1
t3	28.22
t4	8.17
t5	45.45
t6	27.32
t7	32.12
t8	43.04
t9	27.38
t10	36.31
t11	50.04
t12	323.57

Source: Researcher Processed Data

Table 12. Cycle Time of Segmental Pierhead Erection Cycle with Crawler Crane at Span 4

Time Code	Cycle Time (Minutes)
	Span 4
t1	16.53
t2	9.02
t3	32.37
t4	7,2
t5	44.42
t6	26.36
t7	32.23
t8	44.1
t9	26.22
t10	34.03
t11	49.59
t12	322.07

Source: Researcher Processed Data

Table 13. Cycle Times of Segmental Pierhead Erection Cycle with Crawler Crane at Span 5

Time Code	Cycle Time (Minutes)
	Span 5
t1	19.09
t2	8.45
t3	28.2
t4	8.58
t5	42.55
t6	27.39
t7	35.08
t8	42.02
t9	27.37
t10	35.31
t11	48.15
t12	322.19

Source: Researcher Processed Data

The next step is to calculate the productivity of the beam lifter as a lifting tool for the span 1-5. Here are the steps for calculating the productivity of the beam lifter:

Total cycle time = Total t12 total (5 segmental pierheads)
= t12 pierhead 1 + t12 pierhead 2 + t12 pierhead 3 + t12 pierhead 4 + t12 pierhead 5
= 316.36 + 321.67 + 323.57 + 322.07 + 322.19 = 1605.86 minutes

Average / pierhead $= \frac{Total\ cycle\ time}{jml\ pierhead}$

$= \frac{1605,86}{5}$

$= 321,172\ menit/pierhead$

Productivity = qx$\frac{60}{rata-rata\ perpierhead} x\ efisiensi$

= 1 x $\frac{60}{321,172} x\ 0,75$

= 0.140 pierhead / hour

Productivity / hour = 0.140 pierheads / hour

Productivity / day = 0.140 x 8 hours

= 1,121≈ 1 pierhead / day

4.3. Cost of Segmental Pierhead Erection Work with Beam Lifter

The breakdown of the cost of segmental pierhead erection with beam lifters is done by calculating the performance index of the tool.

Table 14. Beam Lifter Price Data

Alat Berat	Biaya Sewa	Biaya per Hari
Beam lifter	Rp. 800.000.000/bulan	Rp. 26.667.000

Sumber: Data Internal Proyek

Table 15. Data on Wages of Segmental Erection Pierhead Labor with Beam Lifter

Tenaga Kerja	Upah Per Bulan	Upah Per Hari
Tenaga Ahli (*skilled labour*)		Rp. 115.000
Operator	Rp. 5.500.000	Rp. 180.000
Pengarah (*rigger*)	Rp. 7.500.000	Rp. 250.000
Mandor		Rp. 125.000
Pekerja (*labour*)		Rp. 95.000

Sumber: Data Internal Proyek

The data on labor wages in the table above is the wages of each worker that the authors get from the project's internal data. Most of the payment of labor wages is calculated in one working day, but some are paid per month.

Table 16. Workforce on Beam Lifter

Pekerjaan	Sampel 1					Sampel 2				
	a	b	c	d	e	a	b	c	d	e
Pengaturan Lalu Lintas & Pemasangan Aksesoris				1	6				1	7
Pemasangan *Beam Lifter*		1		2	5		1	2		4
Erection Pierhead Segmental	2	1		2	1	4	1	1	2	1	5
Penyambungan Segmen		1		2	1	7		1	2	1	6
Pelepasan Aksesoris LG dengan Segmen Girder		1		1		3		1	1		2
Total Tenaga Kerja	13					13				

Sumber: Data Olahan Peneliti

Information :
a= Expert
b = operator
c = Rigger
d = foreman
e = Worker

Table 17. Beam Lifter Performance Per Pierhead

Day -1	
Working hours	22.00 - 04.30
Total Working Hours	6 Hours 30 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	1
Steering (riger)	2
Foreman	1
Worker (labor)	7
Number of Tools	1
Day 2	
Working hours	22.15 - 05.00
Total Working Hours	6 Hours 45 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	1
Steering (riger)	2
Foreman	1
Worker (labor)	7
Number of Tools	1
Day 3	
Working hours	22.00 - 05.00
Total Working Hours	7 Hours 00 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	1
Steering (riger)	2
Foreman	1
Worker (labor)	7
Number of Tools	1
Day 4	
Working hours	22.00 - 04.30
Total Working Hours	6 Hours 30 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	1
Steering (riger)	2
Foreman	1
Worker (labor)	7
Number of Tools	1

Day 5	
Working hours	22.00 - 05.00
Total Working Hours	7 Hours 00 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	1
Steering (riger)	2
Foreman	1
Worker (labor)	7
Number of Tools	1

Source: Researcher Processed Data

The next step is to calculate the beam lifter performance index for one pierhead. The calculation of the segmental pierhead erection cost index using a beam lifter is done with the following formula:

$$\text{Index} = \frac{Total\ jam\ kerja}{Jam\ kerja\ normal} x \frac{Jml\ tenaga\ kerja/jml\ \ alat\ berat}{Jml\ komponen\ yang\ terpasang}$$

Table 18. Beam Lifter Performance Index for 1 Pierhead

Tanggal	Hari ke-1 Indeks	Hari ke-2 Indeks	Hari ke-3 Indeks	Hari ke-4 Indeks	Hari ke-5 Indeks
Total Jam Kerja (8 jam/480 menit)	390 menit	405 menit	420 menit	390 menit	420 menit
Jumlah Segmen Terpasang	1	1	1	1	1
Jumlah Tenaga Kerja					
Tenaga Ahli (*skilled labour*)	1,63	1,69	1,75	1,63	1,75
Operator	1,63	1,69	1,75	1,63	1,75
Pengarah (*riger*)	0,81	0,84	0,88	0,81	0,88
Mandor	0,81	0,84	0,88	0,81	0,88
Pekerja (*labour*)	5,69	5,91	6,13	5,69	6,13
Alat	0,81	0,84	0,88	0,81	0,88

Table 19. Average Beam Lifter Performance Index for One Pierhead

Rata-Rata Indeks	
Tenaga Ahli (*skilled labour*)	1,69
Operator	1,69
Pengarah (*riger*)	0,84
Mandor	0,84
Pekerja (*labour*)	5,91
Alat	0,84

The following is the calculation result of segmental pierhead erection work using beam lifters per one segment:

Table 20. Total Price for the Installation of One Segmental Pierhead with Beam Lifter

Item	Indeks	Satuan	Harga Satuan		Jumlah	
Tenaga Ahli (*skilled labour*)	1,69	OH	Rp	115.000	Rp	194.350
Operator	1,69	OH	Rp	180.000	Rp	304.200
Pengarah (*riger*)	0,84	OH	Rp	250.000	Rp	210.000
Mandor	0,84	OH	Rp	125.000	Rp	105.000
Pekerja (*labour*)	5,91	OH	Rp	95.000	Rp	561.450
Alat (*beam lifter*)	0,84	Hari	Rp	26.667.000	Rp	22.400.280
				Total	**Rp**	**23.775.280,-**

Sumber: Data Olahan Penelitit

the table above, it can be seen that the total price for segmental pierhead erection using a beam lifter per pierhead is IDR 23,775,280.

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4.4. Cost of Segmental Pierhead Erection Work with Crawler Crane

Details of the cost of segmental pierhead erection with a crawler crane are done by calculating the performance index of the tool.

Table 21. Crawler Crane Price Data

Alat Berat	Biaya Sewa	Biaya per Hari
Crawler Crane	Rp. 500.000.000/bulan	Rp. 16.760.666

Table 22. Data on Segmental Erection Pierhead Labor Wages with Crawler Crane

Tenaga Kerja	Upah Per Bulan	Upah Per Hari
Tenaga Ahli (*skilled labour*)	Rp. 5.000.000	Rp. 160.000
Operator	Rp. 5.000.000	Rp. 160.000
Pengarah (*rigger*)	Rp. 7.500.000	Rp. 250.000
Mandor		Rp. 125.000
Pekerja (*labour*)		Rp. 95.000

Sumber: Data Internal Proyek

The data on labor wages in the table above is the wages of each worker that the authors get from the project's internal data. Most of the payment of labor wages is calculated in one month of work, but some are paid per day.

Table 23. Workforce on a Crawler Crane

Pekerjaan	Sampel 1					Sampel 2				
	a	b	c	d	e	a	b	c	d	e
Pengaturan Lalu Lintas & Pemasangan Aksesoris				1	8				1	8
Pemasangan CC dengan *segmen pierhead*			1		4			1		4
Erection Pierhead segmental Segmen Girder	2	2	3	2	2	2	2	2	1	2
Penyambungan Segmen Girder dengan *Pier*		2	1	1	6		2	1	1	6
Pelepasan Aksesoris CC dengan Segmen Girder		2			3		2			3
Total Tenaga Kerja			16					16		

Sumber: Data Olahan Peneliti

Information :
a = Expert
b = operator
c = Rigger
d = foreman
e = Worker

Table 24. Performance of Crawler Crane Pierhead

Day -1	
Working hours	22.00 - 04.15
Total Working Hours	6 Hours 15 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	2
Steering (riger)	3
Foreman	1
Worker (labor)	8
Number of Tools	2
Day 2	
Working hours	22.15 - 04.00
Total Working Hours	5 Hours 45 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	2
Steering (riger)	3
Foreman	1
Worker (labor)	8
Number of Tools	2
Day 3	
Working hours	22.00 - 04.30
Total Working Hours	6 Hours 30 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	2
Steering (riger)	3
Foreman	1
Worker (labor)	8
Number of Tools	2
Day 4	
Working hours	22.00 - 04.00
Total Working Hours	6 Hours 00 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	2
Steering (riger)	3
Foreman	1
Worker (labor)	8
Number of Tools	2

Day 5	
Working hours	22.00 - 04.15
Total Working Hours	6 Hours 15 Minutes
Number of Attached Pierheads	1
Skilled Labor	2
Operator	2
Steering (riger)	3
Foreman	1
Worker (labor)	8
Number of Tools	2

Source: Researcher Processed Data

The next step is to calculate the crawler crane performance index for one pierhead. The calculation of the segmental pierhead erection cost index using a crawler crane is carried out with the following formula:

$$\text{Index} = \frac{Total\ jam\ kerja}{Jam\ kerja\ normal} x \frac{Jml\ tenaga\ kerja/jml\ \ alat\ berat}{Jml\ komponen\ yang\ terpasang}$$

Table 25. CC Performance Index for Pierhead 1

Tanggal	Hari ke-1	Hari ke-2	Hari ke-3	Hari ke-4	Hari ke-5
	Indeks	Indeks	Indeks	Indeks	Indeks
Total Jam Kerja (8 jam/480 menit)	375 menit	345 menit	390 menit	360 menit	375 menit
Jumlah Segmen Terpasang	1	1	1	1	1
Jumlah Tenaga Kerja					
Tenaga Ahli (*skilled labour*)	1,56	1,44	1,63	1,50	1,56
Operator	1,56	1,44	1,63	1,50	1,56
Pengarah (*riger*)	2,34	2,16	2,44	2,25	2,34
Mandor	0,78	0,72	0,81	0,75	0,78
Pekerja (*labour*)	6,25	5,75	6,50	6,00	6,25
Alat	1,56	1,44	1,63	1,50	1,56

Table 26. Crawler Crane Performance Iendex For On Pierhead

Rata-Rata Indeks	
Tenaga Ahli (*skilled labour*)	1,54
Operator	1,54
Pengarah (*riger*)	2,31
Mandor	0,77
Pekerja (*labour*)	6,15
Alat	1,54

Sumber: Data Olahan Peneliti

The following is the calculation result of segmental pierhead erection work using beam lifters per one segment:

Table 27. Total Price for Installing One Segmental Pierhead with a Crawler Crane

Item	Indeks	Satuan	Harga Satuan		Jumlah
Tenaga Ahli (*skilled labour*)	1,54	OH	Rp 160.000	Rp	246.000
Operator	1,54	OH	Rp 160.000	Rp	246.000
Pengarah (*riger*)	2,31	OH	Rp 250.000	Rp	576.563
Mandor	0,77	OH	Rp 125.000	Rp	96.094
Pekerja (*labour*)	6,15	OH	Rp 95.000	Rp	584.250
Alat (*crawler crane*)	1,54	Hari	Rp 16.760.666	Rp	25.769.524
				Total	**Rp. 27.518.430,-**

Sumber: Data Olahan Peneliti

In the table above, it can be seen that the total price for segmental pierhead erection using a crawler crane per one pierhead is Rp. 27,518,430, -

Table 28. Crawler Crane Comparison of Beam Lifter and Prices

Item	Alat Berat			
	Beam lifter		*Crawler Crane*	
Tenaga Ahli (*skilled labour*)	Rp	194.350	Rp	246.000
Operator	Rp	304.200	Rp	246.000
Pengarah (*riger*)	Rp	210.000	Rp	576.563
Mandor	Rp	105.000	Rp	96.094
Pekerja (*labour*)	Rp	561.450	Rp	584.250
Alat (*beam lifter*)	Rp	22.400.280	Rp	25.769.524
Total	**Rp**	**23.775.280**	**Rp**	**27.518.430**
Persentase perbandingan biaya (%)		46.35%		53,65%

Sumber: Data Olahan Peneliti

4.5. Questionnaire Stage 1

The first stage questionnaire is an early stage questionnaire which aims to see expert responses regarding the variables that have been selected by the researcher through literature studies. Experts provide comments and input on variables so that they are more relevant for use at the next stage. The researcher gave a questionnaire to the experts which consisted of 46 variables. Then the expert will respond to the variables that have been determined by the author.

The results of the first stage questionnaire, namely that there is 1 variable that the expert eliminates, namely as follows:

Table 29. Results of the Phase I Questionnaire

Deleted Variables	
Code	Variable
X35	Payment by Owner to Contractor

Source: Researcher Processed Data

4.6. Questionnaire Stage 2

Furthermore, distributing questionnaires that have previously been validated by experts. Questionnaires were distributed to employees of PT. Acset Indonusa, Tbk in the JAPEK Elevated Toll project 2. Respondents were asked to fill in the level of influence of the variables proposed by the researcher on the two methods of segmental pierhead erection work on the JAPEK Elevated 2 Toll project.

4.6.1. Beam Lifter Validity Test

Requirements for the value of the validity test are if the value of R count> R table; 0.301. Of the 45 variables that had been tested for validity through the SPSS v22 software application, it was found that all variables were declared valid. And 1 dependent variable (Y) is also valid.

4.6.2. Beam Lifter Reliability Test

Reliability test is done to see the extent to which the measurement of a test remains consistent after being repeated on the subject and in the same conditions.

Table 30. Reliability Statistics (Beam lifter)

Reliability Statistics	
Cronbach's Alpha	N of Items
.946	46

Source: Researcher Processed Data

4.6.3. Beam Lifter Correlation Coefficient Test

In the correlation coefficient test, the basis for decision making is if the Sig. <0.05, the value is said to be correlated. The results can be seen in the table below:

Table 31. Correlation Testing for X and Y variables (Beam lifter)

No.	Kode	Signifikasi	Pearson Correlation	Syarat Nilai	Keterangan
1	X1	0,087	0,258	0,05	TIDAK KORELASI
2	X2	0,59	0,082	0,05	TIDAK KORELASI
3	X3	0,646	0,07	0,05	TIDAK KORELASI
4	X4	0,185	0,201	0,05	TIDAK KORELASI
5	X5	0,049	0,294	0,05	KORELASI
6	X6	0,654	0,069	0,05	TIDAK KORELASI
7	X7	0,738	0,051	0,05	TIDAK KORELASI
8	X8	0,2	0,195	0,05	TIDAK KORELASI
9	X9	0,66	0,067	0,05	TIDAK KORELASI
10	X10	0,085	0,26	0,05	TIDAK KORELASI
11	X11	0,939	0,012	0,05	TIDAK KORELASI
12	X12	0,027	0,33	0,05	KORELASI
13	X13	0,997	0	0,05	TIDAK KORELASI
14	X14	0,002	0,448	0,05	KORELASI
15	X15	0,005	0,413	0,05	KORELASI
16	X16	0,023	0,338	0,05	KORELASI
17	X17	0,052	0,291	0,05	TIDAK KORELASI
18	X18	0,003	0,428	0,05	KORELASI
19	X19	0,008	0,39	0,05	KORELASI
20	X20	0,26	0,171	0,05	TIDAK KORELASI
21	X21	0,26	0,171	0,05	TIDAK KORELASI
22	X22	0,156	0,215	0,05	TIDAK KORELASI
23	X23	0,294	0,16	0,05	TIDAK KORELASI
24	X24	0,107	0,244	0,05	TIDAK KORELASI
25	X25	0,378	0,134	0,05	TIDAK KORELASI
26	X26	0,467	0,111	0,05	TIDAK KORELASI
27	X27	0,017	0,353	0,05	KORELASI
28	X28	0,039	0,309	0,05	KORELASI
29	X29	0,154	0,216	0,05	TIDAK KORELASI
30	X30	0,155	0,216	0,05	TIDAK KORELASI
31	X31	0,057	0,286	0,05	TIDAK KORELASI
32	X32	0,001	0,467	0,05	KORELASI
33	X33	0,042	0,305	0,05	KORELASI
34	X34	0,006	0,401	0,05	KORELASI
35	X35	0,027	0,33	0,05	KORELASI
36	X36	0,003	0,432	0,05	KORELASI
37	X37	0	0,509	0,05	KORELASI
38	X38	0,086	0,259	0,05	TIDAK KORELASI
39	X39	0,083	0,261	0,05	TIDAK KORELASI
40	X40	0,003	0,437	0,05	KORELASI
41	X41	0,092	0,254	0,05	TIDAK KORELASI
42	X42	0,55	0,091	0,05	TIDAK KORELASI
43	X43	0,208	0,191	0,05	TIDAK KORELASI
44	X44	0	0,673	0,05	KORELASI
45	X45	0,73	-0,053	0,05	TIDAK KORELASI

The table above shows that there are 17 independent variables (X) that are correlated with the dependent variable (Y).

4.6.4. Beam Lifter Regression Test

Regression test to determine the relationship between the independent variable and the dependent variable.

Table 32. Regression Test Table (Beam Lifter)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.470	.553		.848	.401
	X_44	.868	.145	.673	5.971	.000
2	(Constant)	-.584	.640		-.913	.367
	X_44	.796	.138	.617	5.777	.000
	X_15	.320	.116	.296	2.770	.008

a. Dependent Variable: Y_1

Sumber: Data Olahan Peneliti

Regression equation:
Y '= a + b1X1 + b2X2 + b3X3 + ……. + bnXn Y '= 0.584 + 0.796X44 + 0.320X15

a. The constant is -0.584; means that if X1, X2, Xn are fixed values, then (Y) the value is -0.584 units.
b. The regression coefficient for the variable X44 is 0.796 or 79.6%; This means that if other independent variables are fixed in value and X44 increases by 1 unit, then the Y value will increase by 0.796 units or 79.6%. The coefficient is positive, meaning that there is a positive relationship between X44 and the value of Y, the higher the value of X44, the higher the value of Y. Paying attention to the provision / procurement of utilities in segmental pierhead erection work with beam lifters greatly affects the effectiveness of using the beam lifter itself.
c. The regression coefficient for the variable X15 is 0.320 or 32% and the sig value is 0.008> 0.005; meaning that the variable X15 is deleted because the significance value is greater than the requirement, namely 0.005.

4.6.5. R (R^2) Beam Lifter Determination Test

The coefficient of determination is used to determine the percentage of the influence of the independent variables together on the dependent variable by looking at the total coefficient of determination (R2).

Table 33. Table R2 (Beam Lifter)

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.673[a]	.453	.441	.724	
2	.733[b]	.538	.516	.674	2.044

a. Predictors: (Constant), X_44
b. Predictors: (Constant), X_44, X_15
c. Dependent Variable: Y_1

Sumber: Data Olahan Peneliti

The results of the analysis show that the value of R2 is 0.538 where the percentage of the influence of the independent variables, namely heavy equipment mobilization (X44), and load calculation (X15), on the dependent variable (Y2) is 53.8%. While the remaining 46.2% is influenced by other variables which are not included in this research model.

4.6.6. Crawler Crane Validity Test

Requirements for the value of the validity test are if the value of R count> R table; 0.301.

Of the 45 variables that had been tested for validity through the SPSS v22 software application, it was found that all variables were declared valid. And 1 dependent variable (Y) is also valid.

4.6.7. Crawler Crane Reliability Test

Reliability test is done to see the extent to which the measurement of a test remains consistent after being repeated on the subject and in the same conditions.

Table 34. Reliability Statistics (Crawler Crane)

Reliability Statistics

Cronbach's Alpha	N of Items
.950	46

Source: Researcher Processed Data

4.6.8. Crawler Crane Correlation Coefficient Test

In the correlation coefficient test, the basis for decision making is if the Sig. <0.05, the value is said to be correlated. The results can be seen in the table below:

Table 35. Testing the Correlation of X and Y variables (Crawler Crane)

No.	Kode	Signifikasi	Pearson Correlation	Syarat Nilai	Keterangan
1	X1	0,014	0,362	0,05	KORELASI
2	X2	0,064	0,279	0,05	TIDAK KORELASI
3	X3	0,005	0,413	0,05	KORELASI
4	X4	0,368	0,137	0,05	TIDAK KORELASI
5	X5	0,139	0,224	0,05	TIDAK KORELASI
6	X6	0,024	0,336	0,05	KORELASI
7	X7	0,039	0,309	0,05	KORELASI
8	X8	0,003	0,438	0,05	KORELASI
9	X9	0,020	0,345	0,05	KORELASI
10	X10	0,021	0,344	0,05	KORELASI
11	X11	0,275	0,166	0,05	TIDAK KORELASI
12	X12	0,007	0,397	0,05	KORELASI
13	X13	0,100	0,248	0,05	TIDAK KORELASI
14	X14	0,018	0,35	0,05	KORELASI
15	X15	0,038	0,31	0,05	KORELASI
16	X16	0,001	0,491	0,05	KORELASI
17	X17	0,005	0,416	0,05	TIDAK KORELASI
18	X18	0,000	0,498	0,05	KORELASI
19	X19	0,061	0,282	0,05	TIDAK KORELASI
20	X20	0,051	0,294	0,05	TIDAK KORELASI
21	X21	0,051	0,296	0,05	TIDAK KORELASI
22	X22	0,070	0,272	0,05	TIDAK KORELASI
23	X23	0,071	0,272	0,05	TIDAK KORELASI
24	X24	0,000	0,607	0,05	TIDAK KORELASI
25	X25	0,003	0,437	0,05	KORELASI
26	X26	0,184	0,202	0,05	TIDAK KORELASI
27	X27	0,132	0,228	0,05	TIDAK KORELASI
28	X28	0,016	0,358	0,05	KORELASI
29	X29	0,017	0,353	0,05	KORELASI
30	X30	0,005	0,409	0,05	KORELASI
31	X31	0,000	0,551	0,05	KORELASI
32	X32	0,008	0,392	0,05	KORELASI
33	X33	0,111	0,241	0,05	TIDAK KORELASI
34	X34	0,156	0,215	0,05	TIDAK KORELASI
35	X35	0,673	0,065	0,05	TIDAK KORELASI
36	X36	0,015	0,361	0,05	KORELASI
37	X37	0,125	0,232	0,05	TIDAK KORELASI
38	X38	0,013	0,366	0,05	KORELASI
39	X39	0,044	0,302	0,05	KORELASI
40	X40	0,024	0,337	0,05	KORELASI
41	X41	0,008	0,393	0,05	KORELASI
42	X42	0,763	0,046	0,05	TIDAK KORELASI
43	X43	0,001	0,461	0,05	KORELASI
44	X44	0,000	0,517	0,05	KORELASI
45	X45	0,000	0,513	0,05	KORELASI

Source: Researcher Processed Data

The table above shows that there are 26 independent variables (X) that are correlated with the dependent variable (Y).

4.6.9. Crawler Crane Regression Test

Regression test to determine the relationship between the independent variable and the dependent variable.

Table 36. Regression Test Table (Crawler Crane)

Coefficients*

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	2.106	.505		4.173	.000
	X_31	.488	.113	.551	4.331	.000
2	(Constant)	.357	.667		.536	.595
	X_31	.407	.103	.459	3.963	.000
	X_45	.469	.132	.411	3.542	.001
3	(Constant)	-.170	.641		-.266	.792
	X_31	.330	.098	.372	3.357	.002
	X_45	.408	.124	.357	3.295	.002
	X_44	.303	.104	.323	2.907	.006

a. Dependent Variable: Y_2

Sumber: Data Olahan Peneliti

Regression equation:

Y '= a + b1X1 + b2X2 + b3X3 + ……. + bnXn

Y '= 0.170 + 0.330X31 + 0.408X45 + 0.303X44

a. The constant is -0.170; meaning that if X1, X2, X3, Xn the value is fixed, then (Y) the value is -0,170 units.
b. The regression coefficient for the X31 variable is 0.330 or 33%; This means that if other independent variables are fixed in value and X31 increases by 1 unit, then the Y value will increase by 0.330 units or 33%. The coefficient is positive, meaning that there is a positive relationship between X31 and the Y value, the higher the X31 value, the higher the Y value. Paying attention to stressing PH conditions in

segmental pierhead erection work with the crawler crane greatly affects the effectiveness of using the crawler crane itself.

c. The regression coefficient for the variable X45 is 0.408 or 40.8%; This means that if other independent variables are fixed in value and X45 increases by 1 unit, then the Y value will increase by 0.408 units or 40.8%. The coefficient is positive, meaning that there is a positive relationship between X45 and the Y value, the higher the X45 value, the higher the Y value.This means that by paying attention to the condition of the ground in erection work with the crawler crane, it will further affect the effectiveness of using the crawler crane in segmental pierhead erection work.

d. The regression coefficient for the variable X44 is 0.303 or 30.3% and the sig value is 0.006> 0.005; meaning that the variable X44 is deleted because the significance value is greater than the requirement, namely 0.005.

4.6.10. Crawler Crane R (R^2) Determination Test

The coefficient of determination is used to determine the percentage of the influence of the independent variables together on the dependent variable by looking at the total coefficient of determination (R2).

Table 37. Table R2 (Crawler Crane)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.551a	.304	.287	.701
2	.681b	.464	.438	.622
3	.745c	.555	.523	.573

a. Predictors: (Constant), X_31

b. Predictors: (Constant), X_31, X_45

c. Predictors: (Constant), X_31, X_45, X_44

Source: Researcher Processed Data

The results of the analysis show that the value of R2 is 0.555 where the percentage of the influence of the independent variables, namely heavy equipment mobilization (X11), and load calculation (X50), on the dependent variable (Y2) is 55.5%. While the remaining 44.5% is influenced by other variables which are not included in this research model.

4.6.11. Expert Validation

The next stage, the variables are conveyed back for final validation to the same expert in stage I. Final (expert) validation is carried out by submitting a final (expert) questionnaire to the experts to find out the expert's opinion whether they agree or not and to provide an opinion on the variables that affect the effectiveness of the beam lifter. and crawler cranes in segmental pierhead erection work in order to find out what method is most effective to use in the Jakarta - Cikampek Elevated Toll project 2.

Table 38. Table of Expert Validation Recap (Beam lifter)

Variabel	Pakar 1		Pakar 2		Pakar 3		Kesimpulan
	Setuju	Tidak Setuju	Setuju	Tidak Setuju	Setuju	Tidak Setuju	
Kesediaan Peralatan dan Material (X15)	✔		✔		✔		

Sumber: Data Olahan Peneliti

The results of the final expert validation are as follows:

Table 39. Expert Validation Recap Table (Crawler Crane)

Variabel	Pakar 1		Pakar 2		Pakar 3		Kesimpulan
	Setuju	Tidak Setuju	Setuju	Tidak Setuju	Setuju	Tidak Setuju	
Kondisi *Stressing* PH (X31)	✔		✔		✔		
Keadaan Tanah (X45)	✔		✔		✔		

Sumber: Data Olahan Peneliti

5. Conclusion

a. From the aspect of time, the results of the calculation of cycle time and productivity in the segmental pierhead erection work are as follows:

Table 40. Comparison of Segmental Pierhead Erection Cycle Times

Alat	Rata-rata Waktu Siklus (menit)	Jumlah *Pierhead* (per hari)
Beam Lifter	358,444 menit	3 segmental PH/ 1 pierhead
Crawler Crane	321,172 menit	3 segmental PH/ 1 pierhead

Sumber: Data Olahan Peneliti

The difference in time is due to the erection of the segmental pierhead using a beam lifter for too long when moving the tool from 1 pier to the next so that in the preparation stage of segmental pierhead erection work using a beam lifter it takes a long time to move the lifting equipment.

b. From the aspect of cost, the calculation of the performance index of the tool can be concluded as follows:

Table 41. Comparison of Segmental Pierhead Erection Costs

Alat	Harga (per 1 *pierhead*)
Beam Lifter	Rp. 23.775.280,-
Crawler Crane	Rp. 27.518.430,-

Sumber: Data Olahan Peneliti

It can be seen in the table above that segmental pierhead erection work using beam lifters is cheaper than the cost of segmental pierhead erection using a crawler crane.

c. The results showed that the variable that affected the effectiveness of segmental pierhead erection using Beam Lifter was the availability of equipment and material (X15) where the percentage of influence of these variables with the dependent variable (Y) was 53.8%.

d. Meanwhile, the research results show that the variables that affect the effectiveness of segmental pierhead erection using a crawler crane are stressing conditions PH (X31) and soil conditions (X45) where the percentage of influence of these variables with the dependent variable (Y) is 55.5%. So it can be seen that segmental pierhead erection using a crawler crane is more effective than using a beam lifter. Where the percentage of influence (crawler crane) on variable Y is 55.5%.

6. Suggestion

In the Toll Jakarta - Cikampek Elevated 2 project, segmental pierhead erection with beam lifters and crawler cranes can be used both, but the use of the crawler crane method is better used because it is considered to be faster efficient and can speed up the schedule even though the crawler crane method is more expensive than the beam. lifter however the difference is only slight.

The erection method was chosen for the next project which is almost the same as the Jakarta - Cikampek Elevated 2 Toll project so that it is better to examine all the factors that are likely to occur during the project, so that work methods do not change in the middle of the work (Cabinet Secretariat Of The Republic Of Indonesia, 2019).

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