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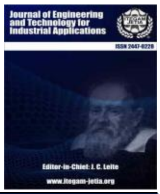

RESEARCH ARTICLE OPEN ACCESS

EVALUATING PRODUCTIVITY AND COSTS OF CONCRETE CASTING FOR STRUCTURAL ELEMENTS

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ABSTRACT

Indonesia has many construction companies due to its growing building construction sector. The productivity of heavy equipment plays a crucial role in project completion time and construction costs. A study comparing casting volume using Revit software is essential for the construction sector. Researchers are using Revit software to determine casting materials and assess casting equipment's productivity, such as portable pumps used for casting beams and floor slabs, concrete buckets used for casting columns, and casting costs. This quantitative research is a testament to our commitment to precision, as it utilizes actual project data, such as daily casting mapping and concrete supply. The data is then meticulously processed to produce output, such as differences in concrete volume between Revit software and on-site realization, the productivity of casting equipment, and casting costs. The analysis shows significant differences in material usage for casting on the 10th and 11th floors, directly impacting future construction projects' efficiency and cost-effectiveness.

I. INTRODUCTION

Project construction involves various activities to achieve specific objectives within a defined timeframe. It requires adequate resources such as skilled labor, materials, equipment, and practical implementation methods. Additionally, it involves managing costs and adhering to project timelines with a clear beginning and end [1]. A construction project is a series of well-planned, short-term activities that yield prompt and effective results. The 5M factors (man, materials, machine, money, and method) are pivotal in the decision-making process of a construction project [2],[3], [4]. These factors, which encompass human resources, building materials, construction equipment, project budget, and construction methods, guide the project's progression, ensuring the right tool weight, material selection, material volume, and workforce allocation.

Tool-heavy equipment is integral to civil engineering, as these specialized tools aid in various stages of the construction process, from laying the foundation to completing the roof [5]. They are particularly crucial in large-scale construction projects [6], where their use is essential for efficiency and timely task completion, resulting in the desired output within a shorter timeframe.

The tower crane is primarily composed of critical components such as the base section, mast section, climbing frame, support frame, slewing ring, slewing mast, cat head/tower top, jib, counter jib, counterweight, cabin sets, access ladder, trolley, hooks, and tie ropes[7],[8]. Each of these components plays a crucial role in the operation of the tower crane. The tower crane's functions include vertical movement (hoisting) for lifting and lowering loads, horizontal movement (trolley) for track traversal, and rotational movement (swing) for job rotation. The tower crane facilitates concrete movement from a truck mixer to the casting location using concrete buckets attached to the crane's hook[9],[10].

Nearly a century ago, Max Giese and Fritz Hull proposed pumping concrete [11]. This technique allows for quicker concrete delivery and `construction, setting new pumping height records. However, it can be complex and hazardous, leading to annual accidents [8],[12],[13]. Practical guidelines have been developed, and a versatile portable pump, the Frog Pump, can reach heights of over 200 meters, making it invaluable for high-rise construction [14-16]. On the other hand, a tower crane is a powerful and robust piece of equipment used for hoisting and transporting materials to elevated or high locations [17]. Typically employed in building construction projects, the tower crane is crucial in lifting heavy materials to facilitate construction work at great heights[18]. However, it is essential to note that in specific projects, using tower cranes may be challenging and necessary. Alternatives exist, and the decision to use this specific tool depends on the nature and requirements of the project, keeping in mind the substantial weight of the materials being handled.

These factors necessitate the contractor to carefully select suitable equipment, sources, power people, and project costs [19]. In project development, tools play a pivotal role in construction work. Emphasizes that a tool's operation's function and method, including its efficiency, safety features, and ease of use, must be thoroughly evaluated during the selection process to ensure optimal productivity [20]. This emphasis on efficiency empowers the audience, making them feel in control of the project's success [21].

Productivity is a critical factor that significantly influences the results of a construction project. Increased productivity can reduce the time spent on a project, reducing costs [22]. Conversely, tools that hinder productivity can inconvenience workers and inflate costs, underscoring the weight of each decision in project development. This highlights the audience's responsibility and accountability in ensuring optimal productivity, empowering them to make decisions integral to the project's success.

Chacón, highlight that work casting, as one component of many, significantly affects the speed of a project [23]. The large volume of construction beams and plates on the floor means that the productivity of all casting equipment directly impacts the project's time and costs [24-26]. It underscores the importance of your role in cost management. Your expertise and decisions are crucial in managing the costs and ensuring the project's success, making you an integral and valued part of the project's success.

Based on the description, the researcher will evaluate casting volumes in the field with volume calculation with Revit 3D software, productivity in tools casting concrete bucket and pump portable (Frog Pump), and cost foundry.

II. MATERIALS AND METHODS

II.1 MATERIALS

The research will analyze the casting columns, beams, and floor plates evaluation on Floor 10 and Floor 11 for the Surakarta Mother's Hospital Building construction project. The study will also analyze the productivity of crucial construction equipment such as the Portable Pump (Pump Frog) and the Tower Crane with a bucket, which plays a crucial role in the construction process. Count productivity on the 10th floor and 11th floor of the tool heavy pump portable for casting columns, beams, and plates, as well as productivity bucket on the Tower Crane For casting columns. The Unit Price Analysis Work (AHSP) for casting will also be evaluated. The project location can be seen in Figure 1, which depicts the conditions, environment, and boundaries of the construction site.

Figure 1: Mother's Hospital Building Construction Project Location.
Source: Author, (2024).

II.2 METHODS

Our data collection process is thorough and reliable. We will obtain primary data directly from sources for specific calculations and gather secondary data from oral or written sources for various preparations. Once all the necessary data for the final project is collected, it will be meticulously processed using Revit 3D software for 3D modeling software [27], [28], ensuring the results' reliability and your confidence in the project's outcomes.

Calculating time delay and adequate time will be required to calculate the productivity count for casting beams and floor plates using the Portable Pump (Pump Frog). The productivity count for casting columns using the Tower Crane with a bucket will involve necessary times for hoisting, slewing, trolley movement, landing, unloading, and loading. Furthermore, a calculation coefficient will be used to analyze price units, considering human resources, building materials, construction equipment, project budget, and construction methods. These factors guide the project's progress and ensure proper consideration for tool weight, material selection, material volume, and workforce allocation. Flow diagram research that can seen in Figure 2.

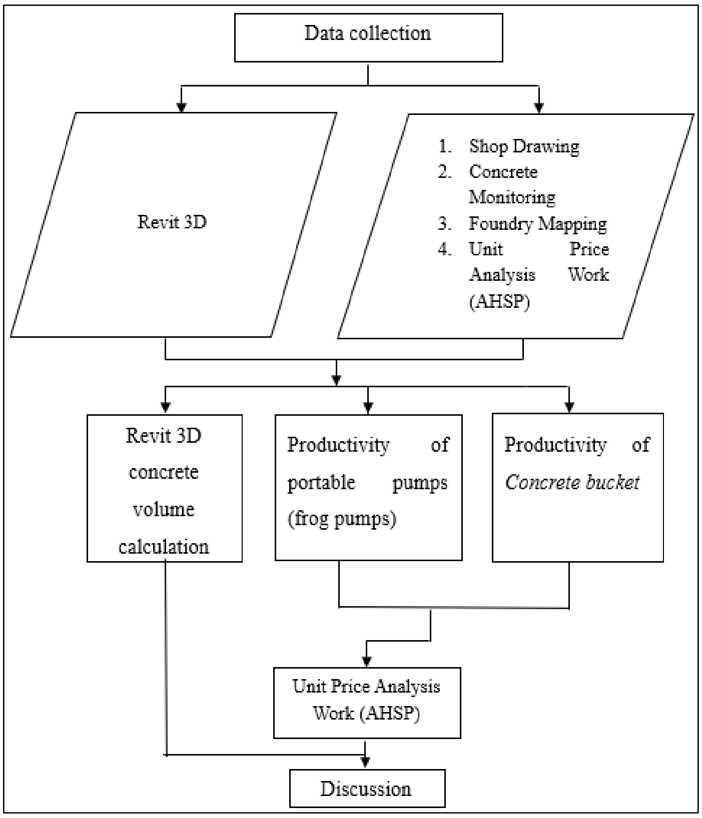

Figure 2: Research Method Flow Diagrams.
Source: Author, (2024).

III. RESULTS AND DISCUSSIONS

An evaluation casting was conducted to assess the suitability of the Revit 3D application in the field for constructing building. The analysis revealed that the casting zone on the 10th floor included casting head columns, beams, and plates. This information is presented in Figure 3. Figure 4 shows the 3D image of the casting zone on the 11th floor, including casting head columns, beams, and plates.

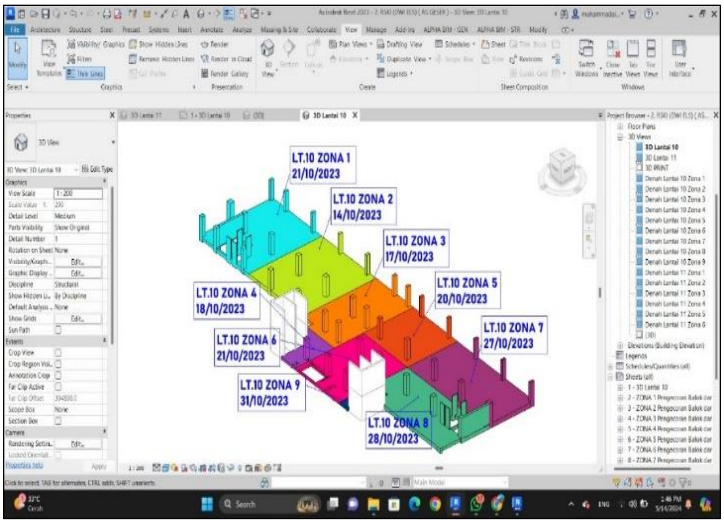

Figure 3: Displays the 3D view of the casting zone on the 10th floor of building.
Source: Author, (2024).

A comparison of the evaluation output results for casting concrete on the 10th floor using Revit 3D and the actual field conditions is presented in Table 1. The results indicate significant differences in the volume calculations for Zones 2, 3, 6, and 7. These differences, which are crucial for our project, may be attributed to waste and leftovers, as well as nonconformity in the plate floor or lack of precision by 125 mm. A graphical representation of the differences in the results is shown in Figure 5.

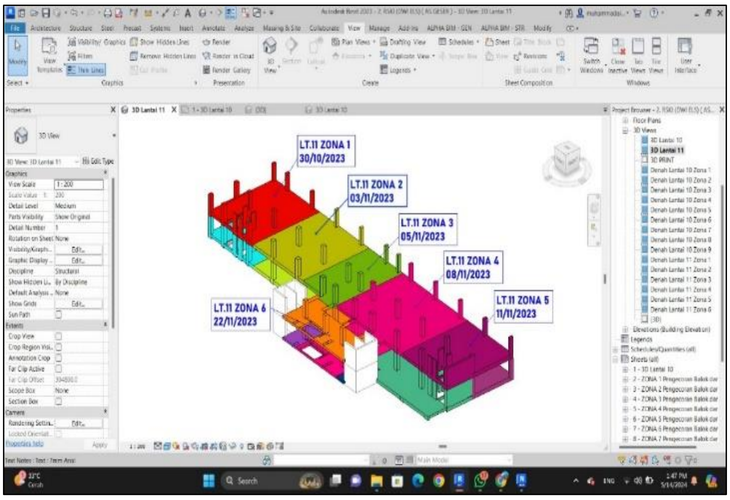

Figure 4: 3D View display 11th Floor Foundry.
Source: Author, (2024).

Table 1: Comparison Results of Concrete Volume with BIM Revit 3D and Realization 10th Floor Field.

Zone	Realization Field (m^3)	BIM Revit 3D (m^3)	Difference (m^3)
1	54	54.7	0.70
2	66	61.26	4.74
3	50.07	44.46	5.61
4	18.00	10.64	7.36
5	37.08	34.22	2.86
6	48	40.05	7.95
7	72	61.45	10.55
8	48	44.24	3.76
9	5,811	4.18	1.63

Source: Author, (2024).

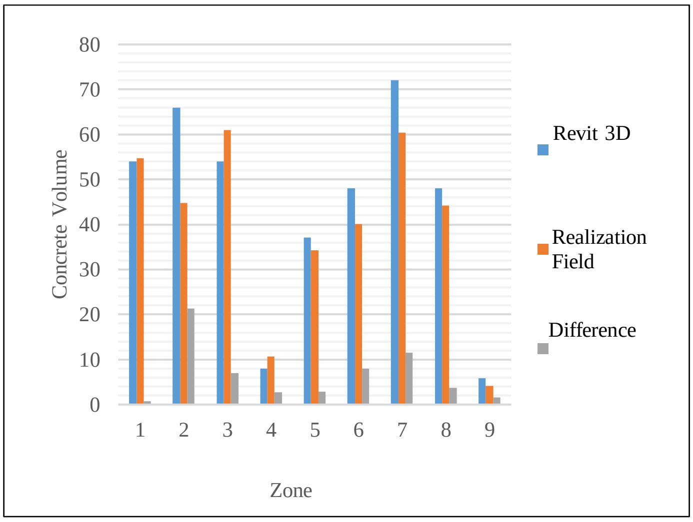

Figure 5: Concrete Volume Analysis Graph in the Field with Revit 3D.
Source: Author, (2024).

Similarly, the evaluation output results for casting concrete on the 11th floor are presented in Table 2, indicating differences in volume calculations for Zones 2, 5, and 6. These differences, which underscore the need for precision in our work, may be attributed to factors such as waste and leftovers, as well as nonconformity in the plate floor or lack of precision by 125 mm. A comparative analysis graph is presented in Figure 6.

Table 2: Comparison Results of Concrete Volume with BIM Revit 3D and Realization 11th Floor Field.

Zone	Realization Field(m^3)	BIMRevit 3D(m^3)	Difference(m^3)
1	54	53.72	0.28
2	72	60.62	11.38
3	60	52.52	7.48
4	84	80.26	3.74
5	66	52.47	13.53
6	42.8	31.27	11.53

Source: Author, (2024).

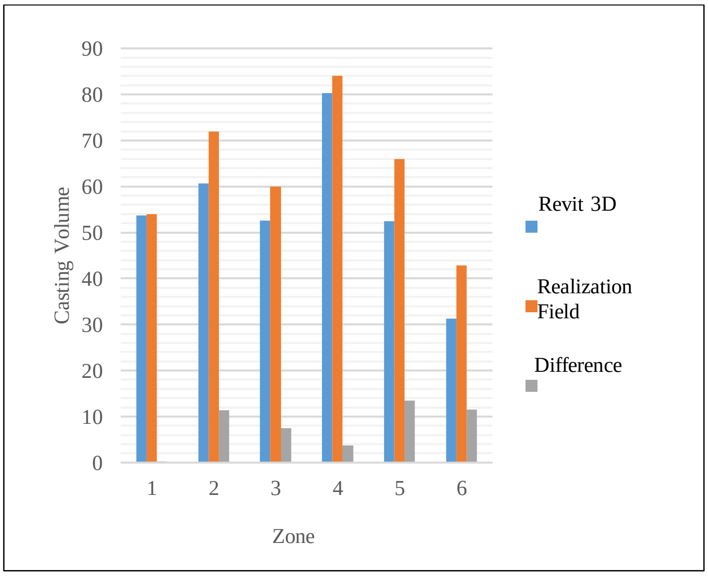

Figure 6: Comparative Analysis Graph of 11th Floor Concrete Volume.
Source: Author, (2024).

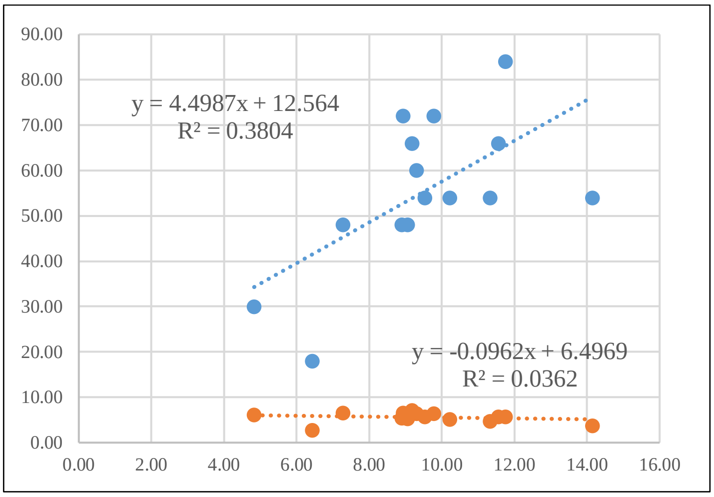

Figure 7: Effect of Volume and Time on Productivity of Portable Pumps.
Source: Author, (2024).

Calculating Portable Pump Productivity (Frog Pump) derived from concrete supply and sample intervals is a meticulous and precise process. This data is then analyzed, considering time delay, effectiveness, and total Time. The delay influences the total Time in the day. The average productivity of the portable pump at the foundry plate on the 10th floor and 11th floor, as seen in Table 3, is a result of these precise calculations, ensuring the accuracy of the results. This study comprehensively analyzes the effect of Volume and Time on productivity. Figure 7 illustrates the factors that significantly impact productivity, underlining the thoroughness and importance of this analysis, which is crucial for understanding the dynamics of portable pump productivity.

Table 3: Average Productivity of Portable Pumps in Foundries plate 10th Floor and 11th Floor.

Zone	10th floor	11th floor	10th floor	11th floor
	(m^3 /hour)	(m^3 /hour)	(m^3 / day)	(m^3 / day)
1	14,15	11.32	113.19	90.63
2	11.55	8.92	92.36	71.4
3	9.53	9.18	76.24	73.50
4	6.43	11.74	51.43	93.99
5	8.89	9.30	71.11	74.42
6	7.27	10.22	58.18	81.77
7	9.77	-	78.19	-
8	9.06	-	72.45	-
9	4.83	-	38.61	-
Average	9.05	10,11	72.42	80.95

Source: Author, (2024).

The Figure 6 shows the R Square values (R2) for Volume (X1) and Time (X2) as predictors of productivity. Volume has a moderate R2 value of 0.3804, while Time has a weak R2 value of 0.0362. The correlation coefficients (r) for Volume and Time are 0.144 and 0.001, respectively, indicating weak correlations with productivity. This comprehensive analysis considers both variables simultaneously and independently. The results indicate a strong relationship between Volume and time (independent variables) and productivity (dependent variable), explaining 77.77% of the productivity.

Concrete buckets and heavy tower cranes are used at the foundry to construct columns. The tower crane GHD7032-12 is used for casting columns. It is fast, agile, and efficient. Table 4 shows the average productivity of tower cranes with concrete buckets on the 10th and 11th floors. This table also analyzes the influence of volume and time on productivity, as depicted in Figure 8.

Table 4: Average TC Productivity with Concrete Bucket Floor 10 and Floor 11.

Kolom	10th floor	11th floor	10th floor	11th floor
	(m^3 /hour)	(m^3 /hour)	(m^3 / day)	(m^3 / day)
1	4.79	4.53	38.39	36.25
2	2.25	3.84	18.01	30.77
3	3.96	4.66	31.68	37.31
4	4.93	4.33	39.47	34.69
5	3.72	5.44	37.78	43.52
6	4.70	5.48	37.61	35.90
7	4.99	5.21	39.91	41.71
8	5.27	5.21	42.23	41.75
9	7.96	4.96	63.69	39.75
10	-	5.06	-	40.54
Average	4.84	4.78	38.76	38.22

Source: Author, (2024).

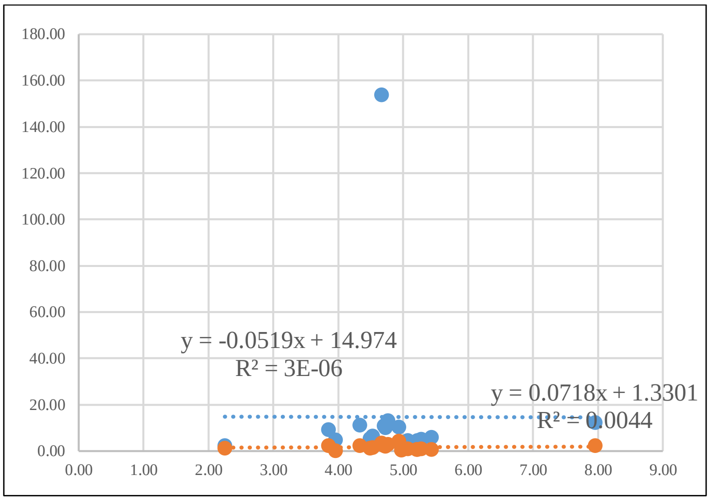

Figure 8: Chart Effect of Volume and Time on TC Productivity with Concrete.
Source: Author, (2024).

The R Square value determines how well the independent variables (volume and time) predict the dependent variable (productivity). The obtained R2 values for volume and time are considered weak, indicating a weak correlation between these variables and productivity. The analysis indicates that volume and time have a feeble influence on productivity, with an R2 value of 0.0056.

Based on the meticulously calculated productivity for casting columns, beams, and plate floors, the researcher can estimate the cost of the concrete volume using two different tools. The Portable Concrete Pump (Frog Pump) is used for casting beams and plate floors, while TC with Concrete Buckets is used for casting columns. By calculating the cost of casting one cubic meter for each zone, we can determine the total costs for casting columns on the 10th and 11th floors. The prices are based on Unit Price Analysis Work of Surakarta and can be found in Table 5.

Table 5: Recapitulation of Total Column Casting Prices.

Floor	Zone	Volume (m^3)	Cost 1 m^3 (IDR)	Total cost (IDR)
10	Zone 1	13.16	1,123,560	14,613,496
	Zone 2	2.52	1,135,618	2,806,825
	Zone 3	4.80	1,133,397	5,332,928
	Zone 4	10.36	1,124,434	11,506,935
	Zone 5	10.08	1,126,765	11,189,055
	Zone 6	10.92	1,124,129	12,126,075
	Zone 7	3.64	1,123,434	4,041,374
	Zone 8	5.04	1,126,957	5,594,942
	Zone 9	12.32	1,123,076	13,665,058
11	Zone 1	6.44	1,126,142	7,152,023
	Zone 2	9.24	1,124,933	10,266,891
	Zone 3	15.40	1,123,247	17,101,265
	Zone 4	11.20	1,124,434	12,439,929
	Zone 5	5.88	1,126,765	6,438,147
	Zone 6	5.32	1,125,060	5,908,361
	Zone 7	3.64	1,122,469	4,040,916
	Zone 8	4.48	1,130,292	5,908,361
	Zone 9	2.24	1,141,056	2,487,027
	Zone 10	4.48	1,130,584	4,973,799

Source: Author, (2024).

Evaluating the productivity and cost of concrete casting for structural elements, such as slabs and columns, involves a comprehensive analysis of various factors, including labor and equipment. As civil engineers, construction project managers, and professionals involved in concrete casting operations, your role is integral in this process. Casting productivity is greatly influenced by the efficiency of tools and labor, which directly affects the output in the casting process [29]. Research shows that the productivity of casting using a concrete pump is higher than using a tower crane. These differences highlight the importance of selecting the right tools to improve productivity metrics, which is essential for identifying areas for improvement in foundry operations [30]. In addition, labor efficiency is essential in reducing costs and increasing overall productivity in concrete casting [31]. Therefore, a thorough evaluation of labor and equipment and productivity metrics, with your active involvement, is essential to improve the efficiency and cost-effectiveness of concrete casting for structural elements [32].

IV. CONCLUSIONS

Our study analyzed casting productivity on the 10th and 11th floors. We found discrepancies in zones 1-9 on the 10th and 1-6 on the 11th floors. Productivity of foundry beams and plates, time with buckets, and TC productivity were compared. Our analysis revealed a significant influence of volume and time on productivity, with a correlation of 0.60. The cost for casting beams and plates on the 10th floor was IDR 530,670,938; on the 11th floor, it was IDR 469,403,363. The total cost for casting columns was IDR 80,876,688 on the 10th floor and IDR 75,781,783 on the 11th floor.

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