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PRODUCTIVITY EVALUATION USING THE WORK STUDY METHOD IN CASTING WORK

Ayu Fatimah Sari [1*], Griselda Junianda Velantika [2,*]

[1] Civil Engineering Department, Politeknik Negeri Malang, Malang, Indonesia
[2]Civil Engineering Study Program, UPN Veteran Jawa Timur, Surabaya, Indonesia

*Corresponding author: ayu.fatimah@polinema.ac.id

ABSTRACT

The construction project's goal must be achieved through good productivity. Two of the key elements that guarantee project success are workers' and machines' productivity. Their combined productivity will reflect the ability of a team to complete a project. The work study method, or sometimes referred to as time and motion study, is used to measure and assess productivity. This study uses an observational approach and combines qualitative and descriptive research methods. The subjects of this study are concrete casting workers and mixer truck machines. The objects of this research are the existing methods of the project and the duration. The productivity analysis's findings indicate that certain aspects of the task can be enhanced to raise productivity levels. The productivity that has been proposed with the work study method and the man-machine chart as the tool shows an average increase in concrete casting workers of about 13%, and an increase in the mixer truck machine of roughly 36%.

Keywords: man-machine chart, productivity, readymix concrete casting, time and motion study, work study

Introduction

Indonesia's economic growth has driven large-scale infrastructure development. Sustainable infrastructure development is crucial to support economic growth. The government's efforts to improve welfare extend beyond economic support infrastructure to the housing sector. According to data from the Central Statistics Agency (BPS), Indonesia's population increased by 5.4% between 2020 and 2024 [1]. The high annual population growth has led to a surge in demand for housing. This has led to numerous housing developments in various regions across Indonesia.

To meet the development targets of construction projects, good labor productivity is essential. Engineers define productivity as the utilization of production or the efficiency of labor [2]. This is a crucial factor in ensuring project success, and a high level of labor productivity demonstrates the workers' ability to complete assigned tasks. Mismatches between scheduling plans and actual results can occur if project planning fails to take labor productivity into account.

Estimating productivity is difficult because of the varying productivity factors. Furthermore, the conditions prevailing in each project impact labor productivity. These factors can be divided into internal and external factors, including project conditions, project support facilities, work experience, management organization, and other factors that can affect total productivity [3].

Project management is a complex topic. Each element complements the others. Properly managing these elements can improve overall project performance. Optimizing the machinery used on a project is one way to accelerate performance, aside from relying on human productivity [4]. Wise and efficient use of machinery not only speeds up the process but also reduces costs in terms of human labor.

Efforts to improve productivity require knowledge of baseline productivity. Data on labor productivity and machine utilization can assist project managers in increasing productivity. Efforts to improve productivity aim to improve planned productivity values, requiring complete field data to achieve this. One of the best ways to increase productivity is to reduce ineffective work hours, particularly by improving individual work ethic [5].

This study observed and evaluated initial productivity. The method used is a time and motion study, also known as a work study. This method was developed using work maps in the form of flow process charts and man-machine charts

as supporting tools. Data processing using a work study is about minimizing idle time or eliminating inefficient work activities [6].
Observations were conducted at two locations, namely housing X in Surabaya and housing Y in Sidoarjo, with the work studied being casting work using ready-mix concrete.

Methods

Observations were conducted in two housing locations, namely housing X in Surabaya and housing Y in Sidoarjo. The subjects of this study were ready-mix concrete casting workers and truck mixer machines. In housing X, the number of research samples was 12 ready-mix concrete casting workers and 2 truck mixer machines. While in housing Y, the number of research samples was 13 ready-mix concrete casting workers, and also 1 truck mixer machine. The object of this study was to observe the existing project processes and methods, and the time or duration of each production process, which includes productive time and unproductive time.
After conducting observations, the data obtained from the field was then analyzed using a work study method using flow process charts and man-machine charts. The results of the observations were then determined, and productivity improvements were planned by improving work procedures.

Results

Data Collection

Data collection in this study used the observation method. Data collection was conducted at two locations, namely, housing development project X, Surabaya, and housing Y, Sidoarjo. This observation method was to obtain primary data in the form of the process of work stages, the duration of each job, and the work method in ready-mix concrete casting work. The researcher observed each process and the duration of the casting work by 3 ready-mix trucks. The process observation referred to the existing method that occurs in the field. Observations of the duration of each job were taken from the average of three observations. Data for the project location, ready-mix truck concrete load volume, and casting purpose are shown in Table 1.

Table 1. Project Data, Readymix Truck Volume, and Element Type

	Project	Volume	Element Type
Truck 1 and 2	Housing X	$6m^3$	Sloof
Truck 3	Housing Y	$5m^3$	2^{nd} Floor Slab

The process of the work stages, along with the duration of the process stages, are shown in Table 2 for the casting work of 1 readymix truck with a capacity of 6 m3.

Table 2. Work Stages Process and Duration for Truck 1

Work Description	Duration (seconds)
Site Preparation	375
Fresh Concrete Unloading	3190
Casting	2916
Cleaning	892

Table 3 shows the process of the work stages along with the duration of the process stages for the casting work of 2 readymix trucks with a capacity of 6 m3. The process of the work stages along with the duration of the process stages is shown in Table 4 for the casting work of 3 readymix trucks with a capacity of 5 m3.

Table 3. Work Stages Process and Duration for Truck 2

Work Description	Duration (seconds)
Truck 2 is waiting for truck 1 to finish	1745
Site Preparation	222
Fresh Concrete Unloading	2318
Casting	2418
Cleaning	985

Table 4. Work Stages Process and Duration for Truck 3

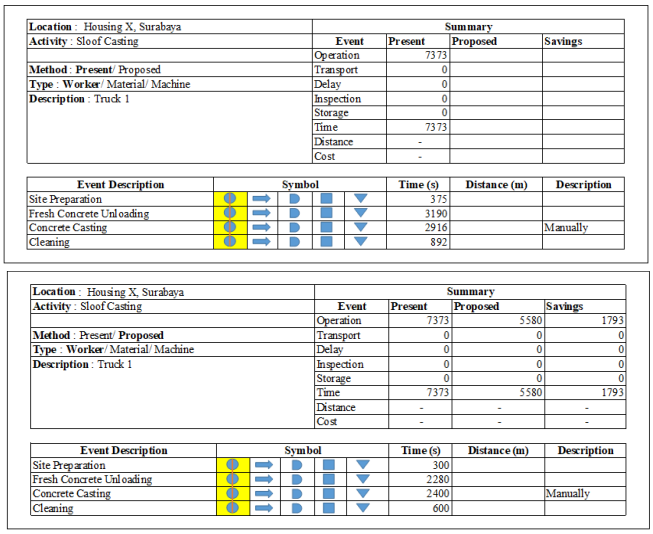
Work Description	Duration (seconds)
Site Preparation	468
Fresh Concrete Unloading	811
Transporting fresh concrete to 2^{nd} floor	2720
Casting	4796
Cleaning	619

Discussion

Data Processing Using a Flow Process Chart

The collected data will then be processed using a flow process chart. A flow process chart or process flow map is a map that depicts all productive and unproductive activities involved in the work process [7]. Analysis using this type of work chart helps reduce cycle time by reducing delays or even eliminating wasteful or inefficient activities. The flow process chart used here is a worker-type, a process flow chart that records what workers do.

A present flow process chart is a form of process flow map



Location : Housing X, Surabaya	Summary			
Activity : Sloof Casting	Event	Present	Proposed	Savings
	Operation	7373		
Method : Present/ Proposed	Transport	0		
Type : Worker/ Material/ Machine	Delay	0		
Description : Truck 1	Inspection	0		
	Storage	0		
	Time	7373		
	Distance	-		
	Cost	-		

Event Description	Symbol	Time (s)	Distance (m)	Description
Site Preparation		375		
Fresh Concrete Unloading		3190		
Concrete Casting		2916		Manually
Cleaning		892		

Location : Housing X, Surabaya	Summary			
Activity : Sloof Casting	Event	Present	Proposed	Savings
	Operation	7373	5580	1793
Method : Present/ Proposed	Transport	0	0	0
Type : Worker/ Material/ Machine	Delay	0	0	0
Description : Truck 1	Inspection	0	0	0
	Storage	0	0	0
	Time	7373	5580	1793
	Distance	-	-	-
	Cost	-	-	-

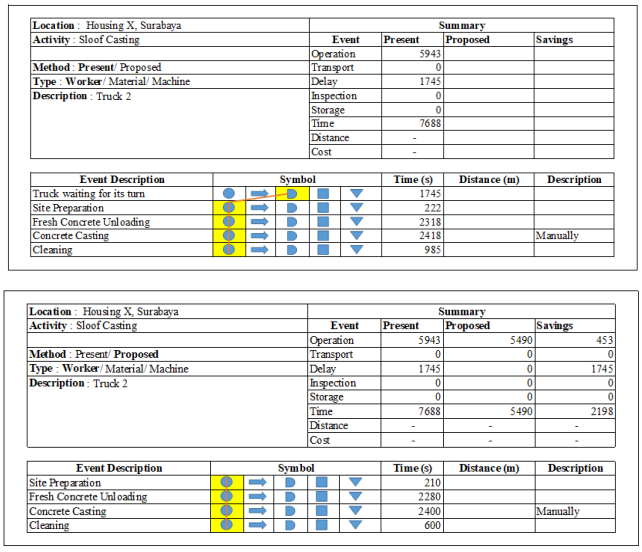
Event Description	Symbol	Time (s)	Distance (m)	Description
Site Preparation		300		
Fresh Concrete Unloading		2280		
Concrete Casting		2400		Manually
Cleaning		600		

Figure 1. Present and Proposed Flow Process Chart for Truck 1

that shows the actual conditions of a production process. A proposed flow process chart is a map of the process flow proposed to improve productivity in the production process. Savings are the time savings achieved [8].

The present and Proposed Flow Process Chart for readymix truck 1 will be shown in Fig. 1. Compared to the original operational activity data, there is a reduction in time from each activity, namely operational activities that cause a reduction in the total time as a whole. Time reduction can be based on observations. If, during the observation, there are ineffective or unproductive activities, the unproductive time can be reduced so that only productive time remains. The duration of time obtained is data taken directly from the field. Therefore, the written time does not have a formula.

Furthermore, for the second ready-mix truck, which is a continuation of the first truck, the present chart will show a delay that will be eliminated in the proposed chart because it is considered an unproductive activity, including by reducing unproductive hours in operational activities. Both results are shown in Fig. 2.



Location : Housing X, Surabaya	Summary			
Activity : Sloof Casting	Event	Present	Proposed	Savings
	Operation	5943		
Method : Present/ Proposed	Transport	0		
Type : Worker/ Material/ Machine	Delay	1745		
Description : Truck 2	Inspection	0		
	Storage	0		
	Time	7688		
	Distance	-		
	Cost	-		

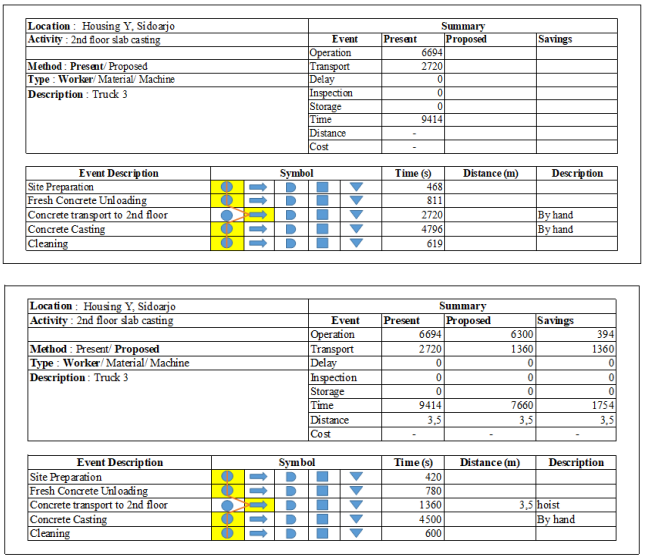
Event Description	Symbol	Time (s)	Distance (m)	Description
Truck waiting for its turn		1745		
Site Preparation		222		
Fresh Concrete Unloading		2318		
Concrete Casting		2418		Manually
Cleaning		985		

Location : Housing X, Surabaya	Summary			
Activity : Sloof Casting	Event	Present	Proposed	Savings
	Operation	5943	5490	453
Method : Present/ Proposed	Transport	0	0	0
Type : Worker/ Material/ Machine	Delay	1745	0	1745
Description : Truck 2	Inspection	0	0	0
	Storage	0	0	0
	Time	7688	5490	2198
	Distance	-	-	-
	Cost	-	-	-

Event Description	Symbol	Time (s)	Distance (m)	Description
Site Preparation		210		
Fresh Concrete Unloading		2280		
Concrete Casting		2400		Manually
Cleaning		600		

Figure 2. Present and Proposed Flow Process Chart for Truck 2

Truck 3, which is located in a different location from trucks 1 and 2, namely at the Y housing complex, has a fairly different present flow process chart, namely that in addition to operational activities, there will be transport activities, namely transport to the 2nd floor because it is a second-floor slab casting activity. Unfortunately, this process is still carried out manually by workers. Then, in the proposed chart, it will be proposed to reduce these operational and transport activities, especially by replacing manual methods with machines or tools. These two flow process chart images will be shown in Fig. 3.



Location : Housing Y, Sidoarjo	Summary			
Activity : 2nd floor slab casting	Event	Present	Proposed	Savings
	Operation	6694		
Method : Present/ Proposed	Transport	2720		
Type : Worker/ Material/ Machine	Delay	0		
Description : Truck 3	Inspection	0		
	Storage	0		
	Time	9414		
	Distance	-		
	Cost	-		

Event Description	Symbol	Time (s)	Distance (m)	Description
Site Preparation		468		
Fresh Concrete Unloading		811		
Concrete transport to 2nd floor		2720		By hand
Concrete Casting		4796		By hand
Cleaning		619		

Location : Housing Y, Sidoarjo	Summary			
Activity : 2nd floor slab casting	Event	Present	Proposed	Savings
	Operation	6694	6300	394
Method : Present/ Proposed	Transport	2720	1360	1360
Type : Worker/ Material/ Machine	Delay	0	0	0
Description : Truck 3	Inspection	0	0	0
	Storage	0	0	0
	Time	9414	7660	1754
	Distance	3,5	3,5	3,5
	Cost	-	-	-

Event Description	Symbol	Time (s)	Distance (m)	Description
Site Preparation		420		
Fresh Concrete Unloading		780		
Concrete transport to 2nd floor		1360	3,5	hoist
Concrete Casting		4500		By hand
Cleaning		600		

Figure 3. Present and Proposed Flow Process Chart for Truck 3

Data Processing Using Man-Machine Chart

A man-machine chart is a chart that shows the activities of more than one subject (worker, machine, or equipment), and each is recorded on a time scale to show the interrelationships [9]. The man-machine charts presented come in two formats: present (actual) and proposed. The present chart will show the subject's actual productivity, while the proposed chart will show methods and improvements to increase productivity.

Before creating a man-machine chart to calculate productivity, an Activity Cycle Diagram (ACD) must first be created. An ACD is a method for modeling the interactions of system objects. Creating an ACD requires understanding the components and the key activities performed by each component [10]. Fig. 4. Will show the ACD of the casting activity, which has been combined from the ACD components of the workers and machines.

In Fig. 5, the Present Man-Machine Chart of 1 readymix truck in housing X shows 57% worker productivity and 100% equipment productivity. Meanwhile, in the Proposed Man-Machine Chart, after increasing worker productivity by one of which is by casting while waiting for the concrete to finish unloading, it shows an increase in worker productivity of 80%.

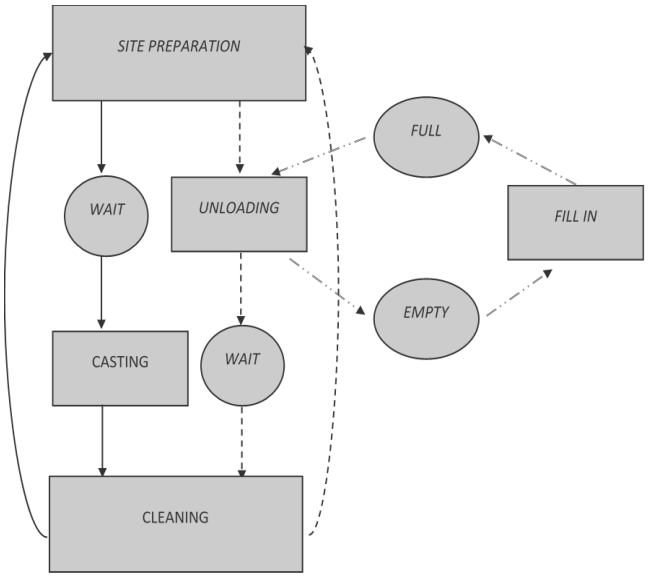


Figure 4. Activity Cycle Diagram (ACD) Concrete Casting Activity

Moving on to ready-mix truck 2, due to having to wait for truck 1 to finish, truck 2 had to experience idle time, which ultimately resulted in machine productivity decreasing to 59% while workers were at 70%. This situation was corrected in the proposed chart by eliminating idle time, so that machine productivity could increase to 100% and workers to 79%. An overview of this activity will be shown in Fig. 6.

Work Type:	Readymix Concrete Casting			
Machine Type:	Mixer Truck 1			
Number of Workers	12		**Method** : **Present**/ Proposed	
Activity Description	**Worker**		**Machine**	
	Worker	**Time (dt)**	**Machine**	**Time (dt)**
Site Preparation	Work	375	Work	375
Fresh Concrete Unloading	Idle	3190	Work	3190
Casting	Work	2916	**FINISHED**	
Cleaning	Work	892		
Summary				
	Worker		**Machine**	
Idle Time (second)	3190		0	
Working Time (second)	4183		3565	
Total cycle time (second)	7373		3565	
Productivity (%)	57		100	

Legends: : *working time* : *idle time*

Work Type:	Readymix Concrete Casting			
Machine Type:	Mixer Truck 1			
Number of Workers	12		**Method** : Present/ **Proposed**	
Activity Description	**Worker**		**Machine**	
	Worker	**Time (dt)**	**Machine**	**Time (dt)**
Site Preparation	Work	300	Work	300
Fresh Concrete Unloading	Idle	1140	Work	2280
Casting	Work	3540	FINISHED	
Cleaning	Work	600		
Summary				
	Worker		**Machine**	
Idle Time (second)	1140		0	
Working Time (second)	4440		2580	
Total cycle time (second)	5580		2580	
Productivity (%)	80		100	

Legends: : *working time* : *idle time*

Figure 5. Present and Proposed Man-Machine Chart Truck 1

Work Type:	Readymix Concrete Casting					
Machine Type:	Mixer Truck 2					
Number of Workers	12			Method : Present/ Proposed		
Activity Description	Worker			Machine		
	Worker	Time (dt)		Machine	Time (dt)	
Truck waiting for its turn	Work	1745		Work	1745	
Site Preparation	Work	222		Work	222	
Fresh Concrete Unloading	Idle	2318		Work	2318	
Casting	Work	2418		FINISHED		
Cleaning	Work	985				
Summary						
	Worker			Machine		
Idle Time (second)	2318			1745		
Working Time (second)	5370			2540		
Total cycle time (second)	7688			4285		
Productivity (%)	70			59		

Legends: : working time
: idle time

Work Type:	Readymix Concrete Casting					
Machine Type:	Mixer Truck 2					
Number of Workers	12			Method : Present/ Proposed		
Activity Description	Worker			Machine		
	Worker	Time (dt)		Machine	Time (dt)	
Site Preparation	Work	210		Work	300	
Fresh Concrete Unloading	Idle	1140		Work	2280	
Casting	Work	3540		FINISHED		
Cleaning	Work	600				
Summary						
	Worker			Machine		
Idle Time (second)	1140			0		
Working Time (second)	4350			2580		
Total cycle time (second)	5490			2580		
Productivity (%)	79			100		

Legends: : working time
: idle time

Figure 6. Present and Proposed Man-Machine Chart Truck 2

The 3 ready-mix trucks located in residential area Y show a fairly high original productivity of 90% worker productivity and 100% machine productivity. However, this can be improved by reducing unproductive worker activities so that worker productivity can increase to 95% and machine productivity remains the same. This is shown in Fig. 7.

Work Type:	Readymix Concrete Casting					
Machine Type:	Mixer Truck 3					
Number of Workers	13			Method : Present/ Proposed		
Activity Description	Worker			Machine		
	Worker	Time (dt)		Machine	Time (dt)	
Site Preparation	Work	468		Work	468	
Fresh Concrete Unloading	Idle	811		Work	811	
Transport to 2nd floor	Work	2720		FINISHED		
Casting	Work	4796				
Cleaning	Work	619				
Summary						
	Worker			Machine		
Idle Time (second)	811			0		
Working Time (second)	8603			1279		
Total cycle time (second)	9414			1279		
Productivity (%)	91			100		

Legends: : working time
: idle time

Work Type:	Readymix Concrete Casting					
Machine Type:	Mixer Truck 3					
Number of Workers	13			Method : Present/ Proposed		
Activity Description	Worker			Machine		
	Worker	Time (dt)		Machine	Time (dt)	
Site Preparation	Work	420		Idle	420	
Fresh Concrete Unloading	Idle	390		Work	780	
Transport to 2nd floor	Work	1750		FINISHED		
Casting	Work	4500				
Cleaning	Work	600				
Summary						
	Worker			Machine		
Idle Time (second)	390			0		
Working Time (second)	7270			1200		
Total cycle time (second)	7660			1200		
Productivity (%)	95			100		

Legends: : working time
: idle time

Figure 7. Present and Proposed Man-Machine Chart Truck 3

Conclusion

In this study, which focuses on the productivity of workers in a case study of casting activities in housing construction using the work study method, the results of increased productivity are as follows.

1. The increase in worker productivity for truck 1 is 23%; truck 2 is 10%; and truck 3 is 5%.
2. The increase in mixer machine productivity for truck 1 is 32%; truck 2 is 39%; and truck 3 is 51%

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