JOURNAL OF APPLIED MECHANICAL ENGINEERING INNOVATION

Journal homepage: https://journal.uny.ac.id/publications/jamei

Lean Manufacturing and Manufacturing Cycle Effectiveness Analysis of the Fabrication Process for the PT Pou Yuen Workshop Construction

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ARTICLE INFO

Article history:

Received	16.09.2025
Revised	26.09.2025
Accepted	06.10.2025

Keywords:

lean manufacturing, manufacturing cycle effectiveness, fabrication process, production effectiveness

ABSTRACT

This study aims to increase production effectiveness in the fabrication process for the PT Pou Yuen Indonesia workshop construction by applying Lean Manufacturing and Manufacturing Cycle Effectiveness (MCE). The research used a quantitative descriptive method by taking representative samples from the overall production process in the cutting, setting, and submerged arc welding (SAW) lines. Data were collected through interviews, observation, documentation, and measurements of process time and transfer distance. The results show that the most effective cutting method is the method used by MSS, which applies a double-nozzle cutting process. In the setting process, the most effective methods are those used by MKR and MSS because they require fewer workers and have shorter process times than SST. In the welding process, the most effective method is the method used by MKR because flux is supplied during the welding process. Several types of waste were identified, including waiting time, transportation waste, inventory waste, motion waste, and processing waste. Applying the recommended process methods can reduce the total production process time by 9,011.99 seconds for one WF beam and reduce transfer distance by 2,070 m.

1 Introduction

Production is the activity of processing raw materials into semi-finished or finished products by involving labor, machines, and auxiliary tools so that the product has greater added value [1]. Production processes are required to be effective and efficient in order to reduce production costs. One important factor in improving production effectiveness is production process time. In practice, production processes often contain activities that do not add value for customers. These activities are known as non-value-added activities and should be eliminated to improve production effectiveness. Lean Six Sigma approaches are commonly used in manufacturing, service, and production systems to reduce waste and improve process performance [2]. In lean manufacturing, waste elimination and continuous improvement are important principles for improving production performance [3]. Therefore, production time caused by non-value-added activities can be reduced and the overall production process can be improved.

PT Bukaka Teknik Utama Tbk. (Road Construction Equipment Business Unit) received a project to construct a workshop for PT Pou Yuen Indonesia located in Cianjur, West Java. The scope of work included the fabrication process up to finishing. Fabrication was carried out by four subcontractors: three subcontractors worked on fabrication, and one subcontractor worked on blasting and painting.

The fabrication process was performed by three subcontractors, namely PT Surya Smartekindo (SST), PT Mekar Kontruksindo (MKR), and PT Mulia Sarana Sejahtera (MSS). Because the work was carried out by different subcontractors, the working methods varied even though the product and type of work were the same. Differences in working methods also caused differences in processing time.

Only two forklifts were available to serve all material-handling activities in the workshop; therefore, delays in moving materials often occurred. Although the workshop was equipped with overhead cranes (OHC), each crane could only move along its installed rail. Each block had only one crane, and each crane was set to operate according to its own block. As a result, the crane could not move materials from the cutting block to the setting block, which made the role of forklifts highly important.

2 Method

2.1 Research type

This research used a quantitative descriptive method to obtain a direct description of the conditions occurring in the field, particularly those related to the planned research scope [4].

2.2 Research variables

The research variables were all elements that became the objects of observation. The independent variables were production operators, production machines, and workshop layout. The dependent variables were process time and waiting time.

2.3 Research framework

The research stages are presented in Figure 1.

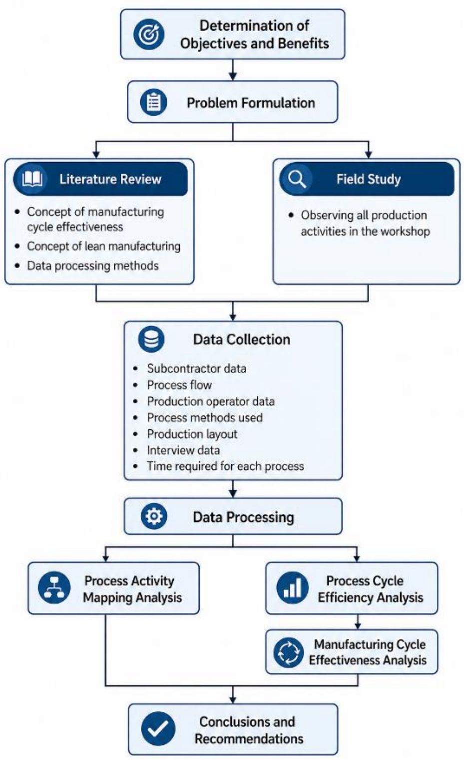

Figure 1. Methodological framework

2.4 Data collection techniques

This research used four data-collection techniques: interviews, observation, documentation, and measurements. Interviews were conducted using an unstructured interview technique. This method allows the researcher to ask questions freely without using a systematic and complete interview guide for data collection. Observations were conducted on operators in the cutting, setting, and welding sections. The focus of observation was the process method used and the production activities in the cutting, setting, and welding lines.

Documentation was carried out on the production floor, focusing on the cutting, setting, and welding lines. The documentation emphasized the activities performed in each line. Measurements included time measurement and length measurement. Time was measured using a SKMEI DG 1426 stopwatch for all processes in the cutting, setting, and welding lines. Length was measured using a TAJIMA 7.5 m/25 ft roll meter.

2.5 Data analysis technique

The data analysis technique used was descriptive data analysis, in which data were collected, processed, and described. The analysis consisted of data collection, data reduction, data presentation, and drawing conclusions. In the data-collection stage, the researcher collected data from all sources through interviews, observation, and documentation of the processes conducted on the production floor. Data reduction was performed in several stages: grouping and summarizing data, processing the reduced data, and finally compiling concepts related to the research topic. The descriptive statistics used in this research consisted of the mean, median, and standard deviation. The following equations were used: $M = \Sigma X/N$; $Me = X((N+1)/2)$ for odd data; $Me = (X(N/2) + X((N/2)+1))/2$ for even data; and $SD = \sqrt{(\Sigma(xi - \bar{x})^2/n)}$.

Table 1. Data tendency categories

Coefficient interval	Category
$X \geq Mi + 1.5\ Sdi$	Very constant
$Mi \leq X < Mi + 1.5\ Sdi$	Constant
$Mi < X < Mi - 1.5\ Sdi$	Less constant
$X < Mi + 1.5\ Sdi$	Not constant

The processed data were presented systematically as a collection of all process data and descriptions of the existing process parameters. Because this study aimed to identify efficient production methods, the final stage consisted of improvement recommendations based on the data-processing results.

3 Result and discussion

3.1 Cutting process

In the MKR cutting process, plate cutting was conducted using a single nozzle and required one production operator. Deformation was prevented using an intermittent cutting method. Because intermittent cutting was applied, an additional process was required to cut the remaining interruption points. The cutting speed was set at knob position 4. The average time to cut one plate was 8,347.41 seconds.

Table 2. Recapitulation of the MKR cutting process

Item	Description
Subcontractor	MKR
Human resources	1 operator
Deformation-prevention method	Intermittent cutting
Cutting speed	4
Cycle time	8,347.41 seconds

In the SST cutting process, plate cutting was conducted using a single nozzle and required one production operator. Deformation was also prevented using an intermittent cutting method, which required an additional process to cut the remaining interruption points. The cutting speed was set at knob position 3.5. The average time to cut one plate was 8,485.86 seconds.

Table 3. Recapitulation of the SST cutting process

Item	Description
Subcontractor	SST
Human resources	1 operator
Deformation-prevention method	Intermittent cutting
Cutting speed	3.5
Cycle time	8,485.86 seconds

In the MSS cutting process, plate cutting was conducted using a double nozzle and required one operator and one helper. Deformation was prevented using auxiliary plate pieces that were tack-welded directly while cutting was in progress by the helper. The plates were removed after the workpiece temperature decreased. The cutting speed was set at knob position 4. The average time to cut one plate was 4,078.48 seconds.

Table 4. Recapitulation of the MSS cutting process

Item	Description
Subcontractor	MSS
Human resources	1 operator and 1 helper
Deformation-prevention method	Using plate pieces
Cutting speed	4
Cycle time	4,078.48 seconds

3.2 Setting process

In the MKR setting process, the setting work was performed by two workers by installing supports on the side of the WF beam. The setting process used Gas Metal Arc Welding (GMAW), and material movement was supported by an overhead crane. The average setting time was 2,664.48 seconds.

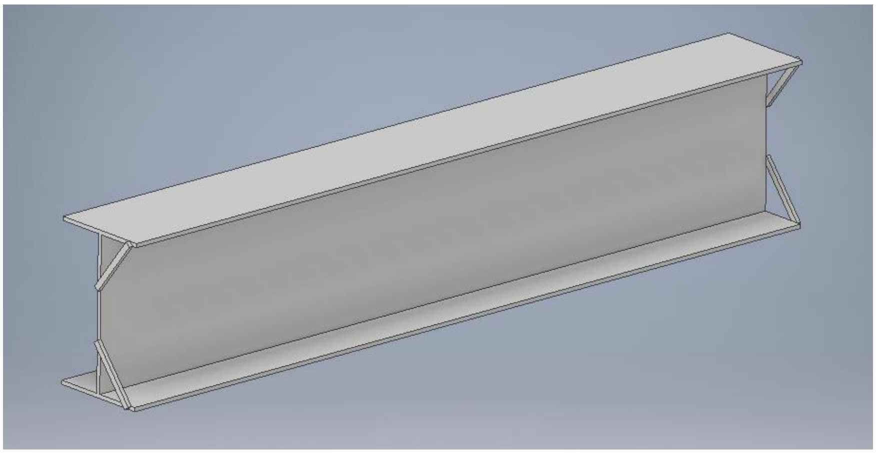

Figure 2. Side support installation used by MKR

Table 5. Recapitulation of the MKR setting process

Item	Description
Subcontractor	MKR
Human resources	2 workers
Welding machine	GMAW
Material-handling equipment	OHC
Cycle time	2,664.48 seconds

In the SST setting process, the setting work was performed by three workers by installing supports on the side and middle of the WF beam. The setting process used GMAW, and material movement was supported by an overhead crane. The average setting time was 2,732.64 seconds.

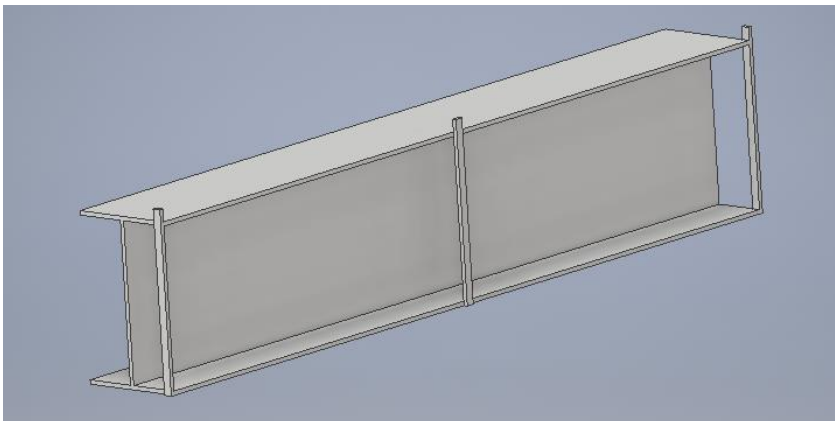

Figure 3. Side and middle support installation used by SST

Table 6. Recapitulation of the SST setting process

Item	Description
Subcontractor	SST
Human resources	3 workers
Welding machine	GMAW
Material-handling equipment	OHC
Cycle time	2,732.64 seconds

In the MSS setting process, the setting work was performed by two workers by installing supports on the side of the WF beam. The setting process used GMAW, and material movement was supported by an overhead crane. The average setting time was 2,676.69 seconds.

Table 7. Recapitulation of the MSS setting process

Item	Description
Subcontractor	MSS
Human resources	2 workers
Welding machine	GMAW
Material-handling equipment	OHC
Cycle time	2,676.69 seconds

3.3 Welding process

Welding is an important process in metal fabrication because it joins metal components permanently using heat and welding materials [5]. In the MKR welding process, welding was performed by two operators on both sides simultaneously to minimize deformation caused by uneven heat when welding is carried out alternately. Flux was supplied manually during the welding process because the flux hopper could not be installed due to obstruction by the upper part of the WF beam. The welding process used an SAW machine. The average welding time was 702.28 seconds.

Table 8. Recapitulation of the MKR welding process

Item	Description
Subcontractor	MKR
Human resources	2 operators
Welding machine	SAW
Flux supply	Supplied during the welding process
Cycle time	702.28 seconds

In the SST welding process, welding was performed by two operators simultaneously on both sides. Flux was supplied before the welding process by spreading it along the welding path. Because a support was installed in the middle of the WF beam, the welding process had to be paused to pass the support, which increased the welding time. The process used an SAW machine. The average welding time was 828.59 seconds.

Table 9. Recapitulation of the SST welding process

Item	Description
Subcontractor	SST
Human resources	2 operators
Welding machine	SAW
Flux supply	Supplied before the welding process
Cycle time	828.59 seconds

In the MSS welding process, welding was performed by two operators simultaneously on both sides. The storage area for cut-plate products was shared with SST, so moving the cut plates required more time than in SST. Flux was supplied before the welding process by spreading it along the welding path. The process used an SAW machine. The average welding time was 831.28 seconds.

Table 10. Recapitulation of the MSS welding process

Item	Description
Subcontractor	MSS
Human resources	2 operators
Welding machine	SAW
Flux supply	Supplied before the welding process
Cycle time	831.28 seconds

3.4 Efficiency analysis

Production efficiency is influenced by process flow, cycle time, waiting time, material handling, and layout arrangement [6]. The three production processes were carried out by three subcontractors using different process methods. These different methods caused different process times. The effectiveness of each process can be assessed from the time required to complete the process.

The most effective cutting process was the method used by MSS because cutting one plate required only 4,078.48 seconds. Although MSS used two workers, if MKR were assumed to use two workers simultaneously to cut two plates at the same time, the process time would still be 8,347.41 seconds for two plates, while MSS would require 8,156.96 seconds for two plates.

The most effective setting methods were those used by MKR and MSS because their process times were almost the same and were shorter than SST. The setting method used by SST was less effective because it required a longer process time and the support installed in the middle of the welding path interfered with the SAW welding process.

The most effective welding method was the method used by MKR because welding one line required only 702.28 seconds. The use of flux was also more effective because flux was supplied during the welding process.

Manufacturing Cycle Effectiveness can be used to evaluate the proportion of value-added processing time compared with the total production cycle time. The efficiency of each process can be seen from the Manufacturing Cycle Effectiveness (MCE) value. Based on the MCE calculation, the SST subcontractor had the highest effectiveness value.

Table 11. MCE calculation results for the three subcontractors

Subcontractor	Processing time	Cycle time	MCE
MKR	8,489.70 seconds	11,714.17 seconds	0.72
SST	8,793.50 seconds	12,047.09 seconds	0.73
MSS	5,207.05 seconds	7,586.45 seconds	0.69

3.5 Waste analysis

Waste identification is an important step in process improvement because it helps determine non-value-added activities that reduce production performance [7]. Several types of waste were found in the field. Waiting time occurred when operators waited for forklifts to move plates to the cutting block, move cut products to the WF setting block, move WF beams from setting to welding, move welded WF beams to assembly, and wait for cut plates for the WF setting process.

Transportation waste was caused by limited crane movement for inter-block transfer and by long distances between production blocks. Motion waste occurred because the spacing between workshop columns was too narrow for moving materials longer than 10 m. Processing waste occurred because the production process did not run effectively.

The main problems identified from the waste analysis were material-handling equipment, namely forklifts and overhead cranes, and the production methods used. Two improvement solutions are proposed. First, the production layout should be changed so that each process is integrated into one block while other processes are separated. With this layout, material movement can be performed using the overhead crane, and forklifts are only used for movements outside the crane coverage area. Second, the process method should be changed by adopting the double-nozzle cutting method used by MSS, the two-support setting method used by MKR and MSS, and the welding method used by MKR in which flux is supplied during welding.

3.6 Saving calculation

Based on the analysis of process methods and identified waste, savings can be achieved in production and transportation. Changes in process methods affect the number of workers required for each process. The most significant difference occurs in the cutting process because the helper wage is lower than the operator wage. A reduction in the number of workers also occurs in the SST setting process, which initially required three workers and was reduced to two workers.

Table 12. Human-resource savings

No.	Work	Subcontractor	Initial HR	After improvement
1	Cutting	PT Mekar Kontruksindo (MKR)	2 operators	1 operator and 1 helper
1	Cutting	PT Mulia Sarana Sejahtera (MSS)	1 operator and 1 helper	1 operator and 1 helper
1	Cutting	PT Surya Smartekindo (SST)	2 operators	1 operator and 1 helper
2	WF setting	PT Mekar Kontruksindo (MKR)	2 workers	2 workers
2	WF setting	PT Mulia Sarana Sejahtera (MSS)	2 workers	2 workers
2	WF setting	PT Surya Smartekindo (SST)	3 workers	2 workers
3	WF welding	PT Mekar Kontruksindo (MKR)	2 operators	2 workers
3	WF welding	PT Mulia Sarana Sejahtera (MSS)	2 operators	2 workers
3	WF welding	PT Surya Smartekindo (SST)	2 operators	2 workers

Changes in process methods also affect the required process time. The implementation of effective process methods reduces the process time by 9,011.99 seconds for all processes required to fabricate one WF beam. Changes in production layout also reduce transfer distance, resulting in a transportation-distance saving of 2,070 m.

4 Conclusion

Based on the data processing and analysis, the effective cutting method is the double-nozzle cutting method used by MSS. The effective setting method is the two-support method used by MKR and MSS because it has a shorter process time and requires fewer workers than the SST method. The effective welding method is the method used by MKR, in which flux is supplied during the welding process. The causes of waste include waiting time due to limited material-handling equipment and discontinuous production flow, transportation waste due to limited OHC movement and long distances between blocks, motion waste due to narrow column spacing, and processing waste due to ineffective production processes. The recommended improvements are to change the production layout and adopt the most effective methods identified in the cutting, setting, and welding processes.

Acknowledgements

The author is grateful to the Department of Mechanical Engineering and Automotive, Universitas Negeri Yogyakarta for all the support extended in conducting research.

Conflicts of Interest

The authors declare no conflict of interest.

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