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DESIGNING LINE BALANCING FOR AMMUNITION BOX PRODUCTION USING HEURISTIC METHOD

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Abstract *In Indonesia, the military equipment producer belongs to State-Owner enterprise. The demand for such equipment is increasing every year, so ammunition box sub-department asked their workers to work overtime and the total cycle time of ammunition box lid is higher than that of the ammunition box. Heuristic approaches, namely the Birnie Helgeson (RPW) and Moodie Young, are used to overcome these issues. This study aims to improve line balancing efficiency of ammunition box production. The findings showed that the Moodie Young method resulted in a 7.98% increase in line efficiency of the ammunition box lid and 21.77% increase in that of the ammunition box. In addition, the balance delay value decreased as much as the line efficiency. There are 9.09 and 152.87 decrease in the* smoothing index*of the ammunition box lid and the ammunition box. The Moodie Young method cut the total labor cost to 9,597,170 rupiahs.*

Keywords*: Line balancing, Heuristic Method, Helgeson Birnie (RPW), Moodie Young and labor cost.*

1. Introduction

Fierce competition in industrial sector forces companies to develop competitive advantage. Time is an important aspect to win business competition, more particularly business competition in manufacturing industry [1]. A company should have an excellent performance in order to provide good service and gain high customer satisfaction. In this context, service refers to quality assurance and time efficiency (particular amount of time to fulfill customer's request). One method to meet customer's request is to measure labor time. Measuring labor time allows company to identify how much time they need to complete an operating activity and use the information to improve and evaluate their performance and develop a more efficient work schedule [2].

In Indonesia, the military equipment producer belongs to State-Owner enterprise. Currently, production is located in Bandung Municipality (for weapon) and Turen, Malang Municipality (for ammunition). Military equipment producer's activities include design and development, engineering, assembly, manufacturing and maintenance. The focus of this study is Military equipment producer in Turen which is responsible for producing ammunition. Due to confidentiality, the researchers are unable to explain certain aspects of production in detail. Besides ammunition, military equipment producer in Turen also produces has several products such as link belts, ammunition boxes, and casing.

The unit of analysis in this study is ammunition box. Ammunition box is a box to store ammunition military equipment producer in Turen produces. It is made of SPCC steel plate and carbon wire steel. Ammunition box supporting product sub-department is responsible for producing the ammunition box. This sub-department is under the department of equipment and support production. The ammunition box consists of two parts; the first is ammunition box lid, namely lid, hinges, cap, connector, clasp, lock, handle, plate of the handle, cover, assembly, paint and silk. The second part is ammunition box which consists of wall, base, hinges, bar hinges, lock, handle, assembly and painting. Both the lid and ammunition box are sent to the final assembly line.

This year, the military equipment producer in Turen received a 32,000 ammunition box demand. According to the Department of Supporting Product, it has been the highest product demand so far. Table 1

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described the 2014-2018 ammunition box demand.

Table 1 Ammunition Box Demand between 2014 and 2018

Year	Demand (unit)	Production Time (Month)
2014	17,729	10
2015	20,766	11
2016	15,000	9
2017	10,000	8
2018	32,000	On-going

Based on Table 1, the annual ammunition box demand is fluctuating. To solve the fluctuation demand, the ammunition box sub-department asked their workers to work overtime and moves operators from one working station to another to compensate shortage of labor. As the consequence, the military equipment producer in Turen has to spend higher cost for overtime work. Based on the observation, the researchers found out that there are several issues or activities that do not contribute any additional value to particular working station in the ammunition box production. As an example, the operators have to move both the raw materials or finished goods themselves. As the result, there are excessive piles of WIP (Work In process) components in Station 3 and 7. Table 2 provides a preliminary description on production line of the ammunition box.

Table 2 Production Line of the Ammunition Box

WS	Component	Operator (individual)	Time (second)
1	Lid plate and hinges	1	166.72
2	Cap, connector, clasp, and lock	1	219.21
3	Handle, handle plate and cover	1	202.73
4	Assembling	2	192.32
5	Painting	4	140.56
6	Silk	1	95.44
Total for ammunition box lid		10	**1,016.96**
WS	Component	Operator (individual)	Time (second)
7	Wall	1	250.67
8	Base, hinges, bar hinges	1	198.64
,9	Lock and handle	1	117.74
10	Assembling	2	168.56
11	Painting	4	157.74
Total for ammunition box		9	**893.35**
Total		19	1,910.31

Table 2 showed that the total cycle time for the ammunition box lid was 1016.96 seconds and that for the ammunition box was 893.35 seconds. They can affect efficiency of the whole production line because too much time is spent for assembling the ammunition box (bottleneck). The following is the picture describing piles of the ammunition box in the final assembly line (the workers were unable to attach the lid to the ammunition box).

Fig. 1 Piles of The Ammunition Box In The Final Assembly Line

To solve this issue, the manufacturer in Turen needs an effective method that measures how much time they need to finish production. The most suitable method to measure standardized production time is stopwatch time study. The method helps measuring production time (production cycle time) and breaking it down into standardized time for each working element. Once standardized time for each working element has been established, the company can decide number of working stations they need using the line balancing

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method that balance different working elements in production [3]. The line balancing methods used in this study are the Helgeson Birnie or Ranked Positional Weight (RPW) and the Moodie Young method. The methods match work element sequence that begins with one or many separated working elements but then these elements are combined at the end of the production since the method does not match a linear work element sequence [4]. Suggestions for each method can be compared to the existing criteria, namely line efficiency, balance delay and smoothness index. The following procedure is output calculation in order to develop description about each working element and number of operators for each working station. The research purposes of this study are to balance line production and to increase line efficiency. Based on the elaboration, it is expected that the study provides recommendation for companies to decide working elements in production process, and total raw material for each production. As an addition, the line balancing method provides information about working element in a new working station and suitable labor to meet an increasing demand for ammunition box.

2. Research Methodology

The study was categorized as descriptive study which provides clear information about particular phenomena [5]. Descriptive study focuses on actual issues taking place during the study. Research and development method is series of process or step to develop or improve an observed object or phenomenon

2.1 Steps of the Study

1. Field Study,
2. Literature Study,
3. Identification of Problem,
4. Formulation of Problem,
5. Formulation of Objectives.

2.2 Data Collection and Data Analysis

Data collection is an activity of recording information related to an observed object to support a study/ research. There were two types of data collection in this study, namely:

1. Primary Data
   The study required information about work station division, working element and time for each element.
2. Secondary Data
   The study also required information about the manufacturer profile, product specification and targeted demand between 2014 and 2018.

2.3 Data Analysis

Data analysis refers to step conducted to solve issues discussed in an academic study. The data analysis consisted of:

a. Identify risk in data uniformity and data adequacy test,
b. Establish performance rating of each working element,
c. Establish allowance based on the westing house system,
d. Determine standardized time,
e. Determine labor for each working element using the Heuristic method (RPW and Moodie Young),
f. Decide the most suitable recommendation based on performance criteria,
g. Determine labor cost.

3. Findings and Discussion

This section discussed the data and steps of data analysis in order to solve some issues the manufacturer encountered.

3.1 Working Element

Table 3 Total Working Element

Component	Total Working Element
A. Plate (lid)	5
B. Hinges (lid)	6
C. Cap	6
D. Connector	2
E. Clasp	6
F. Lock	2
G. Handle	5
H. Handle plate	4
I. Cover (lid)	3
J. Assembling (lid)	4
K. Painting (lid)	3

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L. Silk (lid)	2
M. Wall	12
N. Base	2
O. Hinges	8
P. Bar hinges	1
Q. Lock	5
R. Handle	3
S. Assembly (ammunition box)	4
T. Painting (ammunition box)	3
U. Final Assembling	1
V. Marking	1
Total	88

Table 3 showed the components of the ammunition box and one work station responsible for one or several components. Work station 1, plate and hinges, is one of the work stations in making the ammunition box lid. Labeling each working element with number (number 1 to 88) facilitated the data collection process.

3.2 Standardized Time

Table 4 showed standardized time spent for working station 1 to 10.

Table 4 Standardized Times

No.	Standardized Time	No.	Standardized Time
1	19.20	6	39.58
2	13.25	7	8.59
3	16.44	8	8.92
4	12.80	9	10.06
5	12.85	10	13.14

Based on the table, the standardized time for working station 1 was 19.20 seconds.

3.3 Precedence Diagram

Predence diagram was developed in order to identify the preliminary condition (See Appendix 1 for the diagram). Precedence diagram refers to diagram that describes sequence and relationship between working elements. Relationship between working elements is a reference for distributing working element for each working station.

3.4 Preliminary Condition Estimation

Preliminary condition estimation can be divided into 2 (two) parts, namely the ammunition box lid and ammunition box. Table 5 showed the line efficiency score, line balance score and smoothing index of both the ammunition box lid and the ammunition box.

Table 5 Line Performance (Preliminary)

Ammunition Box	Line Efficiency (%)	Balance Delay (%)	Smoothing index(sec)
Lid	77.32	22.67	100.29
Box	71.27	28.72	189.09

Ammunition box lid output = 31,531
Ammunition box output= 27,574

3.5 Takt Time

The 2018 targeted production is 32,000 ammunition boxes per year. Total effective working day per year is 240 days (20 days per month times 12 months per year). Total effective working hour is 28,800 seconds (8 hours times 3,600 seconds). Estimated overtime is 160 hours (20 working days × 8 hours and 2 shifts).

$$Takt\ time = \frac{240\,\frac{day}{year} \times 28{,}800\,\frac{second}{day} + 576{,}000\ sec}{32.000} \quad (1)$$

= 234 seconds/product

The standardized time for all of the elements did not exceed the estimated cycle time.

3.6 Constraints

1. Each working station should finish their work before the estimated cycle time, 234 seconds/product. It means when one working station is unable to finish one

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2. particular task (one part of the ammunition box) faster than 234 seconds, the following working station is responsible for completing the task. The estimated cycle time helps the company meet their targeted production capacity.
3. Several operators work on the same parts at the same time. In other words, workload in each working station should be directly proportional to number of operators in the working station. The Gang process chart help determine workload for each working station.
4. The first few parts of production (in which each ammunition box component is made) are closely related to each other. Therefore, these tasks should be completed at the same working station.

3.7 Helgeson Birnie Method (Ranked Positional Weight)

Analysis was divided into 2 parts, the lid and ammunition box. Table 6 showed result of analysis using the Helgeson Birnie method (line efficiency score, line balance delay score, and smoothing index).

Table 6 Line Performance (Helgeson Birnie)

Ammunition Box	Line Efficiency (%)	Balance Delay (%)	Smoothing index(sec)
Lid	89.74	10.25	79.49
Box	79.19	20.80	130.09

3.8 Moodie Young Method

Similar to the previous analysis, analysis was divided into 2 parts, the lid and ammunition box. Table 7 showed result of analysis using the Moodie Young method (line efficiency score, line balance delay score, and smoothing index).

Table 7 Line Performance (Moodie Young)

Ammunition Box	Line Efficiency (%)	Balance Delay (%)	Smoothing index(sec)
Lid	85.3	14.65	91.2
Box	93.04	6.95	36.22

Ammunition box lid output = 30,890
Ammunition box output = 30,283

3.8 Heuristic Method Analysis

The following step was to determine amount of workload for all working elements using Helgeson-Birnie and Moodie Young (heuristic method). The objective was to select the most suitable design. The indicators were line efficiency, balance delay and smoothing index, annual output and overtime. Table 8 showed the performance and output based on the Helgeson-Birnie and Moodie Young methods.

Table 8 Heuristic Method's Performance Criteria

Ammunition Box Lid	Helgeson-birnie	Moodie Young
Line efficiency (%)	89.74	85.3
Balance delay (%)	10.25	14.65
Smoothing index(second)	79.49	91.2
Output (unit)	29.730	30.890
Overtime (hour)	146.59	68.99
Ammunition box	Helgeson-birnie	Moodie Young
Line efficiency (%)	79.19	93.04
Balance delay (%)	20.80	6.95
Smoothing index(second)	130.09	36.22
Output (unit)	31.130	30.284
Overtime (hour)	53.65	108.85

Line efficiency of the ammunition box lid and ammunition box using the Moodie Young was higher than that using the Helgeson-Birnie method. Based on the Moodie Young method, the line efficiency of the lid was 85.3% and that of the ammunition box was 93.04%. The recommended line efficiency is between 85% and 95% [6]. Thus, based on the line efficiency criterion, the Moodie Young was more suitable than the Helgeson-Birnie.

Decreasing balance delay is the most suitable effort to keep a balance [3]. Balance delay refers to ratio between idle and available time. It is expected that balance reduces waste or idle. Based on the analysis, the Moodie Young caused lower balance delay. Using the method, balance delay of the ammunition box

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lid was 14.65% and that of the ammunition box was 6.95%. Based on the balance day criterion, it was concluded that the Moodie Young was more suitable than the Helgeson-birnie.

The following criterion was smoothness index. The most suitable smoothing indexis one closest to zero because smoothing indexrepresents relative efficiency of balance line; when smoothing indexis zero, each working station spends similar time to finish its task. The analysis showed that the Moodie Young has better relative efficiency. Smoothing indexof the lid was 91.2 seconds and that of the ammunition box was 36.22 seconds. In conclusion, based on the Smoothness Index, the Moodie Young was more suitable than the Helgeson-Birnie.

The fourth criterion was annual output with and without overtime. Based on the Moodie Young method, the output of the lid was 30,890 units (the highest), while the overtime was 68.99 hours. Therefore, the Moodie Young was the most suitable method for the ammunition box lid. Discussing about the ammunition box, the Helgenson-Birnie resulted in more ammunition boxes (output) than the Moodie Young. The Helgeson-Birnie resulted in 31,130 units (ammunition box) and 108.85 hours of overtime. Even though the Helgenson Birnie produced more ammunition boxes and longer overtime, Moodie Young produced similar output but lesser amount of overtime. As the result, the most suitable method for output is the Moodie Young. It has higher line efficiency, lower balance delay, lower smoothness index, higher output and less overtime.

3.9 Comparison Analysis

The Moodie Young was the selected solution. To describe out how effective the method is, the researchers make a comparison between the preliminary condition and the result of the Moodie young. The indicators are efficiency, balance delay, smoothness index, output, overtime, total time, number of work station and number of operator.

Table 9 showed the comparison between the preliminary condition and the result of the Moodie Young. In the first criterion (line efficiency), the Moodie Young increased the efficiency of the ammunition box lid and ammunition box. The method caused a 15.52% increase for the lid and 21.77% increase for the ammunition box compared to the preliminary condition.

In the second criterion (balance delay), the Moodie Young decreased the balance delay of the ammunition box lid and the ammunition box. The method caused a 15.52% decrease for the lid and 21.77% increase for the ammunition box compared to the preliminary condition.

In the third criterion (smoothness index), the Moodie Young caused a 9.09 decrease for the ammunition box lid and a 152.87-second decrease for the ammunition box when compared to the preliminary condition.

In the fourth criterion (total output), the Moodie Young decreased the total output. The method decreased the number of ammunition box lid (output) from 31,531 to 30,890 units. However, it increased the number of ammunition box from 27,574 to 30,283 units. These outputs caused an increase and at the same time, a decrease in overtime. The overtime for the ammunition box lid increased to 40.44 hours but that for the ammunition box decreased to 199.33 hours. Despite of the condition, Moodie Young decreased the amount of overtime, when compared to the preliminary condition, and the method resulted in less overtime than the estimated overtime.

In the fifth criterion (total time or total time spent in one work station to finish producing one unit of the ammunition box), the Moodie Young reduced the total time from 1,910.31 sec (the preliminary condition) to 1,869.38 sec.

The Moodie Young decreased number of the work station. Number of the work station for the ammunition box lid decreased from 6 to 5 work stations, while the work station for the ammunition box decreased from 5 to 4 work stations.

The Moodie Young increased the number of operators for the lid from 10 to 12 operators. The increase was closely related to workload in each work station. Some work stations requires 2 or 3 operators.

More operators are needed so that the time spent in the work station is lower than the takt time. In addition, more operators are needed to increase output. To identify whether or not more operators bring positive influence to the production, the researchers analyzed total labor cost or how much money spent to pay for the operators (wage) and overtime

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Table 9 Comparison between Preliminary Calculation and the Moodie Young Method

Criteria	Preliminary		Moodie Young	
	Ammunition Box Lid	Ammunition Box	Ammunition Box Lid	Ammunition Box
Line Efficiency (%)	77.32	71.27	85.3	93.04
Balance delay (%)	22.67	28.72	14.65	6.95
Smoothing index(Second)	100.29	189.09	91.2	36.22
Output (Unit)	31.531	27.574	30.890	30.283
Overtime (Hour)	28.55	308.18	68.99	108.85
Total Time (Second)	1,910.31		1,869.38	
Number of Work Station	6	5	5	4
Number of Operator	10	9	12	8

Table 10 Total Labor Cost between the Preliminary Condition and the Moodie Young Method

Work Station	Preliminary Condition		Moodie Young Method	
Component	Ammunition Box Lid	Ammunition box	Ammunition Box Lid	Ammunition box
Overtime (hour)	28.55	308.18	68.99	108.85
Number of Operators	10	9	12	8
Wage (1 year)	Rp 308,976,866.00	Rp 278,079,179.00	Rp 370,772,239.00	Rp 247,181,493.00
Overtime (1 year)	Rp 8,498,193.00	Rp 82,559,572.00	Rp 24,642,676.00	Rp 25,920,232.00
Total Labor Cost	Rp 678,113,810.00		Rp 668,516,640.00	
Ratio	Rp 678,113,810.00 - Rp 668,516,640.00 = Rp 9,597,170.00			

Table 10 showed the total labor cost of the preliminary condition and that of the Moodie Young. Overtime referred total demand per year subtracted by output in a year times the longest time spent in one working station divided by time per hour. Number of operator referred to the preliminary condition of the working station and number of operators each working station needed based on the Moodie Young. The operator’s monthly salary was 2,574,807.22 rupiahs or the minimum wage of the Municipality of Malang [7]. Based on the analysis, the annual salary based on the Moodie Young was higher than that at the beginning of the study (preliminary condition). Hiring 1 more operators resulted in a 30,897,686 increase in the annual salary.

Ministerial Decree [8] became the reference for the hourly wage, which was 1/173 of the monthly salary and hourly salary times two. Thus, the hourly wage was 29,766 rupiahs per hour. Based on the analysis towards the overtime wage, the cost in the preliminary condition was 91,057,765 and that after the implementation of the Moodie Young was 50,562,908. Total labor cost in the preliminary condition was 678,113,810 and that after the implementation of the Moodie Young was 668,516,640. In conclusion, the Moodie Young saved the labor cost by 9,597,170.

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5. Conclusion

Based on the analysis towards military equipment manufactur production, it can be concluded that:

1. The implementation of the Helgenson-Birnie and Moodie Young methods for designing the working station for the ammunition box production is as follows:
   a. Based on the Helgenson-Birnie method, the line efficiency of the ammunition box lid is 89.74%, its balance delay is 10.25% and smoothing indexis 79.49. The total work stations are 4 and total output without overtime is 29,730 units per year. Furthermore, the line efficiency of the ammunition box is 79.19%, its balance delay is 20.80% and smoothing indexis 130.09. The total work stations are 4 and total output without overtime is 31.130 units per year.
   b. Based on the Moodie Young method, the line efficiency of the ammunition box lid is 85.30%, its balance delay is 14.65% and its smoothing indexis 91.2. The total work stations are 5 and total output without overtime is 30,890 units per year. In addition, the line efficiency of the ammunition box is 93.04%, its balance delay is 6.95% and its smoothing indexis 36.22. The total work stations are 4 and total output without overtime is 30,283 units.
2. The selected heuristic method is the Moodie Young because it has the highest line efficiency, lowest balance delay and highest output. As an addition, the smoothing indexis the closest to zero. Compared to the preliminary condition, there is a 7.98% increase in the ammunition box lid line efficiency and 21.77% increase in the ammunition box line efficiency. The balance delay decreased as many as the increase in the line efficiency. There is 9.09 decrease in the ammunition box lid smoothing indexand 152.87 decrease in the ammunition box smoothness index. Furthermore, the ammunition box lid output decreased by 641 units and the ammunition box output also decreased by 2,709 units. Both the increase and the decrease resulted in another increase and decrease in overtime, conducted to meet the annual targeted output. There is a 40.44-hour increase in the overtime for producing the ammunition box lid but 199.33-hour decrease in the overtime for producing the. Despite of the fluctuation, the Moodie Young resulted in less overtime compared to that in the preliminary condition and the estimated overtime (160 hours).
3. The Moodie Young reduced the number of work stations for the ammunition box lid from 6 to 5 and also reduced those for the ammunition box from 5 to 4. The Moodie Young increased the number of operators for the ammunition box lid from 10 to 12 but decreased the number of operators for the ammunition box from 9 to 8. However, hiring more operators does not increase any cost. The Moodie Young helped the company saved 9,597,170 rupiahs.

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