IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Improving the performance of an assembly line to increase production capacity using value stream mapping: A study case

To cite this article: W N Cahyo *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **598** 012053

IOP Conf. Series: Materials Science and Engineering **598** (2019) 012053 doi:10.1088/1757-899X/598/1/012053

Improving the performance of an assembly line to increase production capacity using value stream mapping: A study case

W N Cahyo, W A Khaeruzzaman and F W Hasibuan

Universitas Islam Indonesia, Jalan Kaliurang Km. 14,5, Yogyakarta, Krawitan, Umbulmartani, Ngemplak, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55584

14522224@students.uii.ac.id

Abstract. Time in an assembly line is costly. Every movement or activity in a manual handling process effects the duration of a cycle time. This research focuses on how to improve the performance of an assembly line to increase the production capacity of the assembly line by using value stream mapping. The first activity is to find a bottleneck in the assembly line by value stream mapping, then conduct the root cause analysis from the bottleneck to find the root cause. In this research, the bottlenecking workstation layout is ineffective and therefore needs to be improved. By estimating motion in the activities using MOST Work Measurement, the layout is then improved so the operator can achieve a shorter cycle time by reducing the ineffective movements and by that, the assembly line could achieve a better stream flow at a higher capacity. Although the improvements might not seem much because the research could only achieve 0.8 second reduction in cycle time, this still allows the operator to achieve a higher production capacity level by 11.27%.

1. Introduction

Manufacturing today has been going through major shifts and changes from its original version. With the western world adapting automation and computer-integrated technologies to improve its manufacturing, the Japanese industries initiated a customer-value focused method of manufacturing called Lean Manufacturing. With the appearance of lean manufacturing and Japanese industries, methods in industries are always improving every day with the application of Kaizen philosophy. Removal of waste is the main concern for every improvement conducted in the industrial processes that apply Lean Manufacturing. The leaner the amount of waste than the leaner the number of problems that would appear in an industry. Waste is considered the main cause of the many problems that would appear in an industry.

EPSON is known for electronic products such as printers, projectors, and scanners. This company applies Lean Manufacturing principles to conduct effective and efficient manufacturing processes. Due to the demands in the market, the company always tries to improve in every sector possible. This aligns perfectly with the company's vision which is to become the number 1 electronic manufacturer in the world and the company tagline which is "Exceed Your Vision" which means that EPSON aims to exceed its customers' expectations and visions with products and services that help create more colorful and richer lifestyles.

A major segment of production in PT. EPSON Batam is the ink cartridge production line. Production improvement process is conducted for each new line of product. A new assembly line was initiated since

2017 and is still in development for the production process. The industrial engineering section is currently focusing on this assembly line to increase the production capacity of this line. The current target of the line is to achieve 8600 pieces daily, where the status quo of the assembly line currently only reaches around 7800 pieces daily. The hypothesis is that there is a bottleneck in the production line in which will be detected during this thesis project. This thesis research aims to solve the bottleneck problem and propose improvements to the line to help achieve the target assigned by the management of PT. EPSON Batam. One candidate of method used in this study is Value Stream Mapping. Value stream mapping is an established method to support the lean management [1][1][2].

2. Previous Researches on Solving Bottleneck Problems

[3] studied a food processing mixed-model assembly line which produces 10 different types of salads with 9 operators. The main problem in this assembly line is delays and inefficiencies. To solve the problem, the researchers use line balancing and related tools, such as shift analysis and workstation improvement. The goal of this research is to reduce or remove delays and increase productivity and in the end, the line efficiency is improved by 44%, the cycle time reduced by 40% and shift time reduce by 45%.

A study by [4] tests how "material exposure and part attributes" impact Assembly Line Balancing Problem. The model is tested in a manual assembly line which produces several varieties with a similar product structure that involves different parts with different attributes, such as dimension, weight, shape, and usage frequency. As a result, the location of the parts significantly influences the performance of the operators based on MOST work measurement. In conclusion, including material exposure and the optimum storage size strongly influences picking a time for manual handling and as a result, will also impact the cycle time of the assembly line.

3. Value Stream Mapping

In this paper, value stream mapping is proposed as the method to find the waste in the production line. Value stream mapping has been proved to improve productivity in various fields other than manufacturing, such as in health care [5], construction [6] and in architecture [7]. Value Stream Mapping is one of the many tools used in lean manufacturing. A value stream focuses on added values to the product or service of a company. Basically, value stream mapping is a "material-flow and information-flow mapping" [8]. In a manufacturing company, there are 3 types of operations according to [9]:

a. non-value adding (NVA);
b. necessary but non-value adding (NNVA); and
c. value-adding (VA).

The purpose of value stream mapping is to differentiate activities that are value adding and non-value adding to then remove the waste in a process, in this case an assembly line. Using value stream mapping could benefit many elements in a manufacturing company because value stream map is quick and easy to learn, and it helps to find bottlenecks; it's a group exercise and therefore can involve your workforce as part of your lean improvement program; you can use a completed value stream map as an improvement aide to document transitions to a future state value stream map; it's inexpensive; it can be easily critiqued by your workforce to highlight problems that exist within the process; it helps portray the process from the start of the production process to the end, this way it finds the waste in the process accurately; and it's easy to understand.

4. Research Methods

This research is conducted under three steps; identification, analysis, and improvement. These three steps would be compiling several methods to achieve the final results expected.

4.1. Identification

To identify the problem in assembly line, we conduct the initial detection of the bottleneck by using Value Stream Mapping. By using value stream mapping, the researcher is able to see the elements that are value adding and what are not to the assembly line. This will enable the researcher to identify the bottleneck of the system. The bottleneck will be detected from which workstation has a flow percentage of 100% or more. The data collected to develop a value stream map is cycle time records, assembly process flow, supplier and consumer data, uptime and downtime, and also the takt time.

4.2. Analysis
The data analysis method used in this research is using bottleneck analysis and root cause analysis. A bottleneck analysis is a detailed process where the author gathers as much information about the manufacturing flow of a particular product or process to detect the bottleneck in the system mapped out by Value Stream Mapping. In this research, the bottleneck is the bottleneck in the assembly line. After the bottleneck is identified, the author conducts data analysis using Root Cause Analysis. The purpose of the root cause analysis is to identify the root cause of the bottleneck. The root cause analysis in this research is using the Five Whys Technique. The five whys technique is the simplest form of root cause analysis. The author selects the five whys technique due to the limited resources of the author. After conducting RCA, because this research focuses on improvements on manual handling operations, to confirm and reassure that there are ineffective activities in the workstation, the researcher conducts MOST Work Measurement to deeply calculate the duration of each movement of the operator. Therefore, the researcher could easily remove the ineffective movements detected using the MOST Work Measurement.

4.3. Improvement
After analyzing the bottleneck in the system, the researcher proposes an improvement to the system for the manual handling operations, whether the improvement would be on the layout or considering the movements conducted by the operator during the assembly operation. This improvement proposal is then applied and evaluated to assure that the improvement is acceptable and does this improvement achieve the objective of the research.

5. Results
The Value Stream Mapping of the current condition is shown on figure A1. VSM is based on the process flow, change over, cycle time, inventory stock, and 21.5 work hours with 80% uptime. The uptime is determined by the company for a 20% downtime in forms of allowance because of maintenance and operator breaks (other than lunch and praying breaks).

From, the current VSM and cycle time records, the results show that the workstation with the highest or long cycle time, which is 7.9 seconds (value adding and non-value adding) and with a flow stream of 107%, is the Manual Parts Combination workstation. In this workstation, the operation is conducted totally manual by 2 operators on 2 stations. Therefore, in this research, the researcher would like to dig deeper into identifying what activities are considered as non-value adding and reducing the amount of non-value adding activities.

To follow up the problem identification from the value stream map, the researcher conducts MOST work measurement to identify the activities conducted during the assembly operation on the second workstation. The best method to conduct MOST Work Measurement is to record all the activities of the workstation and then conduct MOST Work Measurement.

A study by Gnanavel, Balasubramanian, & Narendran (2015) applied Process Map (P-Map), a tool which depicts material and man flow. Even though the research focuses the overall assembly line layout, but this method could also be implemented in this case. The research uses the material and man flow on an assembly line similar to value stream mapping but using the data of distance and the movement of the materials and operator. The current P-Map of the workstation is shown on figure 1. This shows how the material and man flow is not efficient and there are many movements that go back and forth which ineffective. This analysis might not seem scientific, but this is based on practical analysis and process mapping methods. The total amounts of movements are 7 movements. The total distance travelled by the operator is 200 cm per cycle.

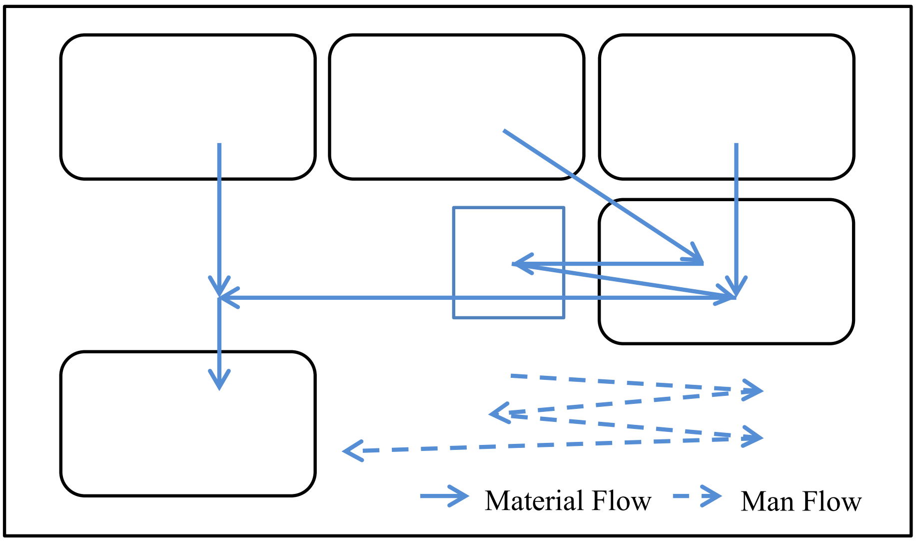

Figure 1. Current Workstation P-Map

Based on the process map of Manual Part Combination, the layout should be adjusted to remove unnecessary movements that would cause an increase to the cycle time. The proposed p-map is shown on figure 2. The proposed layout would only require 6 movements and a total travel distance of 80 cm for the operator per cycle.

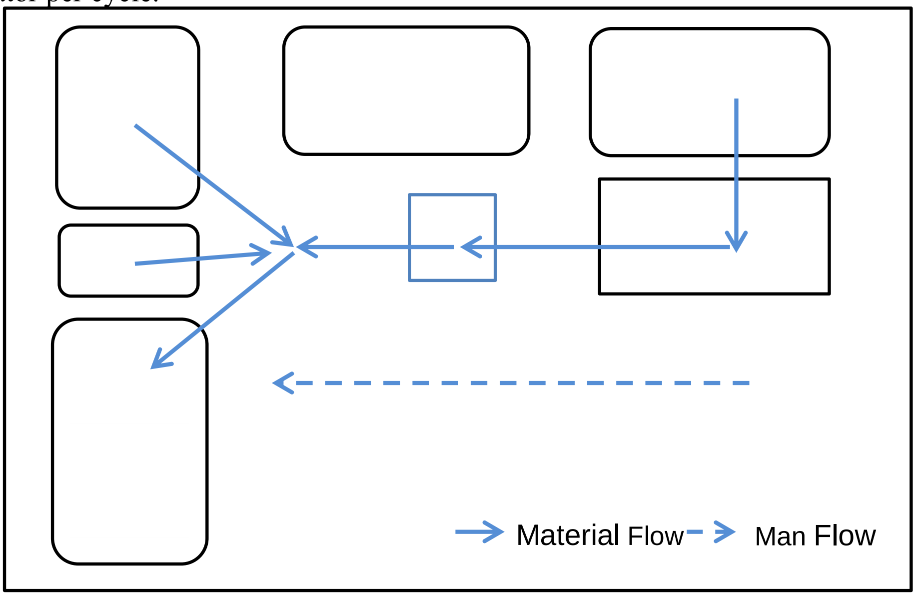

Figure 2. Proposed Workstation P-Map

As a result, the layout should be adjusted to remove unnecessary movements that would cause an increase to the cycle time. The reasoning for the proposed layout is as follows:

a. Move the Cage part closer to the Pillar because it is the first process of assembly in this station to remove unnecessary movements.
b. Move the Frame part after the Jig process to avoid the counter flow movement of the operator. Consider an easily reachable range from operator's position.
c. Rotate the Finished Assembly case to be in a vertical position to provide more space for the operator to reach and assemble the tube and frame parts.
d. All part placements are within the reachable distance of the operator.

The improvement in the workstation resulted in a better value stream flow as shown on figure A2, even though the workstation with the bottleneck is the same workstation as before and has a higher flow which is 122% but the workstation could produce in a higher capacity per hour. The improvement results an increase in production capacity by 11.27% or a difference of 41 pieces per hour from 365 pieces per hour to 406 pieces per hour.

6. Analysis and Discussions

The main question for the Root Cause Analysis to identify the main cause of the bottleneck is, "Why is the Cycle Time 7.9 seconds?" To answer this question, the researcher conducts Five Whys to find the root cause of this bottleneck problem. Table 1 shows the 5 Whys and the answers to the questions.

Table 1. 5 Whys for Root Cause Analysis

Why 1	**Why is the Cycle Time 7.9 seconds?** The cycle time is 7.9 seconds because there are inefficient activities.
Why 2	**Why are there inefficient activities?** There are inefficient activities because the layout is not effective.
Why 3	**Why is the layout not effective?** The layout is ineffective because the placements of the parts are not in same order as the assembly sequence.
Why 4	**Why is the placement of the parts not in the same order as the assembly sequence?** The placements of the parts are not according to the sequence because the operator prefers the placement of the parts to be easily reachable.
Why 5	**Why does the operator prefer the placement of the parts to be easily reachable?** The operator prefers the placement of the parts to be easily reachable because the operator feels more comfortable conducting the repetitive activities in such way.

From the analysis above, the main problem is that the current layout is not effective because of the uncomfortable placement for long period of repetitive activities. Therefore, to reduce the cycle time, the layout should be improved to achieve lower cycle time in order to improve the workstation and achieve more balanced assembly line.

To quantify the achievement of the improvement, the researcher calculated the improvement not only based on the cycle time, but also the output capacity that the assembly line could achieve with the proposed layout. Here, the researcher compares the production level of the assembly line based on the results of the improved value stream map and the improvement resulted in an increase of 11.2% which is from 7838 pieces per day to achieve 8721 pieces per day.

7. Conclusion

To improve the assembly line, a layout improvement had to be applied. Due to the process that is handled by manpower, ergonomics and layout effectiveness is a major key factor to increase productivity. The tools and methods used as a reference to propose the improvement are Value Stream Mapping, Cycle Time Recording, Activity Analysis, MOST Work Measurement, and Root Cause Analysis. Even though, the improvement may not seem much, but the improvement has enabled the operator to achieve the target that is given by the management of PT. EPSON Batam. Therefore, the assembly line is more productive and could achieve a higher level of production capacity by 11.2%.

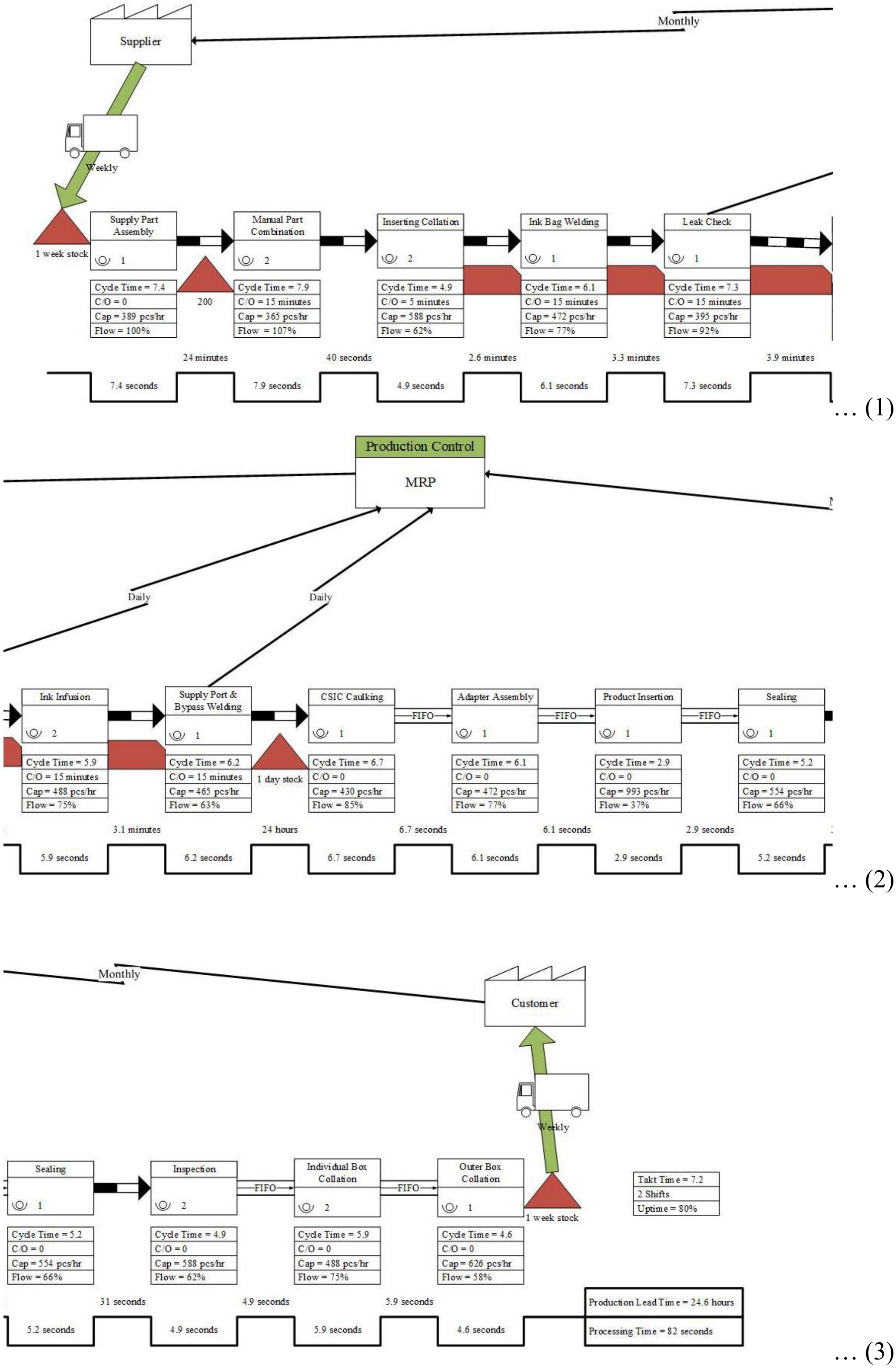

Figure A1. This figure shows the value stream map of the assembly line before the improvement is conducted.

IOP Conf. Series: Materials Science and Engineering **598** (2019) 012053 doi:10.1088/1757-899X/598/1/012053

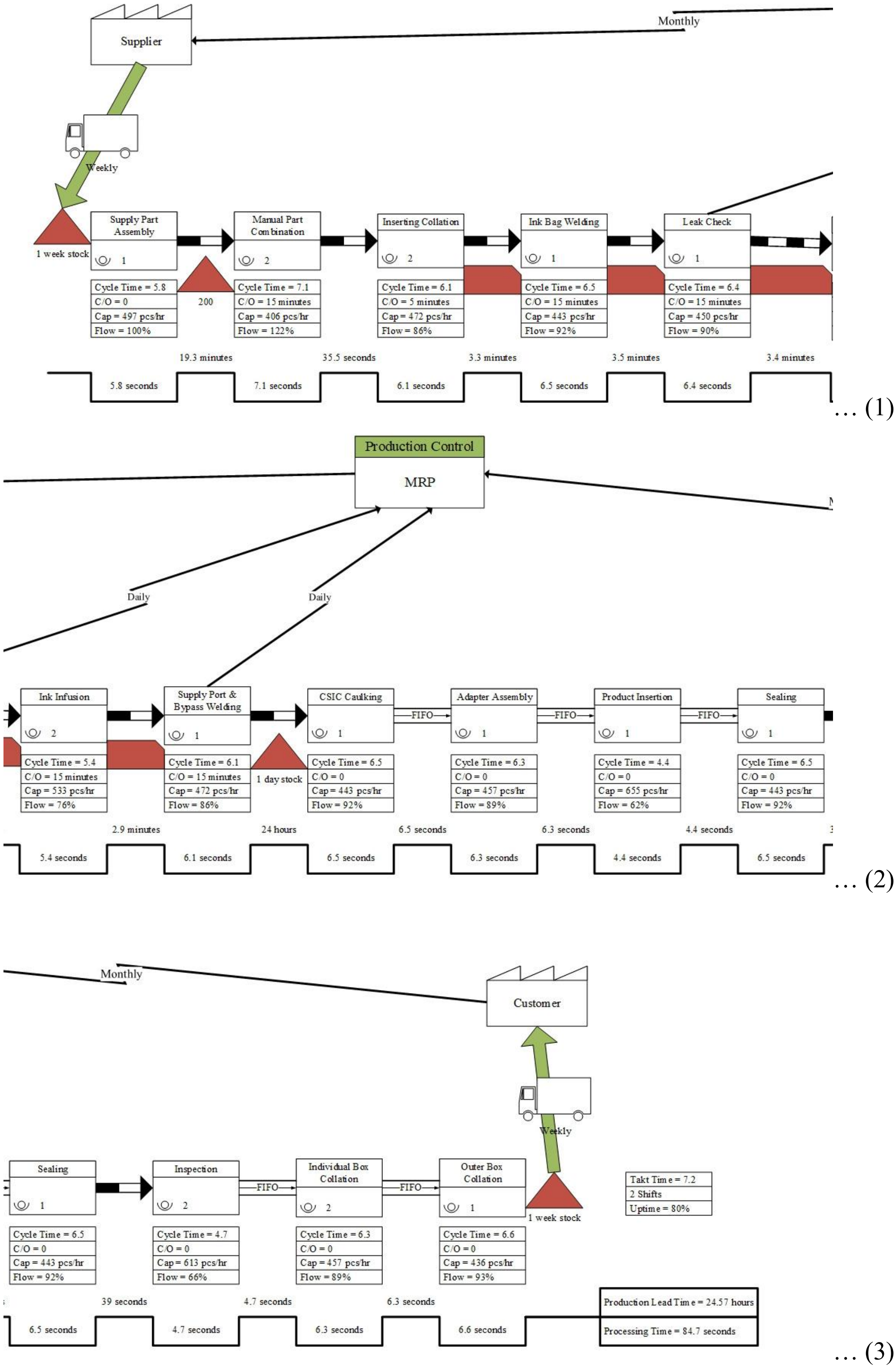

Figure A2. This figure shows the value stream map of the assembly line after the improvement is conducted.

References

[1] J. K. Liker 2004 *Toyota way: 14 management principles from the world's greatest manufacturer* (New York: McGraw-Hill)
[2] P. Poór 2014 *IEEE 12th International Symposium on Applied Machine Intelligence and Informatics*
[3] T. Rohac 2014 *Analysis and following optimization of business processes*, University of West Bohemia.
[4] M. Savsar, A. E. Elsaadany, R. Hassneiah, and A. Alajmi 2017 *In.C.Ind.Eng.Eng.Man*.
[5] M. Bortolini, M. Faccio, M. Gamberi, and F. Pilati. 2016 *Ifac.Papersonline.*
[6] D. V. K. M. D. E. D. J. S. M. J. A. T. F. R. S. L. G. K. S. R.L. Kaale 2005 *Ann.Emerg.Med* **46**
[7] D. T. K. D. &. R. R. Matt. 2013 *Procedia CIRP* **12** 402-07
[8] M. M. B. A. L. R. &. A. T. C 2010 *IGLC*.
[9] M. Rother and J. Shook 1999 *Learning to See: value-stream mapping to create value and eliminate muda* (Massachusetts: Lean Enterprise Institute).
[10] Y. Monden 1993 *Toyota Production System: An Integrated Approach to Just-in-Time* (Norcross, GA: Industrial Engineering and Management Press).