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# Design of Toyota Production System Based on Heijunka Principles to Increase Human Work Productivity

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**Original Research Article**

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**Abstract:** PT Nexus Fashion & Sports is a manufacturing industry that produces work gloves and sports. The company's current production system has not been able to run effectively and in balance because production demand and production planning always change. Applying the right production system can provide the right production process. The Toyota Production System (TPS) can help companies cope with demand fluctuations and control production planning in a controlled manner. The basis for the implementation of TPS is the principle of heijunka, namely the fundamental removal of mura, muri, and muda. This study aims to measure the effectiveness of the production process and design the TPS based on the principle of heijunka to improve the productivity of human labor. Analysis of production process effectiveness using manufacturing cycle effectiveness (MCE) method was 67% and improvement proposal was 69%. Production rate balancing (mura) on production scheduling of TPS design based on heijunka principle using mixed model scheduling method produces daily flat based production. Alignment of workload (muri) using work load analysis method in March and April 2017 TPS design based on the principle of heijunka there were advantages of 1 person and 4 people. The average human work productivity of TPS design based on heijunka principle increased by 1.10%.
**Keywords**: Heijunka, Toyota Production System, Manufacturing Cycle Effectiveness, Productivity, Average Production.

## INTRODUCTION

Competition in the industrial world today is very tight and changes occur very quickly, resulting in similar companies competing to win the competition. Conditions of intense competition also forced the company to constantly change, by applying a more effective and efficient production system [1]. The company must make continuous improvements to maintain its competitiveness, because the company has various resource constraints. One company that has an edge in industrial competition in a competitive business environment is Toyota. Toyota has introduced a strategic production system, the Toyota Production System (TPS) with various techniques such as just in time, kaizen, one piece flow, jidoka, and heijunka [2]. TPS is adopted by many companies in the world because it hopes his company will be as effective and efficient as Toyota. Companies that adopt TPS are not always able to run optimally because companies do not invest in human resources and do not create sustainable culture [3].

PT Nexus Fashion & Sports is a manufacturing company that produces work gloves and sports gloves. The company is producing on order. In a certain period of time the company always accepts orders of gloves from various buyers abroad with various models, so the company tries to fulfill the order by arranging the production schedule. The current production scheduling, as well as the number of products produced each day are not the same or uneven. This resulted in uneven production activity, uneven workload of workers and machinery, and could result in high levels of waste. The amount of production produced unevenly is due to the buyers often ask for some of its order products to be delivered at a certain time that can not be expected by the company.

Products produced by PT Nexus Fashion & Sports are of different kinds, so production is done in rotation every one month. It is a basic characteristic for designing the principle of heijunka that is the fourth principle on the Toyota Way. Heijunka does not make products based on the actual order of customer orders, but takes the total number of orders in one period and flattens them so that they are made in the same amount and mix each day [2]. The principle of heijunka is defined as a uniform production system based on specified targets so as to reduce workload fluctuations [4]. Achieving

heijunka is fundamental to the TPS to eliminate the mura, which is the basis of eliminating muri and muda especially in the production process of which many products [3].

During this time the management of PT Nexus Fashion & Sports never make measurements of the effectiveness of the production process. Fluctuating production levels also make the company difficult to determine the level of effectiveness of production. Productivity effectiveness can be analyzed using a manufacturing cycle effectiveness approach in order to help companies improve [5]. Man as one of the input factors for the company to produce a product. It is very affect on the productivity of human labor, because if the number of human (workers) is not in accordance with the number of products produced can harm the company. The result of observation shows that the productivity of human work has decreased. This is because the number of workers is not proportional to the amount of production targeted in production at the company.

## MATERIALS AND METHODS

This study emphasized on 7 types of waste that occur in the company, workload, production scheduling and product demand in March and April 2017. The assumption used was the material inventory always met, each worker worked according to the number of working days, the dominant waste was accumulated 75 % final result of the calculation process of identification of waste. Data processing was done through stages: maker flow process chart to describe the whole activity of production process. Determination of standard time in every activity of production process used stopwatch time study method. Analyze the effectiveness of the production process used the Manufacturing Cycle Effectiveness (MCE) method by separating standard time on value added activities (operations) and non value-added activities (transport, inspection, waiting, and storing) with Equations (1) and (2) [6].

$$Cycle\ Time = Processing\ Time + Waiting\ Time + Moving\ Time + Inspection\ Time \quad (1)$$

$$Manufacturing\ Cycle\ Effectiveness = \frac{Processing\ Time}{Cycle\ Time} \quad (2)$$

Analysis of company production system was done based on heijunka principle through stages: muda, ie identifying seven wastes using waste assessment model method with equation of waste assessment alogorithm [7]. Mura, which is to analyze the equilibrium of production levels in the company's production system. Muri, which calculates workload in accordance with the number of production scheduled on the production system in the company using work load analysis method by Equation (3) [2].

$$WLA = \frac{Number\ of\ Products \times Working\ Process\ Time\ of\ each\ unit}{working\ day \times working\ hours} \times 1\ person \quad (3)$$

Designing Toyota Production System based on heijunka principle was done through stages muda [8], which is the improvement design to minimize waste using fishbone diagram with man factor, machine, material, method, environtment or 4M1E [9] and method of failure mode effect and analysis. Stages used are: identification system and system elements and identify the failure and its effects [10]. Determine the severity of the effects of a failure (Saverity), the frequency of failure that occurs (Occurrence), and the level of accuracy to detect failure (Detection). Calculate Risk Priority Number (RPN) by Equation (4).

$$RPN = Severity \times Occurrence \times Detection \quad (4)$$

Mura is designing production level equilibrium using mixed model scheduling method according to the demand data of production through the following steps [11]. The determination of daily production (Equation (5)) schedule for some model or product type.

$$Daily\ Production = \frac{Total\ demand\ for\ each\ product}{Total\ working\ days} \quad (5)$$

Specify the cycle time for each product by Equation (6).

$$Cycle\ Time = \frac{\text{Process Time}}{\text{Daily Production Amount}} \quad (6)$$

The determination reciprocal link cycle time for each product by Equation (7).

$$1\frac{unit}{unit} of\ time = \frac{1}{Cycle\ Time} \quad (7)$$

The determine ratio of the minimum total number of units in a sequence to the sequence time by Equations (8) and (9).

$$Total\ Sequence\ Time = \sum (Cycle\ Time\ x\ n) \quad (8)$$

$$Sequence = \frac{Process\ Time}{Total\ Sequence\ time} \quad (9)$$

The determination order of sequences and product sequences. Muri, which was to calculate the work load according to the amount of production that was designed on the mura and provide the number of worker proposals using work load analysis method. Calculate the value of work productivity in the company and the design of Toyota Production System with the following equation (10).

$$P = \frac{total\ output\ produced}{Number\ of\ Workers\ Hired} \times 100\% \quad (10)$$

## RESULTS AND DISCUSSION

The production activities of PT Nexus Fashion & Sports gloves consist of 21 production activities, which are 14 operating activities, 4 inspection activities, and 3 transportation activities. The used of stopwatch time study method resulted in standard time of cutting process 222.42 seconds, setting 135.69 seconds, sewing 47.98 seconds, inspect 238.30 seconds, 30.49 seconds, quality final 34.29 seconds, and packing 148.75 seconds. The effectiveness of production process using manufacturing cycle effectiveness method was 67%. Increasing the effectiveness of the production process was accomplished through process improvement by eliminating the second checking activity on the inspect unit, providing supervision on the first check of the unit and checking the gloves on the final quality unit, so that the production effectiveness value increases to 69%. Waste identification used waste assessment model results in waste category (O) 14.49%, (I) 14.26%, (D) 18.19%, (M) 17.39%, (T) 14.55% (P) 8.87%, and (W) 12.26%.

The Design of Toyota Production System (TPS) Based on the Heijunka Principles. The Muda principle was used to minimize the dominant waste, the calculation of risk potential number (RPN) in Table-1 can be seen 3 potential causes of failure with the greatest RPN value and proposed improvement plan are:

**Table-1: Biggest RPN and Proposed Improvement Plan**

| Failure Mode | Potential Causes of Failure | S | Potential Failure Effects | O | D | RPN | Rank | Maintenance plan |
|---|---|---|---|---|---|---|---|---|
| *Defect* | Daily production targets are not fixed | 8 | Daily production output fluctuates | 9 | 8 | 576 | 1 | Create a flat production schedule daily |
| *Over production* | The amount of labor is not balanced | 8 | High work load | 9 | 7 | 504 | 2 | Determine the ideal amount of labor |
| *Motion* | Workers often paced moving goods | 6 | Many movements on the production floor | 9 | 7 | 378 | 3 | Moving activity using material handling |

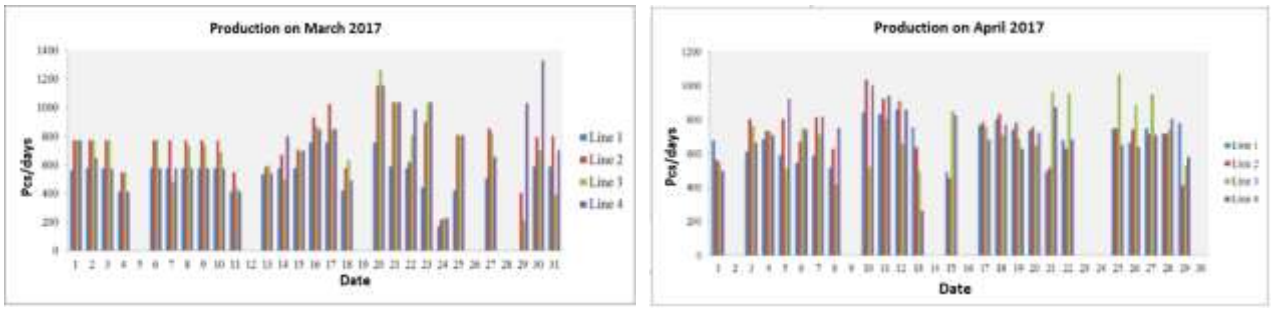
Mura, scheduled the production of TPS design based on heijunka principle using mixed model scheduling method for production demand. A product is generated through a sewing unit with 4 production lines presented in Table-2.

**Table-2: Calculation Method Mixed Model Scheduling 7 Hours Working in April 2017**

| Line | Style | Unit | Unit /Day | Cycle Time | 1/CT | PS* | SC* | TPS* | TSC* | S* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lup | 6288 | 349 | 1.20 | 1/1.20 | 9 | 10.80 ≈ 11 | 19 | 32.74 | 12.83 |
| | Lup WC | 2694 | 150 | 2.80 | 1/2.80 | 4 | 11.20 ≈ 11 | | | |
| | FR Leather Kevlar | 4230 | 235 | 1.79 | 1/1.79 | 6 | 10.74 ≈ 11 | | | |
| 2 | TR-1G1286 | 3406 | 189 | 2.20 | 1/2.20 | 12 | 26.40 ≈ 26 | 46 | 157.69 | 2.66 |
| | Seude Movement | 2000 | 111 | 3.78 | 1/3.78 | 7 | 26.46 ≈ 26 | | | |
| | Techfire Switch | 2975 | 165 | 2.55 | 1/2.55 | 10 | 25.50 ≈ 26 | | | |
| | KO-1G2437 | 1129 | 63 | 6.60 | 1/6.60 | 4 | 26.40 ≈ 26 | | | |
| | Ivo2 | 2276 | 127 | 3.31 | 1/3.31 | 8 | 26.48 ≈ 26 | | | |
| | MVP Tacktech | 1424 | 79 | 5.29 | 1/5.29 | 5 | 26.45 ≈ 26 | | | |
| | TR-1G1286 | 3661 | 203 | 2.03 | 1/2.03 | 14 | 28.42 ≈ 28 | | | |
| 3 | Ultimate Grip | 1550 | 86 | 4.74 | 1/4.74 | 6 | 28.44 ≈ 28 | 50 | 170.18 | 2.47 |
| | Seude Movement | 3199 | 178 | 2.36 | 1/2.36 | 12 | 28.32 ≈ 28 | | | |
| | Covert | 1867 | 104 | 4.04 | 1/4.04 | 7 | 28.28 ≈ 28 | | | |
| | Covert | 1600 | 89 | 4.72 | 1/4.72 | 6 | 28.32 ≈ 28 | | | |
| | SG20P | 1333 | 74 | 5.68 | 1/5.68 | 5 | 28.40 ≈ 28 | | | |
| 4 | Seude Movement | 999 | 56 | 7.75 | 1/7.75 | 5 | 38.75 ≈ 39 | 69 | 195.70 | 2.15 |
| | FR Leather Kevlar | 4069 | 226 | 1.86 | 1/1.86 | 21 | 39.06 ≈ 39 | | | |
| | Supergrip Orange | 1525 | 85 | 4.93 | 1/4.93 | 8 | 39.44 ≈ 39 | | | |
| | Exot-Sven | 4026 | 224 | 1.86 | 1/1.86 | 21 | 39.06 ≈ 39 | | | |
| | Exot-Swp | 2592 | 144 | 2.82 | 1/2.82 | 14 | 39.48 ≈ 39 | | | |

* PS = Product Sequence, SC = Sequence Time, TPS = Total Product Sequence, TSC = Total Sequence Time, S = Sequence.

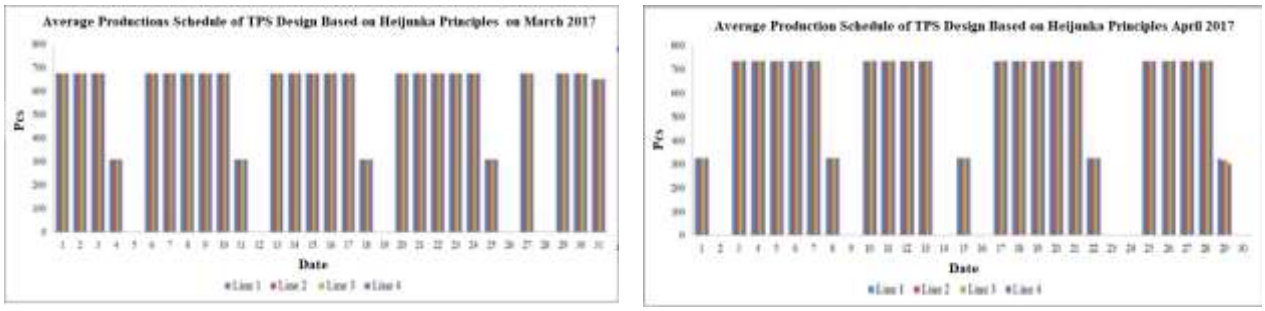
Figure-1 shows the daily production scheduling of PT Nexus Fashion & Sports and production levels in unbalanced companies. While Figure-2 is a picture of average production level of TPS Based on Heijunka Principles in March and April 2017.




(a) (b)

**Fig-1: Scheduling of Production Results**

**(a) March and (b) April 2017 from Production System in Company**



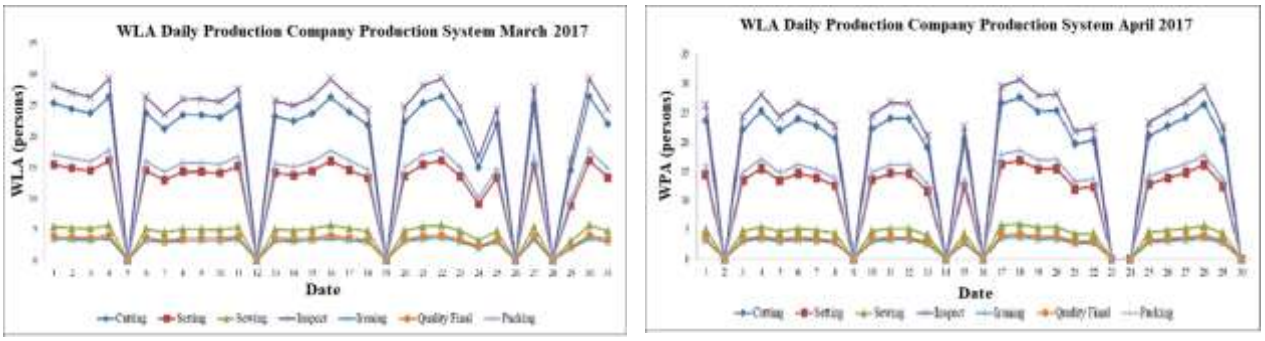

(a) (b)

**Fig-2: Average Production Schedule of TPS Design Based on Heijunka Principles (a) March and (b) April 2017**

Muri, the calculation of workload in accordance with the number of production scheduled using Work Load Analysis (WLA) method to obtain the number of proposed TPS design workers based on heijunka principle [11] is presented in Table-3, while WLA Daily Production System Production Company and WLA Daily Production TPS Design Principle Heijunka can be seen in Figure-3 and 4.

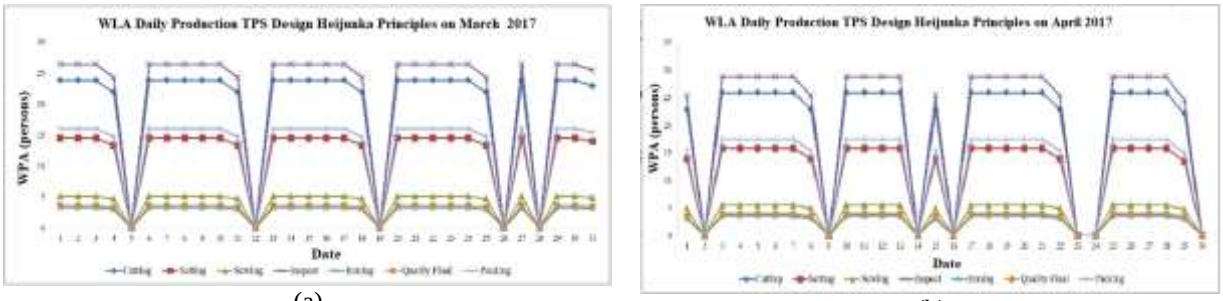
**Table-3: Comparison of Number of Workers of TPS Heijunka Principle With Average WLA**

| No | Unit | Average WLA | Average Workers | Proposed Workers | Description |
|---|---|---|---|---|---|
| 1 | *Cuting* | 25.22 Persons | 26 Persons | 26 Persons | Ideal |
| 2 | *Setting* | 15.39 Persons | 16 Persons | 16 Persons | Ideal |
| 3 | *Sewing* | 190.44 Persons | 191 Persons | 193 Persons | More than 2 Persons |
| 4 | *Inspect* | 28 Persons | 28 Persons | 29 Persons | More than 1 Person |
| 5 | *Ironing* | 3.46 Persons | 4 Persons | 4 Persons | Ideal |
| 6 | *Quality Final* | 3.89 Persons | 4 Persons | 4 Persons | Ideal |
| 7 | *Packing* | 16.98 Persons | 17 Persons | 18 Persons | More than 1 Person |




(a) (b)

**Fig-3: WLA Daily Production Company Production System**
**(a) March and (b) April 2017**




(a) (b)

**Fig-4: WLA Daily Production TPS Design Heijunka Principles**
**(a) March and (b) April 2017**

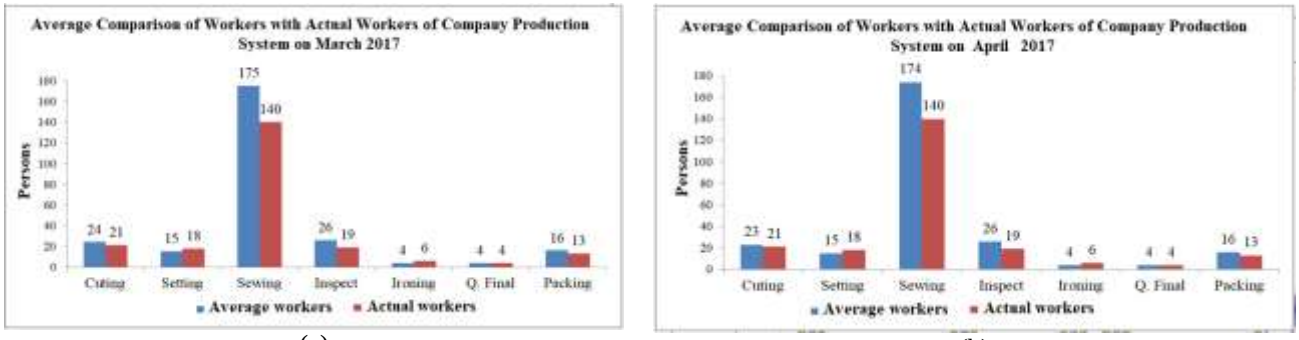
**Human Work Productivity**

The productivity of labor is shown as the ratio of the amount of production (output) generated per workforce in each working hour (input). Here are the results of the calculation of human labor productivity on March and April 2017 can be seen in Table-4 dan Figure-5.

**Table-4: Average Comparison of Human Labor Productivity**

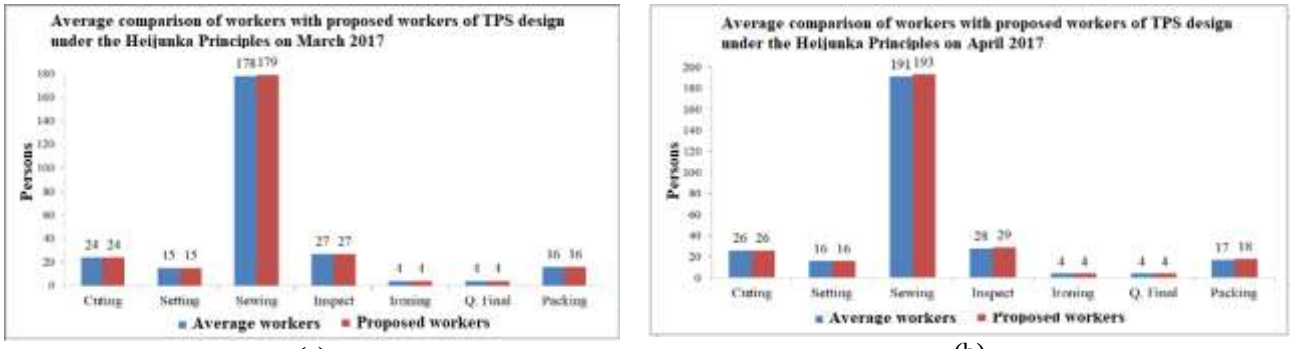
| Unit | March 2017 | | April 2017 | |
|---|---|---|---|---|
| | Company Production System (%) | The Heijunka Principal TPS Design (%) | Company Production System (%) | The Heijunka Principal TPS Design (%) |
| *Cutting* | 110.16 | 97.78 | 109.37 | 97.01 |
| *Setting* | 78.41 | 95.45 | 77.84 | 96.18 |
| *Sewing* | 124.76 | 99.46 | 123.86 | 98.75 |
| *Inspect* | 135.14 | 96.47 | 134.17 | 96.54 |
| *Ironing* | 52.85 | 80.43 | 52.47 | 86.44 |
| *Quality Final* | 89.16 | 90.45 | 88.52 | 97.22 |
| *Packing* | 119.80 | 98.74 | 118.93 | 94.33 |
| Average | 101.47 | 94.11 | 100.74 | 95.21 |

Figure-6 shows that the human work productivity of TPS design based on heijunka principle is greater than the company's production system seen in unit setting, ironing, and quality final. While the human work productivity of TPS design based on heijunka principle is smaller than the company's production system seen in cutting, sewing, inspect, and packing unit. The human work productivity of TPS design based on heijunka principle was smaller than the company's production system. It was caused a workload in the company's production system that exceeds the number of workers employed (input). The workers employed (input) was caused by the fluctuating amount of output as the result of the buyer requesting some of its order products immediately sent at a certain time.




(a) (b)

**Fig-5: Average Comparison of Workers with Actual Workers of Company Production System (a) March and (b) April 2017**




(a) (b)

**Fig-6: Average comparison of workers with proposed workers of TPS design under the Heijunka Principles on (a) March and (b) April 2017**

On the other hand, the condition of the number of workers or people employed (an input factor in the calculation of productivity) of TPS design based on the principle of heijunka was better than the company's production system. Table-5 shows the comparison of the number of labor between the company's production systems and the TPS of heijunka principles.

**Table-5: Number of Workers Comparison**

| Number of workers | March 2017 | | April 2017 | |
|---|---|---|---|---|
| | Company Production System | Heijunka Principal Design TPS | Company Production System | Heijunka Principal Design TPS |
| deficiency | 48 Persons | - | 46 Persons | - |
| advantages | 5 Persons | 1 Person | 5 Persons | 4 Persons |

Based on Table-5 above and the number of products produced, the average labor productivity results obtained from the company's production system decreased by 0.73%, while the TPS design based on heijunka principle increased by 1.10%.

## CONCLUSION

The identification of the Toyota Production System (TPS) design based on the Heijunka Principle was able to balance the production rate (mura). The production rate (Mura) based on the total production demand in March and April 2017 by using the mixed model scheduling method. It could balance the daily production level according to the available working time. Alignment of workload (Muri) by using work load analysis method based on the amount of daily production leveled by the ideal number of workers and excess 1 person (March 2017) and excess 4 persons (April 2017). Excess of the person was allocated to reduce the excessive workload in daily production.

## REFERENCES

1. Beju, L. D. (2014). Educating Students On Lean Manufacturing And Pull Production Using Games. In *Balkan Region Conference on Engineering and Business Education*(Vol. 1, No. 1, pp. 157-160). De Gruyter Open.
2. Liker, J. K. (2006). The toyota way: 14 prinsip manajemen dari perusahaan manufaktur terhebat di dunia. *Penerbit Erlangga, Jakarta*.

3. Fernando, R. (2008). *Analisis Efisiensi Proses dan Tenaga Kerja Di Lini Quality Gate pada PT Toyota Motor Manufacturing Indonesia*, (Magister Thesis) avaiable in Universitas Indonesia data base, Jakarta.
4. Amran, T. G., & Imdam, I. A. (2009). Perancangan jadwal produksi dengan menggunakan metode heijunka untuk mendukung pengembangan sistem produksi konvensional ke sistem produksi toyota (studi kasus: pt adyawinsa dinamika). *Industrial and Systems Engineering Assessment Journal (INASEA)-Discontinued*, *10*(2).
5. Saftiana, Y. E., & Andriyanto, R. W. (2007). Analisis Manufacturing Cycle Effectiveness Dalam Meningkatkan Cost Effective Pada Pabrik Pengolahan Kelapa Sawit. *Jurnal Akuntansi dan Keuangan*, *12*(1), 107-121.
6. De Araujo, L. F., & De Queiroz, A. A. (2009, September). A conceptual model for production leveling (heijunka) implementation in batch production systems. In *IFIP International Conference on Advances in Production Management Systems* (pp. 81-88). Springer, Berlin, Heidelberg.
7. Lippolt, C.R. and Furmans, K., (2008), Sizing of Heijunka-controlled Production Systems with Unreliable Production Processes in International Federation for Information Processing (IFIP), *Lean Business Systems and Beyond, Tomasz Koch, ed.; (Boston: Springer),* 257, 11–19.
8. Rawabdeh, I. A. (2005). A model for the assessment of waste in job shop environments. *International Journal of Operations & Production Management*, *25*(8), 800-822.
9. Lyashenko, V., Matarneh, R., Sotnik, S., and Belova. N., (2018), Modeling of the Forming Process for Aluminum Detail, *Saudi Journal of Engineering and Technology (SJEAT)*, 3(4), 219-227.
10. Gaspersz, V., (2001). *Production Planning and Inventory Control Berdasarkan Pendekatan Sistem Terintegrasi MRP II dan JIT Menuju Manufacturing 21*, Jakarta, PT Gramedia Pustaka Utama Publisher.
11. Casey, J. T., Brinton, T. S., & Gonzalez, C. M. (2009). Utilization of lean management principles in the ambulatory clinic setting. *Nature Reviews Urology*, *6*(3), 146.