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REDUCING DIRECT LABOR COSTS THROUGH U-SHAPED CELLULAR LAYOUT IN INJECTED AUTOMOTIVE COMPONENTS INDUSTRY

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Abstract: Reducing direct labor costs can be used to create a low operation cost as the way for winning future markets including injected automotive components. This paper aims to provide an overview of direct labor costs reduction in injected automotive components through a U-shaped cellular layout as part of the lean concept. Over a decade, many types of research had already used the lean concept to solve problems in production activity through lean tools. In this paper, several lean tools such as Takt time, value stream mapping, and U-shaped cellular will be used for reducing direct labor costs that have increased yearly in Indonesia since 2015. Those lean tools will be performed in a job-shop of injected automotive components. After performing the U-shaped cellular layout, the direct labor costs were reduced to 25 % by combining the job held by two operators to become one operator.
Key words: Cost reduction, Takt time, value stream mapping, U-Shaped cellular layout

1. INTRODUCTION

The increase in labor costs already happened in Indonesia since 2015. This condition start when the government of Indonesia launched a new regulation regarding standard minimum payment. In this regulation, the government will announce a standard minimum payment as a minimum salary of an employee in Indonesia regarding the economic growth every year (Peraturan Pemerintah Republik Indonesia, 2015). It was recorded from 2016 until 2018, the minimum salary already increased twice around 8 % each year. It means that all company in Indonesia including injected automotive components industry needs to increase their employee's salary by following the new standard minimum payment that has already been decided by Indonesia's government. The increase in employee salary certainly has an impact on direct labor costs which includes manufacturing costs.

The manufacturing costs can be defined as the total cost to produce a product. It consists of direct labor costs, direct material costs, and manufacturing overhead (Ostwald & TS McLaren, 2004). While producing a product, manufacturing costs that are needed to run the production line smoothly have to consider for deciding the product price. Hypothetically, if the manufacturing cost is higher than the product price, the company will suffer losses. This condition had possibly happened if the direct labor costs always increase while the production line still runs without any improvements. Otherwise, if the product price is higher than the manufacturing cost, the company will get a profit. However, the product price cannot be easily increased regarding the price pressure from nowadays global automotive supplier conditions (Roland Berger, 2017).

The global automotive supplier study was highlighted by Roland Berger as one of the largest strategic consultants in the world which expertise in the automotive area. Based on their study, automotive suppliers need to reconsider the business model for winning the future market. One consideration that needs to consider is creating a new and lower operating cost base (Roland Berger, 2019). It contradicts the actual conditions in Indonesia, where there is an annual increase in minimum salary every year that affects operating cost. This condition will lead automotive suppliers in Indonesia cannot win the future global market if there is no improvement in their production line for reducing the direct labor costs.

Meanwhile, the increase in labor costs can be simply be done by reducing the number of employees who perform production activities. However, this method still has to develop by referring to an actual condition in the production line which needs to produce the product based on customer demand. In one of injected automotive components industries in Indonesia, a job-shop production line was performed for fulfilling the customer demand. The production line was set as an I-shaped production line that makes employees need to finish a batch product in one process, then move the batch product to the next process. This condition already can meet the customer demand that already promise before. Therefore, an improvement needs to provide for reducing direct labor costs without sacrificing the promise to the customer to face the increase of standard minimum payment every year in Indonesia.

Reducing direct labor costs has already become one of the benefits of cellular manufacturing. These benefits were already surveyed by asking 32 companies in the United State of America that already used cellular manufacturing. The result of this survey will be shown in the table 1.

Table 1. Benefits of Cellular Manufacturing (Wemmerl & Hyer, 1989)

Benefits	Average Improvement
Setup time reduction	41.4 %
Throughput time reduction	24.3%
Reduction in WIP Inventory	19.4%
Quality Improvement	15 %
Reduction in Material Handling	21%
Direct Labor costs reduction	7.2%
Reduction in number of fixtures	34%
Improved machine utilization	23.4%
Reduction space	16.2%
Improved Job satisfaction	26.7%
Reduction in number of pieces of equipment	25%

As shown in table 1, cellular manufacturing has already been proved can be used to improve the production line by giving several benefits to the production line. It has shown cellular manufacturing successfully reduces 7.2% of direct labor costs. It means that cellular manufacturing can be used as one of the methods for facing the increase of direct labor costs every year in Indonesia.

2. LITERATURE STUDY

Cellular manufacturing can be defined as the applications of the group technology principles in a manufacturing environment in which the parts with similar processing requirements and machines are grouped in distinct manufacturing. This cellular manufacturing also creates a flexible work environment that can be combined with several jobs that will be performed by the employee (Venkataramanaiah, 2008). Others proposed a multi- objective model to improve the fitness of the employee to perform the job in cells, and to create effective teams (Askin & Huang, 2001). Moreover, cell loading and labor allocation problems that created a three-stage structure have already been examined. The solutions to sequencing, labor allocation, and cell loading problems are already provided (Süer & Dagli, 2005).

In more comprehensive, cellular manufacturing refers to a manufacturing system that groups and organizes the manufacturing resources which are operators, machines, tools, buffers, and handling devices in performing production activity (Silva & Alves, 2004). Cellular manufacturing is the major element in lean concept as the most successful manufacturing system from Japanese industries. Cellular manufacturing aims to produce the product with minimum process time, waiting time, and transportation by smoothening the process (Sundar et al., 2014).

Nowadays, the lean concept been already been applied in many organizations and already become an interesting option for many companies as it promotes the more effective utilization of resources, elimination of waste, and focus on creating value for the customer (Rymaszewska, 2013). This concept has already been applied in much previous research in different business lines. For instance, the lean concept already used optimizing cable harness assembly industry by eliminating Non-Value-Added activity (NVA) from operations and balance cycle time in system (Klašnja et al., 2019).

Moreover, the lean concept also increases efficiency and effectiveness through 5 S methods and line output improvement in the beverage industry. The 5S method already increases the efficiency on the micro-level. Then, the rest of the study was performing line output improvements through observing, measuring, and final analyzing the results of work to establish the time required for finishing the job by a qualified worker when working at a defined level of performance (Veza et al., 2011).

In the clothing industry, the lean concept was applied to reduce the consumption of resources and reduce pollutants by lean principles and tools such as value streaming mapping (VSM), 5S, Kaizen, TPM, Poka-yoke mechanisms, are used to achieve this trend by diagnosing, measuring, improving and supporting the sustainability of production systems (Maia et al., 2013).
In the implementation of cellular manufacturing, several lean tools can be used to make the framework of direct labor costs reduction. The lean tools that will be used in this research will be summarized and compared in the table 2.

Table 2. State of the art, (Veza, Gjeldum, Celent, et al., 2011)(Maia et al., 2013)(Klašnja et al., 2019))

	Veža, I., Gjeldum, N., & Celent, L. (2011)	Maia, L. C., Alves, A. C., & Leão, C. P. (2013)	Klašnja, N., Sremčev, N., Vukelić, Đ., Simeunović, N., & Lazarević, M. (2019)	This Research 2019
Business line	Beverage Industry	Clothing Industry	Cable Assembly	Injection Industry
Objective	Process efficiency	Sustainable development	Optimizing working station	Direct labor costs reduction
Process type				
Job-shop	-	√	-	√
Flow Shop	√	-	√	-
Lean tools				
5 S	√	√	√	-
Takt time	√	-	√	√
Line	√	-	√	√
Balancing	-	√	√	√
Value Stream	-	-	-	√
Mapping				
U-shaped				

In table 2, the comparison between this research and previous research that used the lean concept was shown. This research will perform in the injection industry that produces the injected automotive components. The lean tools that are used in this research are Value streaming map (VSM), Takt time, Line balancing, and U-shaped cellular layout.
Value stream mapping (VSM) can be defined as the flow of converting the raw material into finish product through the mapping of process and information flows essential to every product including Value-Added activity (VA) and Non-Value-Added activity (NVA) (Rother & J Shook, 2003). Value Stream mapping has already been used in much previous research to help show the actual condition of the production line and find the Non-Value-Added activity (NVA) as the improvement opportunists. For instance, Value Stream Mapping (VSM) has already successfully reduced the travel time for increasing productivity in the process of picking orders (Purba & S Aisyah, 2018). Moreover, Value Stream Mapping (VSM) also can be reduced lead time and increase cycle time efficiency by observing Non-Value-Added activity (NVA) in the current state (Ikatrinasari & Haryanto, 2014).
Next, Takt time can be defined as the unit of time within which a product must be produced to match the customer's order. Takt time can be a design parameter used in production settings for tuning the rate of work output to the customer's rate (Frandson & Tommelein, 2014). The importance of measuring Takt time due to the costs and inefficiency factors in the production line, which includes storage and working in process, purchasing of raw materials, spending on salary, the cost of missed opportunities to produce other goods, and capital costs for excess capacity (Rahani & Al-Ashraf, 2012). By considering the Takt time, the production line can be set as efficiently as possible to reduce direct labor costs. The correct ways to solve problems in the production line such as labor costs issues can be done by considering Takt time that can be simulated by using a standardized work combination chart (Kosaka et al., 2009). Then, Line balancing can be defined as the way to seek a balance between processes to another process for supporting the model's optimization. Several processes are performed repeatedly on any workpiece which enters a station, whereby the period time between two entries is referred to as cycle time (Boysen et al., 2007). If the cycle time in one process is higher than in another process, the unbalancing conditions will be appearing that show by operator waiting and operator over the job.
Eventually, the U-shape cellular line as the special type of cellular manufacturing used in lean concepts is normally formed since both ends of the line are located narrowly together. U-shaped lines aim to reduce the number of work station, improve line balancing, visibility, communication, quality, flexibility, material handling, and maximize operator use (Miltenburg, 2001). Moreover, in production activity, a U-shaped

production line increases the possible interaction among employees that improved by moving employees, workstations, or both into cellular manufacturing (Metternich et al., 2013). Previous research has shown that a U-shaped cellular layout was developed by several operating modes that refer to the way the operators are organized inside a cell. This could take the form of working balance, baton touch, rabbit chase, bucket-brigades, or Toyota Sewing System (TSS) (Alves, 2018). Those operating modes have their advantages regarding the actual condition of the production line.

3. RESEARCH METHODOLOGY

In case of reducing direct labor costs in the injection production lines, a framework needs to provide as a guideline to perform the improvement activity. The systematic method was inspired by previous research that used the lean concept to improve the production line as shown in the state of the art in table 2. Therefore, this research will follow several steps as a framework of direct labor costs reduction for facing the increase in labor costs. The following framework will be shown in the figure 1.

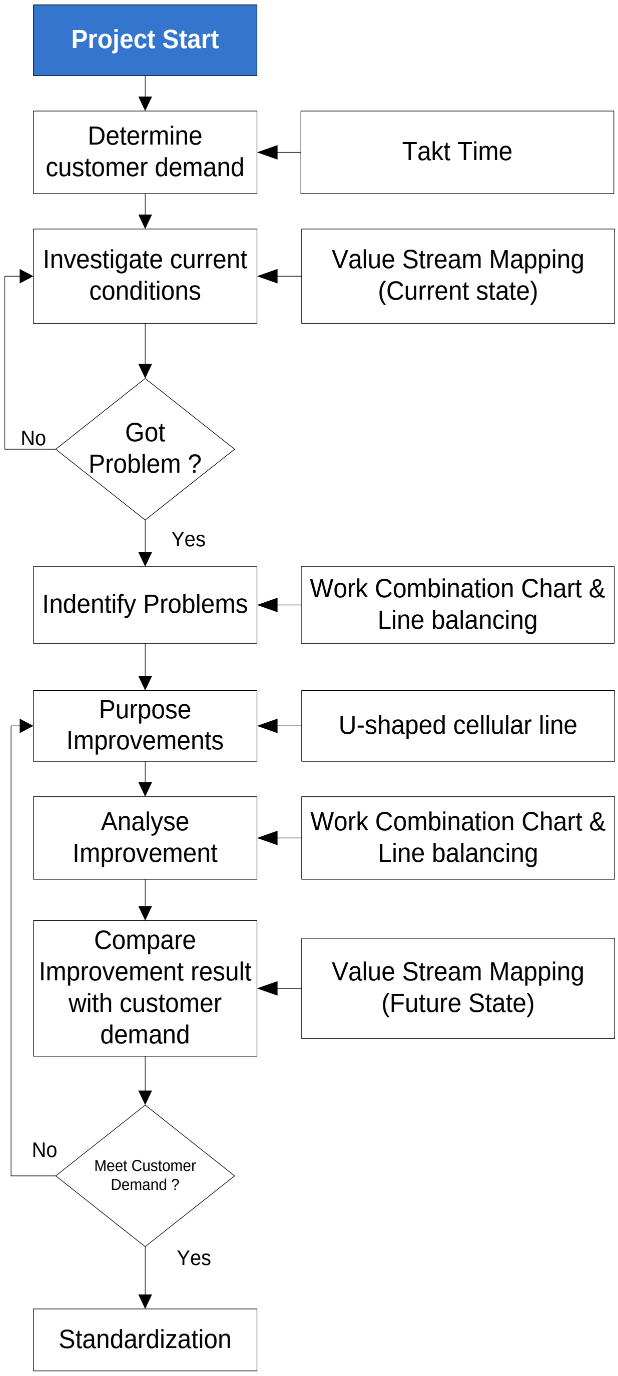


Fig. 1. Research framework

4. RESULTS AND DISCUSSION

In performing a research framework of direct labor costs reduction, a production line of injected automotive components will be used as a pilot project. The production line was performed by creating a job-shop production line. The production line had five job-shops which are Injection Line, Cap Assembly Line, Air Blow Line, Spray Line, and Inspection Line. This production line was producing an interior cap holder for the Automotive Industry.

4.1 Determining Customer demand

In performing direct labor costs reduction activity, determining customer demand will become the first step. The customer demand will be determined by using Takt time. Usually, Takt time will be calculated in seconds per piece which means the total second that needs to produce a single product. In finding the Takt time, the quantity of customer demand per month and total working hours per month have to determine. The calculation of Takt time can be determined by dividing the total working hours per month by the quantity of customer demand per month. The total working hour already decided by management which is 5 workdays per week and 14 working hours per day that divided into two shifts. Then, the customer demand is already decided by the customer as monthly demand.

In producing an interior cap holder, the injection line was set two shifts with 7 working hours per shift or equal to 1.108.000 seconds per day. This condition makes the injection line have 308 hours per month if the working day per month is 22 working days. Then, the customer orders are 200 thousand products per month. The Takt time of the interior cap holder is calculated as shown below where *tt* is Takt time, T is total available production time, and D is total demand (Schneider et al., 2015).

$$tt = \frac{T}{D} = \frac{2\, shifts \cdot 7\, hours \cdot 22\, days \cdot 3600\, s}{200000\, pieces} = 5.5\, s/piece \quad (1)$$

In equation 1, the Takt time of an interior cap holder is equal to 5.5 seconds per piece. If one of the processes in the injection line cannot achieve this Takt time, an interior cap holder cannot be supplied to the customer on time which caused a delayed delivery. This condition can make customer complaints that effected to customer satisfaction. Sometimes, there is overtime to complete the job for avoiding a delayed delivery. However, this way will increase the manufacturing cost that will affect direct labor costs that yearly increase in Indonesia. Therefore, this Takt time can be used as a minimum time needed to produce a single product for fulfilling customer demand on time without additional labor costs.

4.2 Investigating Current Conditions

After determining customer demand through Takt time, the current conditions need for investigating to find out whether the current conditions can meet customer demand or not. The current conditions will be investigated through Value stream mapping for describing the actual production flow from raw material until an interior Cap holder. The Value stream mapping of the production line of an interior Cap holder will be shown in the figure 2.

As known before, the customer demand is already determined through Takt time. This Takt time can be compared to each process in current conditions which is determined through cycle time. The cycle time was observed in the production line as seconds per piece with the assumption of no major quality problem when producing the product. If the cycle time is longer than Takt time, it means the process cannot meet customer demand with normal working hours.

In figure 2, it is shown that the Cap ASSY process had a cycle time that is longer than the Takt time which means the Cap ASSY process cannot follow the customer demand. Otherwise, the Air Blow process was performing faster than customer demand. This condition can make unbalancing problems between the operator in Cap ASSY process and air blow & cleaning process. The unbalancing problem will affect the production line output. Therefore, an improvement activity needs to perform for solving these problems.

4.3. Identifying problem

Next, an improvement in the Cap ASSY process and air blow process need to perform after identifying the problem that happened in those processes. The problem identification will start by identifying the actual process flow that happened in the production line which is shown in the figure 3.

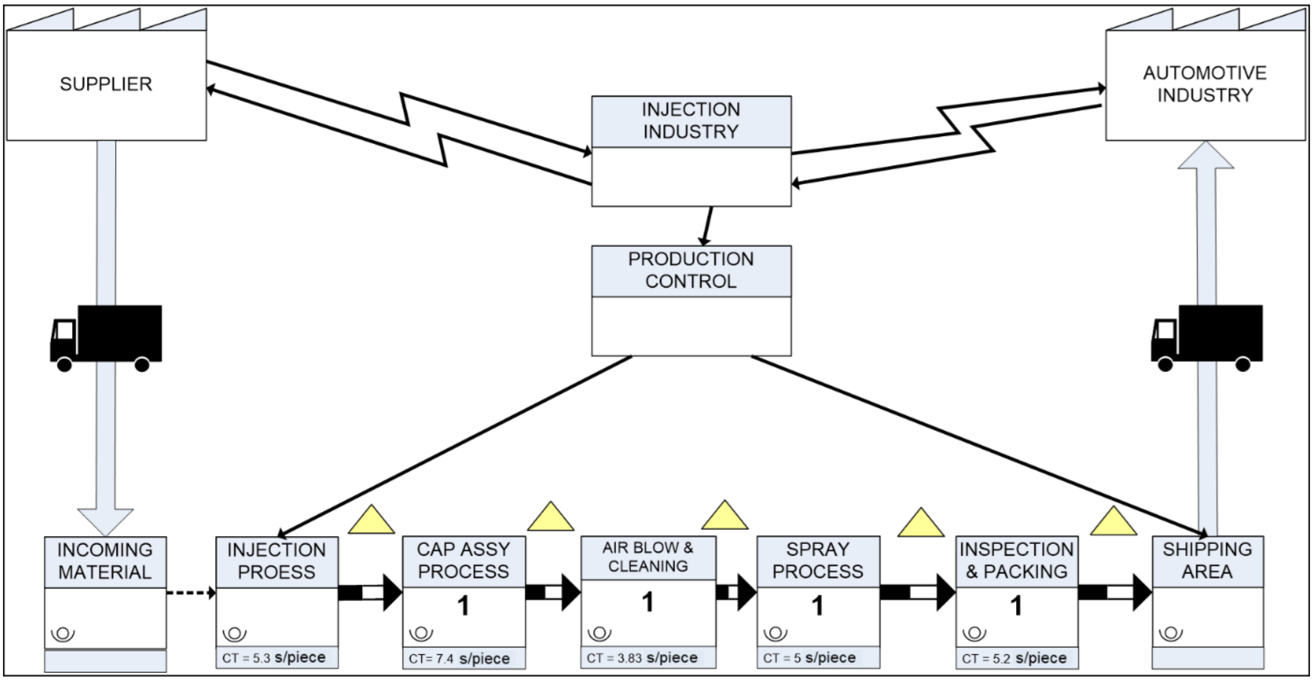


Fig. 2. The current state of the injection line

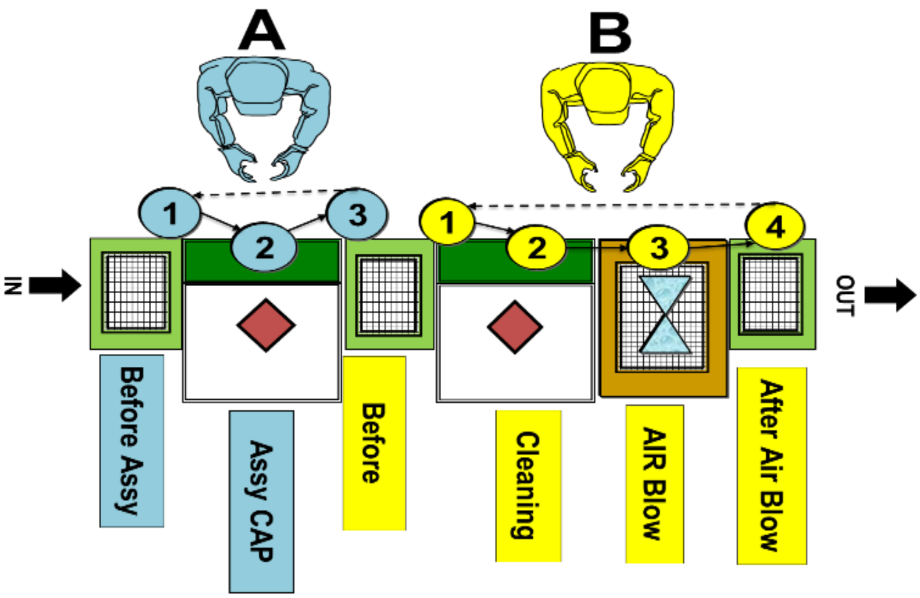


Fig. 3. Current process flow

In figure 3, it is shown that the Cap ASSY process and air blow process was run by two operators. Operator A was performing Cap ASSY process by assembling the injected part to spray jig and set in pallet as batch size. Then, operator B will take the pallet that is already full of injected parts and perform cleaning and air blow proses.

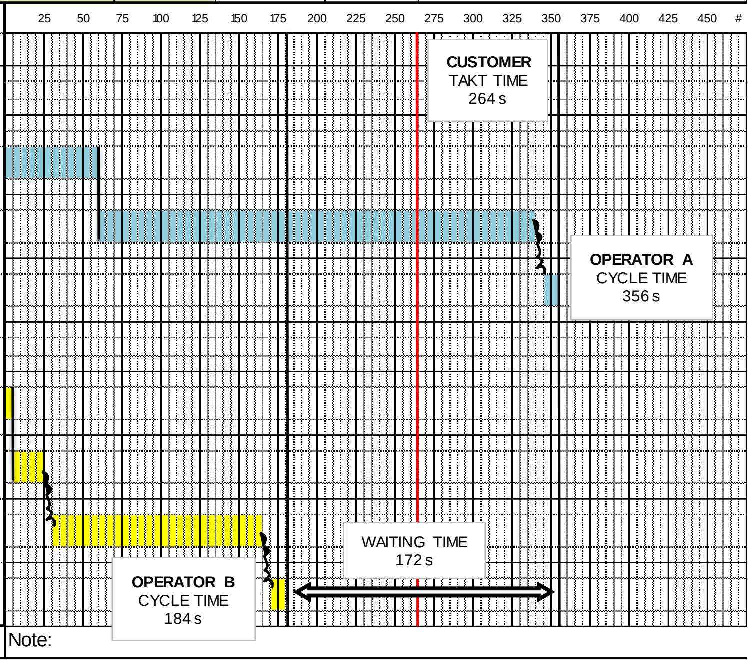
The detail of job elements of operator A and B will be described through the work combination chart which is shown in the table 3.

It is shown in table 2 that operator B is faster than operator A. This condition will make operator B need to wait for operator A to finish the job. Currently, operator A will be performing advanced production for making a buffer stock for operator B. However, this condition makes operator A needs to do overtime for making buffer stock that creates additional cost. Then, by referring to the customer Takt time, it seems that operator A cannot achieve the customer demand, while operator B can make overproduction. In this condition, job elements of operator A and operator B need to observe to find out the cause of unbalancing production line. Therefore, line balancing needs to perform in those processes by combining job elements to achieve the customer Takt time.

Table 3. Work combination chart of current conditions

LINE NUMBER	1	WORK COMBINATION CHART	Order/month	200000 PCS	Takt time	5.5 s	Manual Labor	
PROCESS NAME	ASSY CAP - AIRBLOW		w orking day/month	22 DAY	Cycle time	7.4 s	Automatic Production	
AREA	INJECTION		Working Hr/day	14 Hr	Ouput/month	149434 PCS		
MODEL	INTERIOR CAP-HOLDER		Column scale	5	Judgement	DELAY	Walking	
DESIGN	664W						Waiting	

TURN	OPERATION CONTAIN	TIME M	TIME A	TIME W
OPERATOR A				
1	Taking injected part as much as 48 pieces and spray jig as much as 8 pieces. Then, Marking the product.	61		
2	Next, performing ASSY process by combining 6 pieces of injected part with 1 spray jig and arrange the completed spray jig into pallet as much as 8 spray jig	280		5
3	Finally, moving the full pallet that consist 8 spray jig into next process	10		
OPERATOR B				
1	Taking full pallets from previous process and putting in cleaning process.	5		
2	Then, performing cleaning process by using IPA chemical	20		5
3	After cleaning, performing air blow process for each spray jig and putting into rack after cleaning	139		5
4	Finally, arrange spray jig that already clean into pallet	10		
	Total	525	0	15



4.4. Purposing an improvement

Next, an improvement needs to perform in the Cap ASSY process and air blow process regarding unbalancing the production line. The line balancing will be applied as the job combination between operator A and operator B that will be run in U-shaped cellular that has been proved effectively can reduce direct labor costs. As known in table 4, operators have performed the job as batch production which completed a pallet of the injected parts. This way is the difference from cellular manufacturing which performs the job in a single piece. It means a single injected part is moved from one process to another process. Moreover, table 4, also found that operator B need to wait for operator A that caused an unbalanced production line. This happened because operator A need to finish the batch size of the injected parts that need longer time than operator B. That’s why operator B did nothing after finishing their job.

By considering the U-shaped cellular layout, the way how to finish the job will be to change from batch size to a single size. This way can be applied by combining job elements and re-arrange the job element based on customer demand as shown in the figure below.

In figure 4, the operator will be set to perform job elements by one piece’s flow. The cleaning process and Cap ASSY were combined. Then, the injected part that has already been cleaned and assembled will continue to air blow process. Finally, the injected part will be arranged to the pallet and ready to move to the next process.

4.5. Analyzing Improvement

After purposing an improvement which is a U-shaped cellular layout, the detail of job elements needs to analyze whether meets customer requirements or not. The detailed job element of the U-shaped cellular layout will be shown in the table below.

In table 4, the line balancing was performed by combining the job elements. As shown, operator A will take 6 injection parts and 1 jig spray. Then, operator A was performing marking the product with a marker. Next, operator A will assembly 6 injection parts with a spray jig. After assembled, the 6 of injection parts will be cleaned by using IPA chemical. After cleaning, operator A was performing Air blow process.

Finally, the full assembled spray jig will be arranged into the pallet for the next process. Then, operator A will repeat those job elements for as many as 8 cycles for fulfilling a pallet that consists of 48 pieces of the injected part. It means that operator A needs 253 seconds to finish the job, while the customer Takt time required 264 seconds to finish the job that the Takt time is equal to 5.5 seconds per piece. This condition makes the U-shaped cellular layout can meet the customer as the way to satisfy the customer.

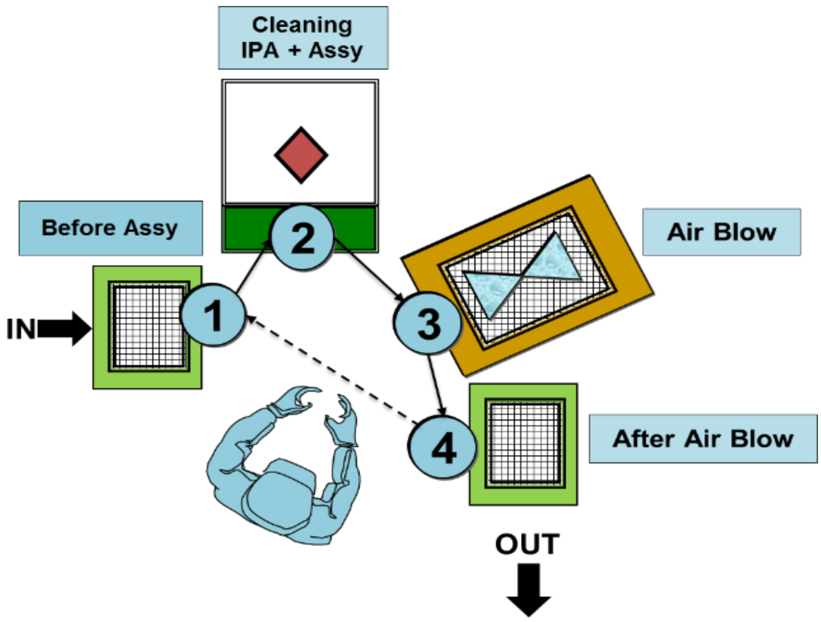


Fig. 4. After improvement process flow

Table 4. Work combination chart of U-shaped cellular layout

LINE NUMBER	1	WORK COMBINATION CHART	Order/month	200000 PCS	Takt time	5.5 s	Manual Labor
PROCESS NAME	ASSY CAP - AIRBLOW		working day/month	22 DAY	Cycle time	7.4 s	Automatic Production
AREA	INJECTION		Working Hr/day	14 Hr	Ouput/month	149434 PCS	
MODEL	INTERIOR CAP-HOLDER		Column scale	4	Judgement	DELAY	Walking
DESIGN	664W						Waiting

TURN	OPERATION CONTAIN	TIME M	TIME A	TIME W	20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 #
OPERATOR A					OPERATOR A CYCLE TIME 252 s; CUSTOMER TAKT TIME 264 s
1	Taking 6 injection part and 1 spray jig and marking the product.	8			
2	Then, performing ASSY process by assemblying 6 injected part into spray jig and cleaning the part using IPA chemical	12			
3	Next, performing air blow to a full assembly spray jig	4			
4	Finally, arranging the full assembly spray jig that already airblow in pallet and repeat turn 1 until 4 as much as 8 times	4		4	
	Total	28	0	4	Cycle 1, Cycle 2, Cycle 3, Cycle 4, Cycle 5, Cycle 6, Cycle 7, Cycle 8

4.6. Comparing improvement result

After analyzing the improvement, the result of improvement needs to compare for facing the increase of direct labor costs every year in Indonesia. Currently, the total operators who perform production activities are four operators. The two operators who perform the spray process and inspection process was not improved because already achieved the Takt time. Otherwise, the 2 operators who performed Cap ASSY process and air blow process were improved by a U-shaped cellular layout application to balance the production line.

The application of a U-shaped cellular layout was successfully reduced the direct labor costs in the injection line. It had shown that line balancing that performs in a U-shaped cellular layout only needed one operator. The operator only needed to process the injected part one by one. This method was adopted from a cellular manufacturing system that performs production activity using one-piece flow which allows a single piece of the product is produced and moved between operations (Marodin et al., 2015).

Regarding the increase of direct labor costs that happened in Indonesia, the U-shaped cellular layout that applied was successfully reduced the direct labor costs by combining the job element of two operators to become one

operator. This improvement also can reduce the overtime that was previously performed to make buffer stock. The total operator who performs production activity in the injection line is reduced from four operators become three operators.
Eventually, the total direct labor costs were reduced after applying a U-shaped cellular layout. It is automatically can be found by seeing the reduction of the operator who performs production activity and total overtime that happened. By percentage, the direct labor costs were reduced around 25 % because there is one operator that has been reduced. The reduction of operators can be seen through Value stream mapping as shown in the figure below.

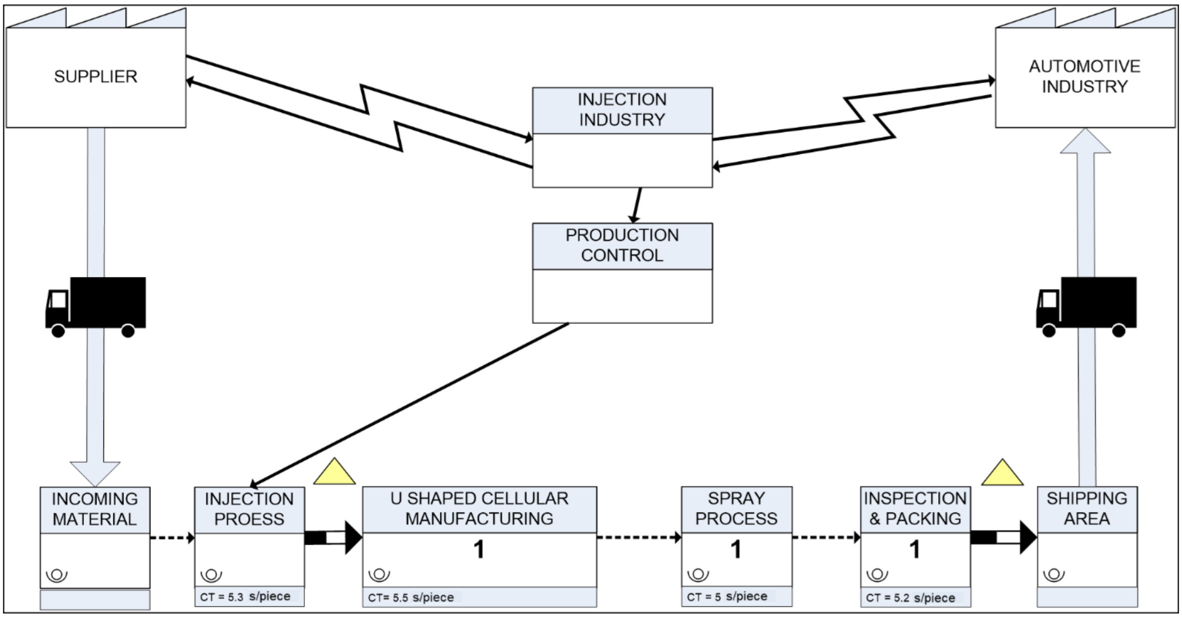


Fig. 5. The future state of the injection line

4.7. Standardization

The U-shaped cellular layout has already been applied and the improvement result has already been achieved. For continuing the improvement, standardization will be provided to keep the results of improvement. The standardization can describe from standard operating procedures and work instructions (Mir et al., 2016).

5. CONCLUSIONS

The application of lean tools can be used as a way to solve the problem in production activity. The lean tools such as Takt time, value stream mapping, line balancing, and U-shaped cellular can be set as a framework for facing the increase of direct labor costs every year in Indonesia. This paper shows the way to perform the improvement by considering customer demand by comparing the current state with Takt time and choosing the proper area to perform improvement. Moreover, this paper also shows the application of a U-shaped cellular layout to reduce direct labor costs that successfully reduce one operator by performing job combinations in a U-shaped cellular layout. As the result, U-shaped cellular layout can have reduced one operator in the injection line without sacrificing customer demand that reduced 25 % direct labor costs.
However, the application of a U-shaped cellular layout was not applied in all processes. In the future state, the U-shaped cellular layout is only applied in the bottleneck process. For further research, the U-shaped cellular layout needs to be applied totally in the injection line from the injection machine until the inspection process by using the framework that has already been provided before. This application of total cellular layout will give more benefit for facing the increase of direct labor costs every year in Indonesia.

6. REFERENCES

1. Alves, A. C. (2018). U-shaped cells operating modes: A review and a hands-on simulation comparison. *International Journal of Industrial Engineering and Management*, *9*(2), 87–97.
2. Askin, R., & Huang, Y. (2001). Forming effective worker teams for cellular manufacturing. *International Journal of Production Research*, *39*(11), 2431–2451.
3. Boysen, N., Fliedner, M., & Scholl, A. (2007). A classification of assembly line balancing problems.

European Journal of Operational Research, *183*(2), 674–693.
4. Frandson, A., & Tommelein, I. (2014). Development of a takt-time plan: a case study. *In Construction Research Congress 2014: Construction in a Global Network*, 1646–1655.
5. Ikatrinasari, Z. F., & Haryanto, E. I. (2014). Implementation of Lean Service with Value Stream Mapping at Directorate Airworthiness and Aircraft Operation, Ministry of Transportation Republic of Indonesia. *Journal of Service Science and Management*, *07*(04), 291–301. https://doi.org/10.4236/jssm.2014.74026
6. Klašnja, N., Sremčev, N., Vukelić, D., & Lazarević, M. (2019). Optimization of Cable Harness Assembly Systems Based on Lean Concept Application. *International Journal of Industrial Engineering and Management*, *10*(1), 115–123.
7. Kosaka, G., Kishida, M., Silva, A., & Guerra, E. (2009). Implementing Standardized Work at ThyssenKrupp in Brazil. *Lean Institute Brasil*, 1–13.
8. Maia, L., Alves, A., & Leão, C. (2013). Sustainable work environment with lean production in textile and clothing industry. *International Journal of Industrial Engineering and Management*, *4*(3), 183–190.
9. Marodin, G. A., Saurin, T. A., Tortorella, G. L., & Denicol, J. (2015). How context factors influence lean production practices in manufacturing cells. *International Journal of Advanced Manufacturing Technology*, *79*(5–8), 1389–1399.
10. Metternich, J., Bechtloff, S., & Seifermann, S. (2013). Efficiency and Economic Evaluation of Cellular Manufacturing to enable Lean Machining. *Procedia CIRP*, *7*, 592–597. http://dx.doi.org/10.1016/j.procir.2013.06.038
11. Miltenburg, J. (2001). U-shaped production lines : A review of theory and practice. *International Journal of Production Economics*, *70*(3), 201–214.
12. Mir, M., Casadesús, M., & Petnji, L. H. (2016). The impact of standardized innovation management systems on innovation capability and business performance: An empirical study. *Journal of Engineering and Technology Management*, *41*, 26–44.
13. Ostwald, P., & TS McLaren. (2004). *Cost Analysis and Estimating for Engineering and Management*. Prentice Hall.
14. Peraturan Pemerintah Republik Indonesia Nomor 78 Tahun 2015 Tentang Pengupahan, Pasal 3 (2015).
15. Purba, H., & S Aisyah. (2018). Productivity improvement picking order by appropriate method, value stream mapping analysis, and storage design: A case study in automotive part center. *Management and Production Engineering Review*, *9*(1). https://doi.org/10.24425/119402
16. Rahani, A., & Al-Ashraf, M. (2012). Production Flow Analysis through Value Stream Mapping : A Lean Manufacturing Process Case Study. *Procedia Engineering*, *41*, 1727–1734.
17. Roland Berger. (2017). *Global Automotive Supplier Study 2018*.
18. Roland Berger. (2019). *Global automotive supplier study highlights*.
19. Rother, M., & J Shook. (2003). *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda*. Lean Enterprise Institute.
20. Rymaszewska, A. (2013). When a set of tools is not enough- lean placed strategically. *International Journal of Industrial Engineering and Management*, *4*(4), 215–220.
21. Schneider, U., Friedli, T., Basu, P., & Werani, J. (2015). Operational Excellence in Practice—the Application of a Takt-Time Analysis in Pharmaceutical Manufacturing. *Journal of Pharmaceutical Innovation*, *10*(2), 99–108. https://doi.org/10.1007/s12247-014-9210-5
22. Silva, S. do C., & Alves, A. (2004). A Framework for Understanding Cellular Manufacturing Systems. *E-Manufacturing: Business Paradigms and Supporting Technologies*, 163–172.
23. Süer, G., & Dagli, C. (2005). Intra-cell manpower transfers and cell loading in labor-intensive manufacturing cells. *Computers & Industrial Engineering*, *48*, 643–655.
24. Sundar, R., Balaji, A. N., & Satheeshkumar, R. M. (2014). Review on Lean Manufacturing Implementation Techniques. *Procedia Engineering*, *97*, 1875–1885.
25. Venkataramanaiah, S. (2008). Scheduling in cellular manufacturing systems : an heuristic approach. *International Journal of Production Research*, *46*(2), 429–449.
26. Veza, I., Gjeldum, N., & Celent, L. (2011). Lean Manufacturing Implementation Problems in Beverage Production Systems. *International Journal of Industrial Engineering and Management (IJIEM)*, *2*(1), 21–26.
27. Wemmerlöv, U., & Hyer, N. (1989). Cellular Manufacturing in the U . S . Industry : A Survey of Users. *The International Journal of Production Research*, *27*(9), 1511–1530.

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