REDUCING MANUFACTURING LEAD TIME AND WASTES IN RIDE-ON CARS PRODUCTION LINE IN PT. XYZ THROUGH VALUE STREAM MAPPING IMPLEMENTATION

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Abstract *-- This research is empirically designed to implement Value Stream Mapping to PT. XYZ's ride-on cars production line as well as showing effectiveness of Value Stream Mapping to manufacturing lead time and wastes reduction. This research examines ride-on cars production process in PT. XYZ where data were obtained mainly from direct observation in January 2018 and some from plant's data. Former data showed fluctuation in manufacturing lead time. Furthermore, only one out of seven wastes was firstly detected by production team which was defect rate shown in November and December 2017 data. Value Stream Mapping is one of lean manufacturing tools used to reduce wastes which also leads to manufacturing lead time reduction. The result of this research finds that Value Stream Mapping is efficient in identifying wastes of motion, transportation, and waiting as well as reducing most of wastes after implementation in PT. XYZ is done and finally impacted on manufacturing lead time reduction.*

Keywords: *Lean Manufacturing, Flow Process Chart, Process Activity, Value Stream Mapping, Wastes, Manufacturing Lead Time*

I. INTRODUCTION

Lean manufacturing has been defined as a multi-dimensional approach that covers a wide variety of management practices, including just-in-time, quality systems, constraints management, layout design, technology, inventory management, work teams, cellular manufacturing, supplier management and other practices in an integrated system (Shah & Ward, 2003). One of lean manufacturing tools is Value Stream Mapping or commonly known as VSM (Rother & Shook, 1998). The value stream mapping process will likely expose value added activities (VA) and non-value added activities (NVA) (Patel & Chauhan, 2015).

Indonesia is a huge market opportunity for plastic toys manufacturing and companies since the growth of birth rate in Indonesia let alone in 2015 is increased to 1.49% according to Surapaty

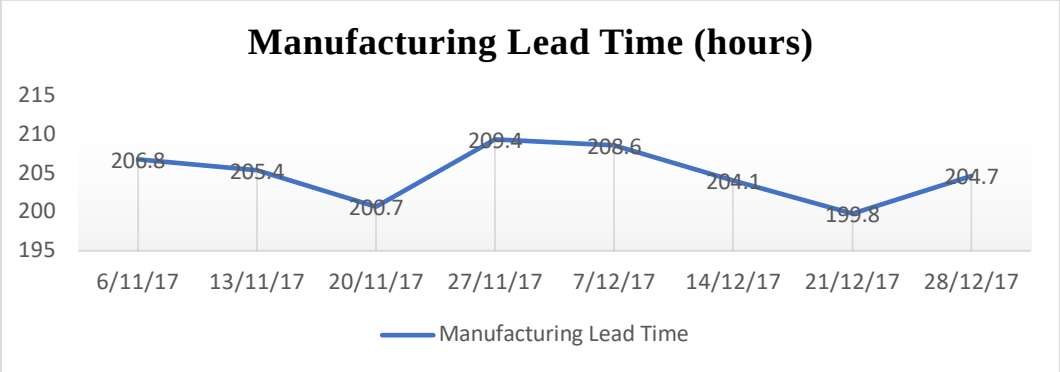
(2015) which meant that in 2015 there were 4.5 million children born and which amount was the same with Singapore population. By having that statement, Indonesia's opportunity to receive national income from toys industry should be huge, however, most of the toys mainly were made from China (Lukas S. , 2013). Table 1.1 shows plastic toys import activities in Indonesia from 2013 to 2015. However, in 2015, the imported amount started to decline due to implementation of Indonesia National Standard (SNI) regulation that aims for safety of toys, since then Indonesia's local toys industry and producers have risen to beat the import according to Sutjiadi (2018) the head of Indonesian Toys Association.

Plastic Toys Import Activities in Indonesia from 2013 to 2015

TOYS DESCRIPTION	2013	2014	2015
Tricycles, scooters, pedal cars and similar wheeled toys	$11,416,982	$13,834,889	$5,042,924
Electric trains toys, including tracks, signals and other accessories	$2,029,151	$1,933,233	$1,565,879
Other reduced size ("scale") models and similar recreational models	$15,584,099	$18,103,319	$17,175,368
Numerical/alphabetical/animal blocks or cut-out; word builders/making set	$1,117,510	$1,857,173	$904,068
Skipping ropes	$51,540	$460,330	$53,714
TOTAL IMPORT	$30,199,282	$35,788,944	$24,741,953

Source: http://kemenperin.go.id/jawaban.php?id=34280-29247 retrieved on January 15th, 2018

PT. XYZ is the first make-to-stock plastic toys manufacturing company located in Makassar, Sulawesi Selatan. There are various kinds of toys produced by PT. XYZ such as ride-on cars for toddlers, cars, cooking set, football, ring doughnuts, and piggy banks. There are a lot of pressure coming not only from outside but also from local producers, therefore to remain competitive, an action needs to be done. One of newest production lines in PT. XYZ is ride-on cars.



Ride-On Cars Manufacturing Lead Time in hours Per Batch from November 2017 to December 2017

Source: Data Obtained from PT. XYZ

As shown in Figure 1.2, the total manufacturing lead time per batch in hours was different for every batch. The chart in Figure 1.2 shows that there is fluctuation in manufacturing lead time for each batch.. In order to reduce manufacturing lead time, first, wastes need to be identified. However, the only waste recognized by the manufacture was part defects. Table 1.2 shows the defect rate from production process in November and December 2017. VSM needs to be applied to identify if there are other wastes beside defect occurred in ride-on cars production line in PT. XYZ.

The purpose of this research is to implement Value Stream Mapping to PT. XYZ's ride-on cars production line in order to obtain concept of lean manufacturing as well as reducing wastes and manufacturing lead time. This research also aims to measure the effectiveness of implementing Value Stream Mapping and the changes before and after implementation in PT. XYZ's ride-on cars production line.

II. LITERATURE REVIEW

Lean Manufacturing

Lean manufacturing is defined as an integrated systematic set and multi-dimensional approach of production model which combines practices such as just-in-time, total quality management (TQM), total preventative maintenance (TPM), human resource management (HRM), inventory management, strategies in product development, supply management to make

a continuous improvement (Womack, et al., 1991); (McLachlin, 1997); (Shah & Ward, 2003). Furthermore, lean manufacturing has the purpose to maximize value added activities by eliminating wastes and activities accounted as non-value added from manufacturing operations of a company (Krajewski, et al., 2013).

In lean manufacturing, there are times where waste is an important part of production process which adds value to the firm and therefore cannot be eliminated. Below are the seven wastes according to Womack and Jones (1996).

1. **Transportation.** Transportation waste is defined as movement of product that does not add value. It is a process to move work in process (WIP) material from a station to another. The waste of transport causes higher in cost and longer lead times.
2. **Inventory.** Inventory waste is defined as more materials, parts, or products on hand than the customer needs right now. Waste in inventory happens when the amount of stock and work in process exceed the amount of requirement necessary to produce goods or services just in time.
3. **Motion.** Motion waste is defined as movement of people that does not add value. Waste of motion is any motion of man or equipment that does not add value to the product or service.
4. **Waiting.** Waiting waste is defined as idle time created when material, information, people or equipment is not ready. Waste of waiting is any idle time produced when two interdependent process are not completely synchronized.
5. **Overproduction.** Overproduction waste is defined as producing more than the customer needs right now. Overproduction is the worst kind of waste because it causes other wastes and obscures the need for improvement. Overproduction waste results from producing more (or faster) than required.
6. **Over-processing.** Over processing waste is effort that adds no value from the customers viewpoint, therefore it is putting more into the product than is valued by the customer. Over processing is usually caused by no standardization of best techniques or unclear specification/ quality acceptance standards.
7. **Defects.** Defect waste is defined as work that contains errors, rework, and mistakes or lacks something necessary. Waste of correction includes additional work performed on a product or service; usually caused by or unclear operating procedure/ specifications.

Process Activity

Process activity is defined as a set of activities that belongs to a particular process that defines even the smallest measurable amount of work to be performed to convert some portion or process inputs into a desired outputs. All activities included in the same process create a definition of work to be performed by the process (Quality Scotland Organization, 2003). In process activity, there is value added activity which is any movement or action that can add value to raw materials toward completion and can only be defined as valuable if it meet the customers' needs (Womack & Jones, 1996) (Tilley, 1989); and non-value added activity which is any action that does not increase the worth of what is delivered to customer and does not change the product or assembly (Ketkamon & Teeravaraprug, 2009).

Process Chart

A process chart is a visual portray of events and information related to the occurring during a series of actions or preparations. There are two types of process chart which are operation process chart and flow process chart (American Society of Mechanical Engineers, 1947). Process chart is divided into operation process chart which is a visual portray of the process at which materials are introduced into the process, and of series of inspections and all operations which includes information considered desirable for analysis (Groover, 2007); and flow process chart which is a graphic portray of the sequence of all operations, transportations, inspections, delays and storages occurring during a process or procedure, and includes information considered desirable for analysis such as time required and distance moved (American Society of Mechanical Engineers, 1947).

Time Study

Time study is known as a work measurement technique that careful time measurement of the task with a time measuring instrument, adjusted for any observed variance from normal effort or pace and to allow adequate time for such items as foreign elements, unavoidable or machine delays, rest to overcome fatigue and personal needs (Institute of Industrial & Systems Engineers, 1982). According to Niebel and Freivalds (1998), time study is a procedure using stopwatch timing to establish a standard. Time study uses a timekeeping device such as stopwatch to record the time taken to accomplish a task and it is often used when there are repetitive work cycles of short to

long duration, wide variety of dissimilar work is performed, or process control elements constitute a part of the cycle (Karsten, 1996). There are few concepts used for time study. *Performance rating* is defined as the assignment of a percentage to the operator's average observed time, based on the actual performance of the operator as compared to the observer's conception of standard performance. *Allowance* is defined as the time added to normal time to provide for personal delays, unavoidable delays and fatigue. Allowance is counted after finish counting normal time to account the interruptions, delays and slowdowns caused by fatigue in every work assignment. Allowance needs to be counted therefore the resulting standard time is fair and readily maintainable by average worker performing at a steady and normal pace. *Observed time* is the elemental time for one cycle, obtained either directly or by subtracting successive watch times. *Normal time* is defined as the time required for the standard operator to perform the operation when working at a standard pace, without delay for personal reasons or unavoidable circumstances. *Standard time* is defined as a unit time value for a work task, as determined by the proper application of appropriate work measurement techniques by qualified personnel (Niebel & Freivalds, 1998).

Value Stream Mapping

Value Stream Mapping (VSM) is widely used lean tool aimed at eliminating waste or muda obtained from designing the process of mapping the material and information flows required to coordinate the activities performed by manufacturers, suppliers and distributors to deliver products to customers (Singh & Garg, 2011). The map consists of a current state drawing, future state drawing, and implementation plan. VSM spans the supply chain from the firm's receipt of raw materials or components to the delivery of the finished good to customer or distributor. By creating VSM, managers can identify the source of wasteful non-value-added activities (Krajewski, et al., 2013). Furthermore, value stream mapping is beneficial to reduce process cycle times and implement process improvement (Rother & Shook, 1998) (Seth, et al., 2008). There are few terms in VSM. *Takt time* represents the average pace of sales over a specific time period. It defines the time available to produce one part. It is the overall available production time in a chosen time interval divided by the overall forecasted customer demand for the time interval (Shingo & Dillon, 1989). *Changeover time or setup time* is defined as the total of time consumed from changing some equipment or device or system from the last production batch's part to the first following batch's production good (Gade, et al., 2016) (Kerberdle, 2008). *Cycle time* is defined as the time taken to

do a process, therefore it includes the time from when an operator starts a process until the work is ready to be passed on (Niebel & Freivalds, 1998). *Operational time* is defined as the total time that is dedicated to a product in a specific operation (Niebel & Freivalds, 1998). *Manufacturing lead time* is defined as the time taken from the time production is authorized, to the time it is completed and the material is available for use to fill demand by the customer or the next stage (Karmarkar, 1993).

Single Minute Exchange of Dies

Single Minute Exchange of Die (SMED) is a process of reducing setup or changeover time by classifying elements as internal or external to a machine's operating time and then converting the internal elements therefore they can be done externally (Shingo & Dillon, 1985). In SMED, setup operation is divided into two parts which are internal setup and external setup. Internal setup is an operation setup that can only be done whenever machine is not in operation or shut down for instance attaching or removing the dies. External setup is the setup operation that can be done when the machine is still running. These operations can be performed either before or after the machine is shut down; for example, getting the equipment ready for the setup operation can be done before the machine is shut down. The application of SMED aims to optimize machine utilization, enabling small lot sizes, reducing production times, reducing the time that machine does not operate. Furthermore, it also aims on shortening preparation and machine adjustment times and reducing stocks (Shingo & Dillon, 1985); (Ferradas & Salonitis, 2013); (Gade, et al., 2016).

III. METHODOLOGY

This is an applied research which type is descriptive comparative research. It is descriptive since this research aims to describe about process of reducing lead time and wastes in ride-on cars production line in PT. XYZ by determining which activities are classified into value added and which are classified into non-value added ones. This research also aims to see the impact of manufacturing lead time and wastes after implementing Value Stream Mapping and then comparing the before and after implementation. Furthermore, this research uses a positivism paradigm in quantitative approach since it contains of quantitative data using analysis and numerical measurement.

Data is obtained both primarily and secondarily. Primary data is gained from direct observation in PT. XYZ and secondary data is internal documentation of PT. XYZ specifically in manufacturing department. Flow process chart is used to determine which activities are included into value added and which are included into non-value added ones. There is four symbols used in the table, circle shape for operation throughout the production process, small arrow shape indicates for transporting products to stations, capital D indicates a delay, rectangle shape indicates the storage activity, and a rectangle shape indicates inspection activity throughout the production process of ride-on cars production process.

3.1 TIME STUDY

Time study is necessary for this research for a few departments to obtain standard time. There are a few procedures used to conduct time study. First is to select which task to be timed and standardize method of working, selecting operator for study, then record the details, determine number of cycles to be measured based on Table 3.1.

Recommended Number of Observation Cycles

Cycle time in minutes	**Recommended number of cycles**
0.25	100
0.5	60
0.75	40
1.00	30
2.00	20
2.00-5.00	15
5.00-10.00	10
10.00-20.00	8

Source: Niebel and Freivalds (1998), p. 423.

Then determine standard rating, calculate normal time as shown below:

$$Normal\ Time = Observation\ Time \times Performance\ Rating$$

The next step is to determine allowance for operators, and finally standard time is obtained from the formula below:

$$Standard\ Time = Normal\ Time\ \times (1 + Allowance)$$

3.2 VALUE STREAM MAPPING METHODOLOGY

To create current value stream map these following steps are followed-

Step I: Identify product family.

Step II: Material flow of product starts when supplier brings plastic pellets (raw material) to plant, then placed inside the storage before then processed to raw material processing department. After processing plastic pellets into ready-to-use ones then they will be brought to parts department to be pressed and shaped into body, wheels, antlers, and chair and pusher. Next, finished parts will be brought to assembly and packaging department to be turned into finished goods. Essentials needed to make complete current state map is takt time, cycle time (C/T) obtained from time study's standard time, changeover time (C/O), number of operators, uptime in percentage, batch size and inventory levels which are obtained from direct observation and data from plant.

Step III: Identify wastes in the ride-on cars' current value stream map as well as starting to fix areas that needed to be improved such as defect rate, wastes of motion, over-processing, transportation, and waiting using improvement methods in order to attain a lean manufacturing. Furthermore, implementation is done to know how much of those wastes can be removed.

Step IV: Draw propose value stream mapping using the current takt time and cycle time with reduced and improved manufacturing lead time, whereas this design will show ride-on cars' production system after wastes and inefficiency.

3.3 PAIRED T-TEST

A paired t-test is used to compare two populations in different situation of observation whereas one sample can be paired with observations in the other sample (Shier, 2004). In two-tailed test, there will be comparison between significant rate from result of t-test and P value= 5%. If significant rate of t-test< P value then there is a difference between two situation, and vice versa. Since simple paired t-test is done, therefore Microsoft Excel 2013 is used as program.

IV. ANALYSIS

There are three departments in the production line, raw material processing, parts, and assembly and packaging. All activities in each station is analyzed using flow process chart.

Location: PT. XYZ									
Activity: Ride-on cars production process									
Date: 8/2/18									
Operator: K Analyst: N									
Method: Present									
Type: Material									
Event Type	Event Description	Symbol					Time (sec)	Distance (m)	Activity Type
		○	⇨	D	□	▽			
Plastic Pellets (Raw Material)	To pellet machine (710 kg)		✓				306	57.2	Non-value added
	Melt plastic pellets to separate stones and plastic	✓					25,200		Value added
	To oven		✓				29.7	3.2	Non-value added
	Dry plastic pellets	✓					25,560		Value added
	To coloring machine		✓				63	7	Non-value added
	Color plastic pellets	✓					2,250		Value added
	To raw material storage		✓				389	42.2	Non-value added
Wheels (Parts)	Transfer plastic pellet from storage		✓				410.2	87.2	Non-value added
	Mold 4 wheels as a pair	✓					95.68		Value added
	Inspect the wheels as waiting for the next mold to produce part				✓		0		Value added
	To assembly and packaging department					✓	79.8	15	Non-value added
Chairs and Pusher (Parts)	Transfer plastic pellet from storage						410.2	87.2	Non-value added
	Mold chair	✓					145.8		Value added
	Inspect chair and pusher as waiting for the next mold to produce part				✓		0		Non-value added

Event Type	Event Description	Symbol					Time (sec)	Distance (m)	Activity Type
		○	⇨	D	□	▽			
Antlers (Parts)	Transfer plastic pellet from storage						410.2	87.2	Non-value added
	Mold 2 antlers as a pair	✓					71.53		Value added
	Inspect antlers as waiting for the next mold to produce part				✓		0		Value added
	To assembly and packaging department					✓	79.8	15	Non-value added
Body (Parts)	Transfer plastic pellet from storage						410.2	87.2	Non-value added
	Mold	✓					167.4		Value added
	Inspect body as waiting for the next mold to produce part				✓		0		Value added
	To assembly and packaging department		✓				79.8	15	Non-value added
A&P Department	Stick stickers	✓					513.9		Value added
	Assemble, inspect and pack the final good	✓					576.8		Value added
Total		9	6	0	4	2	2310	204.4	

4.1 TIME STUDY

Below is the summary of time study approach:

Station	Body	Antlers	Chair and Pusher	Wheels	Sticker	Assembly and Packaging
Average (second)	137.68	58.58	117.28	86.02	556.36	558.45
Performance Rating	1.11	1.1	1.13	1.03	1.02	0.92
Allowance (%)	10	11	10	9	4	0
Numberof Observation	60	60	59	60	59	59
NormalTime (second)	152.14	64.44	132.21	88.59	513.77	576.1
StandardTime (second)	167.35	71.53	145.78	95.68	534.32	576.1

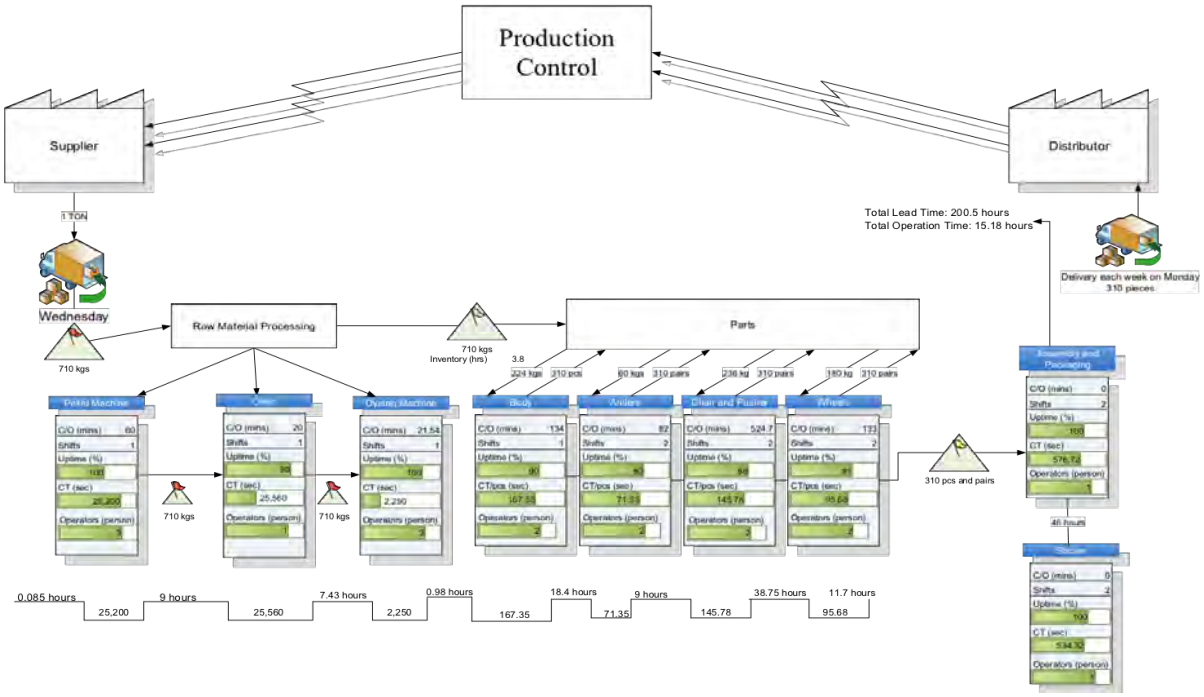
4.2 CURRENT VALUE STREAM MAP

Takt Time Calculation:

$$\text{Takt Time Piece Batch} = \frac{201{,}600 \text{ seconds}}{310 \text{ pieces}} = 650.3 \text{seconds/piece}$$

$$\text{Takt Time Kilogram Batch} = \frac{201{,}600 \text{ seconds}}{1 \text{ batch}} = 201{,}600 \text{ seconds/batch}$$

Current VSM is designed using Microsoft Visio 2013 software. It shows that supplier comes once a week on Wednesday bringing 1000 kilograms of plastic pellets, which is only used 710 kilograms per batch. Furthermore, 310 pieces of finished goods are shipped every week on Monday. As counted in data processing, the result of takt time piece is 650.3 seconds per piece whereas the result of takt time kilogram is 206,100 second/710 kilograms. Therefore, all stations in raw material processing have lower cycle time than the kilogram takt time. Also, all stations in parts and assembly and packaging stations have lower cycle time than the piece takt time. The total manufacturing lead time occurred in the current value stream mapping is 200.5 hours where the total operation time is 15.18 hours.



There are four wastes occurred based from current value stream mapping:

1. Defect rate in parts department caused by too moist raw material due to oven over capacity

Station	Defect Rate (%)
Body	10
Antlers	20
Chair and Pusher	12
Wheels	9

2. Transportation in raw material processing and parts department

Colored plastic pellets are not directly distributed to molding machine; instead, they are being stored back in raw material storage. This cause unnecessary motion since the distance from dyeing machine to raw material storage is 42.2 meters that take 3.1 minutes of time. Furthermore, the distance from dyeing machine to molding machines are shorter which is 15 meters away than if the operator moves plastic pellets from raw material storage.. However, since oven and dyeing machine are placed in one building, therefore this non-value adding activity cannot be eliminated nor reduced anymore.

3. Waiting in antlers station

Due to the machine breakdown, operators cannot work and wait for the mechanist to fix the machine breakdown problem. Therefore, this causes waste in waiting.

4. Motion in chair and pusher station

There is bottleneck detected in chair and pusher where they have the biggest changeover time. This is caused by keep changing the mold of chair and pusher every time operator finishes to produce either chair or pusher. The total overtime labor hours spent for keep changing the mold for fifteen days are 47.15 hours.

5. Motion in assembly and packaging department

Although there is no defect detected in this sticker, however the motion of sticking the sticker to parts are really slow because instead of using machine, this department uses worker. Below are the calculation of number of worker required for sticker department.

$$Number\ of\ worker\ required = \frac{Cycle\ Time}{Station\ Takt\ Time}$$

Therefore, number of work required for sticker and parts department is 2 workers.

$$Number\ of\ worker\ required = \frac{534.32\ seconds}{531.2\ seconds} = 1.1 = 2\ workers$$

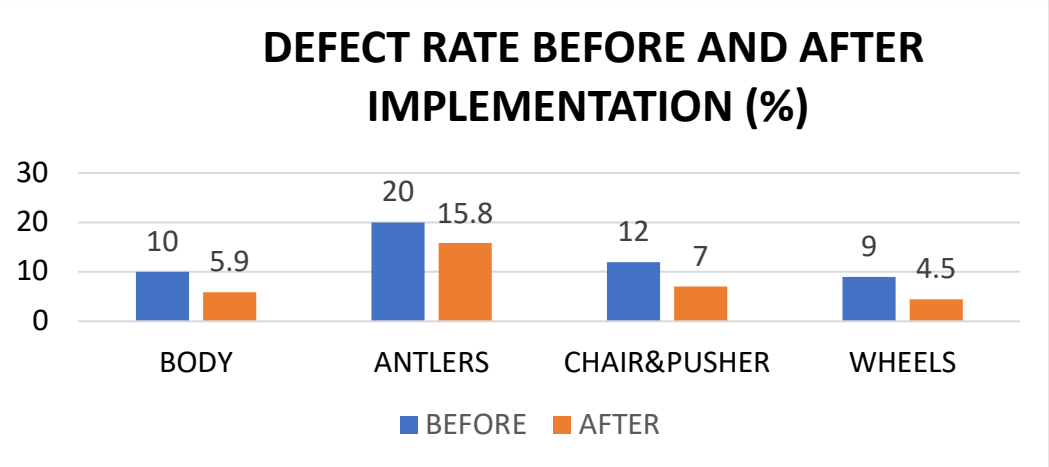
V. FINDINGS AND DISCUSSION

There are some proposed improvements to reduce the amount of wastes in ride-on cars production line as stated below:

1. Defect: Plastic pellets moist tester since according to ECSLAB (2008), a moisture check of the pellets prior to drying helps the injection molding is important in order to optimize drying time, thus achieving significant energy cost savings. Other proposal includes reducing oven capacity and oven maintenance.
2. Transportation: Temporary storage placed in dyeing machine area to shorten the distance.
3. Waiting: Machine maintenance for antlers part machine.
4. Motion for chair and pusher: Single Minute Exchange of Dies (SMED) implementation in order to reduce internal setup time. Also inside SMED implementation, buying pneumatic gun is necessary to reduce the time for removing and applying bolts.
5. Motion for assembly and packaging department: Additional worker.

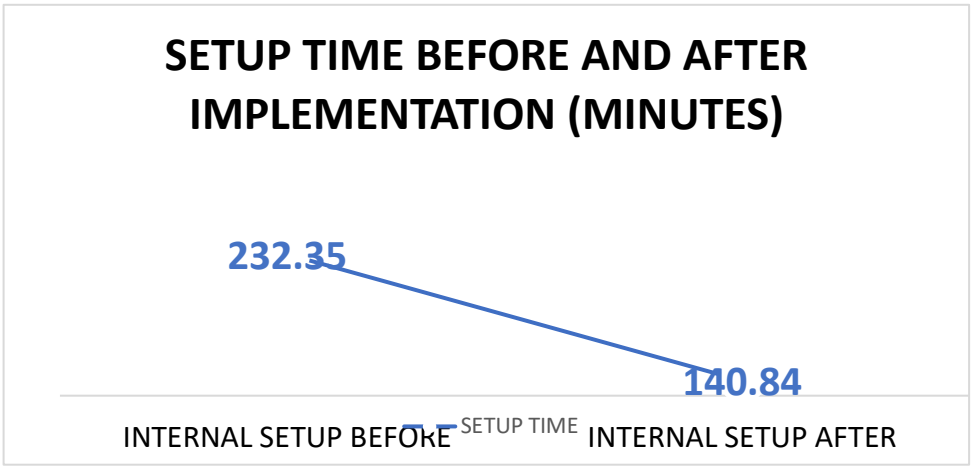
However, not all proposals can be implemented due to company policy, and for those which are implemented:

1. Defect rate is reduced when oven capacity is reduced from 200 kilograms to 180 kilograms

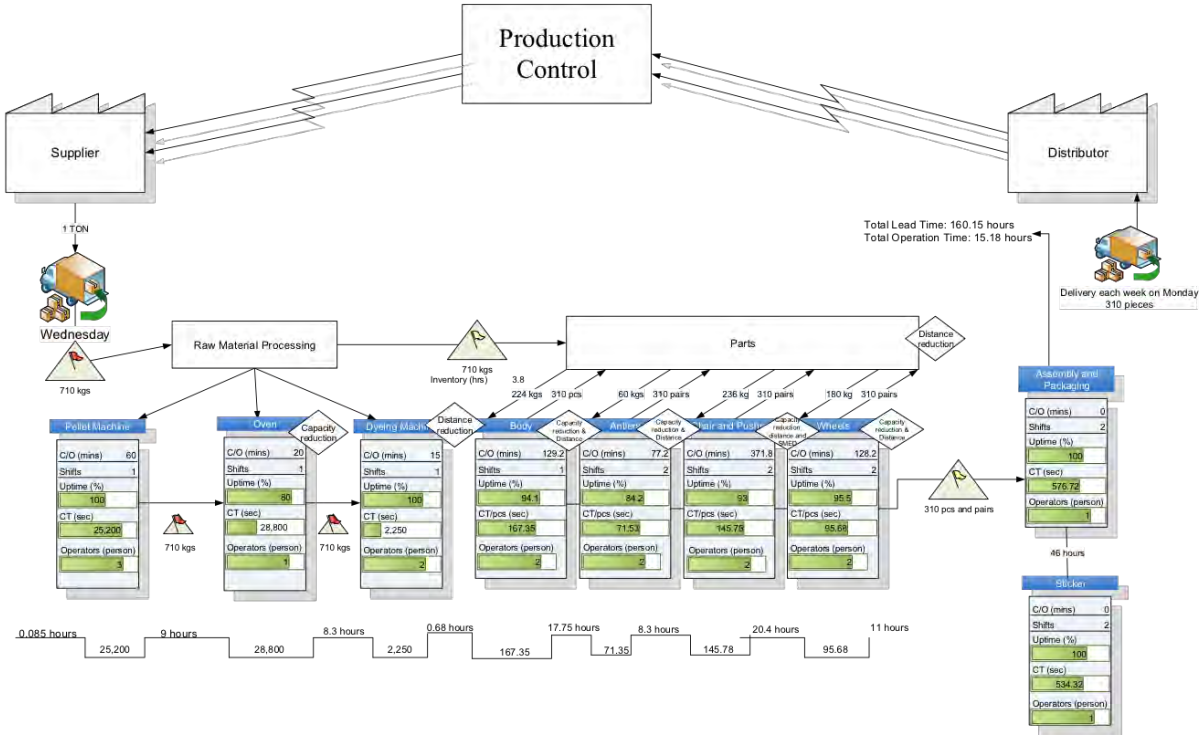


2. Waste of transportation is reduced due to replacement for temporary storage from raw material storage to dyeing machine area

3. SMED implementation to reduce waste of motion in chair and pusher station



All of the implementations make impact on Future Value Stream Mapping as stated below and the paired t-test shows significancy since P Value is 0.046 in which is lower than required, 0.05. Thus the implementation is scientifically approved.



VI. CONCLUSION , IMPLICATIONS AND RECOMMENDATIONS

Conclusion

This research concludes that by implementing Value Stream Mapping, there is reduction in manufacturing lead time and wastes. Out of eight proposed improvements, there are three of them can be implemented. Although it seems like more improvement were denied, however two implementations have big effect on whole production process, while one implementation which uses SMED method succeeded to reduce 20.5% of former setup time. First, there is reduction in waste of defect, which is reduction to 5.9% in body part, 15.8% in antlers part, 13% in chair and pusher part, and 4.5% in wheels part. Furthermore, waste of transportation is also reduced by 42.2 meters and impacted to raw material processing department and parts department. By applying SMED in chair and pusher setup molding activity, internal activity is reduced to 140.84 minutes and some activities are changed to external setup and parallel setup, therefore waste of motion is reduced. To conclude, overall manufacturing lead time for ride-on cars production line is reduced from 200.5 hours to 160.15 hours or as much as 20.5%. This reduction of manufacturing lead time is significant by using paired t-test in Microsoft Excel 2013. However, there are several proposed improvements cannot be implemented due to the price of tools and short period of time given to implementation. To conclude, application of Value Stream Mapping to PT. XYZ's ride-on cars production line is efficient to identify as well as reducing most of wastes that resulted in manufacturing lead time reduction.

Practical Implication

Value Stream Mapping helped PT. XYZ's ride-on cars production line to have better and more detailed view of production flow therefore wastes can be easily identified. Flow process chart also helped company to categorize which activity is value added and which is not value added activity. By reducing oven capacity to 180 kilograms, wastes of defect in raw material processing and parts department were successfully reduced. Furthermore, providing space for colored plastic pellets in dyeing machine reduced waste of transportation in raw material processing and parts department. Finally, application of Single Minute Exchange of Dies (SMED) successfully reduced setup time in chair and pusher station therefore impacted in reduction in motion waste. By doing implementation in PT. XYZ based on proposal improvement, Future Value Stream Mapping showed reduction in overall manufacturing lead time.

Recommendation

Future study is needed in order to recognize the rest of wastes such as over processing, over production and inventory. Plastic pellet moisture meter tester is not only beneficial to reduce the defect of raw material but also can impact to whole part production process to reduce defect rate. Therefore, for the next research, this tool may be used to eliminate the waste of defect considering the high cost. By having longer time for research, maintenance can probably be done therefore resulted in waste of waiting elimination. Furthermore, waste of motion in Sticker Station can also be reduced if there is additional in operator.

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