

Lean Manufacturing Approach using SMED Method and Value Stream Mapping on The Spring Beds Production Floor

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Abstract

P.T. Alpha Jaya Manunggal Mandiri is a manufacturing company engaged in the furniture sector. In the spring bed production line, the time required to produce one spring bed requires a long machine set-up time and has many non-value-added operations. The first step is to minimize the spring bed production time and the distance of spring bed production by doing a waste analysis on the spring bed production process to identify the non-value activity and then remove that process. After that, create a new alternative layout with the S.L.P. method. The new alternative layout was created using process activity mapping to compare spring bed production time and distance from the old layout and the new alternative layout. Then, the set-up time on spring bed production is reduced by implementing a single SMED method. Then the last step is creating current value stream mapping and future value stream mapping. Then comparing the efficiency of current value stream mapping and future value stream mapping. From implementing SMED, removing the non-value-added activity, and implementing the new layout of spring bed production. With this implementation, the set-up time and the spring bed production process were reduced, reducing the set-up time on the spring bed production process and increasing the efficiency of value stream mapping.

Keywords

Value Stream Mapping, SMED, Process Activity Mapping, Waste Analysis, Layout

1. Introduction

P.T. Alpha Jaya Manunggal Mandiri is a company engaged in manufacturing established in 1998 located in Tangerang and engaged in the furniture industry. The company sells products in the form of spring beds and accessories such as bed frames, cots, mattress backs, and various other accessories. P.T. Alpha Jaya Manunggal Mandiri has an office on Jl. Arjuna Utara 10, West Jakarta and factory at Jl. Raya Kuta Bumi Km 6, Tangerang with an area of 5250 m². P.T. Alpha Jaya Manunggal Mandiri is a manufacturing company engaged in the furniture sector to produce cots, bedframes, spring beds, pillows, etc. The production process on each production line has a different production time. Making one spring bed requires a long machine set-up time and has many non-value-added operations in the spring bed production line. This condition causes waste in the spring beds production process, which is carried out in the form of waste of motion, waste of waiting, waste of transportation, etc. Based on the results of the research conducted at the spring beds production line, the following are the objectives in minimizing the set-up time and waste at the spring beds production line:

- a) Removing non-value-added operation on spring beds production process to minimize lead time and cycle time.
- b) Implementing SMED method to minimize the set-up time in the spring beds production process.
- c) Creating future value stream mapping on spring beds production line at P.T. Alpha Jaya Manunggal Mandiri.

2. Literature Review

2.1 Lean Manufacturing

Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Waste is defined as anything customers do not add value to and are unwilling to pay for (Salim et al., 2021).

2.2 Waste

In lean manufacturing, "waste" is defined as anything that doesn't add value to a product. "Value" in manufacturing is anything that a customer would be willing to pay. So, waste is any cost incurred in a process that does not benefit the customer (Chandra et al., 2021).

2.3 Time Study

A manufacturing time study is a structured process of directly observing and measuring human work using a timing device to establish the time required to complete the work by a qualified worker when working at a defined level of performance (Heap, 2015).

2.4 Set-up Time

Setting up a machine to change from one product to the next is the most significant part of the process for many manufacturing processes. Because it is a hassle, we try to do it as infrequently as possible, so we don't get good at it, and it takes a long time, and we need to run large batches to justify our long set-up times. Implementing a Lean Enterprise turns this theory on its head – we want to reduce inventory and make smaller batches, so we need to set-up more often and reduce the time it takes so our costs don't blow out. (George, 2012).

2.5 Lead Time

Manufacturing lead time refers to the duration between the start of processing an order and the time the production process is over. It is the time between processing the raw materials and the finished product. In some instances, it is always referred to as production lead time (Senapati, 2012).

2.6 Westinghouse Method

There is a scale of crisp numerical values for each factor in the usual Westinghouse method. In this study, a fuzzy rule-based approach is used to determine the performance values of the workers depending on the vague decision-making structure (Cevikcan, 2016). The Westinghouse rating method was created and published in 1927. The four components of this approach are skill, effort, circumstances, and consistency. There are six categories in the Westinghouse method: bad, fair, medium, good, excellent, and superskill. Additionally, each class has two additional degrees higher or lower (Cevikcan et al., 2012).

2.7 Allowance

Allowances in time study can be defined as the extra time figures which are to be added to the basic time of an operation to account for personnel desires, delays, fatigue of operators, any particular situation and the policies of the firm or organization. The standard time of a job is obtained by adding various allowances to the basic or normal time of the job (Souraj et al., 2010).

2.8 SMED (Single-Minute Exchange of Dies)

SMED is an acronym for the lean production method – SMED. Developed by Shigeo Shingo, a Japanese Industrial Engineer, the methodology provides an efficient and timely transfer from one product to the next in a manufacturing process (Tampubolon et al., 2021). Equipment setup times can be shortened by using the theory and methods known as SMED. The goal of SMED is to complete setup times in fewer than ten minutes, or a single digit in terms of minutes. Manufacturing big quantities allowed for the lowest feasible proportion of idle time per unit produced, which was the best strategy to reduce the cost of idle machines during setup operations prior to the introduction of the SMED technique. The ideal quantity of each manufacturing lot was attained, when the costs of inventory were equal to the expenses of idle equipment during the changeover of tools (Min and Pheng., 2007).

2.9 Value Stream Mapping

Value stream mapping is a lean management tool that helps visualize the steps needed from product creation to delivering it to the end customer. As with other business process mapping methods, it helps with introspection (understanding your business better) and analysis and process improvement (Hines et al., 1997). The mapping (VSM) process involves mapping the information and material flows necessary to coordinate the tasks carried out by manufacturers, suppliers, and distributors in order to deliver products to customers. A current state map was initially created, from which the cause of waste was found and the opportunity for applying various lean techniques was discovered (Sundar et al., 2014).

2.10 Process Activity Mapping

Process mapping is the graphical representation with illustrative descriptions of how things get done. It helps the participants visualise the process's details closely and guides decision making. One can identify the major areas of strengths and weaknesses in the existing process, such as individual steps' contribution to the process. Further, it helps to reduce the cycle times and defects in the process and enhances its productivity (Amrina, 2020).

2.11 Layout Planning

Layout planning is the process of making decisions about how to physically organize all of the resources that are accessible in a production system and take up space inside a facility. This kind of layout decision is made while developing a new facility or making any adjustments to the resources, such as moving a machine or hiring a new employee. Layout planning may also be done when a facility is expanded or when space is reduced. Layout planning is one of the most important aspects of Lean manufacturing. In some cases, it would be one of the solutions introduced in the Improve phase of DMAIC methodologies in lean six sigma projects (Gozali et al., 2020).

3. Methods

The methods of minimizing the waste and set-up time at the spring beds production line are formed into a flowchart. The methodology flowchart for reducing the waste and set-up time at the spring beds production line can be seen in Figure 1.

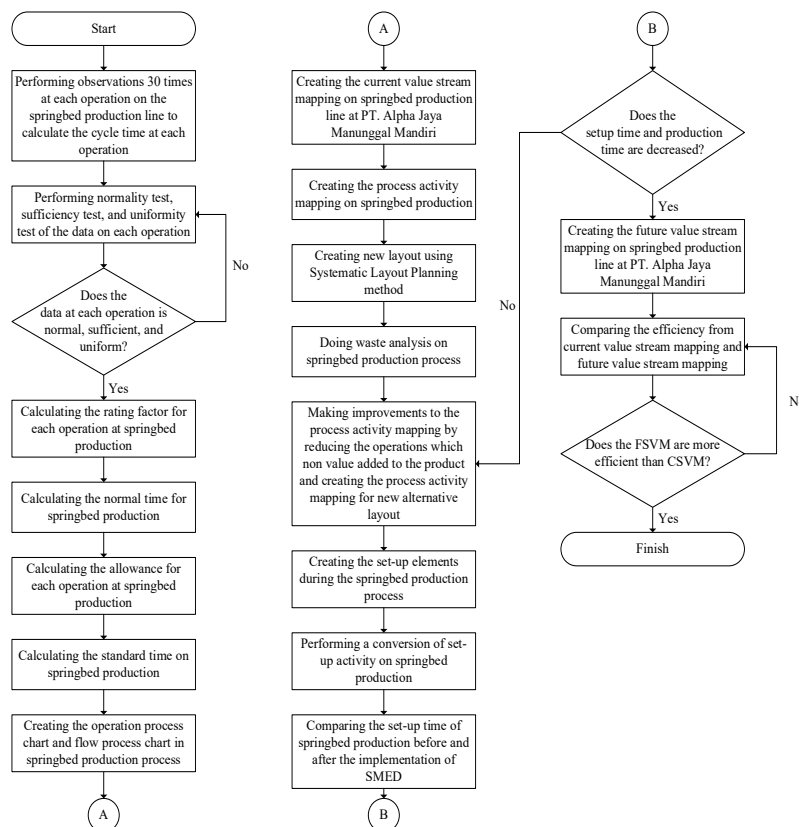


Figure 1. Flowchart Minimizing Waste and Set-up Time at Spring beds Production Line

4. Data Collection

4.1 Process Activity Mapping

Every activity in the spring beds production process is described and recorded in process activity mapping. Process activity mapping for spring bed products can be seen in Table 1.

Table 1. Process Activity Mapping

Process	Activity Description	Machine/ Tool	Distance (m)	Time (seconds)	Number of Workers	O	I	T	D	S
Springbed Frame Production Station	To the raw material storage	Carlift	2	45	1					
	Searching raw material		1.5	15	1					
	Taking the raw material to the springbed frame production making station		16	225	1					
	Putting the raw material to the spring coiling machine	Hand	1.5	205	1					
	Setup spring coiling machine	Hand	0	240	2					
	Spring coiling process	Spring Coiling Machine	0	600	2					
	Inspection of number and uniformity of spring size	Hand	0	160	2					
	Moving spring to the pocket assembly machine	Hand	2.5	65	1					
	Pocket assembly process	Assembly Pocket Machine	0	500	1					
	Moving the springbed frame to the assembly station	Assembly Pocket Machine	2	70	1					
Springbed Edge Wire Production Station	To the raw material storage	Carlift	2	45	1					
	Searching raw material		1.5	15	1					
	Taking the raw material to the springbed edge wire production making station	Carlift	19	280	1					
	Taking the gauge to measure the length of springbed wire	Hand	3	15	1					
	Springbed wire cutting process	Plier	0	65	1					
	Inspection of the size of the wire formed for the springbed edge wire	Hand	0	25	1					
	Bending the wire into a square shape using pliers	Plier	0	30	1					
	Taking the springbed edge wire	Hand	1	15	1					
Taking the springbed edge wire to the assembly station	2.5		95	1						
Assembly Springbed Station and Foam Sticking Station	Taking the springbed frame and springbed edge wire	Hand	1	30	1					
	Doing the measurement	Gauge	0	15	1					
	Taking the hogring stapler	Hand	0.5	10	1					
	Assembly process on springbed		0	615	1					
	Moving the springbed to the foam sticking station	Walking Pallet	3.5	100	1					
	Taking cotton felt layer and supesoft foam layer	Hand	2	85	4					
	Attaching the cotton felt layer and the supesoft foam layer	Spray gun	0	1200	4					
Moving the springbed to the tape edge and packing station	Hand	2.5	75	4						
Springbed Fabric Production Station	To the raw material storage	Walking Pallet	2	45	1					
	Taking the raw material to the springbed frame production making station	Walking Pallet	1.5	70	1					
	Putting the raw material to the quilting machine	Hand	8	100	2					
	Quilting Process	Quilting Machine	0	720	2					
	Cutting the quilted fabric	Cutter	0	60	1					
	Sewing and embroidery the quilted fabric that has been cut	Sewing Machine and Embroidery Machine	0	120	1					
	Fabric embroidery process	broidery Mac	0	720	1					
Taking the embroidered fabric to the tape edge station	Hand	5.5	125	1						
Tape Edge and Packing Station	Moving the springbed to the tape edge workdesk	Hand	1	45	4					
	Tape edge process	Tape Edge Machine	0	1500	4					
	pection the final result of spring	Gauge	0	625	4					
	Springbed packing station	Hand	0	300	2					
Moving the springbed to the storage of finished product	Walking Pallet	2.5	90	1						
Storage	Storage Springbed Product	Walking Pallet	0	50	1					
Total			84.5	9410		26	3	11	0	1

4.3 Waste Analysis

Waste that occurs on the production floor is based on direct observations in the field. The waste that appears on the production floor is waste of transportation, waste of inventory, waste of motion, waste of waiting, and waste of defects from all 7 wastes. Waste that occurs on the production floor is categorized into 3 categories, namely Value Added (V.A.), Non-Value-Added (N.V.A.), and Necessary Non-Value-Added (NNVA). Waste analysis can be seen in Table 2.

Table 2. Waste Analysis

Process	Activity Description	VANVA/ NNVA	Waste							
			T	I	M	W	O	O	D	
Springbed Frame Production Station	To the raw material storage	NNVA								
	Searching raw material	NVA								
	Taking the raw material to the springbed frame production making station	NNVA								
	Putting the raw material to the spring coiling machine	NNVA								
	Setup spring coiling machine	NNVA								
	Spring coiling process	VA								
	Inspection of number and uniformity of spring size	NNVA								
	Moving spring to the pocket assembly machine	NNVA								
	Pocket assembly process	VA								
	Moving the springbed frame to the assembly station	NNVA								
Springbed Edge Wire Production Station	To the raw material storage	NNVA								
	Searching raw material	NVA								
	Taking the raw material to the springbed edge wire production making station	NNVA								
	Taking the gauge to measure the length of springbed wire	NVA								
	Springbed wire cutting process	VA								
	Inspection of the size of the wire formed for the springbed edge wire	NNVA								
	Bending the wire into a square shape using pliers	VA								
	Taking the springbed edge wire	NVA								
Assembly Springbed Station and Foam Sticking Station	Taking the springbed frame and springbed edge wire	NNVA								
	Doing the measurement	NNVA								
	Taking the hogring stapler	NNVA								
	Assembly process on springbed	VA								
	Moving the springbed to the foam sticking station	NNVA								
	Taking cotton felt layer and supersoft foam layer	NNVA								
	Attaching the cotton felt layer and the supersoft foam layer	VA								
	Moving the springbed to the tape edge and packing station	NNVA								
Springbed Fabric Production Station	To the raw material storage	NNVA								
	Taking the raw material to the springbed frame production making station	NVA								
	Putting the raw material to the quilting machine	NNVA								
	Quilting Process	VA								
	Cutting the quilted fabric	VA								
	Sewing and embroidery the quilted fabric that has been cut	VA								
Tape Edge and Packing Station	Fabric embroidery process	VA								
	Taking the embroided fabric to the tape edge station	NNVA								
	Moving the springbed to the tape edge workdesk	NNVA								
	Tape edge process	VA								
	Inspection the final result of springbed	NNVA								
Storage	Springbed packing station	VA								
	Moving the springbed to the storage of finished product	NNVA								
Total	Springbed storage	NVA								
			13	1	22	5	0	0	0	

4.4 Initial Layout

The initial layout of the P.T. Alpha Jaya Manunggal Mandiri factory can be seen in Figure 2.

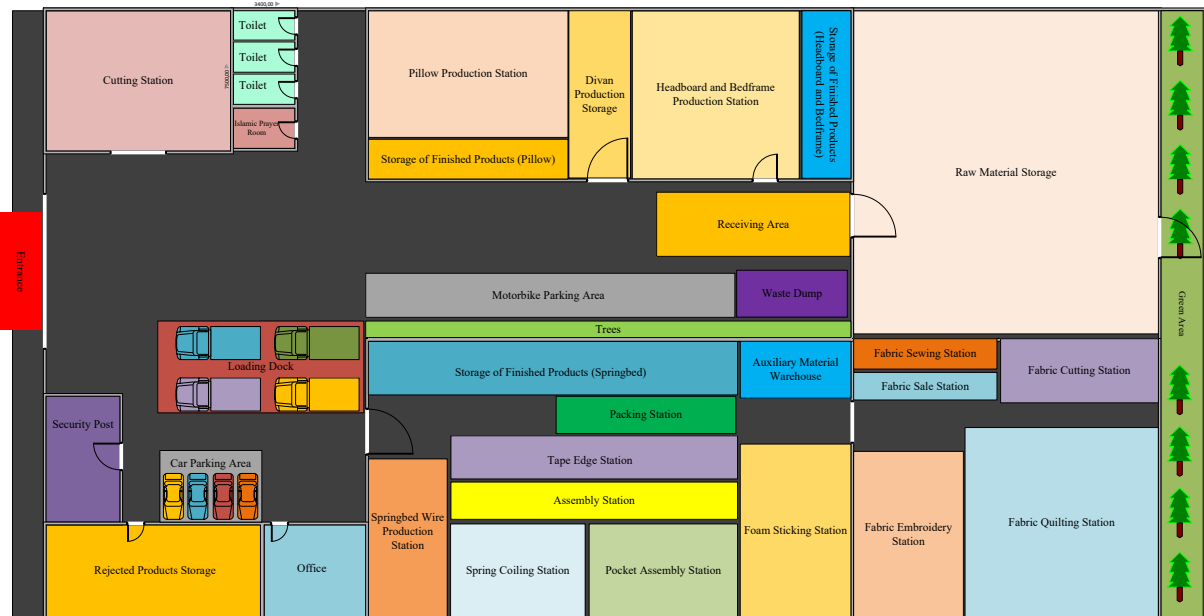


Figure 2. Initial Layout PT. Alpha Jaya Manunggal Mandiri Factory

4.5 Alternative Layout

From the initial layout of the P.T. Alpha Jaya Manunggal Mandiri factory, some waste occurs, such as waste of movement because the distance between the production station is too far, etc. The new alternative layout was created using the S.L.P. Method to reduce the waste at all factory layouts. So the new alternative layout can increase the spring bed's production effectivity by decreasing the distance and production time. The new alternative layout can be seen in Figure 3.



Figure 3. New Alternative Layout

5. Results and Discussion

5.1 Numerical Results

Based on the observation performed 30 times at each operation on the spring beds production line, the cycle time can be found by using the average cycle time value from 30 times measurement. After the cycle time is obtained, the rating factor is needed to find the normal time. The rating factor can be found using the Westinghouse method. After getting the rating factor, the normal time for each process can be found by multiplying cycle time and rating factor. Then, the standard time can be found using the allowance from the normal time. The cycle time, rating factor, normal time, allowance, and standard time can be seen in Table 3.

Table 3. The Cycle Time, Rating Factor, Normal Time, Allowance, and Standard Time

Number	Operation	Cycle Time	Rating Factor	Normal Time	Allowance (%)	Standard Time
1	O-1	2.7	1.11	2.99	14	3.41
2	O-2	3.85	1.09	4.2	20	4.78
3	O-3	9.43	1.09	10.28	20	11.72
4	I-1	1.06	1.09	1.16	18	1.32
5	O-4	6.77	1.10	7.45	21	8.49
6	O-5 & I-2	1.34	1.09	1.46	18	1.66
7	O-6	1.66	1.09	1.81	18	2.06
8	I-3	1.3	1.09	1.42	18	1.62
9	O-7	1	1.11	1.11	14	1.27
10	O-8	3.47	1.09	3.78	20	4.31
11	I-4	1.35	1.09	1.47	18	1.68
12	O-9	8.21	1.10	9.03	21	10.29
13	O-10	7.13	1.07	7.63	22	8.7
14	O-11	8.92	1.07	9.54	22	10.88
15	O-12 & I-5	9.35	1.09	10.19	18	11.62
16	O-13	9.48	1.09	10.33	20	11.78
17	O-14	1.34	1.09	1.46	18	1.66
18	O-15	1.54	1.09	1.68	18	1.92
19	I-6	0.753	1.09	0.82	18	0.94
20	O-16	9.59	1.09	10.45	18	11.91
21	I-7	0.657	1.09	0.72	18	0.82
22	O-17	27.4	1.09	29.87	20	34.05
23	I-8	1.76	1.09	1.92	18	2.19
24	O-18	3.49	1.11	3.87	18	4.41

The total cycle time for the spring bed production process is 123.55 minutes, the total normal time for spring bed production is 133.64 minutes, and the total standard time for spring bed production is 153.49 minutes.

5.2 Set-up Time Comparison Before SMED and After SMED

After implementing single minutes exchange of dies, there is a decrease in set-up time in the spring beds production process. The comparison of the set-up time of spring bed production before implementation of SMED and after the performance of SMED can be seen in Table 4.

Table 4. Comparison of Set-up Time Before SMED and After SMED

Comparison	Before SMED (second)	After SMED (second)
Internal Activity	710	434
External Activity	0	165
Eliminated Activity	0	111

Before doing production, there is a set-up process in the spring beds production process. The SMED method is implemented to reduce set-up time by moving various activities that can be done without turning on the machine to external movements and eliminating activities that can be done before the production process. Spring beds set-up activity conversion can be seen in Table 5.

Before implementing SMED, all set-up activities are classified as internal activities, which causes the set-up time in the production process to take quite a bit of time. After the implementation of SMED, there is some activity converted into an external activity such as taking the raw material from the raw material storage, etc. By converting some internal activities to external activities, the set-up time for the spring beds production process was reduced by 165 seconds, decreasing the set-up time by 23.23%. Then, from the implementation of SMED, some set-up activity has been eliminated because the set-up activity can be done before the production process starts, such as taking the gauge from the auxiliary materials warehouse, etc. The set-up time from eliminating some set-up activity was reduced by 111 seconds, which decreased by 15.63%. From the implementation of SMED, the total set-up time was reduced from 710 seconds to 434 seconds which reduced the set-up time by 38.86%.

Table 5. Spring beds Set-up Activities Conversion

Process	Activity	Time (seconds)	Internal	External
Springbed Frame Production Station	Taking the raw material from the raw material storage	15		✓
	Connecting the spring coiling machine to the electric socket	12	✓	
	Turning on the spring coiling machine	13	✓	
	Putting the raw material to the spring coiling machine	10		✓
	Setting the size and the amount of spring	17	✓	
	Taking the spring from the spring coiling machine	13		✓
	Moving the spring to the pocket assembly machine	8	✓	
	Connecting the pocket assembly machine to the electric socket	10	✓	
	Turning on the pocket assembly machine	11	✓	
	Tidying the spring in the assembly pocket machine	16		✓
	Setting the size of springbed frame on the pocket assembly machine	12	✓	
	Moving the springbed frame to the assembly station	25	✓	
Springbed Edge Wire Production Station	Taking the raw material from the raw material storage	15		✓
	Putting the raw material to the springbed edge wire production making station	8		✓
	Taking the gauge from the auxiliary materials warehouse	14	X	X
	Taking plier from the auxiliary materials warehouse	14	X	X
	Moving the springbed edge wire to the assembly station	25	✓	
Assembly Springbed Station and Foam Sticking Station	Taking the springbed frame	20	✓	
	Taking the springbed edge wire	12	✓	
	Taking the hogging stapler from the auxiliary materials warehouse	11	X	X
	Taking the hogging from the auxiliary materials warehouse	11	X	X
	Moving the springbed to the foam sticking station	25	✓	
	Taking the cyclohexane glue from the auxiliary materials warehouse	10		✓
	Connecting the glue tank to the adhesive spray gun machine	23	✓	
	Setting the knob for adjusting the amount of liquid out of the nozzle	14		✓
	Setting the wind pressure inside the adhesive spray gun	11		✓
	Setting the knob for adjusting the area of glue spray	16		✓
	Taking the gauge from the auxiliary materials warehouse	10	X	X
	Taking the cutting machine from the auxiliary materials warehouse	10	X	X
	Connecting the cutting machine to the electric socket	8	✓	
	Moving the springbed to the tape edge and packing station	20	✓	
	Springbed Fabric Production Station	Taking the raw material from the raw material storage	20	
Putting the raw material to the quilting machine		17		✓
Connecting the quilting machine to the electric socket		12	✓	
Setting the fabric pattern to be made by quilting machine		23	✓	
Moving the quilting fabric to the fabric cutting station		8	✓	
Taking the scissors from the auxiliary materials warehouse		14	X	X
Moving the fabric to the sewing and sale station		10	✓	
Connecting the sewing machine and the sale machine to the electric socket		7	✓	
Moving the fabric to the embroidery machine		9	✓	
Taking the thread from the auxiliary materials warehouse		10	X	X
Setting the fabric embroidery pattern on the embroidery machine		18	✓	
Moving the fabric to the tape edge and packing station		20	✓	
Tape Edge and Packing Station	Taking the springbed	19	✓	
	Taking the embroidered fabric	9	✓	
	Connecting tape edge machine to the electric socket	10	✓	
	Taking the thread from the auxiliary materials warehouse	10	X	X
	Adjusting the height of tape edge machine	7	✓	
	Moving the springbed to the packing station	25	✓	
	Taking the plastic from the auxiliary materials warehouse	7	X	X
Moving the springbed to the finished product storage	16	✓		
Total Time (Second)		710	434	165

5.3 New Process Activity Mapping

The new process activity mapping was made from the new alternative layout. The distance and production time have been reduced by using the new layout. Some non-value-added activity has been eliminated, so the processing time of spring bed production becomes more efficient. The new process activity mapping for alternative layout 1 with eliminating the non-value-added activity can be seen in Table 6. The process activity mapping for alternative layout 2 with eliminating the non-value-added activities can be seen in Table 7.

Table 6. New Process Activity Mapping for Alternative Layout 1

Process	Activity Description	Machine/Tool	Distance (m)	Time (seconds)	Number of Workers	O	I	T	D	S	
Springbed Frame Production Station	To the raw material storage	Carlift	2	45	1						
	Searching raw material		1.5	15	1						
	Taking the raw material to the springbed frame production making station		16	225	1						
	Putting the raw material to the spring coiling machine		1.5	205	1						
	Setup spring coiling machine	Hand	0	240	2						
	Spring coiling process	Spring Coiling Machine	0	600	2						
	Inspection of number and uniformity of spring size	Hand	0	160	2						
	Moving spring to the pocket assembly machine	Hand	2.5	65	1						
	Pocket assembly process	Assembly Pocket Machine	0	500	1						
	Moving the springbed frame to the assembly station	Assembly Pocket Machine	4	70	1						
Springbed Edge Wire Production Station	To the raw material storage	Carlift	2	45	1						
	Searching raw material		1.5	15	1						
	Taking the raw material to the springbed edge wire production making station		19	280	1						
	Taking the gauge to measure the length of springbed wire	Hand	3	15	1						
	Springbed wire cutting process	Plier	0	65	1						
	Inspection of the size of the wire formed for the springbed edge wire	Hand	0	25	1						
	Bending the wire into a square shape using pliers	Plier	0	30	1						
	Taking the springbed edge wire	Hand	1	15	1						
	Taking the springbed edge wire to the assembly station		2.5	95	1						
	Assembly Springbed Station and Foam Sticking Station	Taking the springbed frame and springbed edge wire	Hand	1	30	1					
Doing the measurement		Gauge	0	15	1						
Taking the hogging stapler			0.5	10	1						
Assembly process on springbed		Hand	0	615	1						
Moving the springbed to the foam sticking station		Walking Pallet	3.5	100	1						
Taking cotton felt layer and supesoft foam layer		Hand	2	85	4						
Attaching the cotton felt layer and the supesoft foam layer		Spray gun	0	1200	4						
Moving the springbed to the tape edge and packing station		Hand	2.5	75	4						
Springbed Fabric Production Station		To the raw material storage	Walking Pallet	2	45	1					
		Taking the raw material to the springbed fabric production station	Walking Pallet	8	100	1					
	Putting the raw material to the quilting machine	Hand	0	70	2						
	Quilting Process	Quilting Machine	0	720	2						
	Cutting the quilted fabric	Cutter	0	60	1						
	Sewing and embroidery the quilted fabric that has been cut	Sewing Machine and Embroidery Machine	0	120	1						
	Fabric embroidery process	Embroidery Machine	0	720	1						
	Taking the embroidered fabric to the tape edge station	Hand	5.5	125	1						
	Tape Edge and Packing Station	Moving the springbed to the tape edge workdesk	Hand	1	45	4					
		Tape edge process	Tape Edge Machine	0	1500	4					
Inspection the final result of springbed		Gauge	0	625	4						
Springbed packing station		Hand	0	300	2						
Storage	Moving the springbed to the storage of finished product	Walking Pallet	2.5	90	1						
	Storage Springbed Product	Walking Pallet	0	50	1						
Total			85	9410		26	3	11	0	1	

Table 7. New Process Activity Mapping for Alternative Layout 2

Process	Activity Description	Machine/Tool	Distance (m)	Time (seconds)	Number of Workers	O	I	T	D	S	
Springbed Frame Production Station	To the raw material storage	Carlift	2	45	1						
	Taking the raw material to the springbed frame production making station		3	40	1						
	Putting the raw material to the spring coiling machine		1.5	205	1						
	Setup spring coiling machine	Hand	0	240	2						
	Spring coiling process	Spring Coiling Machine	0	600	2						
	Inspection of number and uniformity of spring size	Hand	0	160	2						
	Moving spring to the pocket assembly machine	Hand	2.5	65	1						
	Pocket assembly process	Assembly Pocket Machine	0	500	1						
	Moving the springbed frame to the assembly station	Assembly Pocket Machine	3.5	60	1						
	Springbed Edge Wire Production Station	To the raw material storage	Carlift	2	45	1					
Taking the raw material to the springbed edge wire production making station		6.5		96	1						
Springbed wire cutting process		Plier	0	65	1						
Inspection of the size of the wire formed for the springbed edge wire		Hand	0	25	1						
Bending the wire into a square shape using pliers		Plier	0	30	1						
Taking the springbed edge wire to the assembly station		Hand	2.5	95	1						
Assembly Springbed Station and Foam Sticking Station		Taking the springbed frame and springbed edge wire	Hand	1	30	1					
		Doing the measurement	Gauge	0	15	1					
		Taking the hogging stapler		0.5	10	1					
		Assembly process on springbed	Hand	0	615	1					
	Moving the springbed to the foam sticking station	Walking Pallet	1.5	40	1						
	Taking cotton felt layer and supesoft foam layer	Hand	1.5	60	4						
	Attaching the cotton felt layer and the supesoft foam layer	Spray gun	0	1200	4						
	Moving the springbed to the tape edge and packing station	Hand	1.5	45	4						
	Springbed Fabric Production Station	To the raw material storage	Walking Pallet	2	45	1					
		Putting the raw material to the quilting machine	Hand	3	38	2					
Quilting Process		Quilting Machine	0	720	2						
Cutting the quilted fabric		Cutter	0	60	1						
Sewing and embroidery the quilted fabric that has been cut		Sewing Machine and Embroidery Machine	0	120	1						
Fabric embroidery process		Embroidery Machine	0	720	1						
Taking the embroidered fabric to the tape edge station		Hand	8.5	175	1						
Tape Edge and Packing Station		Moving the springbed to the tape edge workdesk	Hand	0.5	30	4					
		Tape edge process	Tape Edge Machine	0	1500	4					
		Inspection the final result of springbed	Gauge	0	625	4					
	Springbed packing station	Hand	0	300	2						
	Moving the springbed to the storage of finished product	Walking Pallet	1	35	1						
Storage	Storage Springbed Product	Walking Pallet	0	50	1						
Total			44.5	8704		21	3	11	0	1	

The comparison of the new process activity mapping for the old layout, alternative layout 1, and alternative layout 2 can be seen in Table 8.

Table 8. Comparison of Old Layout, Alternative Layout 1, and Alternative Layout 2

Comparison	Old Layout	Alternative Layout 1	Alternative Layout 2
Total Activity	41	36	36
Operation Time	9410 seconds	8704 seconds	8568 seconds
Distance	85 meters	44.5 meters	36.75 meters

After eliminating the non-value-added activity after waste analysis, the total activity of the process activity mapping for the alternative layout 1 and alternative layout 2 decreased from 41 activities to 36 activities which decreased by 12.2%. The total operation time of the old layout was 9410 seconds by implementing waste analysis and creating the new layout. The total operation time was decreased. The total operation time for alternative layout 1 is 8704 seconds and the total operation time for alternative layout 2 is 8568 seconds. The total distance of the old layout was 85 meters by implementing waste analysis and creating a new layout. The total distance was decreased. The total distance for alternative layout 1 is 44.5 meters and the total distance for alternative layout 2 is 36.75 meters. From the process activity mapping, the alternative layout 2 has the least total operation time of 8568 seconds. The reduction of total operation time by 8.95% and had the least distance of 36.75 meters. The new distance reduction of the spring beds production process by 56.77%. So the new alternative layout 2 was chosen to become the new layout for P.T. Alpha Jaya Manunggal Mandiri.

5.4 Value Stream Mapping

Value stream mapping is a lean manufacturing tool that helps us to understand the flow of materials and information in a process. Value stream mapping includes all value-adding and non-value-adding activities required to process a product from raw materials to delivery to customers. The current value stream mapping of the spring bed production process can be seen in Figure 4.

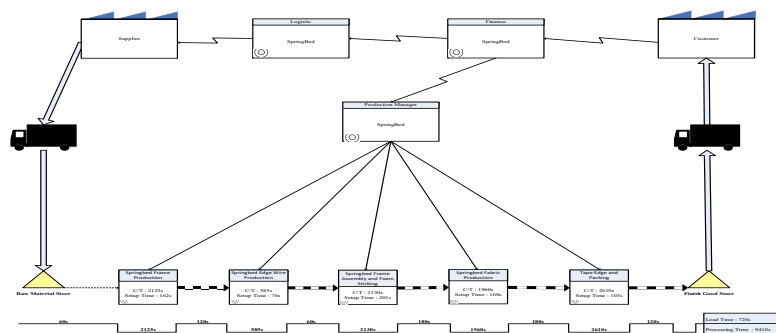


Figure 4. Current Value Stream Mapping

Future value stream mapping is made based on the alternative layout that has been chosen, which is the alternative layout 2. Future value stream mapping contains a series of process orders entering the company, then ordering materials and receiving the raw material warehouse until it reaches the customer. The future value stream mapping can be seen in Figure 5.

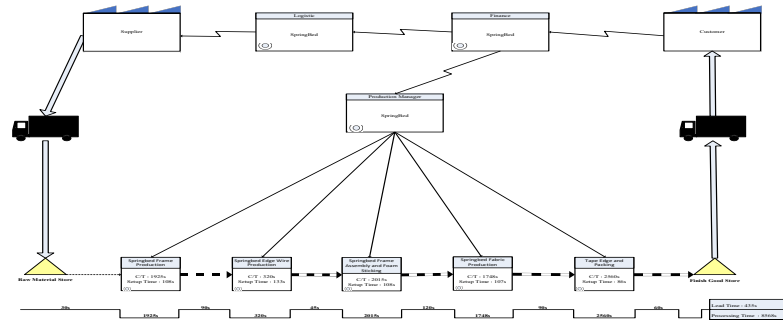


Figure 5. Future Value Stream Mapping

The efficiency between current value stream mapping and future value stream mapping can be seen in Table 9.

Table 9. Value Stream Mapping Efficiency

Operation	Standard Time CSVM	Standard Time FSVM	Reduction Percentage (%)
Spring beds Frame Production	2125 seconds	1925 seconds	9.58
Spring beds Edge Wire Production	585 seconds	320 seconds	45.3
Spring beds Frame Assembly and Foam Sticking	2130 seconds	2015 seconds	5.4
Spring beds Fabric Production	1960 seconds	1748 seconds	10.82
Tape Edge and Packing	2610 seconds	2560 seconds	0.2

The percentage of standard time between current value stream mapping and future value stream mapping on operation spring beds frame production reduced by 9.58%, on spring beds edge wire production reduced by 45.3%, on spring beds frame assembly and foam sticking reduced by 5.4%; on spring beds fabric production reduced by 10.82%; and on tape edge and packing reduced by 0.2%.

5.5 Proposed Improvement

Based on this research, the implementing SMED method on the spring beds set-up process, eliminating non-value-added processes and implementing the new layout could decrease spring beds set-up, lead time, distance, and production time. The comparison between the old layout and the new layout can be seen in Table 10.

Table 10. The Comparison Between New Layout and Old Layout

Comparison	Old Layout	New Layout	Percentage
Set-up Time	710 seconds	434 seconds	- 38.86 %
Lead Time	720 seconds	435 seconds	- 39.58%
Distance	85 meters	36.75 meters	- 56.77%
Production Time	9410 seconds	8568 seconds	- 8.95%

The set-up time from the old layout is 710 seconds and from the new layout is 434 seconds, which decreased set-up time by 38.86%. The lead time from the old layout is 720 seconds and from the new layout is 435 seconds, which decreased lead time by 39.58%. The distance from the old layout is 85 meters and from the new layout is 36.75 meters, which reduced the distance by 56.77%. The production time from the old layout is 9410 seconds and from the new layout is 8568 seconds, which reduced production time by 8.95%.

5.6 Validation

From the 30 data collected, it is necessary to do a normality, uniformity, and adequacy test to determine whether the collected data is normal, uniform, and sufficient. The normality test was done using Software Minitab by using the Anderson-Darling method. If the P-value is greater than 0.05, then the collected data is normal. The uniformity tests were done by finding the U.C.L. and L.C.L. If the data distribution is not beyond the U.C.L. and L.C.L., then the collected data

is uniform. The adequacy test used a confident level of 95% and a significance level of 5%. If N is greater than N', the collected data is sufficient. From the normality test, all operations have a P-value greater than 0.05, so all the operation data collected were normal. All operation data ordered do not exceed U.C.L. and L.C.L. from the uniformity test, so the data collected were uniform. All the collected data is greater than N' from the adequacy test, so the data collected were sufficient.

6. Conclusion

From the waste analysis that has been done, there is 5 non-value-added activity in the spring beds production process. The non-value-added activity then will be eliminated to reduce spring bed production time. Then the new alternative layout was created by using Systematic Layout Planning (S.L.P.) Method. The new alternative layout has been made in 2 forms: alternative layout 1 and layout 2. From the alternative layout, the distance and operation time were decreased. The total activity of the process activity mapping for the alternative layout 1 and alternative layout 2 decreased from 41 activities to 36 activities which decreased by 12.2%. The total operation time of the old layout was 9410 seconds by implementing waste analysis and creating the new layout. The total operation time was reduced. The total operation time for alternative layout 1 is 8704 seconds and the total operation time for alternative layout 2 is 8568 seconds. The total distance of the old layout was 85 meters by implementing waste analysis and creating a new layout. The total distance was decreased. The total distance for alternative layout 1 is 44.5 meters and the total distance for alternative layout 2 is 36.75 meters. From the process activity mapping, the alternative layout 2 has the least total operation time of 8568 seconds, which decreased the total operation time by 8.95% and had the least distance of 36.75 meters, which reduced the distance of the spring beds production process by 56.77%. So alternative layout 2 was chosen to become the new layout for P.T. Alpha Jaya Manunggal Mandiri.

Before implementing SMED, the set-up activity total time was 710 seconds. Then after the implementation of SMED, there is some activity converted into an external activity, such as taking the raw material from the raw material storage, etc. By converting some internal activities to external activities, the set-up time for the spring beds production process was reduced by 165 seconds, decreasing the set-up time by 23.23%. Then, from the implementation of SMED, some set-up activity has been eliminated because the set-up activity can be done before the production process starts, such as taking the gauge from the auxiliary materials warehouse, etc. From the implementation of SMED, the total set-up time turned into 434 seconds which decreased the set-up time by 38.86%. From the value stream mapping, the efficiency between current value stream mapping and future value stream mapping on operation spring beds frame production is 90.58%; on spring beds edge wire production is 54.7%; on spring beds frame assembly and foam sticking is 94.6%; on spring beds fabric production is 89.18%; and on tape edge and packing is 99.8%. Also, the lead time after implementing the new layout decreased from 720 seconds to 435 seconds, which decreased lead time by 39.58%.

References

- Amrina, Uly & Fitrahaj, Muhammad Ushali. *Licensed Under Creative Commons Attribution CC BY An Application of Value Stream Mapping to Reduce Waste in Livestock Vitamin Raw Material Warehouse*. International Journal of Science and Research (IJSR). 9. 4(2020).. 10.21275/SR20329062345.
- Cevikcan, Emre & Kilic, H.S.. *Tempo Rating Approach Using Fuzzy Rule Based System And Westinghouse Method For The Assessment Of Normal Time*. 23. 49-67. (2016).
- Cevikcan, E., Kilic, H. S., & Zaim, S. *Westinghouse method oriented fuzzy rule based tempo rating approach*. In Proc. Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management, Istanbul, Turkey (pp. 1670-1677). (2012).
- Chandra, Sharin & Gozali, Lina.. *Application of Lean Six Sigma in P.E.T. Bottle Production Line at P.T. Peace Industrial Packaging*. (2021)
- Gozali, L., Widodo, L., Nasution, S. R., & Lim, N. *Planning the New Factory Layout of PT Hartekprima Listrindo using Systematic Layout Planning (S.L.P.) Method*. In I.O.P. Conference Series: Materials Science and Engineering (Vol. 847, No. 1, p. 012001). I.O.P. Publishing. (2020, April).
- George, Michael. *Lean Six Sigma*. Dallas: Mc Graw Hill. 2002.
- Heap, John. *Time Study*. 10.1002/9781118785317.weom100099. (2015).
- Hines, P. and Rich, N. *The Seven Value Stream Mapping Tools*. International Journal of Operations & Production Management, 17, 46-64. (1997)
- Manbas, Ahmad & Lilyana, & Widodo, Lamto & Gozali, Lina & Maryadi, A.. *Analyze of mitigation waste in reconditioning process of Iron Drum with Lean Six Sigma (Case study at PT Mulya Adhi Paramita)*. I.O.P. Conference Series: Materials Science and Engineering. 528. 012071. 10.1088/1757-899X/528/1/012071. (2019)

- Meyers, F. E., & Stewart, J. R. *Motion and time study for lean manufacturing*. Upper Saddle River, NJ: Prentice Hall. (2002).
- Min, W., Pheng, L. S. *Modeling just-in-time purchasing in the ready mixed concrete industry*. International Journal of Production Economics, 107, 190-201. (2007).
- Salim, A., Christian, Gozali L, Marie, I. A., Daywin, F. J., Irawan, A. P., & Tanujaya, H. *Lean Manufacturing Approach for Improvements of Work System in Furniture Factories (A Case Study in PT. Salim Selamat Sempurna)*. Ieom Proceeding, 2021.
- Senapati, Ajit. *An Extensive Literature Review On Lead Time Reduction In Inventory Control*. International Journal of Engineering and Advanced Technology. (2012).
- Souraj Salah, Abdur Rahim, Juan A. Carretero. *The Integration of Six Sigma and Lean Management*. International Journal of Lean Six Sigma. (2010).
- Sundar, R., Balaji, A. N., & Kumar, R. S. *A review on lean manufacturing implementation techniques*. Procedia Engineering, 97, 1875-1885. (2014).
- Tampubolon, Salmon & Purba, Humiras. *Lean Six Sigma Implementation, A Systematic Literature Review*. International Journal of Production Management and Engineering. 9. 125-139. 10.4995/ijpme.2021.14561. (2021).

Biographies

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