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APPLICATION OF LEAN MANUFACTURING IN THE PRODUCTION OF SPUN PILE USING WASTE ASSESMENT MODEL AND VALUE STREAM ANALYSIS

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ABSTRACT

Lean manufacturing is a concept that can help companies become more efficient and effective especially in reducing wastes. In this paper the writer identified the wastes in the spun pile production process at PT. Adhimix Precat Indonesia using Waste Relationship Matrix (WRM), Waste Assessment Questionnaire (WAQ), Value of Stream Mapping Tools (VALSAT) and Takt Time approaches. Spun piles are used in the construction of road overpass, sea port, or to support the higher layer or platform. The study showed that the dominant wastes that occur during the production process spun pile were wastes in of process, transportation and motion with the percentages of each 28,35 % , 14,12 %, and 13,06 %. The application of process activity mapping from VALSAT offered 12% manufacturing process cycle efficiency, while lowering the activities of non value added offered only 10%.

Key words: Spun pile, Lean Manufacturing, Waste reduction, Value Stream Mapping

1. INTRODUCTION

1.1. Background

Spun pile (pencil) is a type of concrete product used in the construction of road overpass, sea port, or to support the higher layer or platform. As provider of concrete products with very high demand PT. Adhimix Precast Indonesia (API) must have a strategy for sustainability and develop an intensive plan so that all the needs of consumers and market demand could be fulfilled, and to accomplish maximum profit.

API has difficulties in achieving planned daily production target due to some activity wastes that do not give added value to the production process. They are unnecessary movement, long lead time, waiting, and far inter location. One of the effective and efficient management strategies to reduce the wastage rate is the concept of lean manufacturing.

Other difficulty is the unnecessary transfer of join plate raw materials warehouse through a distance of 46 meters to the production place and fixing areas. Still another problem is the 200 meter distance between the readymix concrete transport and the foundry area which add a total of 600 seconds removal. The high number of inspection process has also contributed to the long production lead time.

1.2. Purpose of Study

1. Identify and measure non-value added activities in spun pile production process.
2. Determine and quantify the most dominant types of waste in spun pile production process.
3. Calculate and compare the process cycle efficiency before and after application of lean manufacturing approaches.

2. THEORIES USED IN STUDY

2.1. Lean Manufacturing

Lean manufacturing is a continuous systemic and improvement systematic approach through identifying and eliminating waste which includes non value-added activities.

2.2. Waste Relationship Matrix (WRM)

The seven types of production wastes identified by Shigeo Shingo (Hines and Taylor, 2000) are:

1. Overproduction **(O)**
2. Defect or Reject **(D)**
3. Unnecessary Inventory **(U)**
4. Inappropriate Processing **(I)**
5. Excessive Transportation **(E)**
6. Waiting or Idle **(W)**
7. Unnecessary Motion **(M)**

WRM is a From-To matrix to analyze the criteria of measurement. The column lists the waste while the effect of the waste to another is shown on the lines. Waste Assesment Questionnaire (WAQ) is developed to identify and allocate waste that occurs on the production line (Rawbdeh, 2005). WAQ consists of 68 questions that represent the activity, condition or behavior in specific production floor. Each question on the assessment questionnaire offers three types of answer with a weight of 1, 0.5 and 0. The questions are categorized into four groups: man, machine, material and method.

2.3. Value Stream Mapping (VSM) and Value Stream Analysis Tools (VALSAT)

VSM is a process of visually mapping the flow of information and material aimed at preparing a better performance in the future state map (Jones and Womack, 2000). VALSAT is a tool to map in detail the value stream, which focuses on value adding process to find the cause of the waste that is happening (Hines and Rich, 2008). The seven kinds of detailed most commonly used mapping tools are:
1. Procces Activity Mapping (PAM)
2. Supply Chain Response Matrix (SCRM)
3. Production Variety Funnel (PVF)
4. Quality Filter Mapping (QFM)
5. Demand Amplification Mapping (DAM)
6. Decision Point Analysis (DPA)
7. Physical Structure (PS)

3. METHOD OF STUDY

Figure 1 shows the flowchart of this study. When the research objectives have been formulated, the questionnaires are developed and distributed to the respondents. Answers were collected and processed to develop the results. VSM were used in the beginning and later in the later stage when the identified unnecessary wastes have been eliminated.

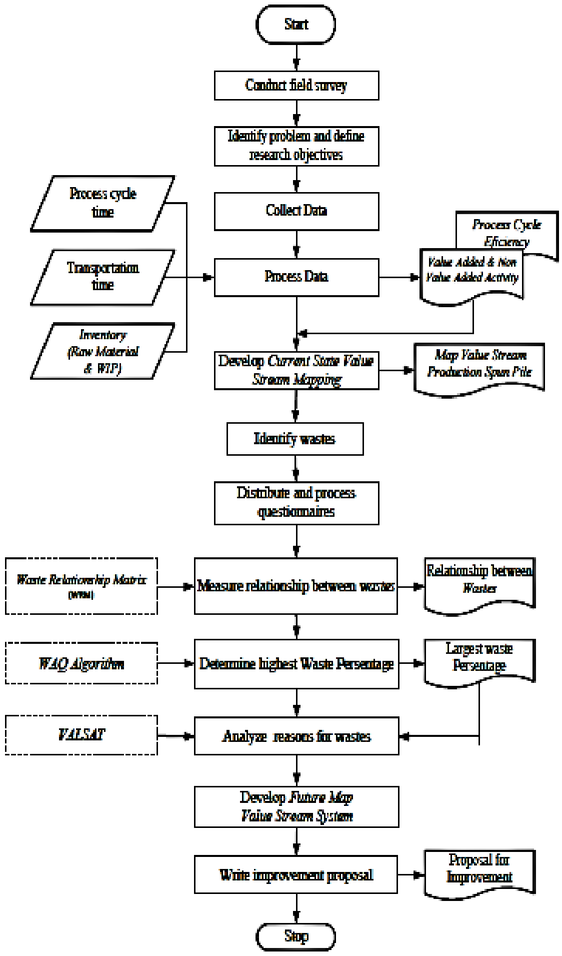

Figure 1. Flowchart of Study

4. RESULT AND DISCUSSION

Figure 2 shows the global flow of spun pile (pencil) production processing. The detail processes of each stage to make perfect final product need different processing times depending on the actual procedures and processes.

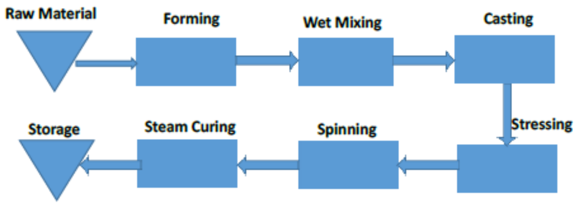

Figure 2. Global spun file production flow

Raw materials for the pencil are iron PC bars and join-plates, fly-ash, sand, split, water and additives like solid or liquid segmicals. Combined raw materials are formed into a wet mixing which later is put into a casting. The casting is later stressed to make it more solid and hard, spinned to make full round, and lastly hot steam cured. When the pencil is cooled down then it is stored.

Table 1 shows the result of current state mapping showing the types of candidate wastes that contribute to long production lead time.

Table 1. Results of current state mapping

Total C/T	19,555.0	second
Total T/T	3,440.4	second
Total Q/T	25,200.0	second
Total C/O	19.0	second
Lead Time Production	48,214.4	second
Total Distance	351.5	meter
Total MP	47.0	MP

Total production time required to produce a spun pile is 48,214.4 seconds (= 13.39 hours). The biggest contribution to the long production lead time are the long queue in hardening the casting for the spun pencil (25,200 seconds or 7 hours), and the steam curing time (19,555 seconds or 5.43 hours).

4.1. Calculation of Takt Time

Total takt time required to complete the task at each work station in the manufacture of spun pile is calculated as follows:

$$Takt\ Time = \frac{\text{Available time per day}}{Daily\ demand}$$

$$Takt\ Time = \frac{72000}{54}$$

$$Takt\ Time = 1344 \text{ second} = 22.4 \text{ minutes.}$$

Further, the optimum number of operators is calculated by dividing the Production Lead Time by the Takt Time as follows:
Optimum number of operators is
48214,4/1344 = 36 operators.

4.2. Identification of Wastes

Efforts to identify wastes is done using WAM three steps namely WRM, WAQ and VALSAT.

4.2.1. Waste Relationship Matrix (WRM)

Table 2 is a tabulation of questionnaires inter-relationship between the level of wastes:

Table 2. Waste Relationship Matrix

F/T	O	I	D	M	T	P	W
O	A	U	O	O	I	X	U
I	O	A	U	U	O	X	X
D	O	E	A	I	I	X	O
M	X	A	E	A	X	A	A
T	E	A	I	A	A	X	A
P	A	E	A	A	X	A	E
W	A	A	I	X	X	X	A

WRM results quantified into values so that percentage the relationship of waste can be calculated. (A= 10, E= 8, I= 6, O= 4, U=2, X= 0). Table 3 shows the result of Waste Relationship Value.

Table 3. Waste Relationship Value

F/T	O	I	D	M	T	P	W	Total	%
O	10	2	4	4	6	0	2	28	10%
I	4	10	2	2	4	0	0	22	8%
D	4	8	10	6	6	0	4	38	13%
M	0	10	8	10	0	10	10	48	17%
T	8	10	6	10	10	0	10	54	19%
P	10	8	10	10	0	10	8	56	20%
W	10	10	6	0	0	0	10	36	13%
Total	46	58	46	42	26	20	44	282	100%
%	16%	21%	16%	15%	9%	7%	16%	100%	-

The table shows that the percentages for “From” Inappropriate Processing (P) and From Transportation (T) give the highest percentages at 20% and 19%. This value indicates that the waste has a great influence to cause other wastes.
The columns “To" with the greatest percentage are given by Overproduction (O), Inventory (I), and Defects (D) at 21%, 16% and 16%.

4.2.2. Waste Assessment Questionnaire (WAQ)

WAQ aims to identify dominant waste using the results from WRM. This is shown on Table 4 (based on WRM values) and Table 5 (based on NQ = number of questions). Table 6 shows the multiplication of Weight of Waste with the Result of Questionnaire.

Table 4. Assessment Based on WRM Values

No	Asfek Question	Type Of Question	Number Of Question	O	I	D	M	T	P	W
1	Man	*To Motion*	9	4	2	6	10	10	10	0
2		*From Motion*	11	0	10	8	10	0	10	10
3		*From Defect*	8	4	8	10	6	6	0	4
4		*From Motion*	11	0	10	8	10	0	10	10
5		*From Motion*	11	0	10	8	10	0	10	10
6		*From Defect*	8	4	8	10	6	6	0	4
7		*From Process*	7	10	8	10	10	0	10	8
67		*From Process*	7	10	8	10	10	0	10	8
68		*From Defect*	8	4	8	10	6	6	0	4
		Total Score		348	454	466	464	324	350	398

Table 5. Weighting Waste Based on NQ

NO	Asfek Question	Type Of Question	Number Of Question	Weights or each type of waste						
				(Wo,k)	(Wi,k)	(Wd,k)	(Wm,k)	(Wt,k)	(Wp,k)	(Ww,k)
1	Man	*To Motion*	9	0,44	0,22	0,67	1,11	1,11	1,11	0,00
2		*From Motion*	11	0,00	0,91	0,73	0,91	0,00	0,00	0,91
3		*From Defect*	8	0,50	1,00	1,25	0,75	0,75	0,75	0,50
4		*From Motion*	11	0,00	0,91	0,73	0,91	0,00	0,00	0,91
5		*From Motion*	11	0,00	0,91	0,73	0,91	0,00	0,00	0,91
6		*From Defect*	8	0,50	1,00	1,25	0,75	0,75	0,75	0,50
7		*From Process*	7	1,43	1,14	1,43	1,43	0,00	0,00	1,14
67		*From Process*	7	1,43	1,14	1,43	1,43	0,00	0,00	1,14
68		*From Defect*	8	0,50	1,00	1,25	0,75	0,75	0,75	0,50
		Score (Sj)		62	66	72	70	62	62	60
		Frequency (Fj)		57	63	68	57	42	36	50

Table 6. Multiplication of Weight of Waste with the Result of Questionnaire

NO	Asfek Question	Type of Question	Average Of Answer	Weights or each type of waste (Wj,k)						
				(Wo,k)	(Wi,k)	(Wd,k)	(Wm,k)	(Wt,k)	(Wp,k)	(Ww,k)
1	Man	*To Motion*	0,58	0,26	0,06	0,04	0,04	0,05	0,05	0,00
2		*From Motion*	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3		*From Defect*	0,17	0,08	0,17	0,21	0,16	0,12	0,09	0,08
4		*From Motion*	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5		*From Motion*	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6		*From Defect*	0,08	0,04	0,08	0,10	0,08	0,06	0,04	0,04
7		*From Process*	0,17	0,24	0,19	0,27	0,39	0,00	0,00	0,19
67		*From Process*	0,25	0,36	0,29	0,41	0,58	0,00	0,00	0,29
68		*From Defect*	0,08	0,04	0,08	0,10	0,08	0,06	0,04	0,04
		Score (sj)		14,15	12,98	12,64	12,50	16,69	35,08	10,29
		Frequency (fj)		41	41	41	33	26	26	28

Table 7. Results of Calculations Waste Assessment Questionnaire

No	*Value Of*	Type Of *Waste*						
		O	I	D	M	T	P	W
1	s_j	14,15	12,98	12,64	12,50	16,69	35,08	10,29
2	f_j	41	41	41	33	26	26	28
3	S_j	62	66	72	70	62	62	60
4	F_j	57	63	68	57	42	36	50
5	Y_j	0,16416	0,127961	0,10583	0,1034	0,1666	0,4087	0,096
6	P_j	160	168	208	255	171	140	208
7	Y_j final	26	21	22	26	28	57	20
8	Final Result (%)	13,01%	10,65%	10,91%	13,06%	14,12%	28,35%	9,90%
9	*Rank*	4	6	5	3	2	1	7

Ranking result for each type of waste is shown on Table 7. The table shows that the dominant waste is obtained by Inappropriate Processing (P) with 28.35%, followed by waste transportation (T) and motion (M) respectively by 14.12% and 13.06%.

Tabel 8. *Process Activity Mapping*

Activities	Part	Sequence	Activity	Tools	Cycle Time (Second)	Cycle Time (Minutes)	distance (Meter)	Number Of Operator	Activities					VA/NVA/NNVA
									O	T	I	S	D	
1	*Raw Material (Join Plate, Iron Roll)*	1	Receiving raw material from Supplier		900	15		1						NNVA
2		2	Inspekstion raw material 1		2460	41								NNVA
3		3	preparation raw material to GBB		3600	60		2						NVA
54	*Spun Pile*	1	Transfer Mold to wheel Spinning	1 Gentry	66	1,1	6	1						NNVA
55		2	Set Up Spinning Machine		5	0,083		1						NNVA
56		3	Time Spinning Round	1 Alat Spinning	450	7,5								VA
57		4	Waste Disposal	1 Gentry + Bak Limbah	223,8	3,73		2						NVA
58		5	Transportation to Pit Curing	1 Gentry	72	1,2	6							NNVA
59		6	Preparation The Result Of Spinning to Pit Curing	1 Gentry	744	12,4								NNVA
60		7	Steam Curing Time	1 Alat Boiler	10800	180		-						VA
61		8	Refrigeration		3600	60		-						VA
62		9	Transfer Product From Pit To Demoulding Area	1 Gentry	210	3,5	8	2						NNVA
63		10	Opening The Bolt and Plate	1 Impact	630	10,5								NNVA
64		11	Opening the Lid Mold	1 Gentry	60	1								NNVA
65		12	Opening the Mold	1 Gentry	186	3,1								NNVA
66		13	Inspection		60	1								NNVA
67		14	Transportation Finish Good To Stockyard	1 Gentry	183	3,05	12							NNVA
68		15	Closing the Mold	1 Gentry	126	2,1								NVA
69		16	Placement Mold to Trolley	1 Gentry + Trolly	54	0,9		1						NVA
70		17	Trolley Removal of a Demoulding	Trolly	60	1	6							NVA
TOTAL					48214,4	803,5733	357,5	47						

Table 8 shows the next step in the Activity Mapping Process for the Spun Pile.

4.2.3. Selection of VALSAT Tool.

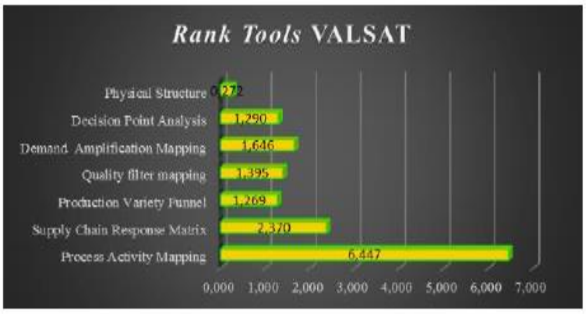

Figure 3. Result of Selection VALSAT Tools

The next stage is to select Detail Mapping Tools according to the type of waste. This is used to analyze the causes of the identified waste. Figure 3 shows the result of the selection process. The most appropriate tools to analyze the causes of waste is the Process Activity Mapping (6.447%) and Tools Supply Chain Response Matrix (2.37%).

4.2.4. Process Activity Mapping (PAM)

Table 9 shows that from the 70 spun pile production activities undertaken there are 41 operating activities, 15 transportation activities, 8 inspection activities, 3 storage activities (raw materials, WIP, and finished good), and 3 delay activities. Total time is 48.214,4 seconds = 14 hours.

Table 9. Calculation and Percentages of PAM

Activities	Total	Time (Second)	Percentage
Operation	41	9260	19%
Transportation	15	3215,4	7%
Inspeksi	8	3054	6%
Storage	3	3885	8%
Delay	3	28800	60%
Total	**70**	**48214,4**	**100%**

Classification	Total	Time (Second)
VA	18	33642,6
NNVA	42	9096,2
NVA	10	5475,6
Total	**70**	**48214,4**
Process Cycle Eficiency		70%
Percentage NNVA		19%
Percentage NVA		11%
TOTAL		**100%**

Storage activities contributed as much as 3885 seconds, or 1.07 hours. This activity should be avoided because it will create a buildup of WIP materials in the production floor and can hamper the production process, and should be placed in a separate area.

Inspection activities which occurs 8 times should be reduced because it is non value added, but will waste manpower time. Transportation activities occurs 15 times, should be reduced to minimize the cost of material handling.

The high percentages of non value added (NVA) and necessary non value added (NNVA) activities need to be reduced. This include (a) long distance (200 meter) between the location of readymix concrete to casting location is wasting time; (b) the presence of WIP storage activities for PC iron bar frame after fixing process; (c) unnecessary process of closing the mold.

4.2.5. Supply Chain Response Matrix (SCRM)

Figure 4 shows the SCRM graph for PC bar which illustrates the relationship between material inventory with the lead time that could be used to identify and evaluate the increase or decrease in inventory levels and the long lead time in each process within the internal supply chain.

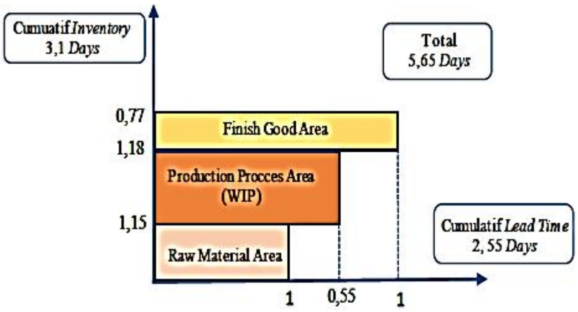

Figure 4. SCRM Graph for PC Bar

High inventory cumulation in the area of production (1.18 day) and raw materials (1.15 day) is caused by the long production process, especially the steam curing and hardening of concrete spun pile. The limited factory production capacity caused the low performance. Cumulative lead time of 2,55 days is very bad and must be reduced.

Figure 5 shows SCRM graph for the cement storage. As the cumulative lead time is 0.87 day the flow of material is running normally. Cement material cumulative inventory storage shows 1.37 day, but this is not a problem because the cement are stored in a silo that can maintain high quality of raw materials.

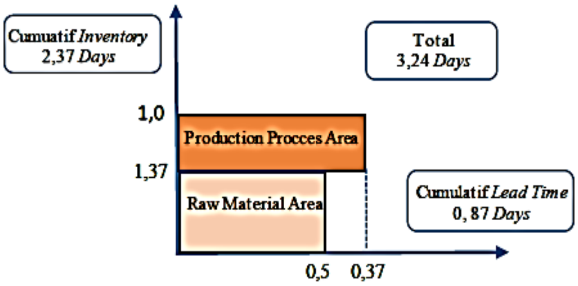

Figure 4. SCRM Graph for PC Bar

5. CONCLUSION

1. Dominant waste in the production process of Spun Pile are Inappropriate Processing (P) with 28.35%; then Transportation (T) with 14.12% and Motion (M) with 13.06%.
2. Activities that are Non-Value Added in the spun pile production are:
   1. Preparation of raw materials to Raw Material Warehouse (RMW)
   2. The transfer of iron rolls of RMW to production area
   3. The transfer of join plate
   4. Transportation of PC bar

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5. Closing the mold when setting them
6. Transportation of truck mixer to the precast location
7. Waste disposal
8. The integration of mold cover
9. Putting the mold to trolley
10. Return of the mold to a depository

3. Application of lean manufacturing method can reduce lead time production by 2.02 hours, increase the production process efficiency by 12%, from 70% to 82% and reduce the percentage of non-value-added activities by 10% from 11% to 1%.

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