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Implementation of Lean Manufacturing to Improve Air Handling Unit Coil Manufacturing in Saudi Air Conditioning Manufacturing Company (SAMCO)

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Abstract: This report aims to improve the production operations of the coils shop of air handling units (AHU) at Saudi Air Conditioning Manufacturing Company (SAMCO) by applying lean manufacturing strategy. The coils shop of AHU experienced several issues which impact negatively on its performance and increase the non-added values. For instance, it suffers from significant amount of scrap, low machines utilization, extra manpower, long machine set up time, and the absence of process safety system. In this report, the required data were collected by three ways; observation, recording and conducting the interviews with the related people. These data were analyzed by a wide range of tools, which are used to apply lean manufacturing such as, value stream mapping, 5S, work standardized, manual handling assessment chart, snook table, one-dimensional cutting optimizer, and mistake proofing. As a result, a significant reduction in the overall cost of coils shops production processes were obtained. For instance, the average machines set up time was reduced by 18 %, number of set up per shift was reduced by 20.8 %, the number of operators was reduced by 26.3 %, the quality of the product was increased and the safety of the processes was enhanced. It is worthy to note the amount of the scrap was dropped by approximately 71 %.

Keywords: Lean Manufacturing, Lean Techniques, Value Stream mapping (VSM), 5S

I. INTRODUCTION

Nowadays, companies recognize the importance of continuously improvement of their systems and operations to survive through competitions. One of the most known concepts which provides an excellent competition is the lean manufacturing system (Womack & Jones, 1997). Applying lean manufacturing system can help the organization to enhance their operations which results in increasing its strength aspects against their competitors (Soderquist & Motwani, 1999). Lean manufacturing is a philosophy that seek to increase value added activities and eliminate waste within the organization. Implementing lean manufacturing techniques have several positive effects for organization such as, reduce operation cost, reduce lead time, improve quality, and increase the productivity. Thus, make a significant impact on company (Dennis, 2006).

SAMCO was founded in 1982, it is private company located in Jeddah city. The current annually output of the factory is more than 500K units. Window room air condition was the first product launched by SAMCO with a joint venture between York Corporation and Juffali family till 1986. In 1989, Juffali started new joint venture with Carrier Corporation, which continue till now. During 1990s, SAMCO started manufacture new types of ACs product as 1. Air Handling Unit, 2. Package Unit and 3. Split Unit.

Nowadays, SAMCO divides their product to residential and commercial. SAMCO has eight assembly lines, three lines for residential product (window room air conditioning, and split system) and five lines for commercial product (package, and air handling unit).

SAMCO has three main feeders' areas that support assembly line to produce a unit. These feeders can be divided into three categories as Press shop, Coil shop and Paint shop.

1. Press shop

This area is to fabricate the required sheet metal components (cabinet, base pan, upper lower, tube sheet, etc.). The key processes in the press shop are coil slitting, punching, bending, and spot welding. After the parts are fabricated, it sent to paint shop for painting.

2. Coil shop

Coil shop is an important area in SAMCO factory due to its high number of processes and the complexity of its processes. There are four sections in coil shop area (window room coil shop, split coil shop, package coil shop, and air handling coil shop). These sections have the same key processes. However, they differ in term of the sizes.

3. Paint shop

SAMCO using powder coating painting to paint the components to provide more reliability, long working life, and prevent rusting. The components are loaded into hangers, which placed on conveyor then the parts moved through some processes (water oven, powder coating booth, and powder coating oven).

II. METHODOLOGY

A. Data Collection Method

This study has used a mix of quantitative and qualitative approaches. The data collection process has taken six months and they were collected by using three main methods as follows:

1- Observation

The researcher observed the steps of processes operation and work motion of the operator

2- Recording

The researcher recorded the number of operators, the time of the process, and counting the inputs and outputs.

3- Interview with operators

The researcher conducted interviews with the operators to investigate regards the process specification, phases, and situations.

B. Tools Used to Analyze Data

This section will include two main parts; general tools which will be applied to all processes, and specific tools which will be used only where they are needed.

General tools

1- Value stream mapping (VSM)

VSM was used to collect and analyze the data of the current status to identify the situation of each process and area of improvement. In addition, it will be used to compare the current and future status.

2- 5S

Apply 5S methodology will depend on each area, the supervisor will work with the employees to define unneeded parts then organize the needed part and tools to increase the efficiency and productivity of the operators. Applied 5S will help to easily standardized the work and reduce the setup time of the process.

4.2.2 Special tools

1- Ergonomic issue

There are two methods used to analyze and solve pipe lifting issue as follows:

a. Manual handling Assessment Charts (MAC)

"The Manual Handling Assessment Charts (MAC) is a tool aimed at employers, health and safety managers and safety representatives and is used by health and safety inspectors. The tool will help individuals to assess the most common risk factors in lifting (and lowering), carrying and team handling operations and was developed to identify high-risk manual handling". (Health and Safety Executive (HSE), 2018)

Before starting the assessment a researcher has to choose appropriate type of assessment (lifting, carrying or team handling), in the case of cutting process is consider as lifting process.

There are three levels of risks for each factor as follows

1. Green (G) low level of risk
2. Amber (A) medium level of risk
3. Red (R) high level of risk

To do the assessment, there is a need to compare the actual situation with the model guide to determine the level of risk (G, A, R) for each factor

For lifting, there are eight factors to determine whether the task is risky or not. These factors are load weight/frequency, hand distance from the lower back, vertical lift region, torso twisting and sideways bending, Postural constraints, grip on the load, floor surface, and other environmental factors, the following is the assessment for each factor:

1- Load weight/frequency

The weight of the object is 38 KG, and the frequency is lift every 30 minutes, as we see from figure 1 the score is A=4. Figure 1 shows the load weight versus frequency for lifting operation

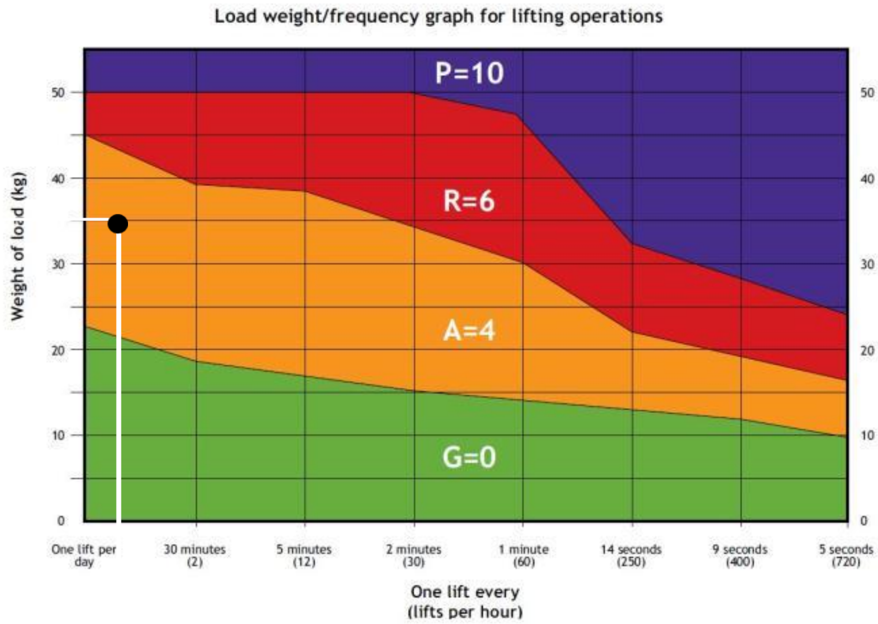

Figure 1. Weight for lifting operations

1- Hand distance from the lower back

With comparing our actual situation (Figure 2) to the guide model (Figure 3) the score should be A=3

Figure 2. Actual hand distance from the lower back

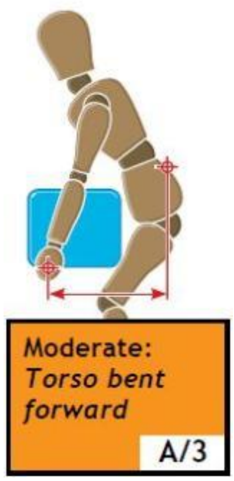

Figure 3. Hand distance from the lower back model

2- Vertical lift region

With comparing our actual situation (Figure 4) to the guide model (Figure 5) the score should be G=0

Figure II. Actual vertical lift region

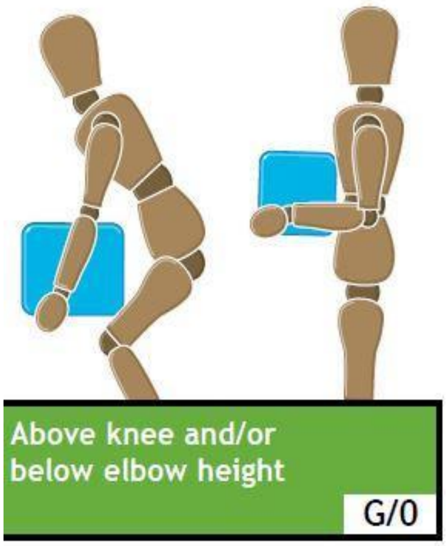

Figure 5. Vertical lift region model

3- Torso twisting and sideways bending

With comparing our actual situation (Figure 6) to the guide model (Figure 7) the score should be G=0

Figure 4. Actual torso twisting and sideways bending

Figure 5. Torso twisting and sideways bending model

4- Postural constraints

There are no postural constraints that force the operator to modify his posture. Thus, the score is G=0

5- Grip on the load

There are no handles to hold the pipe (Figure 8), also the part easy to slip. Thus, based on guide model (Figure 9) the score is R=2

Figure 6. Actual grip on the load

Figure 7. Grip on the load model

7- Floor surface

The floor dry, clean, and in good condition. Thus, the score is G=0

8- Other environmental factors

There are no other factors (extreme of temperature, strong air movement, or extreme lighting condition) present. Thus, the score is G=0

a. Snook's tables

To apply snook's method we need to know the following information

a. The height level: Between knuckle and shoulder.
b. Average lift: One lift every 30 minutes
c. Horizontal distance (Width): 34 CM
d. Distance lift: 25 CM
e. Objected weight: 38 KG

Then we can directly compare the maximum acceptable weight of lift for males from the snook's tables

1- Scrap issue

The one-dimensional cutting stock problem occurs during the first process when the operator cutting required pipe depending on project sequence that causes to increase the amount of the pipe scrap, to solve the issue, one-dimensional cutting stock technique was applied. One-dimensional cutting optimizer was used by building visual basic applications (VBA) in excel program. This system contains a list of required cutting length for one month, then the VBA programming identifies best cutting length combination. Thus, that will help to decrease the amount of scrap as much as possible. Additionally, it will allow the company to utilize their material consumption. Figure 10 shows the interface of the program. Figure 11 shows sequence of pipe cutting

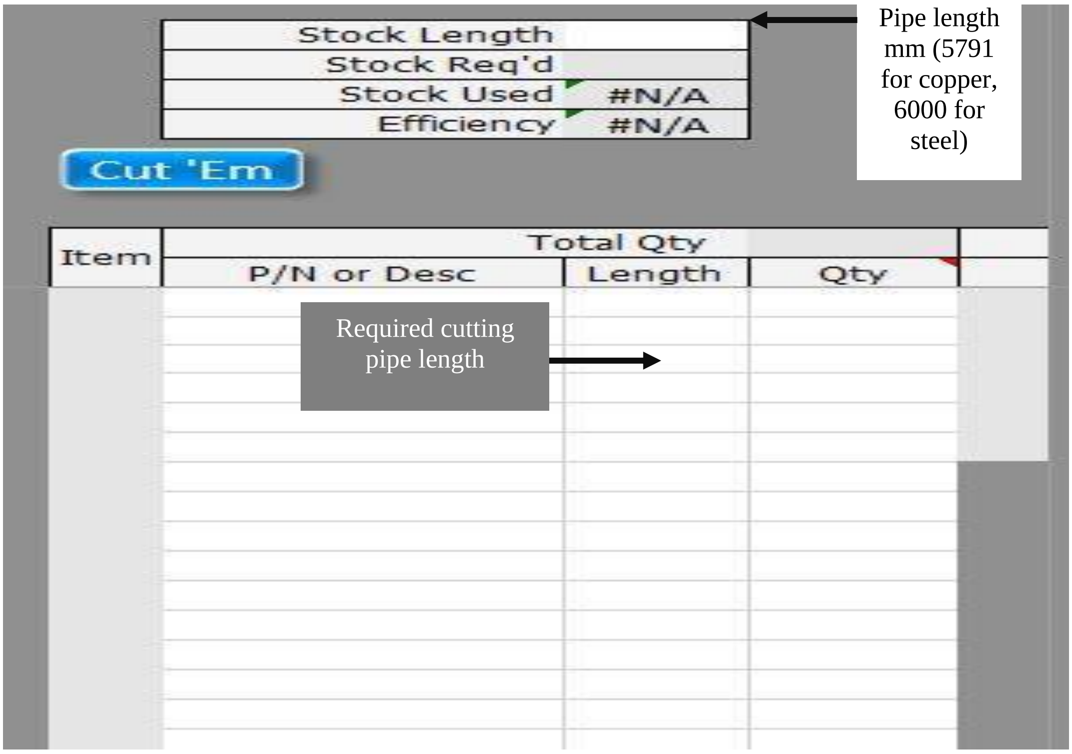

Figure 8. Scrap program interface

Item	Total Qty		191		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	P/N or Desc	Length	Qty		29.0	29.0	314.0	314.0	15.0	15.0	15.0	15.0	15.0	15.0	12.0	12.0	11.0	11.0	11.0	11.0	24.0	24.0	24.0	24.0
1		1766	16	16	3	3	2	2	1	1	1	1	1	1										
2		1449	2	2			1	1																
3		1131	2	2											1	1								
4		464	2	2	1	1																		
5		1802	4	4											1	1	1	1						
6		850	6	6															1	1	1	1	1	1
[illegible]		17	4	4													1	1			1	1		
[illegible]		12	56	56					1	1	1	1	1	1	1	1	1	1	1	1				
[illegible]		20	2	2																				
10		1766	40	40																	1	1		
11		2084	2	2															1	1				
12		1449	16	16					2	2	2	2	2	2			1	1					1	1
13		1734	37	37											1	1			1	1	1	1	2	2
14		496	2	2			1	1																

Cutting combination

Figure 9. Cutting combination

3- Work sequence

The researcher changed the internal method of the sequence from sequence depend on work order to the mix method that depends on both sequence-dependent setup time and works order. Sequence-dependent setup time will help to reduce setup time and number of setups. To implement the method, the supervisor must review monthly sequence and grouped similar job that has same measurements with a similar setup to produce it at the same time without affecting the completion date of the unit. Figure 12 shows the work sequence before changing it.

No.	Project Name	Unit Reference	Schedule Sequence	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep	12-Sep
1	RENOVATION VETERINARY LABS AT FALAJ	39HQM1006H00200226	01	0226											
2	RENOVATION VETERINARY LABS AT FALAJ	39HQM0606H00200227	01	0227											
3	RENOVATION VETERINARY LABS AT FALAJ	39HQM0706H00200228	01	0228											
4	SJMB & GDC PROJECT - STD - B1	39HQM0906S00200012	02		0012										
5	SJMB & GDC PROJECT - STD - B1	39HQM1208S00200013	02		0013										
6	SJMB & GDC PROJECT - STD - B1	39HQM1208S00200014	02		0014										
7	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1612S00209973	03		9973										
8	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1712S00209967	03		9967										
9	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1914S00209966	03					9966							
10	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1914S00209972	03					9972							
11	CAPITAL VIEWS-B1	39HQM1008S00200180	04						0180						
12	CAPITAL VIEWS-B1	39HQM0608S00200181	04						0181						
13	J853 EXTENSION OF SUBSTATION-1 ANNE	39HQM0908S00200116	04						0116						
14	J853 EXTENSION OF SUBSTATION-1 ANNE	39HQM0908S00200117	04						0117						
15	CMW-18081	39HQM0504S00200360	04						0360						
16	CMW-18081	39HQM1006S00200361	04						0361						
17	CMW-18081	39HQM1006S00200361	04							0361					
18	CMW-18081	39HQM1006S00200362	04							0362					
19	CAPITAL VIEW	39HQM1008S00200345	04							0345					
20	AL YOUSEF HOSPITAL	39HQM1006S00200378	05							0378					
21	SJMB & GDC PROJECT - STD - B2 Priority	39HQM0704S00209980	05							9980					
22	SJMB & GDC PROJECT - STD - B2 Priority	39HQM0606S00209981	05							9981					
23	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1910S00209964	06								9964				
24	SJMB & GDC PROJECT - STD - B2	39HQM1914S00209974	06								9974				
25	SJMB & GDC PROJECT - STD - B2	39HQM1610S00209988	06								9988				
26	SJMB & GDC PROJECT - STD - B2	39HQM0604S00200004	07									0004			
27	SJMB & GDC PROJECT - STD - B2	39HQM0706S00209998	07									9998			
28	SJMB & GDC PROJECT - STD - B2	39HQM0906S00200001	07									0001			
29	SJMB & GDC PROJECT - STD - B2	39HQM1006S00209983	07									9983			
30	SJMB & GDC PROJECT - STD - B2	39HQM1006S00209984	07									9984			
31	SJMB & GDC PROJECT - STD - B2	39HQM1106S00209982	08											9982	
32	SJMB & GDC PROJECT - STD - B2	39HQM1110S00209970	08											9970	
33	SJMB & GDC PROJECT - STD - B2	39HQM1312S00200005	08											0005	
34	SJMB & GDC PROJECT - STD - B2	39HQM1408S00200008	09												0008
35	SJMB & GDC PROJECT - STD - B2	39HQM1410S00200006	09												0006
36	SJMB & GDC PROJECT - STD - B2	39HQM1410S00200007	09												0007

Figure 10. Work sequence

2- Return bending template

The researcher worked with the engineering team to create a circuit template for every coil model, the operator should attach the template before insertion of return bending, which will eliminate the probability of the wrong insertion of the return bending. Figure 13 shows the current method of return bending insertion.

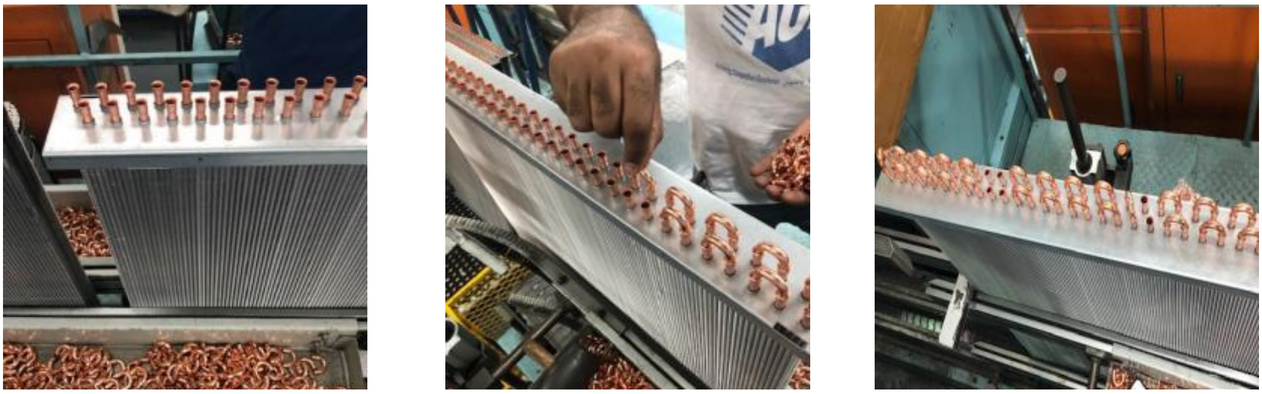

Figure 11. Return bending insertion processes

3- Coil delivery

A discussion was conducted with the industrial engineer team to create a new method for coil transferring. The team created a cart for storage and transferring of the coil from coil shop area to the assembly line. The industrial engineer team built moveable cart based on a specification of the coil.

III. APPLICATION AND RESULT

A. 5S Application

This section shows the application of 5S technique in air handling unit coil shop area

a. CNC drilling machine

Figure 14 shows CNC machine tools before and after applied 5S techniques

Figure 14. Before and after applying 5S techniques on CNC machine

b. Welding and brazing header

Figure 15 shows the area before and after applied 5S. The figure shows the impact of 5S techniques

Figure 15 Before and after applying 5S techniques on welding and brazing process

a. Tube bending and Fin press machine

Figure 16 shows the tools before and after applied 5S techniques

Figure 16. Before and after applying 5S techniques on tube bending and fin press machine

b. Coil expansion and leak test

Figure 17 shows before and after applied 5S techniques on coil expansion and leak test tools

Figure 17. Before and after applying 5S techniques on coil expansion and leak test process

c. Return bending insertion and coil brazing

The following improvement gained from applying 5S and Kanban system. Figure 18, and 19 show the improvement implemented on return bending and manual coil brazing after applied 5S techniques

Figure 18. Before and after applying 5S techniques on return bending and coil brazing

d. Coil storage

Figure 20 shows the old and new cart applied to storage coils

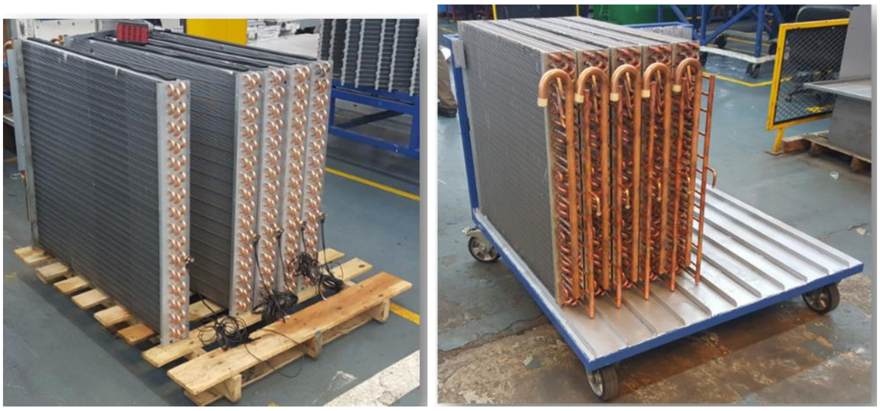

Figure 20. Before and after applying 5S techniques on coil storage

A. Ergonomic issue

The result of the manual handling assessment charts method and snook table method shown in tables 1, and 2

a. Manual handling assessment

Table 1 shows the result of manual handling study conducted on pipe cutting process

Table 1. Manual handling assessment score

Risk Factors	Colour Band (G, A, R, or P)			Numerical Score		
	Lift	Carry	Team	Lift	Carry	Team
Load weight and lift/carry frequency	A			4		
Hand distance from the lower back	A			3		
Vertical lift region	G			0		
Trunk twisting/sideways bending Asymmetrical trunk/load *(carrying)*	G			0		
Postural constraints	G			0		
Grip on the load	R			2		
Floor surface	G			0		
Other environmental factors	G			0		
Carry distance *(carrying only)*						
Obstacles en route *(carrying only)*						
Communication and co-ordination *(team handling only)*						
Total Score				9		

b. Snook table

Table 2. Snook Score

Maximum Acceptable Weight of Lift for Males (kg)

Width	Distance	Percent	Floor level to knuckle height One lift every								Knuckle height to shoulder height One lift every								Shoulder height to arm reach One lift every							
			5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h	5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h	5 s	9 s	14 s	1 min	2 min	5 min	30 min	8 h
		90	8	10	11	15	17	19	19	23	8	11	13	15	15	16	18	19	8	10	12	14	14	15	16	18
		75	***12***	14	17	22	25	28	28	33	11	15	17	20	20	21	23	25	10	14	16	18	19	19	24	24
	76	50	***16***	***19***	22	30	34	37	38	44	14	19	21	25	25	26	29	32	13	17	20	23	24	25	27	30
		25	***20***	***24***	***28***	37	42	47	47	55	17	***23***	26	30	31	32	36	39	***16***	***21***	24	28	29	30	33	36
		10	***24***	***29***	***33***	44	50	54	56	65	***20***	***26***	***30***	35	36	37	41	45	***18***	***24***	***28***	33	33	34	38	42
		90	9	10	12	16	18	20	20	24	9	12	14	17	17	18	20	22	8	11	13	16	16	17	18	20
		75	***12***	15	18	23	26	28	29	34	12	16	18	22	23	23	26	29	11	14	17	21	21	22	24	26
34	51	50	***17***	20	24	31	35	38	39	46	15	20	23	28	29	30	33	36	14	18	21	26	27	28	31	34
		25	***21***	***25***	***30***	39	44	48	49	57	18	24	27	34	35	36	40	44	***17***	22	25	32	32	33	37	41
		10	***25***	***30***	***35***	46	52	57	58	68	***21***	***28***	***32***	40	40	42	46	51	***19***	***26***	***29***	37	37	39	43	47
		90	10	12	14	18	20	22	23	27	11	14	16	20	20	21	23	26	10	13	15	19	19	19	22	24
		75	***15***	18	21	26	30	32	33	38	14	18	21	26	27	28	[illegible]	34	13	17	20	24	25	26	29	31
	25	50	***20***	24	28	35	40	43	44	52	18	23	27	33	34	35	39	43	16	22	25	31	31	33	36	40
		25	***26***	***30***	***35***	44	50	54	55	65	***21***	***28***	32	40	41	42	47	52	***20***	***26***	***30***	37	38	39	44	46
		10	***29***	***35***	***41***	52	59	64	66	76	***25***	***33***	***37***	47	47	49	55	60	***23***	***30***	***35***	43	44	45	51	55

As we can see from table 2 for 75% of men can lift only up to 31 KG if we have the same above situation, but our object weight is 38 KG. Thus, it's above the standard

C. Scrap issue

Table 3 shows the amount of the pipe scrap after implemented the one-dimensional cutting optimizer technique. Table 3 consists of stock required, stock used, efficiency, number of pipes used, and percentage of scrap

Table 3. Pipe scrap after implemented one dimensional cutting optimizer technique

Month	Stock required	Stock used	Efficiency	No. of pipe used	Scrap
Sep-19	283,174.00	289,545.42	97.8%	50	2.25%
Oct-19	332,812.00	340,133.86	97.8%	59	2.20%
Nov-19	360,124.00	368,334.83	97.8%	64	2.28%
Feb-20	295,941.00	302,866.02	97.7%	53	2.34%
Mar-20	312,162.00	319,154.43	97.8%	56	2.24%
Apr-20	346,152.00	354,148.11	97.7%	62	2.31%

D. Work sequence

Figure 21 shows the new sequence after implemented sequence-dependent setup time and works order. The changes show on the yellow highlighted items

No.	Project Name	Unit Reference	Schedule Sequence	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep	12-Sep
1	RENOVATION VETERINARY LABS AT FALAJ	39HQM1006H00200226	01	0226											
2	RENOVATION VETERINARY LABS AT FALAJ	39HQM0606H00200227	01	0227											
3	RENOVATION VETERINARY LABS AT FALAJ	39HQM0706H00200228	01	0228											
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17	CMW-18081	39HQM1006S00200361	02		0014										
18	CMW-18081	39HQM1006S00200362	03		9973										
4	SJMB & GDC PROJECT - STD - B1	39HQM0906S00200012	03		9967										
5	SJMB & GDC PROJECT - STD - B1	39HQM1208S00200013	03					9966							
6	SJMB & GDC PROJECT - STD - B1	39HQM1208S00200014	03					9972							
7	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1612S00209973	04						0180						
8	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1712S00209967	04						0181						
9	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1914S00209966	04						0116						
10	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1914S00209972	04						0117						
21	SJMB & GDC PROJECT - STD - B2 Priority	39HQM0704S00209980	04						0360						
22	SJMB & GDC PROJECT - STD - B2 Priority	39HQM0606S00209981	04						0361						
23	SJMB & GDC PROJECT - STD - B2 Priority	39HQM1910S00209964	04							0361					
11	CAPITAL VIEWS-B1	39HQM1008S00200180	04							0362					
12	CAPITAL VIEWS-B1	39HQM0608S00200181	04							0345					
19	CAPITAL VIEW	39HQM1008S00200345	05							0378					
13	J853 EXTENSION OF SUBSTATION-1 ANNE	39HQM0908S00200116	05							9980					
14	J853 EXTENSION OF SUBSTATION-1 ANNE	39HQM0908S00200117	05							9981					
20	AL YOUSEF HOSPITAL	39HQM1006S00200378	06								9964				
24	SJMB & GDC PROJECT - STD - B2	39HQM1914S00209974	06								9974				
25	SJMB & GDC PROJECT - STD - B2	39HQM1610S00209988	06								9988				
26	SJMB & GDC PROJECT - STD - B2	39HQM0604S00200004	07									0004			
27	SJMB & GDC PROJECT - STD - B2	39HQM0706S00209998	07									9998			
28	SJMB & GDC PROJECT - STD - B2	39HQM0906S00200001	07									0001			
29	SJMB & GDC PROJECT - STD - B2	39HQM1006S00209983	07									9983			
30	SJMB & GDC PROJECT - STD - B2	39HQM1006S00209984	07									9984			
31	SJMB & GDC PROJECT - STD - B2	39HQM1106S00209982	08											9982	
32	SJMB & GDC PROJECT - STD - B2	39HQM1110S00209970	08											9970	
33	SJMB & GDC PROJECT - STD - B2	39HQM1312S00200005	08											0005	
34	SJMB & GDC PROJECT - STD - B2	39HQM1408S00200008	09												0008
35	SJMB & GDC PROJECT - STD - B2	39HQM1410S00200006	09												0006
36	SJMB & GDC PROJECT - STD - B2	39HQM1410S00200007	09												0007

Figure 21. work sequence after implemented sequence-dependent setup time and works order

E. Return bending template

The production team fabricates a template for each coil circuit model based on the engineering team design, figures 22 shows the return bending insertion after improvement implemented.

Figure 22. Return bending insertion after attached the template

F. Coil delivery

Figure 23 shows the cart that created by the industrial engineering team that used to transfer coils to the assembly line

Figure 23. Coil cart

G. VSM

Table 4 and figure 24 show the coil shop status after improvement implemented, they show the details of each process after improvement implemented, the table shows number of machines, process time, number of operators, average setup time/machine, average setup/shift, and machine utilization.

Table 4. VSM after improvment implemented

Machine name	Number of Machine	Process Time (min)	Number of Operators	Average Setup Time(min)/ Machine	Average Setup/Shift	Machine Utilization
Cutting	1	10	1	3	2	0.15
Drilling	1	110		25	3	0.85
Welding	2	70	4	30	4	0.8
Header	1	25		30	5	0.85

Brazing						
Fin Press	1	45	1	20	4	0.8
Hairpin Bending	1	25	1	25	4	0.85
Lacing	-	30	3	10	6	0.15
Expansion	2	120		70	2	1
Coil Brazing	1	60	3	40	5	0.9
Leak Test	1	25		20	7	0.7
Forklift	1	10	1	-	-	0.3

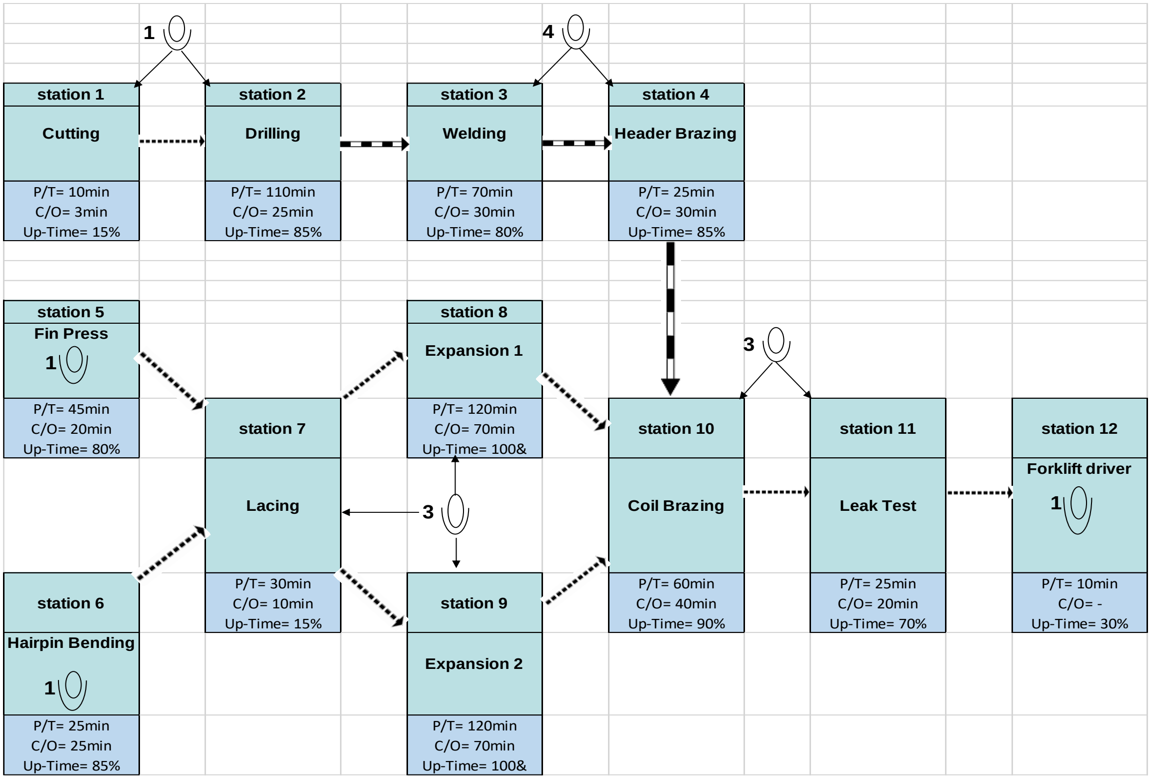

Figure 24. VSM after improvment implemented

IV. RESULTS DISCUSSION

The purpose of this study was to identify the impact of implementation lean manufacturing principles on AHU coil shop. Lean manufacturing system was successfully implemented to improve AHU coil shop area. The following subsections show the impact of lean manufacturing applications on coil shop process.

1. Cutting process

A. Ergonomic issue

The result obtained from manual handling assessment study confirmed that only the grip on the load has high risk, Load weight/frequency and hand distance possess moderate risk, and the other factors have no risk. However, one of the most important points in the test is that there is a historical record for an accident. This is because the shape of the pipe which makes the pipe easy to slip from the operators. Therefore, the supervisor recommended to order a lifting table. In addition, a small table with a roller is fabricated and placed on the lifting table. To eliminate the lifting process, the lifting table is placed in align with the cutting machine. Thus, the operator can easily pull the pipe as the roller will hold the pipe weight. Figure 25 shows the current process after the lifting table is introduced.

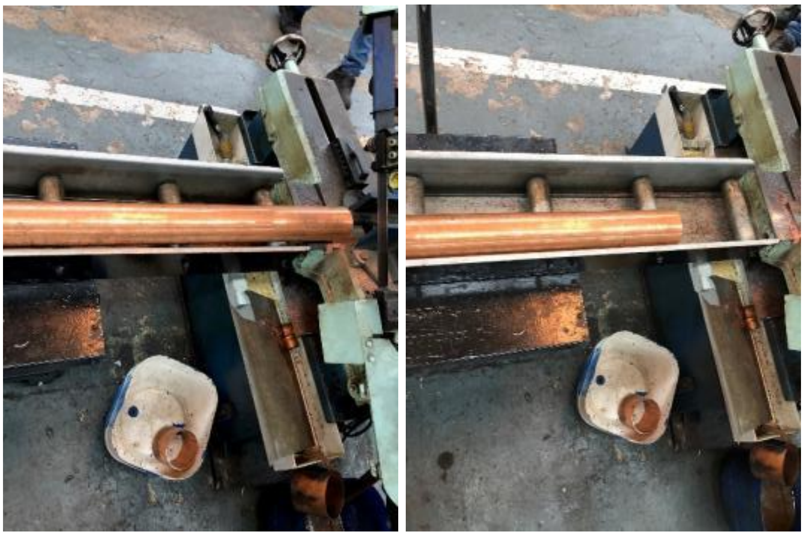

Figure 25. lifting table

B. Scrap issue

Table 5 shows the average scrap and efficiency before and after implementing one-dimensional cutting optimizer technique on the cutting process.

Table 5. Amount of the pipe scrap before and after improvment implemented

Before		After		% of efficiency increase	% of scrap decrease
Avg. efficiency	Avg. scrap	Avg. efficiency	Avg. scrap		
92.7%	7.8%	97.8%	2.3%	5.4%	70.9%

It can be concluded from table 5 that efficiency increased by 5.4%. In addition, there is a rapid decrease in the amount of the scrap (70.9%) which is an outstanding benefit.

2. Work sequence

The implementation of sequence dependent setup time helped the company to reduce the number of average setup time per shift. Table 6 shows different average setup time per shift before and after implemented the sequence dependent setup time.

Table IV. Percentage of decreasing before and after improvement implemented

Machine Name	Average Setup/Shift (Before)	Average Setup/Shift (After)	% of decreasing
Cutting	6	2	66.7%
Drilling	5	3	40.0%
Welding	4	4	0.0%
Header Brazing	5	5	0.0%
Fin Press	6	4	33.3%
Hairpin Bending	6	4	33.3%

Lacing	6	6	0.0%
Expansion	3	2	33.3%
Coil Brazing	5	5	0.0%
Leak Test	7	7	0.0%

As it is shown in table 6 the impact of applying sequence dependent setup time on the average setup per shift is different from one step to another. However, the highest impact was on cutting process which decreased by 66.7%. In addition, drilling process decreased by 40%, fin press, hairpin bending, and expansion process decreased by 33.3%, while the remaining processes did not impact by the new change.

3. Return bending template

The implementation of the return bending template helped the company to eliminate the wrong insertion by 100%.

4. 5S application

Applying 5S technique enabled the company to reduce the number of defective tools by 20%. In addition, implementation 5S have significant impact on reducing the machine setup time. Table 7 shows the setup time differences before and after implemented 5S for each process.

Table 7. Percentage of setup time decreasing before and after 5S implemented

Machine Name	Average Setup Time(min)/Machine (Before)	Average Setup Time(min)/Machine (After)	% of decreasing
Cutting	3	3	0
Drilling	30	25	16.7%
Welding	30	30	0
Header Brazing	60	30	50.0%
Fin Press	20	20	0
Hairpin Bending	30	25	16.7%
Lacing	10	10	0
Expansion	90	70	22.2%
Coil Brazing	40	40	0
Leak Test	20	20	0

As it is seen from table 7, the average setup time machine decreased in several steps. The header brazing process decreased significantly by 50%, the expansion process decreased by 22.2%, and the drilling and hairpin bending process decreased by 16.7%. However, no impact observed in the remaining processes.

V. CONCLUSION AND RECOMMENDATION

This report has investigated applying lean manufacturing principles on one production line (AHU coil shop) at Saudi Air Conditioning Manufacturing Company. There were several lean manufacturing techniques used to improve AHU coil shop such as 5S, work standard, value stream mapping, and mistake proofing. It was shown that implementing lean manufacturing techniques leads to the following results

a. Reduce the number of operators by 26.3% (5 operators).

b. Reduce the average setup time by 18%.

c. Reduce the number of setups per shift by 20.8%.

d. Reduce the amount of the scrap by 70.9%.

e. Eliminate the wrong insertion of return bending.

f. Improve the safety.

g. The tools become more reliable.

h. Improve the skill level of the operators.

In conclusion, these findings have highlighted the potential advantages of applying lean manufacturing techniques on a manufacturing environment. The researcher recommends applying lean techniques on other shop, lines and departments inside the organization.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities

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