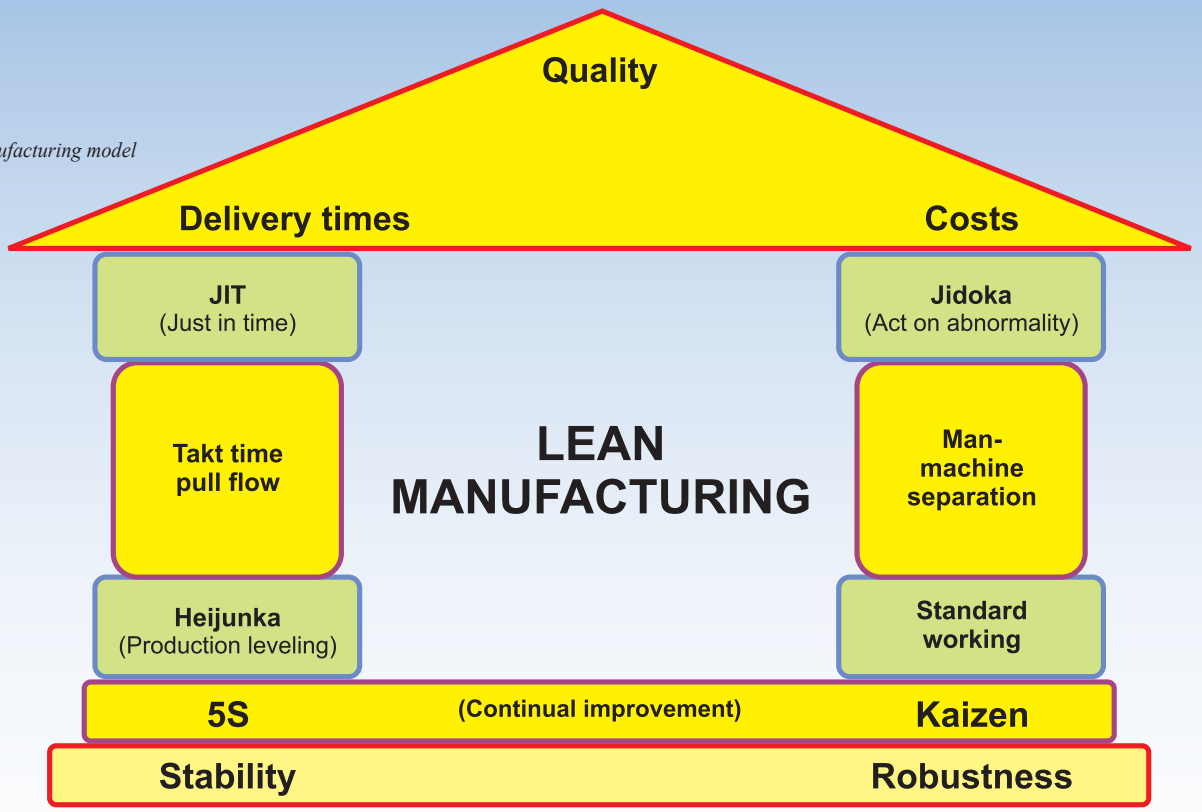

Lean manufacturing model

Implementing Lean Management Principles in HVAC Industry Using Lean Six Sigma Tools

By Jamal Musthafa K M
Director, Mastro Lee Engineering and Management Consultants
Coimbatore

Abstract

A lot of difficulties are faced in project execution of HVAC systems, and it takes more than 6-8 months for completion of installation. This article discusses implementation of Lean Management principles to HVAC projects to reduce the 'mudas' (Japanese term for 'wastes'), bottlenecks and consequently the completion time.

Introduction

The problem faced during the HVAC installation of, say, a high-rise building would, generally, be the number of rejections faced at the entry level process and the amount of time spent for the re-work of ducts. The root cause of the re-work is identified to be the need for reducing costs, which eventually leads to rushing through the work within the limited time available, compromising job quality. Lack of co-ordination between various departments (construction, electrical and HVAC installation team) may also adversely affect job quality, necessitating rework.

The two problem leading extremities – compromising work efficiency to reduce the cost and time taken, and prolonging the installation time – can both be rectified by implementing Lean Management and Six Sigma principles. Six Sigma involves a rigorous, highly focused and effective implementation of proven techniques for a productive endeavour.

DMAIC Process

Define, Measure, Analyse, Improve and Control (DMAIC) steps are used to identify customer requirements and understand the business issues, thereby laying a proper foundation for providing a solution and looking for ways to further optimize it for best results.

Figure 1: DMAIC process

About the Author

Jamal Musthafa is a mechanical engineer from Anna University and an MBA from Manipal University, working as an HVAC and Lean Six Sigma consultant at his own firm Mastro Lee. He is also a trainer for HVAC and Lean Six Sigma.

continued on page 30

continued from page 28

'Define' Phase

In this phase, the company collects the demands and requirements of the customer and states the problems that will be faced while providing the solution by listing an organized overview considering financial and productivity improvement aspects.

The inputs to be considered at the Define phase are listed in *Table 1*.

SIPOC is an acronym that stands for 'Supplier, Input, Process, Output and Customer'. SIPOC is a visual tool used for process improvement, and gives an overview and roadmap for the process from the beginning to the end.

Project Charter

The project charter is a document that guides the project team on understanding the purpose of their work, avoiding confusion by specifying the subject boundaries. This charter lists the problem statement and the remedial measures that are proposed to be followed for satisfying the objectives laid down by the team.

Table 1: Inputs for define phase

Voice of Customer (VOC)	To reduce the installation time of HVAC duct system
Critical to Satisfaction	Completing the project at a faster rate
Critical to Quality (CTQ)	Providing a defect free system
VOC to CTQ	Faster installation
Voice of Design	Completion of the project in nominal time period
Voice of Process	Completion of the project in nominal time period
Defect Opportunities	Improper installation, duct designing, machine positioning, brazing of copper tubes, shielding of copper tubes, gas charging

Team/Project Charter					
Project Name:	Implementing Lean Management Principles in HVAC Industry using Lean Six Sigma Tools				
Last Revision Date:	25-02-2016				
Prepared By:	Mastro Lee Solutions				
Approved By:	NG Pharmacy				
Business Case:			**Opportunity Statement (High Level Problem Statement):**		
NG Pharmacy needs to implement Lean Management to effectively work on the HVAC systems in their plant, to reduce the installation cost, optimize labour management and increase profit, eventually improving the productivity of the company.			If Lean Management is not implemented, the Company may face a significant financial impact, delay in the working time period, conglomeration in the inventory, etc.		
			Defect Definition: Finishing up the work in a rush to reduce labour costs and prolonging the actual completion time period owing to improper co-ordination; both have devastating effects on the overall productivity.		
Goal Statement:			**Project Scope:**		
Set up an organized work flow schedule in order to achieve about 75% improvement in total productivity of the HVAC Installation process.			**Process Start Point:** Site Inspection.		
			Process End Point: Commissioning the project.		
Expected Savings/Benefits: The company can surely anticipate a profit upto 50%.			**In Scope:** Completing the Installation within a short span of time aided by an organized process-flow; budgetary limits being clarified.		
			Out of Scope: Quiescent Labour		
Task/Phase	**Start Date**	**End End**	**Name**	**Role**	**Commitment (%)**
Site inspection	03-01-2016	03-01-2016	Aras Prasad	Supervisor	95
Transportation	03-01-2016	03-01-2016	Naveen	Technician	90
Marking, drilling	03-01-2016	01-03-2016	Hari, Sivakumar	Labourers	92
Placing IDU and ODU	03-11-2016	11-03-2016	Hari, Sivakumar	Labourers	98
Ducts - sheet metal work	03-04-2016	09-03-2016	Hari, Sivakumar	Labourers	85
Ducts - insulation, placement	03-07-2016	15-03-2016	Naveen	Technician	88
Fixing grills	23-3-2016	24-3-2016	Hari, Sivakumar	Labourers	94
Commissioning	25-3-2016	25-3-2016	Aras Prasad	Product Commissioner	96
SigmaXL Copyright© 2006 - 2015, Version 1.0. This template is licensed to registered users of SigmaXL. It is a part of the SigmaXL software and may not be redistributed.					

Figure 2: Charter for an HVAC job

continued on page 32

continued from page 30

Table 2: SIPOC for the project

Supplier	Input	Process	Output	Customer
Mastro Lee	Engineer	Site inspection	Technician, logistics	Mastro Lee
Mastro Lee	Logistics	Transportation of machines tools and equipment	Labourer	Mastro Lee
Mastro Lee	Technician	Marking position for placing IDU	Driller	Mastro Lee
Mastro Lee	Technician	Marking position for placing ODU	Driller	Mastro Lee
Mastro Lee	Technician	Marking position for placing duct	Driller	Mastro Lee
Mastro Lee	Technician	Marking path for grooving	Driller	Mastro Lee
Mastro Lee	Driller	Drilling holes for fixing IDU	Labourer	Mastro Lee
Mastro Lee	Driller	Drilling holes for fixing ODU	Labourer	Mastro Lee
Mastro Lee	Driller	Drilling holes for fixing duct	Labourer	Mastro Lee
Mastro Lee	Driller	Grooving path for copper tubes	Labourer	Mastro Lee
Mastro Lee	Labourer	Inserting threaded rods into holes	Labourer	Mastro Lee
Mastro Lee	Labourer	Providing stands for ODU	Labourer	Mastro Lee
Mastro Lee	Labourer	Inserting clamps for IDU	Labourer	Mastro Lee
Mastro Lee	Labourer	Placing ODU	Labourer	Mastro Lee
Mastro Lee	Labourer	Fastening ODU using bolts and nuts	Labourer	Mastro Lee
Mastro Lee	Labourer	Lifting IDU	Labourer	Mastro Lee
Mastro Lee	Labourer	Fastening IDU using bolts and nuts	Labourer	Mastro Lee
Mastro Lee	Labourer	Sheet metal work for duct	Labourer	Mastro Lee
Mastro Lee	Labourer	Fixing grills in ducts	Technician	Mastro Lee
Mastro Lee	Technician	Acoustic insulation of ducts	Technician	Mastro Lee
Mastro Lee	Technician	Thermal insulation of ducts	Labourer	Mastro Lee
Mastro Lee	Labourer	Placing ducts	Labourer	Mastro Lee
Mastro Lee	Labourer	Lifting ducts	Labourer	Mastro Lee
Mastro Lee	Labourer	Clamping ducts using bolts and nuts	Labourer	Mastro Lee
Mastro Lee	Labourer	Fastening IDU and ducts	Labourer	Mastro Lee
Mastro Lee	Labourer	Providing drain pipes	Technician	Mastro Lee
Mastro Lee	Labourer	Connecting ODU and IDU using copper tubes	Welder	Mastro Lee
Mastro Lee	Welder	Brazing of copper tubes	Technician	Mastro Lee
Mastro Lee	Technician	Insulating copper tubes	Electrician	Mastro Lee
Mastro Lee	Electrician	Providing power supply	Technician	Mastro Lee
Mastro Lee	Technician	Commissioning over flow	Customer	NG Pharmacy

IDU=INDOOR UNIT ODU=OUTDOOR UNIT

'Measure' Phase

This phase, gives an insight on how the process is defined and on what factors the defects are measured. In this phase we tabulate input, process and output to determine the key factors such as work time and cost. Effectiveness and efficiencies are measured.

Effectiveness Measures

- Process time
- Low defectives
- Low error rates

Efficiency Measures

- High productivity
- High profit
- Low cycle time

The quotation given by LG Air Conditioners for the site of NG Pharmacy, Coimbatore is given in *Table 3*.

Table 3: Quotation for ductale split units

Scope of Supply and Prices					
Sl. No.	**Description**	**Qty**	**Unit**	**Dis-count-ed Rate**	**Amount**
1	Supply of factory made air cooled ductable split unit consisting of condensing unit housing, scroll type compressors with corded remote.				
	a. LG make 5.5 TR ductable split unit	1	Nos.	98,000	98,000.00
	c. LG make 8.5 TR ductable split unit	1	Nos.	1,42,000	1,42,000.00
	Total equipment cost				2,40,000.00

Scope of Ancillary Work							
Sl. No.	**Description**	**Qty**	**Unit**	**Unit Rate**		**Amount**	
2	Installation of ductable split (circuits)			Mate-rial	Labour	Material	Labour
	a. LG make 5.5 TR ductable split unit	1	Nos.		5,000		5,000
	c. LG make 8.5 TR ductable split unit	1	Nos.		7,000		7,000
3	Lifting of units	2	Sets		1,000		2000
4	Supply and laying of copper pipe 3/8" and 3/4" HD with insulation and outer taping	15	ft	450	150	6750	2250
5	Supply and laying of copper pipe ½" and 1" HD	15	ft	650	150	9750	2250
6	Supply and laying of electric cables	40	ft	50	25.00	2000	1000

continued on page 34

continued from page 32

7	Supply and laying of drain pipe with insulation inside (2 units)	30	ft	65	25	1950	750
8	Fabrication and fitting of 22G duct	20	sqm	650	250	13000	5000
9	Fabrication and fitting of 24G duct	40	sqm	850	250	34000	10000
10	Supply of ODU stand for 5.5 TR	1	Nos.	4000	1,000	4000	1000
11	Supply of ODU stand for 8.5 TR	1	Nos.	7500	2,500	7500	2500
12	Canvas connection	2	Nos.	2500	100	5000	200
13	Accustic insulation	20	Nos	400	100	8000	2000
14	Supply and return grill	5	sqm	7500	50	37500	250
15	Thermal insulation (nitrile)	40	sqm	650	50	26000	2000
	Sub Totals					1,55,450	43,200
	Ancillary Total including Tax						**1,98,650**
	Grand Total						**4,38,650**

This tabulation helps to determine the amount being spent for the installation of the entire HVAC system.

'Analyze' Phase

This phase is used for the statistical analysis of the problem under study. In this phase, using certain tools, we find the cause of the activities that are slowing down the process, thus helping to suggest a method to bring improved effectiveness in the process.

Cost Benefit Analysis

Cost is one of the key factors for which the installation time of the HVAC is to be reduced, so it is necessary to make an analysis of the amount being spent and pinpoint the reason for wasting a large amount. Without proper scheduling, we would waste manpower, which in turn leads to loss of money.

Profit on HVAC System

The expected profits from the HVAC job are shown in *Table 4* and *5*.

Table 4: Low side profits

Process	Profit ₹
Installation of ducted splits	12,000
Copper pipes	12,800
Electric cables	3,000
Drain pipe	1,050
Fabrication work	6,000
Stand	5,500
Canvas	3,000
Acoustic insulation	5,500
Grill fitting	12,500
Thermal (nitrile) insulation	8,000
Total	**69,350**

Labour charge = ₹ 31,200

Table 5: High side profits

Process	Profit (₹)
Machine billing	70,000

Transportation = ₹ 10,000

The company has 6 workmen:

- 2 for duct working
- 1 head senior technician
- 2 fitters
- 1 helpers

Labour cost for the technicians is shown in *Table 6*.

Table 6: Labour cost

Category	Number	Monthly wages (₹)	Total wages (₹)
Duct workers	2	10,000	20,000
Senior technicians	1	15,000	15,000
Fitters	2	7,000	14,000
Helpers	1	4,000	4,000
Total labour cost per month			53,000

Usually, the company takes 2 months to complete such a project.

The company has an expected margin of ₹1,60,500. If the project is to be finished in 2 months, ₹1,06,000 goes for labour charges and only a meagre amount of profit (₹54,500) is left. Travel and other allowances eat away another ₹4500. The company earns an overall profit of only ₹50,000.

But by implementing Lean Management, all parameters can be optimised leading to increased profitability and productivity.

Lean Parameters

When lean is applied effectively, much waste is eliminated. You order less material and ship less to the job site. You reduce the inventory of materials and tools stored on the site. You also reduce redundant process steps. All of this reduces energy, fuel and materials consumed, aiding green HVAC construction.

The most common types of waste in lean thinking are:

Defects

Defects include wrong installation, defects in fabrication punch lists and many kinds of change orders not meeting the required codes.

Over-production of Goods

Fabricating or ordering material in excess of the requirement leads to stockpiling of materials. Office over-production can include printing more job plans, making more copies of an invoice or report, and ordering more material than needed. This type of waste is the root cause for other wastes including inventory, transportation and motion.

Inventory

This includes raw materials, finished fabrication, spare parts, unused tools, consumables, forms and copies, employee stashes and personal stockpiles. Any material not yet installed and being used by the customer amounts to inventory.

Over-processing

This includes over-engineering, requiring additional signatures on a requisition, multiple handling of timesheets, duplicate entries

continued on page 36

continued from page 34

on forms, and getting double and triple estimates from suppliers. Any step in the process that does not add value is over-processing.

Transportation

This waste happens when material is moved around the shop, loaded on the truck or trailer or hauled to the job site and unloaded.

Motion

Workers looking for materials, tools and information on where/what to work (on) comprise the waste of motion that happens frequently on worksites.

By applying lean techniques, waste is reduced and, consequently, the cost becomes more affordable.

'Improve' Phase

In this phase, the ideas generated are used to mitigate the root causes and evaluate the solutions to select the best ideas. Implementing Lean Tools in the proposed process facilitates piloting a solution. In this example, we shall use the techniques of 5S along with Lean Principles to provide the most suitable solution.

Elements OF 5S

The five elements of 5S are:

Seiri

- Sorting out the inventory by labeling each item
- Providing a common point for accessing all tools
- Determining what is necessary in each work area

Seiton

- Keeping all records of tools and equipment in a tool-box, keeping tag records for the tools
- Keeping the bar code generated for individual technician to record his tools in use
- If the technician loses any tools, he is liable for loss of pay

Seiso

- Maintaining the tools regularly, observing proper rules and returning the fabricated parts to the supervisor
- Maintaining proper storage of the purchased items, and having a check-list of the items stored

Seiketsu

- Following Seiri, Seiton, Seiso and making them a habit
- Having frequent inspections
- Following a standard method of safety and security for workers and workplace and giving it the top priority

Shitsuke

- Educating the workmen on the importance of maintaining and organizing the workplace, safety in workplace and reducing wastes
- Portraying the importance of teamwork and worker coordination
- Getting ideas from the workmen, as they are the ones who actually work and are in the best position to generate ideas for improvement

Team-work and Coordination

It is necessary in the project to work with other teams in an integrated manner and manage things simultaneously. For example, erecting the false ceiling and placement of ducts must be co-ordinated. This will achieve the result of completing the project in time.

Process Plan

From the optimised solutions that are provided, the result is depicted in *Table 7*.

Table 7: Optimized process

Process	No. of Days	Start Date	End Date
Site inspection	1	Day 1	Day1
Transporting materials	1	Day 1	Day1
Marking	1	Day 1	Day1
Drilling	1	Day 1	Day1
Grooving path for copper pipes	2	Day 2	Day 3
Fixing clamps for IDU and ODU	1	Day 3	Day 3
Sheet metal work for duct	4	Day 4	Day 7
Fixing clamps for duct	1	Day 4	Day4
Copper pipe – brazing, insulating and finishing	2	Day 5	Day 6
Electrical wiring	2	Day 7	Day 8
Fixing IDU and ODU	1	Day 9	Day 9
Clamping of ducts	2	Day 10	Day 11
Waiting period for false ceiling	9	Day 12	Day 20
Fixing grills	3	Day 21	Day 23
Commissioning and reporting	1	Day 24	Day 24

This process is shown in the Gantt Chart in *Figure 3*.

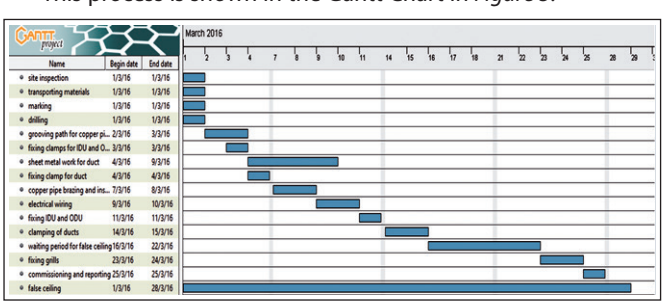

Figure 3: Optimized process on a Gantt Chart

The savings arising from the implementation of the optimized solution are shown in *Table 8*.

Table 8: Outcome of implementing Lean principles

Parameter	Before implementing Lean	After implementing Lean
Total number of working days	60	24
Labour cost (Rs.)	1,06,000	42,400

Figure 4 depicts the improvement achieved after the implementation of Lean, i.e. 56% improvement in profitability and 60% reduction in cycle time.

Control Phase

We have controlled the utilisation of time by implementing Lean principles. The project was pre-planned to effectively utilise manpower and other resources. The ultimate aim of reducing the process time is to reduce the cost, which is achieved through implementation of Lean methods. The progress can be made sustainable only by controlling the performance parameters and repeating the DMAIC cycle.

continued on page 50

continued from page 36

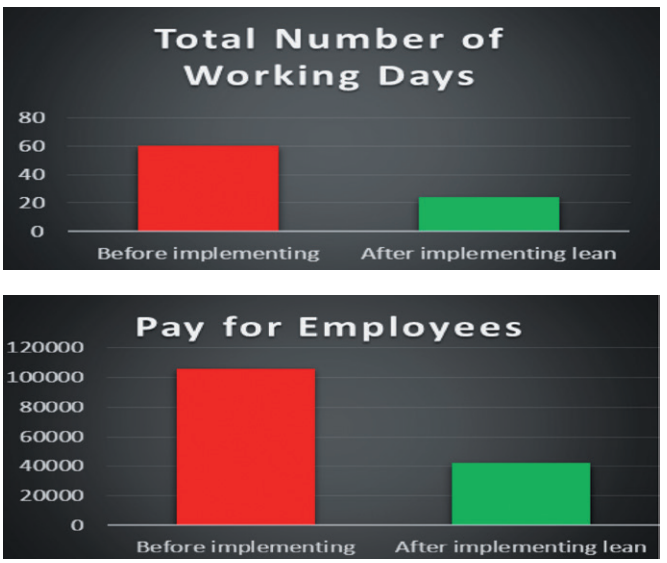

Figure 4: Improvement by implementing Lean

Conclusion

Implementation of Lean principles can help HVAC project execution significantly by cutting down wastes of cost and time.

Acknowledgement

Special thanks to my students Ranjith Kumar, Sekar Kamalakannan and Shanmuga Kumar who have supported my research work.