An Interpretive Structural Model Approach For Reducing Seven Wastes In Lean Manufacturing – A Case Study In Ceramic Tiles Manufacturing Industry

Neelakandan.B*and Dr. C.Muralidharan

Assistant Professor, Department of Manufacturing Engineering
Faculty of Engineering and Technology, Annamalai University
Annamalainagar-608002, India

Professor, Department of Manufacturing Engineering
Faculty of Engineering and Technology, Annamalai University
Annamalainagar-608002, India

neelakandan78@rediffmail.com, bnkapmfgewddeau04@gmail.com ,
muralre@yahoo.co.in

Abstract

In the era of modern manufacturing, the industries are in the pace of world-class manufacturing. This leads to acute global competition and forced them to adopt lean manufacturing strategy. In order to ensure effective implementation of lean concepts, the top management is bounded to analyze its barriers. This paper aims to analyze the seven wastes identified through literature review and opinion of experts in the implementation of lean manufacturing. Interpretive Structural Modeling (ISM) methodology is used to understand the mutual influences among the seven wastes and then to classify these seven wastes on the basis of their driving and dependence powers.

Keywords: Interpretive structural modeling, Seven waste, lean manufacturing, ceramic tiles

1. Introduction

Lean manufacturing is the systematic elimination of waste. Taiichi Ohno (1988), the father of Toyota Production System, defined Waste (Muda) as any human activity, which absorbs resources but creates no value. This paper aims, to categorize the seven wastes, to analyze the contextual relationship among the seven waste with the most distinct modelling approach Interpretive Structural Modeling (ISM).A case study was conducted in a leading ceramic industry to analyze the relationship.

ISM was developed by Prof. John N. Warfield (1974), Director of the Institute for Advanced Study of George Mason University in Fairfax, Virginia. ISM is an advanced Interactive Planning methodology that allows a group of people, working as a team, to develop a structure that defines the interrelationships among a set of elements. The structure is obtained by answering a set of simple questions. The elements to be structured such as objectives, barriers, activities, etc. are defined by the group at the beginning of the ISM planning session. The group also specifies a relational statement that defines the type of relationship desired such as "aggravates", "enhances", "contributes to", "precedes", etc.

The process starts with the identification of elements in a system, their prioritization and categorization through an understanding of their primacy, precedence, and causality over and among each other through independent and dependent linkages that are represented through a multi-level structural model. The ISM methodology is interpretive from the fact that the judgment of the group decides whether and how the variables are related. It is structural too, as on the basis of relationship; an overall structure is extracted from the complex set of variables. It is a modeling technique in which the specific relationships of the variables and the overall structure of the system under consideration are portrayed in a digraph model. ISM is primarily intended as a group learning process, but it can also be used individually.

2. Literature Review

Plenty of literatures incontext with Interpretive Structural Modelling (ISM) and hurdles related to implementation of lean manufacturing are available and few of the important contributions are listed herewith: Kumar.et.al. (2013). identified the variables to implement lean manufacturing system in Indian automobile industry and prioritize them to understand interdependence of the variables of lean manufacturing system implementation using ISM. Albert Chong et.al (2012) applied ISM techniques to analyze the complex dynamics between various lean implementation challenges in a electrical &electronic industry in malaysia. A hierarchical relationship model (HRM) was also developed to organize, impose order, and explain the relationship direction between the lean implementation challenges. Wiwin Widiasih.et.al (2015) developed a integrated model for managing risk in lean manufacturing implementation by integrating several tools. The integration is intended to improve decision making by providing quantitative analysis at each step of risk management. Delphi Method is utilized to identify potential risks, while House of Risk is used to categorize risks into risk events and risk agents and also to rank risk agent. To map relationships between risk events, Interpretive Structural Modeling is used. Giuliano & Tarcisio (2015) used ISM to analyse the barriers to lean production implementation (LPI). Ohno (1988) identifies seven types of Muda shown in Table 1.

Table.1 List of seven wastes.

Code	Seven Waste (Key challenges)
1	Defect
2	Motion
3	Over –Production
4	Processing
5	Waiting
6	Transportation
7	Inventory

3. Case Study

This study is conducted in a leading ceramic industry located in south India. The company is in the pace of implementing lean manufacturing and presently struggling hard to reduce its inventory and to increase its productivity. In the implementation of lean manufacturing elimination of waste plays a key role. The company requires hierarchy of the waste to be concentrated for elimination and to ensure better implementation without wasting its resources. In this research, in order to ascertain key lean implementation challenges in the ceramic industry, two experts from the academia with research interests in the area of lean manufacturing together with two manufacturing division managers working in the company were consulted. The experts from the academia and the industry had a very good working knowledge and firm grasp of the challenges and issues affecting the implementation of lean manufacturing in the ceramic industry. Even though a variety of moulding operations performed in the industry this study limits with products produced from a series of high speed moulding mechanical presses followed by other operations in the manner of stacking, re-stacking, baking in furnace and finally inspection and packing as shown in Figure 1

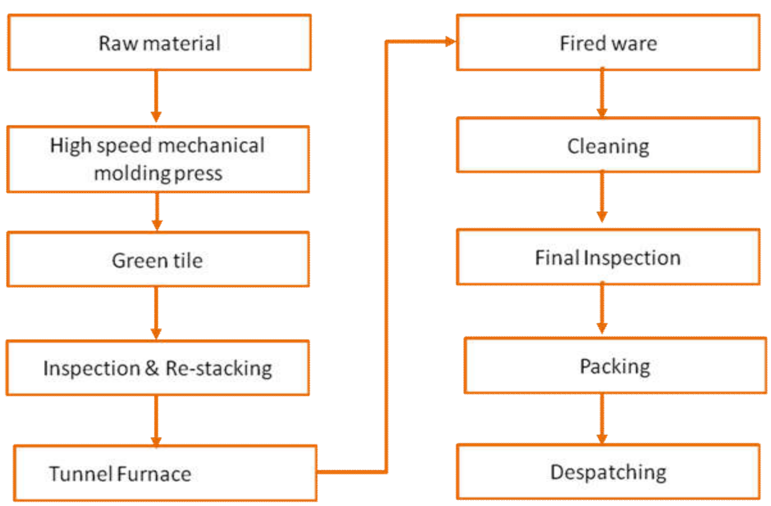

Figure 1 Material Flow Chart- boundary of study

The possibilities of occurrence of seven wastes in our study is shown in Figure 2. For the manufacturing of ceramic tiles alumina powder and refractories are crushed and milled to required grade of fineness. In order to ease forming process additives and binders are blended with the powder. The green tiles in their respective shapes are formed (produced) by high speed mechanical press and they are stacked initially in wooden bats in the moulding press area. The green tiles are then stored in the green tiles storing area. The green tiles stored are then inspected and re-stacked in silicon bats. To avoid sticking of tiles with each other alumina powder is sprayed over each layer of green tiles during re-stacking and baked in tunnel furnace. Then finally, the baked tiles are again inspected and packed

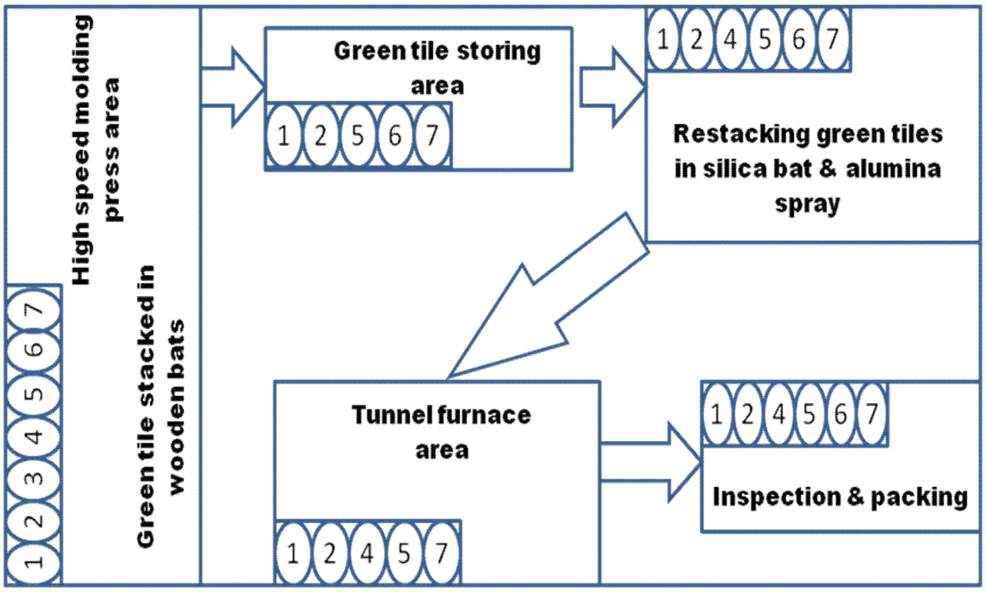

Figure 2 Possibilities of seven waste shown in the work place model layout

Details of each step that has been accomplished are discussed below (Bolanos et al., 2005):

Step-1: Identified seven wastes as key challenges affecting the implementation of lean.

Step-2: Determine contextual relationship between (seven wastes- challenges) of lean implementation and develop a structural self-interaction matrix (SSIM) to indicate pair-wise relationship between them. Table 2 shows the Structural Self-Interaction Matrix (SSIM).

Step–3 Prepare initial and subsequently final reachability matrix that is checked for contextual relation transitivity
The next step involves converting the SSIM into a binary matrix, referred to as initial reachability matrix. Table 3 shows the initial reachability matrix which is obtained by replacing the symbols V, A, X and O with 1 and 0. The following substitution rules were used to prepare the initial reachability matrix.

- if the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix is substituted with 1 while the (j, i) entry becomes 0;
- if the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix is substituted with 0 while the (j, i) entry becomes 1;
- if the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix is substituted with 1 while the (j, i) entry also becomes 1; and
- if the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix is substituted with 0 while the (j, i) entry also becomes 0.

Table 4 shows the final reachability matrix and takes into account all the transitivity relationships among challenges of implementing lean. With the final reachability matrix evaluate the 'driving power', and 'dependence', for all the waste. 'Driving power' for each challenge refers to the total number of challenges (including itself), which it may impact other(s). On the contrary 'dependence' for each challenge, sums up the number of challenges (including itself), which may have an impact by other(s).

Step-4 Perform level partition based on the final reachability matrix, develop digraph and construct ISM**.** These level partition as shown in Table 5 forms a guideline in building digraph as shown in Figure 3.

Table 2 Structural Self-Interaction Matrix (SSIM)

	7.Inventory	6.Transportation	5.waiting	4.processing	3.over production	2.Motion	1.Defect
1.Defect	**V**	**V**	**V**	**V**	**V**	**Ā**	
2.Motion	**V**	**O**	**V**	**O**	**V**		
3.over production	**V**	**O**	**V**	**V**			
4.processing	**O**	**O**	**V**				
5.waiting	**V**	**X**					
6.Transportation	**O**						
7.Inventory							

Table 3 Initial Reachability Matrix

	1.Defect	2.Motion	3.over production	4.processing	5.waiting	6.Transportation	7.Inventory
1.Defect	1	1	1	1	1	1	1
2.Motion	1	1	1	0	1	0	1
3.over production	0	0	1	1	1	0	1
4.processing	0	0	0	1	1	0	0
5.waiting	0	0	0	0	1	1	1
6.Transportation	0	0	0	0	1	1	0
7.Inventory	0	0	0	0	0	0	1

Table.4 Final Reachability Matrix

	1.Defect	2.Motion	3.over production	4.processing	5.waiting	6.Transportation	7.Inventory	***Driving power***
1.Defect	1	1	1	1	1	1	1	7
2.Motion	1	1	1	**1***	1	**1***	1	7
3.over production	0	0	1	1	1	**1***	1	5
4.processing	0	0	0	1	1	**1***	**1***	4
5.waiting	0	0	0	0	1	1	1	3
6.Transportation	0	0	0	0	1	1	**1***	3
7.Inventory	0	0	0	0	0	0	1	1
Dependence power	2	2	3	4	6	6	7	30

*Shows Transitivity

Table 5 Level partitioning

Factor	Reachability	Antecedent	Intersection	Level
1.Defect	1,2,3,4,5,6,7	1,2	1,2	**V**
2.Motion	1,2,3,4,5,6,7	1,2	1,2	**V**
3.over production	3,4,5,6,7	1,2,3	3	**IV**
4.processing	4,5,6,7	1,2,3,4	4	**III**
5.waiting	5,6,7	1,2,3,4,5,6	5,6	**II**
6.Transportation	5,6,7	1,2,3,4,5,6	5,6	**II**
7.Inventory	7	1,2,3,4,5,6,7	7	**I**

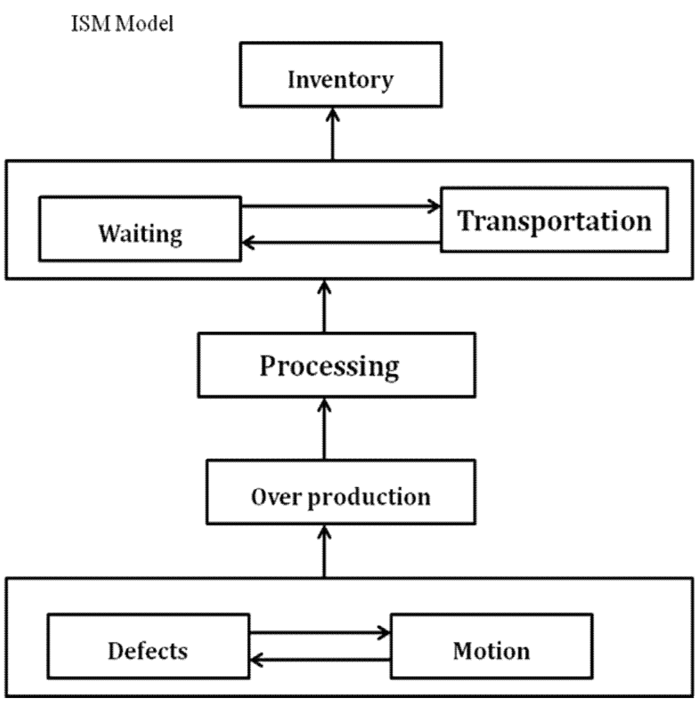

Figure 3 ISM Model –Digraph for seven waste

Step – 5 Analyze the relationship dynamics and categorize lean implementation challenges into groups (MICMAC analysis). The driving power dependence diagram Figure 4 is incorporated with four clusters namely autonomous (A), dependent (D), independent (I) and linkage (L). The significance of these clusters is explained in Table 6.

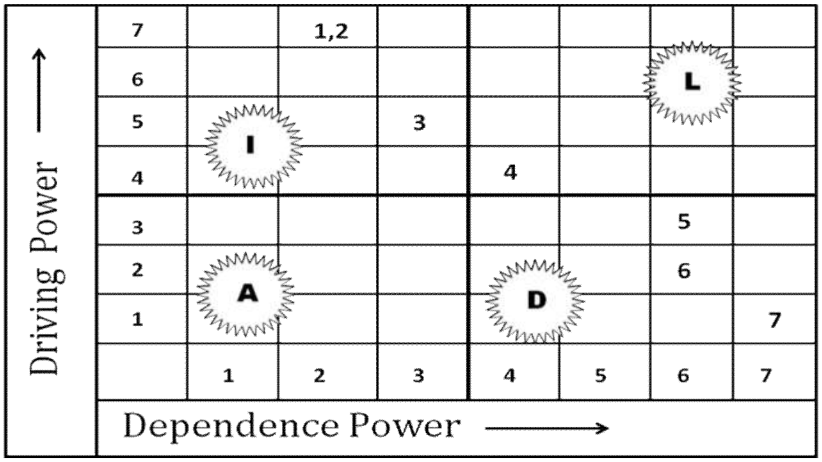

Figure 4 Driving power- dependence diagram

Table 6 Significance of Clusters

Cluster	Nature	Driving power	Dependence power	Position of Challenges.	Finding
A Autonomous	The challenges found in these cluster are relatively disconnected from the system.	Weak	Weak	--	No challenges found in this cluster indicates that all challenges considered plays a significant role.
D Dependent	The challenges found in these clusters are the followers of other challenges.	Weak	Strong	Waiting Transportation inventory	The industry should handle these challenges with special care.
I Independent	The challenges found in this cluster are the key drivers	Strong	Weak	Defects Motion Over-production	acute care should be practiced in handling these challenges.
L Linkage	The challenges in this cluster are considered as unstable.	Strong	Strong	Processing	monitoring is highly essential.

4. Conclusion

Most of the researchers contributed in analyzing the barriers / challenges that hurdle lean implementation. In their contribution they had also included waste elimination as a barrier or as a challenge. The main objective of this study is to analysis the interaction among the seven wastes which are globally accepted and widely found in literatures, and to develop a hierarchy that would help in understanding the wastes in a ceramic industry. Hence an ISM model treating seven waste as barriers / challenges is developed

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