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Ranking of the seven wastes (Muda) for Lean Six Sigma Implementation in Indian SMEs

Ramkumar P N*
Research scholar, Department of Mechanical Engineering
Government Engineering College, Thrissur, Kerala,
680009, India

Dr. Satish K P
Professor, Department of Production Engineering
Government Engineering College Thrissur,
Kerala, 680009, India

Praveen V Venugopal
Assistant Loco Pilot, Office of Chief crew Controller,
Tambaram Depot, Chennai, Tamil Nadu, 600045, India

Abstract:

Lean six sigma (LSS) is mainly waste elimination and defect reduction philosophy which can be done in several ways. Lean manufacturing tries for the elimination of the seven kinds of wastes which is also known as Muda and six sigma tries to reduce the variations in processing and hence defects. The seven wastes defined by lean literature are waiting, overproduction, inventory, over-processing, defects, transportation, motion. This paper investigates whether these seven wastes affect the performance of Indian Small and Medium enterprises (SME). SMEs are important manufacturing firms which contribute much in country's growth. If wastes can be eliminated or minimized in SME sector, their productivity increases and hence their performance. This research develops a new method to identify and rank the seven wastes (Muda) in the SMEs by using suitable questionnaire and method. Direct interview was used to collect information from the SME officials from whom the influence of seven wastes and the inter-relation among the seven wastes in die manufacturing firms was explored. Ranking of wastes were done according to their influence on other wastes in the die manufacturing units. This research is one of the basic steps of the researchers' methodology for implementing LSS in Indian manufacturing SMEs through a model named Identify, Rank, Define, Analyse, Improve and Control (IRDAIC).

Keywords: Seven wastes (Muda), waste matrix, Small and Medium Enterprises (SMEs), Lean Six Sigma, Identify-Rank-Define-Analyze-Improve-Control (IRDAIC)

1. INTRODUCTION

Considering the changes in market conditions, Indian SMEs are striving hard to stay competitive and profitable for a long-term period. One of the methods that can add value to the business is being able to recognise and reduce waste. The seven wastes which should be minimized according to the lean manufacturing practices are: Overproduction, Inventory, Over-processing, Motion, Waiting, Defects, and Transportation [1].

The Micro, Small and Medium Enterprises (MSME) sector has arisen as a highly pulsating and lively sector of the Indian economy over the last five decades. MSMEs generate enormous employment opportunities with comparatively low investment and hence endow significantly to the economic and social development of the country. The MSMEs are broadening their province across various sectors of the economy, manufacturing varied choice of products and services to meet domestic as well as global demands [2]. In literatures, the terms MSME and SME are interchangeably used; this study uses SME. The SMEs all over the world are facing a lot of challenges and problems in doing the business compared to large firms. Defects and most of the physical wastes are commonly visible directly to the operators and/ or the managers. But the wastes like over processing, overproduction, waiting etc are hidden and difficult to identify without measuring.

Paquin (1962) [3] quoted in his book that die design and manufacturing is a large division of tool engineering, is a complex, enthralling subject. The tool design and manufacturing are an art and it requires skilled labourers and precise manufacturing operations. The dies are the important device that make the quality of the final product. So, defects in dies, as well as cost of dies are important for the part manufactures. This research tries to identify and rank the seven wastes of 26 die manufacturing firms by using a questionnaire and analysis which help the organization to take action to reduce higher ranked wastes first.

The researchers developed an LSS based model IRDAIC as a continuation to this study. The model was aimed at SMEs to implement LSS by identifying and ranking their production wastes for improving the productivity. The model was tested and validated by implementing it in manufacturing firms.

2. WASTE RELATIONS

It is obvious that all types of wastes are dependent. Every one of seven wastes influences or vary the other six wastes. Similarly, each type of waste is influenced by others and resulting in increasing the production cost. [4]

For example, if the defect during production is becoming more, it is sure that over-processing will come as the defect part to be reworked. Transportation, waiting, motion etc may also increase when defect increases. In the same way, variations in over-processing, transportation etc. makes variation in waiting time.

It is clear that the relation between each waste may vary according to the condition existing in the particular industry as each industry considers the waste differently. For example, a manufacturer producing customized products may don't have Over-production but may have over-processing or any other. But a manufacturer producing FMCG may have much waste by overproduction.

3. LITERATURE REVIEW

Yamashita (2004) [5] conducted a study of implementing lean manufacturing at a company in Minneapolis area and found that higher quality products with less recourses and capital are achieved by reducing scrap, rework, returns, and waste through the implementation of lean manufacturing.

Domingo [6] in his lecture materials stated the importance of uncovering and eliminating the seven wastes to reach the goal of lean manufacturing.

El-Namrouty and AbuShaaban, 2013 [4] conducted study at Gaza strip to find out the interdependence of seven waste as well as relation between seven waste, lean manufacturing and production cost. The study concluded that, the identification of waste can foster lean implementation and can reduce the production cost significantly.

Praveen et al., 2015 [7] studied the effect of seven wastes in Indian SMEs and concluded that seven waste has their own influence in SME sector. The study also showed that the effect of seven wastes are not same.

Ramadas et al., 2016 [8] studied the relationship between number of defects, production cost and lean implementation at Indian SMEs. The study result showed managerial factors contribute towards the lean implementation.

Mwafak Shakoor et al., 2017 [9] conducted studies at five retail stores at distinct cities of UAE. The aim of the study was to identify the relation between benchmarking, lean implementation, takt and cycle times, resources and waste reduction. The study infers that reduction of resource as well as employees and the waste can reduce the waste and therefore cut the cost of providing retail service.

4. METHODOLOGY

From the literature review, the researchers identified that, seven wastes of lean manufacturing have a great influence in Lean Six Sigma (LSS) implementation in SME sector. Studies conducted in many countries, shows the importance of elimination of those waste in industries. During the initial studies, the researchers conducted a questionnaire survey to find out the influence of seven wastes in Indian SMEs. A suitable hypothesis is formulated and checked. The results reported that the seven wastes affect MSME sector, the effects of seven wastes are not same and each waste affects other wastes and also get affected by the other wastes.

If these wastes affect the production, there is possibility of interrelation in them. Therefore, the relation among them also needed to be found out. This paper tries to rank the seven wastes based on their interdependency by using another questionnaire. A questionnaire and method developed by El-Namrouty and AbuShaaban, 2013 was used for testing the interdependency in this study. Few changes have been made to the scale values, symbols used, relation weights etc of the questionnaire and method by the researchers. The managers of 26 die manufacturing industries responded the questionnaire, considering their working environment. The response was taken through direct interview by discussing the seven wastes and its effect on each other wastes. The questionnaire response was in a Likert 3-point scale. The analysis was completed using Microsoft Excel software. As a result of the analysis, a matrix was formed, which is termed as Waste Matrix. It clearly shows the rank of the seven wastes.

Once the relation among the waste was identified, ranking the wastes according to their influence on others to find out the most influenced waste has been done. After finding the most critical one, possible measures can be taken by the management to reduce or eliminate the critical waste which will thus, increase the performance of the organisation to great extent. When the critical waste is eliminated, automatically the wastes which are influenced by the critical waste also get reduced, which will reduce the loss to certain amount. After eliminating the waste having rank one according to the influence, waste having rank two can be selected and eliminated.

5. ANALYSIS AND RESULTS

In questionnaire, for testing relations between wastes, each type of wastes was denoted using its first letter (as O: Over-production, I: Inventory, P: Over-processing, M: Motion, W: Waiting, D: Defects and T: Transportation). Then, each relation was assigned by the symbol "i-j", For instance, "O-I" indicates the direct effect of overproduction on inventory, and so on.

The weights for each answer are directly recorded and the score was calculated and tabulated. After collecting opinion from all 26 die manufacturing firms, in order to create a final waste relation matrix, the mean of all the responses was found out. The mean values of 26 responses is given in table 1.

Table 1. Waste relation scores and weights

Waste Relation	1	2	3	4	5	6	Score	Weight
T-I	1.8077	1.8462	1.6538	1.7692	1.8077	1.6154	10.50	2
T-M	1.5385	1.3077	1.5769	1.6923	1.3846	1.6154	9.12	2
T-W	1.6154	1.7692	1.7692	1.8462	1.4615	1.5385	10.00	2
T-O	1.4231	1.3462	1.5385	1.3077	1.4615	1.5385	8.62	2
T-P	1.0769	1.0385	1.0385	1.0769	1.0769	1.0769	6.38	1
T-D	1.1923	1.7692	1.6538	1.6154	1.7308	1.5000	9.46	2
I-T	1.8462	1.8462	2.0385	1.8077	1.5769	1.4615	10.58	2
I-M	1.1538	1.1538	1.1538	1.2692	1.0385	1.2308	7.00	1
I-W	1.8077	1.7308	1.5769	1.7692	1.8077	1.6538	10.35	2
I-O	1.5000	1.5385	1.4615	1.3462	1.3462	1.4615	8.65	2
I-P	1.1538	1.0769	1.1538	1.0000	1.0385	1.0385	6.46	1
I-D	1.3077	1.5769	1.5000	1.7308	1.4615	1.3846	8.96	2
M-T	1.0000	1.0769	1.0385	1.0000	1.0385	1.0769	6.23	1
M-I	1.1923	1.1923	1.1538	1.0769	1.1538	1.0769	6.85	1
M-W	2.0000	1.9231	1.8462	2.0000	1.8077	2.0000	11.58	3
M-O	1.0000	1.0769	1.0000	1.0385	1.0385	1.0000	6.15	1
M-P	1.9615	1.8462	2.0000	1.7692	2.0385	1.7692	11.38	3
M-D	1.5385	1.3846	1.6154	1.5385	1.6154	1.3846	9.08	2
W-T	1.4231	1.5769	1.7308	1.5385	1.4231	1.2692	8.96	2
W-I	1.7308	1.8077	2.3077	1.9231	2.0000	2.0385	11.81	3
W-M	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	6.00	1
W-O	1.5385	1.4615	1.5000	1.6154	1.5000	1.2308	8.85	2
W-P	1.1154	1.6154	1.3077	1.3846	1.4231	1.6538	8.50	2
W-D	1.0769	1.3462	1.5000	1.4615	1.3077	1.3462	8.04	1
O-T	1.5769	1.5385	1.4231	1.3462	1.4231	1.5385	8.85	2
O-I	1.1538	1.5769	1.4231	1.4615	1.2308	1.3462	8.19	1
O-M	1.3462	1.2308	1.6154	1.4615	1.2308	1.3462	8.23	1
O-W	1.6538	1.5769	1.5385	1.5769	1.3077	1.4231	9.08	2
O-P	1.0769	1.0385	1.0385	1.1538	1.0000	1.0769	6.38	1
O-D	1.3077	1.5000	1.4615	1.3077	1.3462	1.3462	8.27	1
P-T	1.3462	1.2692	1.3846	1.2692	1.2308	1.1923	7.69	1
P-I	2.1923	2.0769	2.0769	1.9615	2.0385	2.1538	12.50	3
P-M	2.8846	2.4231	2.4615	2.7308	2.3846	2.5385	15.42	4
P-W	2.7692	2.7692	2.8077	2.7692	2.8077	2.7692	16.69	5
P-O	1.0000	1.0385	1.0000	1.0769	1.0769	1.1154	6.31	1
P-D	2.2308	1.8462	2.1923	2.2308	1.9615	2.0769	12.54	3
D-T	2.6154	2.1923	2.1538	2.0000	2.1154	2.2308	13.31	4
D-I	2.8462	2.1923	2.4231	2.6538	2.3846	2.2692	14.77	4
D-M	2.8846	2.4231	2.3846	2.2692	2.2308	2.3462	14.54	4
D-W	2.8846	2.5385	2.5385	2.7692	2.5769	2.5385	15.85	5
D-O	1.0769	1.3462	1.2308	1.1923	1.3462	1.1538	7.35	1
D-P	2.9615	2.8077	2.7308	2.5769	2.9231	2.8462	16.85	5

The score of each relation is found out by adding the points corresponding to six questions. For example, relation Transportation-Inventory score can be found out by

T-I = 1.8077+1.8462+1.6538+1.7692+1.8077+1.6154=10.5000.

Like this score of each waste relation was found out and recorded in score column. According to the score, the relation is classified into five ranges and weight is given to each relation as in table 2. The absolute necessary relation is given most weightage and unimportant relation is given least weightage.

Table 2. Type of relation and weight according to relational score

Range	Type of Relation	Weight
15.61 to 18.00	Absolutely necessary	5
13.21 to 15.60	Especially important	4
10.81 to 13.20	Important	3
8.41 to 10.80	Ordinary closeness	2
6 to 8.40	Unimportant	1

The weights of each and every relation were recorded in the table 3 according to each waste relation. That is from table 1, the relation between T-I was scored 10.50 and weighted as "2" with an ordinary closeness.

Table 3. Wastes Matrix

	T	I	M	W	O	P	D	Score	%	Rank
T		2	2	2	2	1	2	11	12.09	5
I	2		1	2	2	1	2	10	10.99	6
M	1	1		3	1	3	2	11	12.09	4
W	2	3	1		2	2	1	11	12.09	3
O	2	1	1	2		1	1	8	8.79	7
P	1	3	4	5	1		3	17	18.68	2
D	4	4	4	5	1	5		23	25.27	1
Score	12	14	13	19	9	13	11	91		
%	13.19	15.38	14.29	20.88	9.89	14.29	12.09			

In the table 3 score was calculated by adding all the weights for each waste in row-wise and column-wise. For illustration, transportation "T" row-wise score is 2+2+2+2+1+2=11 and column-wise score is 2+1+2+2+1+4=12. The percentage is obtained by dividing this score to the total score, i.e. 11/91*100 for row and 12/91*100 for column. Likewise, for each waste the values were found and tabulated.

The highest percentage obtained for row-wise calculation is for the waste which affects the other wastes most critically. The highest percentage in column-wise calculation is for the waste which is affected more by other wastes. From table 3, "defect" was the most critical waste which is affecting other wastes in the die manufacturing industry. Similarly, "waiting" was the most critical waste which is getting affected by all the other wastes.

Considering the row-wise descending percentage, the wastes are ranked and tabulated at the prearranged column of waste matrix. If tie comes in percentage, the "waste" with higher percentage in column-wise value was granted the higher rank.

El-Namrouty and Abushaaban (2013), in their studies considered both the ranks according to wastes which affects the other wastes and wastes which get affected by other wastes. But in this study, the researchers only concentrated to rank the waste based on their affect to other wastes. Similarly, the scale taken in the questionnaire of El-Namrouty and Abushaaban (2013), was 1, 3 and 5. Whereas, here it was 1,2 and 3. The weight given by the previous research were 2, 4, 6, 8 and 10 and in this research it was 1, 2, 3, 4 and 5.Slight modification in the questionnaire (Table 4 at appendices section) also made with the help of pilot study and direct discussions with subject experts.

6. DISCUSSIONS AND CONCLUSIONS

From the initial studies conducted by the researchers, it was learned that, SMEs are suffering from the seven types of waste in their processes and seven wastes of lean manufacturing are dependent to each other. The wastes within the company decrease the productivity as well as increase the production cost.

From this research which focused exclusively on die manufacturing industries to rank the inter-related wastes. The result shows that the "defect" is the waste which is affecting the other wastes more critically and "overproduction" is the waste which is influencing other wastes least. In the same way, "waiting" is the waste which is critically influenced by other wastes and "overproduction" is the waste which is influenced least by other wastes.

The ranks obtained from this study in the ascending order as Defect- Over processing- Waiting- Motion- Transportation- Inventory- Overproduction.

The researchers developed an LSS based IRDAIC model as a continuation to this study. The model tries to reduce the waste with rank one first and so on. The model was implemented in various SMEs and the results were studied. The result showed

significant improvement in the productivity through reducing the production waste.

The result showed that identification and quantifying of wastes makes the management more cautious for practising waste reduction tool, which helps the firms to improve their performance. Hence this methodology could be useful for SMEs to implement LSS in an easier way.

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APPENDICES:

Table 4: Questionnaire used for this study.

Name of the organization:					**Name of Respondent:**	
Scale of the organization:	Micro	Small	Medium	Large	**Email id:**	
Products Manufacturing:					**Contact No.**	

Question (Tick on the appropriate weight)	**Weight**
1- Does "i" produces "j"?	
Always	3
Sometimes	2
Rarely	1
2- Relation between "i" and "j"?	
"i" increases "j" increases	3
"i" increases "j" reaches a constant level	2
No visible relation	1

2- The effect of "i" due to "j"?	
Appears directly and clearly	3
Often appears, but difficult to understand the relation	2
Rarely appears	1
4- Eliminating the effect of "i" on "j" is achieved by?	
Engineering and complex methods	3
Simple and direct	2
Not bothered	1
3- The effect of "i" due to "j", mainly influences on?	
Quality and productivity	3
Any one of Quality of products only/ Productivity of Resources only	2
No identifiable influences	1
6- In which degree does the effect of "i" on "j" increases Manufacturing Lead time?	
High degree	3
Medium degree	2
Low degree	1

Biographical notes:

Ramkumar P.N. is a Doctoral research scholar in the mechanical engineering department of Government Engineering College, Thrissur, Kerala, India. He holds a bachelor degree in mechanical engineering and master's degree in production Management. He has more than 8 years of teaching experience, which includes 5 years of research experience. His research interest includes lean manufacturing, six sigma and theory of constraints.

Dr. Satish K.P. is a Professor in the Department of Production Engineering at Government Engineering College, Thrissur, Kerala, India. He had his PhD in the Faculty of Engineering, from the Indian Institute of Science, Bangalore, for his research works in the area of Total Quality Management. He has more than 28 years of experience in various fields of academics, research and industry. In addition to regular teaching activities he is also guiding doctoral research scholars in their pursuit of research under University of Calicut and APJ Abdul Kalam Technological University. He is also holding various administrative positions in his institution. He has to his credit more than 30 publications in International Journals, International and National Conferences.

Praveen V. Venugopal is assistant loco pilot in Chennai division of Indian Railway. He holds a Bachelor degree in mechanical engineering and masters in manufacturing systems management. His research interest includes lean principles, total quality management and strategic management.