International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 06 | June 2018 www.irjet.net p-ISSN: 2395-0072

An Empirical Analysis on Lean Approach in Product Development Process in Small and Medium scale Enterprises(SMEs)

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Abstract -The purpose of this work is to analyze the level of recognition of product development process, lean concepts, lean principles, lean tools and techniques in different Small and Medium scale Enterprises in India. The general aim of this work is to determine the lean awareness and understand the contribution of industries towards the lean approach in product development process. Specific objective of this work is to asses lean awareness and lean approach in product development process by Cronbach's Alpha approach. This approach computes Cronbach's Alpha test and the analysis towards lean awareness and lean approach in product development process. It is found to be (0.77) and the selected sectors found to be "Acceptable". The work considered various Small and Medium scale Enterprises.

***Key Words*: Product development process, Lean principles, Lean practices, Lean development**

1.INTRODUCTION

The principles of lean production, or Lean Manufacturing (LM), were developed in the 1960s by Toyota as an evolution of the concept of integrated production and structuring of production practices that were adopted in Toyota plants. This philosophy and management approach were summarized in five principles: value, value stream, flow, pull production and perfection. These principles are associated with the search for overcoming the seven basic types of waste identified as chronic by the Toyota Production System: waiting, overproduction, transportation, defects, inventory, handling and unnecessary processing.

1.1 Background

Lean manufacturing is essential for small and medium enterprises (SMEs) (Dora et al., 2014[1]).SMEs play a very important role in the economy of any country, and it is more so in a developing country like India. They play a role in boosting the economy of a country. SMEs contributes almost 40 percent of the gross industrial value added in the Indian economy. It is estimated that there are over 11 million SMEs in the country today, which comprise 90 per cent of all industrial units. The SMEs alone contribute to 6 per cent of India's gross domestic product (Jeswal, 2012[2]). As per the Third All India Census of Small Scale Industries conducted in 2004, the SMEs have increased from about 80,000 units in 1940s to about 10.52 million units. Their total employment is about 25 million, and they produce about 7,500 products including high-technology products (Srinivasan and Joseph, 2008[3]). In Indian scenario, the government is taking lot of efforts to implement lean principles in SMEs using cluster approach. To enable systematic implementation leanness assessment needs to be done to measure level of implementation of lean in each process. In this context, this article presents a model for leanness assessment incorporated with enablers, criteria and attributes for SMEs. The unique contribution of the study is that a leanness evaluation method has been proposed exclusive for SMEs. The practical relevance of the model has been tested in an Indian SME. To overcome vagueness and ambiguity associated with leanness assessment, Cronbach's Alpha Test has been used. The leanness assessment approach computes Cronbach's Alpha Value, to a analyze the lean awareness level to identify weaker areas. After identifying the weaker areas, proposals for leanness improvement have been identified. The proposals were subjected to implementation in SME for lean performance improvement.

1.2 Cultural Issues in Lean Implementation

Besides the nature of the business environment in India, other prominent challenges to lean and lean thinking as well as lean implementations in industries in India include: (a) how to deploy lean thinking in an environment characterized by intricate relationships mentioned in the previous paragraphs, (b) how to identify the right starting point for lean implementation and lean implementation programs, (c) how to engage, in a meaningful way, a workforce that has tirelessly implemented a number of other scientific management systems, (d) how to deploy lean in ISO-certified industries that have successfully delivered targets as per shareholder requirements, and (e) how to overcome the forces of production uncertainties and lean change requirements that may actually disrupt and/or counter efforts in lean implementations. While a number of lean theories and concepts exist, it is important to explore the applicability and extent of applications of such theories in the context of their applications. To this end, exploratory and

empirical studies can provide more insight and an in-depth understanding of how lean dynamics and lean thinking can be re-packaged for sustainable and successful lean transformations in Indian industries.

2.LEAN DEVELOPMENT

A lean approach to product development is a valuable asset and its base is the importance of appropriate integration of people, processes, tools and technologies to add value to the consumer and society (Morgan & Liker, 2006[4]). Two factors support this premise. Firstly, while the gap on the performance of production decreases, the difference between the best performance and the rest of the competitors concerning the development of products tends to increase. In addition, the current levels of efficiency in manufacturing presage that the focus on production will have diminishing returns in the future. Second, even if a strong production system can influence the quality and productivity, the ability to influence the value set by the consumer is much higher in the early stages of the product development process and decreases as the development nears release stage of the new product. The authors prepared a summary presented in Table-1, which identifies the tools that are best suited to treat the PDP waste.

2.1 Lean Principles in Product Development Environment

Mascitelli (2004)[5] presents the development of lean product with the main goal of achieving integration between product development activities and the manufacturing process, i.e., a type of co-development. The author presents five principles for lean product development:

Principle 1: Define precisely the customer's problem and identify the specific function to be performed to resolve the problem;

Principle 2: Identify the process faster by which the identified functions can be integrated into a low cost and high quality product;

Principle 3: Remove any waste item and redundant or unnecessary cost, to reveal a great product solution;

Principle 4: Listen often and interactively to the voice of the customer throughout the development process;

Principle 5: Introduce methods and cost reduction tools both in their business practices and in their culture, to allow continuing cost reduction.

2.2 Lean Practices in Product Development

Dal Forno et al. (2008)[6] present a compilation of the main lean practices in the development of products mentioned in the literature:

Value Stream Mapping: aims to develop a picture of the current state to view some waste and calculate the lead time. After, in the future state map and action plan, improvements are planned;

Visual management: visual management, whether electronic or physical form, consider the standardization, in order to facilitate a common understanding of the team, it makes them visible problems and shows the project scope with quality indicators, time and cost.

SBCE: On Set Based Concurrent Engineering, the entire development team establishes and develops a set of parallel and independent alternatives through the stages of the PDP and at the end, the best alternative is generated and tested in order to do it right the first time (Schäfer & Sorensen, 2010[7]; Madhavaram & Appan, 2010[8]).

3.RESEARCH METHODOLOGY

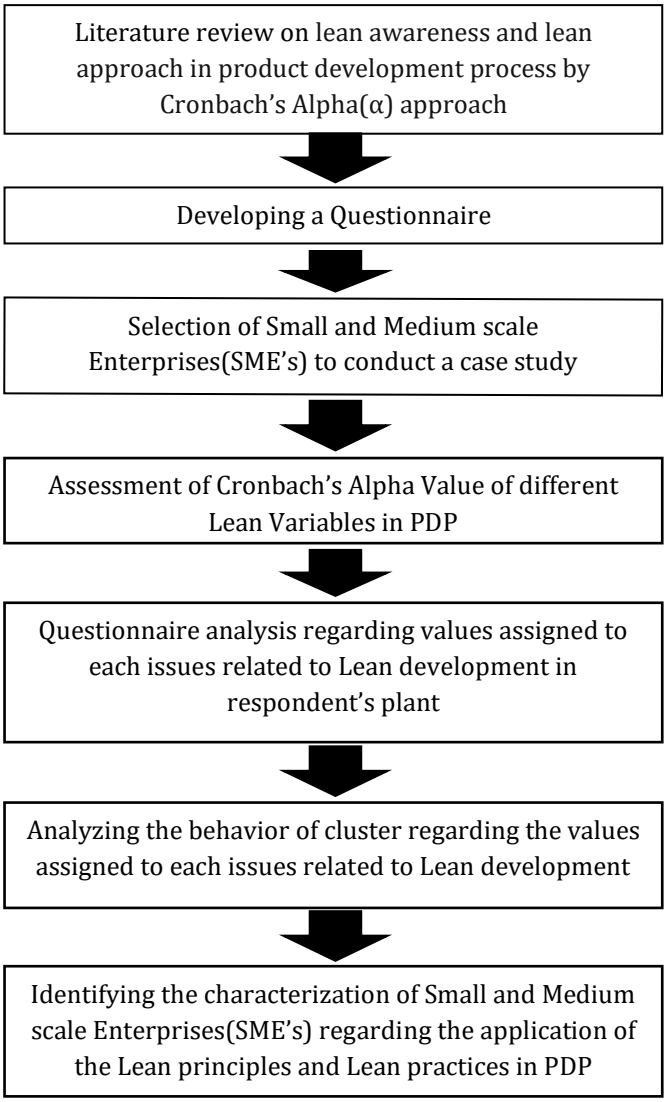


Table-1: Application of tools of Lean Manufacturing in Product Development Process wastes

Product Development Process Waste	Applicable Lean Tools
Waiting	Mapping the value stream
	Total productive maintenance
	Improved customer / supplier relation
	Reducing the number of suppliers
	Synchronized production
	Receipt / supply just in time
Transport	Mapping the value stream
	Group technology
	Work in continuous streaming / reduction of the lot size
	Total productive maintenance
Movement	Mapping the value stream
	Work in continuous streaming / reduction of the lot size
	5S
Unnecessary Processes	Mapping the value stream
	5S
Stock	Mapping the value stream
	Work in continuous streaming / reduction of the lot size
Overproduction	Mapping the value stream
	5S
	Synchronized production
Defects	Mapping the value stream
	Quality control tools
	Zero defect
	Failsafe tools

3.1 Small and Medium Enterprises

The present work focuses on assessing lean awareness and perception of lean implementations in various industrial sectors in India. The population of interest for this study consisted of a number of companies categorized, for purpose of analysis, as follows; (a)Automobile, (b) Pump, (c)Garments, (d)Hygiene and Health, (e)Steel, (f)Foundry. Chart-1 shows the Distribution of Respondents with respect to Industrial Sectors.

3.2 Research Variables

Research variables used to develop the questions contained in the questionnaire, which were used in the analysis of the results, were determined from the literature on the principles and practices of Lean Development. Hence, the analysis of the results from these variables allows the results to be evaluated in terms of the principles and lean product development practices of the companies analyzed.

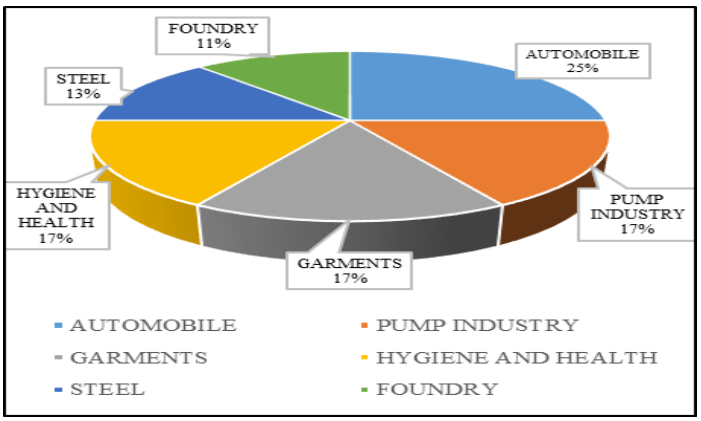


Chart-01: Distribution of Respondents with respect to Industrial Sectors

Table-2: Research Variables and their elements and questions where they are contained

Variable (V)	Elements	Questionnaire Questions
V1: Lean Development Tools	Value stream mapping application in PDP	1, 2, 3, 4, 5, 8 and 9
	Use of SBCE	
	Visual management of ongoing projects	
V2:Lean Development Principles	Application of lean concepts in PDP	6, 7, 10, 11 and 12
	Dedicated project teams existence	
	existence of a project leader / chief engineer with extensive	
	experience in the project area	
	Development of the technical capabilities of the Development Engineers	
	Senior management involvement in all stages of the PDP	
	Re-Use of existing knowledge	
	Integration between areas of PDP and manufacturing	

Before testing the relationship between the different types of variables identified, Forza (2002)[9] states that it is necessary to translate them into observable operational elements and / or subject to measurement, i.e. to perform the operation of the constructs, by presenting elements that will be taken as the basis of observation to analysis of each construct. For this, the variables were deployed into a set of elements that could transcribe or illustrate more clearly these variables in the structured questionnaire. Each variable can be directly or indirectly related to one or more questions of the questionnaire, through its elements. The research variables, their respective elements deployment and the questions in which they are contained are shown in Table -2.

3.3 Analysis Units

The choice for analysis units that have the Lean Manufacturing was given by the fact that they should already be in possession of lean concepts, and this fact may be seeking to apply these concepts in other areas of the organization, e.g., in product development process. Moreover, if the company has a performance level evolved in Lean Manufacturing, it is expected that it seeks to apply these concepts in product development, which is a process that precedes production and therefore the company could improve more the production performance if it also has lean concepts implemented in the PDP.

The selection, according to the sources used, resulted in a population identified of 70 companies to which the questionnaire was submitted, and 85.7% of these companies, i.e., 60 companies returned completed questionnaires. Among the 70 companies, 7 were ignored and 3 were not replied. Chart-2 shows the No of companies replied, ignored and not-replied.

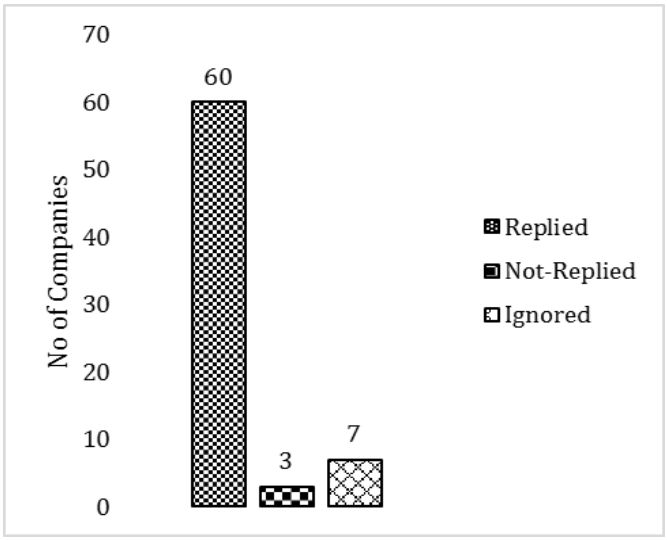


Chart-2: No of Companies replied, Not Replied & Ignored for the Questionnaire analysis

4. RESULT

4.1 Descriptive Analyses of Companies

This section presents the descriptive characterization of the 60 companies.

Table-3: Companies Market/Industry

Market/Industry	No of Companies
Automobile	15
Pump	10
Garments	10
Hygiene and Health	10
Steel	8
Foundry	7

Adopting the criteria for classification of the size of the companies which takes into account the number of employees, it was observed that 87% of the sample is made up of Medium Enterprises (considering the size of the interviewed unit) and the remaining 13% are Small Enterprises.

The area of performance of the professionals interviewed was the product development area, since the purpose of this paper is founded on the implementation of lean concepts in the product development process. Once the study of contextual factors of the organization requires that the respondent has an insight into both the micro process acting as the macro process in which it operates and also the organization as a whole, questionnaires were sent to the care of the head of PDP. Chart-3 shows the distribution of positions of the professionals who answered the questionnaire.

Regarding the degree of importance that the PDP has within the company's competitiveness strategy, all respondents believe that product development has a high degree of importance in the competitive strategy of the company. It is expected that companies that have this high degree have more strategic interest in allocating resources in the PDP, seeking effectiveness and efficiency of these investments, and may thus be more advanced at the level of implementation of lean concepts in the PDP.

It is also expected that companies with a greater coverage of PDP scope to have a greater interest in the allocation of resources to this process. Chart-4 shows the coverage of the PDP scope of the evaluated companies. For the classification of the coverage of the PDP scope, we used the following scale:

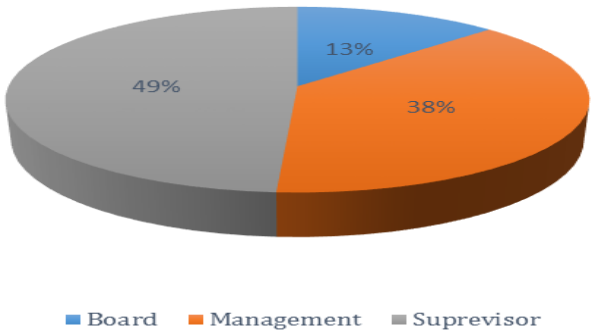


Chart-3: Area of the interviewed employees

Low - only minor changes / adjustments in existing products;
Average - small and large changes / adjustments in existing products;
High – small and minor changes / adjustments in existing products and the development of new products and / or technologies.

Approximately 80% of the sample's companies have a high coverage of the PDP scope, which makes sense when compared to the fact that all have the product development area interviewed plan and also consider that the PDP has a high degree of importance in the competitive strategy of the company.

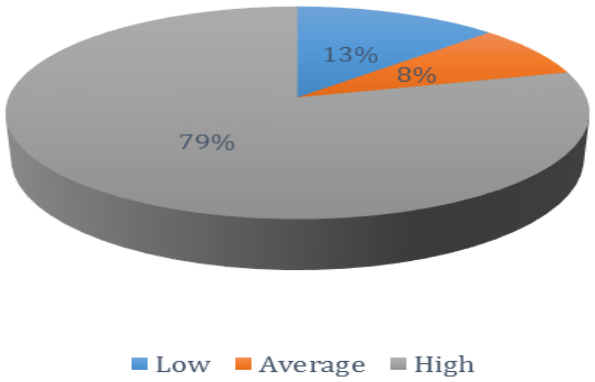


Chart-4: Coverage of PDP scope of the Companies

4.2 Descriptive Analysis in relation to the Lean Development Application

Table-4 shows the information regarding the frequency of notes assigned to the research variables (questions) on the Lean Development presence in the respondent's plant, as well as their respective means, standard deviations and Cronbach's Alpha Value.

It can be observed that the overall average of the variables in relation to Lean Development in the respondent plant is 0.77, which indicates that Lean Development is perceived as Poor in the companies.

The answers showed the average of Lean Development Tools(V1) were questions 1, 2, 3, 4, 5, 8 and 9 with averages of 0.77, 0.79, 0.78 0.81, 0.80, 0.75 and 0.77 respectively and the average of Lean Development Principles such as questions 6, 7, 10, 11 and 12 with average of 0.78, 0.75, 0.82, 0.76 and 0.76

Questions 4 and 5, regarding the use of SBCE, a basic and specific tool of LD showed the highest use of this tool, with averages of 0.81 and 0.80, the internal consistency of the Cronbach's Alpha is Acceptable. Concerning the application of value stream mapping tool, represented by questions 1, 2 and 3 are relatively slightly larger, with average respectively of 0.77, 0.79 and 0.78. According to Cronbach's Alpha Internal consistency was Acceptable.

The cluster analysis, presented in the following section, will complement the analysis of the results, so that it is possible to obtain a more robust conclusion.

4.3 Cluster Profile

The analysis shows the formation of 6 clusters. Chart-5 illustrates the Cronbach's Alpha Value of Small and Medium scale Enterprises and the Chart-6 illustrates the overall Cronbach's Alpha Value of the Industrial Sectors.Chart-7 illustrates the Questionnaire Analysis regarding values assigned to each issue related to Lean Development in the respondent plant and Chart-8 illustrates the Behavior of Industries regarding values assigned to each question

4.4 Automobile Industry

The Automobile cluster represents 25% of the sample, i.e. it is composed of 15 of the 60 companies in the sample. This cluster is formed by companies from all sectors of the sample and according to Cronbach's Alpha Internal consistency for both the application of lean principles and application of lean practices is "Acceptable".

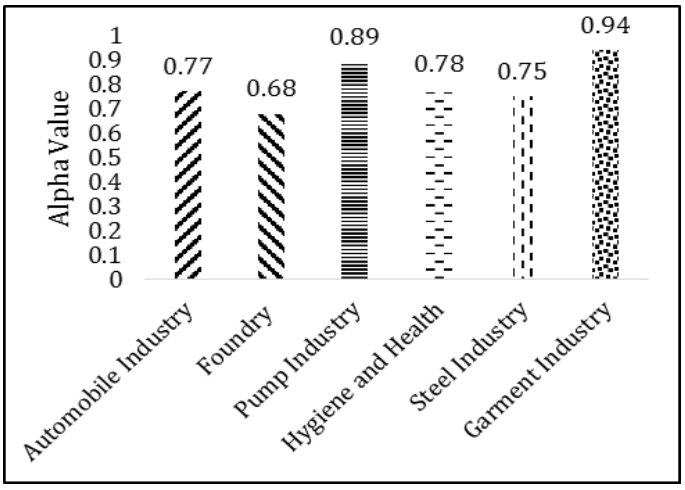


Chart-5: Cronbach's Alpha Value of Small and Medium scale Enterprises(SME's)

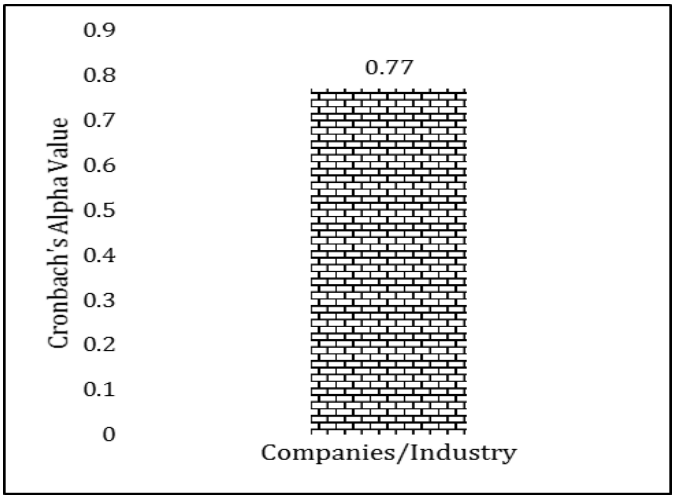


Chart-6: Overall Cronbach's Alpha value of Small and Medium scale Enterprises(SME's)

4.5 Foundry

The Foundry cluster represents 11% of the sample, i.e. it is composed of 07 of the 60 companies in the sample. This cluster is formed by companies from Foundry Industry sectors of the sample and according to Cronbach's Alpha Internal consistency of both Lean Development Tools (V1)and Lean Development Principle(V2) is "Questionable".

4.6 PUMP

The Pump Industry cluster represents 17% of the sample, i.e. it is composed of 10 of the 60 companies in the sample. This cluster is formed by companies from Pump Industry sectors of the sample and according to Cronbach's Alpha Internal

Table-4 Structured Questionnaire

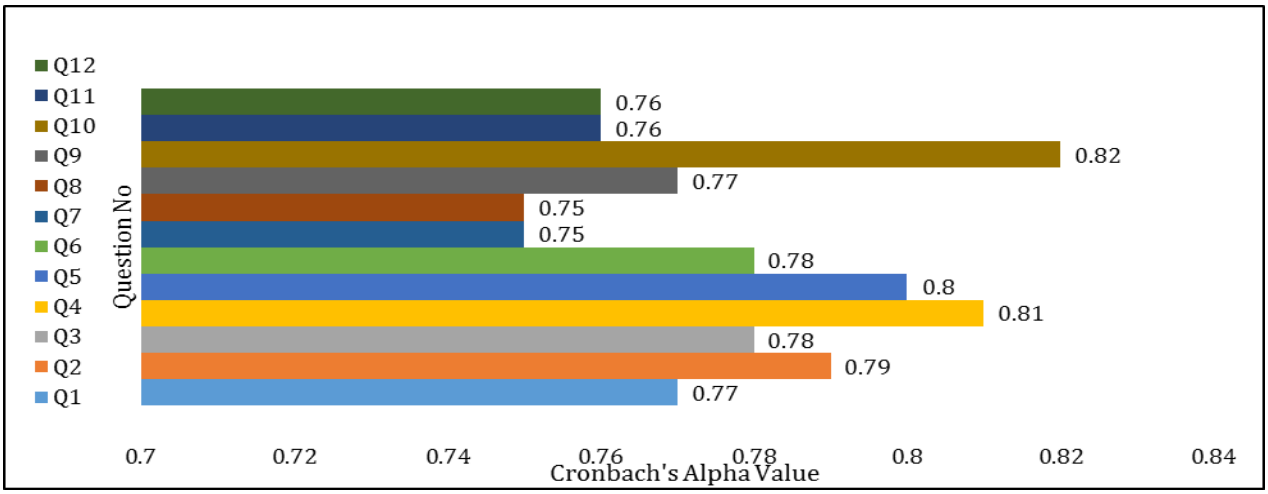
S.NO	QUESTION	1 NEVER	2 IN MINORITY TIMES	3 SOME TIMES	4 MOST OF THE TIME	5 ALWAYS	AVEREGE	STANDARD DEVIATION	CRONBACH'S ALPHA
		RESPONSE RATE(% and No of Companies)							
1	Does the company (plant) apply the value stream mapping (VSM) in the product development process?	15.00	13.35	53.30	16.66	1.10	19.98	19.67	**0.77**
		9.00	8.00	32.00	10.00	1.00			
2	Are improvement tools applied to the waste points identified in the value stream mapping of the PDP?	18.33	45.00	28.33	5.00	3.33	20.00	17.32	**0.79**
		11.00	27.00	17.00	3.00	2.00			
3	Is the value stream mapping done after the application of improvement tools in waste points Initially identified?	18.33	45.00	28.33	8.33	0.00	20.00	17.56	**0.78**
		11.00	27.00	17.00	5.00	0.00			
4	Does the company (plant) begin to develop all alternative of project solution identified early in the project? Does it eliminate the solutions as they present failures until it reaches a single final solution?	3.33	75.00	13.33	1.66	6.66	20.00	31.07	**0.81**
		2.00	45.00	8.00	1.00	4.00			
5	The company does not define the product specifications before starting the development of it, but only as the project progresses and few solutions are being developed, so that the capacity of these solutions meet the requirements define the product specifications.	28.33	56.66	5.00	8.33	1.66	20.00	22.97	**0.80**
		17.00	34.00	3.00	5.00	1.00			
6	Does the company (plant) elect a chief engineer/ leader for each project of a new product with high technical and managerial experience and with at least 5 years of experience in the project area?	1.66	5.00	25.00	50.00	18.33	20.00	19.29	**0.78**
		1.00	3.00	15.00	30.00	11.00			

Table-4 Continued

S.NO	QUESTION	1 NEVER	2 IN MINORITY TIMES	3 SOME TIMES	4 MOST OF THE TIME	5 ALWAYS	AVEREGE	STANDARD DEVIATION	CRONBACH'S ALPHA
		RESPONSE RATE(% and No of Companies)							
7	Does the company (plant) develop the technical Capabilities of each product development engineer favoring the improvement and deepening expertise in their areas?	0.00	6.66	45.00	40.00	8.33	20.00	20.85	**0.75**
		0.00	4.00	27.00	24.00	5.00			
8	Are the main targets deadlines, critical points and progress of the projects are available in a clear and visual way for all areas involved in the project?	16.66	0.00	11.66	45.00	26.66	20.00	16.96	**0.75**
		10.00	0.00	7.00	27.00	16.00			
9	Are the available data in a clear and visual way for the project team, described in the previous question, constantly updated?	18.33	1.66	25.00	38.33	16.66	20.00	13.34	**0.77**
		11.00	1.00	15.00	23.00	10.00			
10	Is the senior management of the plant involved in all stages of the product development process?	5.00	10.00	5.00	58.33	21.66	20.00	22.48	**0.82**
		3.00	6.00	3.00	35.00	13.00			
11	Are the people who acquire specific technical knowledge to develop a project allocated to the development of new projects that use the same knowledge?	5.00	6.66	21.66	41.66	25.00	20.00	15.00	**0.76**
		3.00	4.00	13.00	25.00	15.00			
12	Is the integration between the areas of manufacturing and product development high?	0.00	0.00	13.33	80.00	6.66	20.00	33.99	**0.76**
		0.00	0.00	8.00	48.00	4.00			
Cronbach's Alpha Value									**0.77**

Table-5: Characterization of Company/Industry regarding the application of the principles and Lean Practices in their PDP

Industry/Company	Number of Companies	% Samples	Research Variable	
			Lean Development Tools	Lean Development Principles
Automobile	15	25	Acceptable	Acceptable
Foundry	7	11	Questionable	Questionable
Pump	10	17	Good	Good
Hygiene and Health	10	17	Acceptable	Acceptable
Steel	8	13	Acceptable	Acceptable
Garments	10	17	Excellent	Excellent



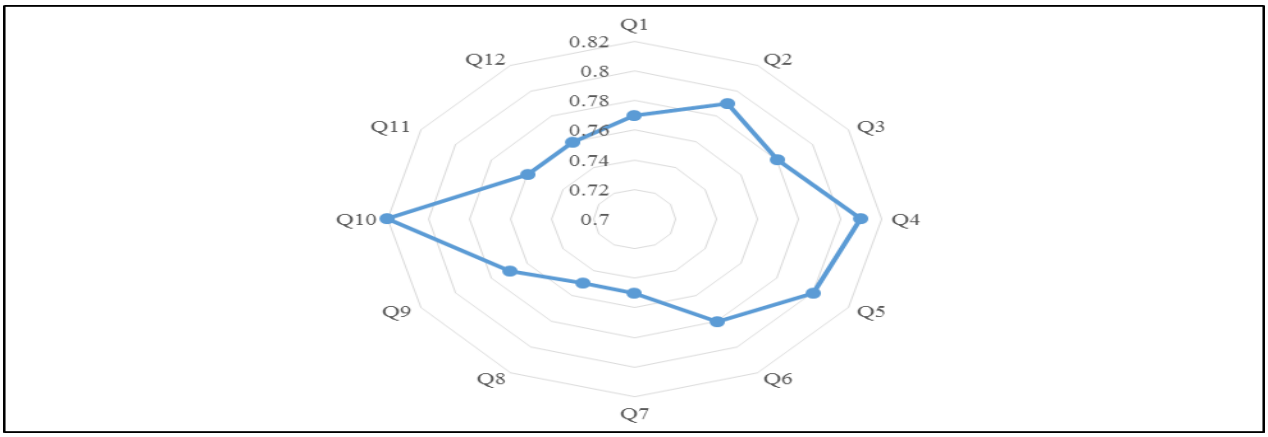


Chart-07: Questionnaire Analysis regarding values assigned to each issue related to Lean Development in the respondent plant in the form of Bar Chart and spider chart

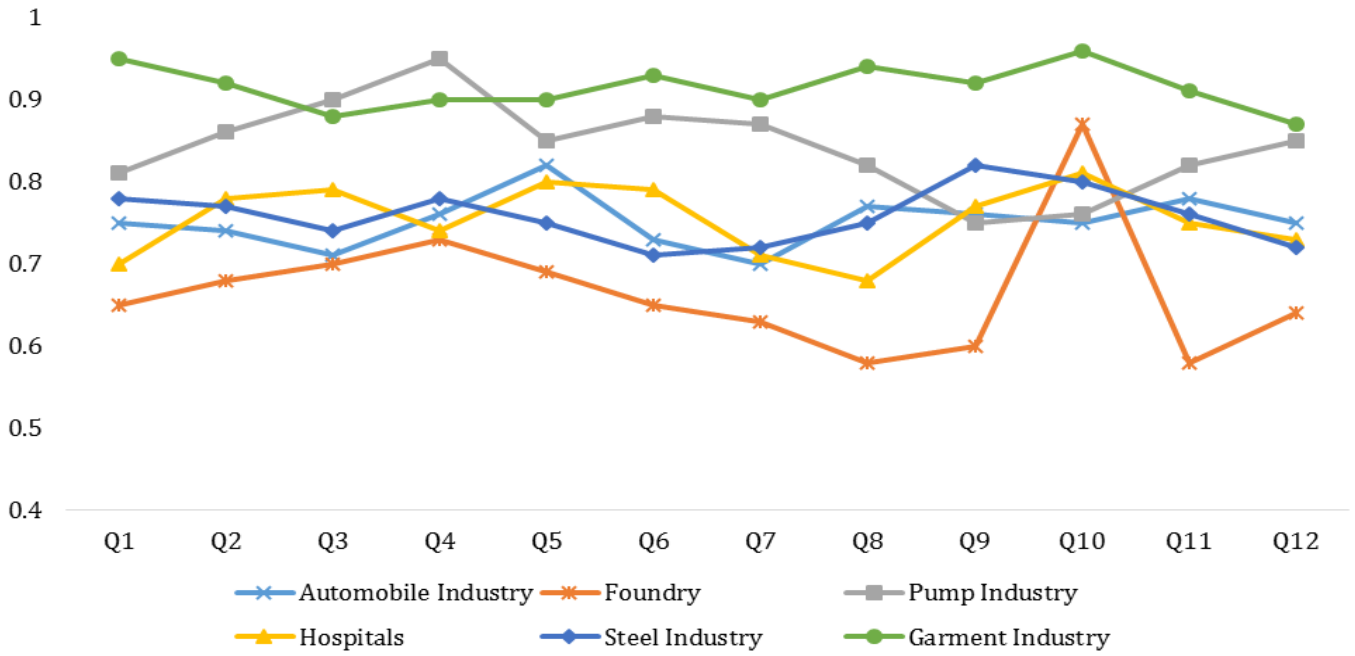


Chart-08: Behavior of clusters regarding values assigned to each issue related to Lean Development in the respondent plant consistency of both Lean Development Tools(V1)and Lean Development Principle(V2) is "Good".

4.7 Hygiene and Health

The Hygiene and Health cluster represents 17% of the sample, i.e. it is composed of 10 of the 60 companies in the sample. According to Cronbach's Alpha Internal consistency of both Lean Development Tools(V1)and Lean Development Principle(V2) is "Acceptable".

4.8 Steel

The Steel Industry cluster represents 13% of the sample, i.e. it is composed of 08 of the 60 companies in the sample. This cluster is formed by companies from Steel Industry sectors of the sample and according to Cronbach's Alpha Internal consistency of both Lean Development Tools(V1)and Lean Development Principle(V2) is "Acceptable".

4.9 Garments

The Garment Industry cluster represents 17% of the sample, i.e. it is composed of 10 of the 60 companies in the sample. This cluster is formed by companies from Garment Industry sectors of the sample and according to Cronbach's Alpha Internal consistency of both Lean Development Tools(V1)and Lean Development Principle(V2) is "Excellent".

Table 3 shows the comparison of these results, showing the characterization of clusters for the application of the principles and lean practices in their PDP.

According to the Statistics area of literature, a typical observations should be considered not to introduce a bias in the estimation of data grouping structure, or cluster (Hair et al., 2006). Therefore, as the authors conclude, efforts should be made to examine whether the results can be generalized to the population of interest.

5.Conclusion

Most of the companies (85.7%), seeks to use the lean development through the application of lean principles and practices in the product development process.

About half of the companies (42.8%) not transferred to lean principles learned from Lean Manufacturing for the PDP, and still failed to apply lean practices of product development.

Only about 20% of companies could, in addition to the principles also apply lean practices, albeit moderately. This allows question whether these companies have actually learned the Lean approach, with its principles, practices, and understood the importance for consolidation, to incorporate the principles and practices in the PDP.

It is true that one of the lean practices, SBCE, is an innovative way to develop new products, which goes against common sense in the area, which requires more knowledge and

experience of the project team, which hinders the implementation of this practice and requires greater maturity of the PDP.

It is recommended to identify and analyse the reasons why the number of companies not to extend the principles and lean practices learned in the LM for the product development process. It is possible that some companies are not yet aware of the possibility of transferring the LM concepts to other areas of the company.

In addition, some companies may consider having the LM deployed in production, without having it in fact. Apply some concepts and tools alone does not mean, in fact, to have the Lean Manufacturing implemented and to obtain sufficient knowledge and belief to extend its application in the production chain.

Also, the cultural issue of some companies, as well as specific product development subculture which in some cases can prioritize the convenience of viewing little standardization and greater degrees of freedom in the conduct of PDP activities, can interfere in this transfer process learning.

It is common, e.g., the view that the dynamism and creativity of specific PDPs are inconsistent with concepts and practices of standardization and continuous improvement. Another hypothesis is that companies can not be managed applying the LM concepts successfully and therefore, can not see gains in applying them in other areas. Either way, a study to clarify this question is quite relevant.

A possibility of continuing the research is to review the questionnaire and seek ways to achieve a significantly larger sample of companies.

The results presented in this study are a rich source of data for the beginning of understanding the current situation of LD in Indian companies.

The same can be used as a starting point for further studies, such as case studies or action research that approach not only a practice or a lean principle specifically, but, the set of practices and lean principles so that the LD can be, indeed, evaluated and understood as a whole.

A better understanding of this phenomenon may contribute to the definition of practices and guidelines, from an academic and business consulting point of view that can contribute to better implementation and overcoming difficulties in the use of LD.

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