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Critical success factors of lean manufacturing for Indian ceramic industries: Modelling through interpretive ranking process

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In India, majority of manufacturing organizations comes under small and medium size enterprises (SMEs) that are recognized as backbone for the economy by contributing a significant amount in gross domestic product (GDP). In the competitive business environment, SMEs are trying to enhance the value of their production and services on decimating the non-productive activities from their manufacturing systems. It has been reported in previous explorations that lean manufacturing (LM) is an approach to recognize and eliminate different forms of waste from the production process, and improve the business performance. Therefore, SMEs has to follow lean manufacturing to ensure sustainable profitability. To optimise the LM implementation benefits, organization/s must see the different success factors thoroughly. So far, critical success factors (CSFs) of lean manufacturing in labour intensive SMEs were not explored systematically. In this study, CSFs for implementing lean are extracted from literature and were analysedand validated after discussion held with relevant industrial experts/academicians. Interpretive ranking process (IRP) technique was employed to observe the relationship amongst the CSFs. To check the interpretations and pair-wise comparison, a dominance system graph for each performance measures was developed. The results revealed that regular training and education for workers, proper selection of lean tools/techniques and low scrap/rework/elimination of waste are the most CSFs for implementing lean in Indian ceramic SME sector.

Keywords: Lean manufacturing, Critical success factors, Ceramic industry, Interpretive ranking process (IRP), SMEs

1 Introduction

In globalization and world-wide competitive market, the revenue generated by industries is going down and manufacturing resources are getting costly. Therefore, manufacturing businesses are searching to adopt new manufacturing strategies which enhance the production performance. To keep competitive or even survival many manufacturing industries are adopting concept of Lean Manufacturing (LM). Lean manufacturing is a novel concept in manufacturing which is focused on minimizing the non-value added activities or "lean waste" and delivers sustainable competitive benefits to organizations[1]. There are numerous factors that drive the organization or become hurdle/hinder for successful lean implementation in an organization. The driving factors which motivates are known as "critical success factors" and the obstructing factors are known as "barriers". Critical Success Factors (CSFs) are defined as the factors which impart ease in implementation of lean in an organization. Bhadu *et al.*[2] mentioned that there are many important barriers like; lack of top management commitment and leadership, resistance to change and adopt innovations, poor organizational culture, and fear of failure etc. These obstructions are to be mitigated for lean implementation and diffusion. Therefore, the study aims in developing the ranking of CSFs which considerably persuade the productive execution of LM in Indian small and medium enterprises (SMEs).

In India, majority of manufacturing companies comes under SMEs, which are recognized as backbone for the economy by contributing 30% of GDP, providing employment opportunities to about 460 million people and contributes 45% of the total export, but still not achieved full potential[3]. The ceramic industries in India comes under SME's and have found fastest progress in demand mainly due to development in infrastructure, and housing sector attributed to various key schemes launched by Government of India. So, there is an increasing demand for sanitary products, wall and floor tiles, and insulators. This reflects the importance of SME's in India. Panizzolo *et al.*[4] has reported that India is becoming a preferred site in international manufacturing arena around the world and has generated a lot of opportunities. Ceramic product

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organization is an unstructured labour intensive type organization and faces challenges to remain competitive for their survival, like in process inventory which blocks capital, reworks and rejections, poor quality items, equipment-related issues, breakdowns, pollution (Dogra *et al.*[5], and high energy consumption are other issues of SME's in India. Therefore, adoption of novel framework, especially in SMEs, demands for the factors that may powerfully encourage their management to adopt framework[6]. The encouraging factors that are called as CSFs are generally economic, social, environmental and organizational[7].

The present study is carried out with an objective to identify the CSFs and analyse their correlation for effectiveness in case of SME's particularly in ceramic sector. These industries gained more attention in India (Western Rajasthan) being hub of raw material, and initiatives taken by Government of India for their betterment. An attempt has been also made to build up a model, based on hierarchy which depicts the interrelationship among the CSFs of lean implementation. An assortment of procedures was conducted to recognize the CSFs of lean implementations. Therefore, Interpretive ranking process (IRP) is applied to demonstrate the CSFs.

2 Materials and Methods

2.1 Literature review

Several factors which drive the LM implementation have been studied. An extensive case study was made by Gandhi *et al.*[8] to highlight the drivers/CSFs related to lean implementation in manufacturing SME's. They mentioned that top management commitment, technological up-gradation, and current-future legislation are most important drivers for Indian manufacturing SMEs. A survey questionnaire was attempted in 68 different firms and afterwards analysed through extended case studies to examine the main obstructions to lean implementation[9]. Four CSFs (enhancing performance, team building, increasing competitive and customer pressure) were listed for lean implementation amongst all sizes of enterprises. Moreover, Lande *et al.*[10] dedicated their study to investigate and prioritized CSFs in SMEs, and found that management commitment and leadership, employee training, and customer satisfaction are most vital CSFs. Many research papers were identified from the literature containing the study of LM critical success factors, although lot of articles are available related to lean CSFs as discussed, but it was difficult to consider all the CSFs in present study. Therefore, 12 CSFs were identified based on experts view from academia and industry which are highly relevant to ceramic industries and meets out our research objectives. The findings may assist the policy makers and management by providing an insight in developing strategies for lean implementation for sustainable development in Indian SME's, specifically ceramic industries. The brief description of each selected CSFs are as follows:

2.1.1Top management commitment and attitude

The commitment of top management and attitude isa critical CSF that helps to implement new process for every type of organization. Lean implementation is not an easy task, especially in labour intensive ceramic sectors, if the employees commitment & attitude is poor, than it might lead to failure in LM implementation process[7,11]. Thus, for flourishing the lean implementation, process management commitment and style is recognized as critical. This help in developing vision which facilitates in generating a performance culture and improves employee participation and performance, and provides effective solution to problems[12-13].

2.1.2 Organization culture

According to Dorota Rymaszewska[14], cultural barrier presents challenges awaiting the future lean implementation. Managing appropriate organizational culture is crucial and expects clarity in the thinking of managers regarding particular norms and their values that helps an organization in achieving its strategic objectives[15-16].

2.1.3 Proper selection of lean tools/techniques

The majority of small medium enterprises are facing complexities to LM implementation due to unsuitable implementation methodology, poor understanding and wrong selection of lean practices (Belhadi *et al.*[16], and this is a main pitfall. Therefore, Sangwan *et al.*[7] mentioned that ceramic enterprises need to pay meticulous concentration to their implementation methodology, training for effective lean implementation in SMEs.

2.1.4 Stock/inventory level reduction

High level of stock and inventory is primary critical barrier of the labour intensive type organization. This higher level of inventory leads to higher required storage expenses and area. Therefore, reduction of material stock is vital for ceramic organizations and there is huge scope for inventory reduction with the help of lean production process[7].

2.1.5 Workplace organization and housekeeping optimization

Workplace organization and housekeeping optimization plays an important role in enhancement of productivity. Improved workplace is one of key factors of the organization for increase in efficiency, which naturally lead to an enhancement in organization's yield and production[7,17].

2.1.6 Customer's satisfaction

The aim of LM is to become more approachable to customers demand, where the customer has ample choices. Reduction in the inventory, human efforts and lead time are primary drivers for lean implementation in any firm[17-18]. Lean implementation enhances overall customer contentment in respect of quality, reliability, delivery and response time etc. and minimizes customer grievances and rejections[8].

2.1.7 High product variety/customer specific products

Present manufacturing scenario is mainly characterized by customer specific products, which leads in increased varieties of quality products. To provide variety of products as per customers' needs is difficult for traditional mass producing organizations[19]. To stay ahead in competitive business market, organizations need to be flexible to respond rapidly and this increasing flexibility is key CSF for lean accomplishment[7].

2.1.8 Low scrap/rework/elimination of waste

The Indian ceramic industries are facing challenges to remain competitive for their survival, like in process inventory which blocks capital, reworks and rejections[5,7]. Poor quality, higher reworks and rate of rejection increases the cost for raw material and waste disposal. Therefore, improvement in quality and elimination of waste is a most vital CSF for lean accomplishment in ceramic industries[20].

2.1.9 Regular training and education for workers

Swarnakar *et al.*[13] mentioned that training and education is key success factor for lean implementation. Ali *et al*.[21] has also mentioned training as the CSF for Lean Six Sigma practices on performance of business in Malaysia. Poor education and training of employees for any type of organization might leads to poor operation performance and quality of products[22]. Regular training and education improves proficiency and carrier capabilities also helping in boosting morale of the employees in ceramic SMEs.

2.1.10 Standardization of operating procedures

Standardization of operating procedures is also a lean implementation driver which allows operators and workers to perform task the every time and by following a predefined standard and process. There are three elements of standardization of operating procedures *i.e.* takt time, work sequence and standard in-process inventor, which makes product safest, easiest, and most effective way[17].

2.1.11 Increase in flexibility and market share

Organizations are more involved in reporting their business social responsibility status willingly to boost their position in the market[23]. Therefore, a successful development strategy should be evaluated on behalf of organization's flexibility to respond to business and market changes[24].

2.1.12 Balanced workload on different workstation

Distribution of the uneven burden on different workstations enhances lead time of production and minimizes overall outcomes. Allocation of evenly workload within the workstations leads to optimum efficiency of assembly line, and reduces lead time and producing higher outputs[25].

2.2 Methodology

The first step was review of research articles on CSFs/drivers in the productive implementation of the lean concept. Depending on the frequency of occurrence of CSFs observed in research articles, 12 CSFs specific for ceramic industries were identified after discussion held with academician and practitioners. A survey questionnaire was prepared and data collected was analysed. Later on, research model was prepared and finally CSFs were ranked. The survey methodology adopted in present work is depicted in Fig. 1.

2.2.1 Development of survey questionnaire and data collection

Based on the extended literature review, twelve CSFs were identified and discussed. A survey

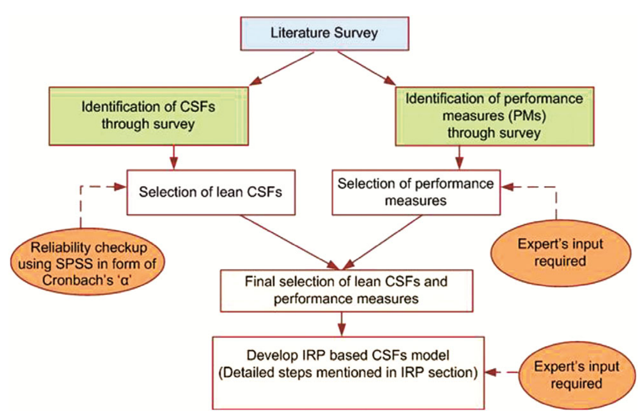

Fig. 1 — Research methodology.

questionnaire was prepared for collecting the data comprises of two sections. The first section consists of general information of the organization, whereas second section comprises questions about CSFs to LM implementation. Respondents were asked to rate the CSFs intensity indicated in the survey questionnaire with 5-point Likert scale system of rating (1 for completely disagree, 2 for least, 3 for less, 4 for moderate, and 5 for very high impact). The objective of conducting survey was to generate the CSFs which drive the organization, increase in productivity and effective implementation of leanness in the system. Therefore, in first phase called pre-testing, questionnaire was discussed with three experts from academia to assess the draft, it was then amended inline to the comments received from them for more clarity. Afterwards, the questionnaire was sent to professionals from ceramic industry and was asked to identify any ambiguous syntax, unfamiliar question to arrive at highly effective questionnaire. Ceramic industries in India are mostly SMEs, which are known for shortage of trained and skilled human resources to pursue lean implementation. Therefore, questionnaire was collected from respondents having a minimum two years of experience, who better understands the production process. 120 survey questionnaires in Google form were sent via email introducing the objective of research to engineers, quality managers, production managers and owners of ceramic industries. 87 complete responses were obtained with the response rate of about 72.5%.

2.2.2 Data analysis

To begin with, the data collected from survey used for analysis purpose has to be reliable and validated. Reliability is the consistency or the degree to which the questions used in survey enlisting CSFs will elicit same information for an individual at different time, *i.e*. same information under identical conditions. However, validity of data is considered to be the degree to which the CSFs measure the factor they have claimed to be measured. Data was analysed by using statistical testing tool (SPSS statistical software). The mean, standard deviation and Cronbach's alpha values for each and every CSF were computed. To ascertain the reliability of questionnaire and measure internal consistency, the Cronbach's alpha value was computed for each item for all received responses for every scale in survey. Cronbach's alpha values may vary from 0 to 1, and values above 0.70 may be expressed for demonstrating internal consistency. According to Bonnetti and Thomas[22] lower value of Cronbach's alpha of 0.60 may also be considered as reasonably acceptable. But, when the alpha values are very less, some of the items have to be removed to amend the value.

However, relationship among variables is required to be determined for validation of data and measuring samples adequateness and correlation matrix. Corrected Item Total Correlation (CITC) test describes the correlation statistics of an item and mentions that if, an item in the set of tests is inconsistent with average behaviour of others and weather needs to be discarded[26]. The correlation value lower than 0.2 or 0.3 shows that the item does not correlates with the overall score of total items, thus, it may be dropped. In first round of test on twelve CSFs, three CSFs were having CITC score below 0.3 as "workplace organization and housekeeping optimization", "high product variety/customer specific products" and "standardization of operating procedures". Therefore, these CSFs were eliminated and a set of same tests were carried out again. The second rounds test results has observed nine CSFs having mean value of more than 0.3, were considered as CSFs in lean implementation and finalized for ranking with interpretive ranking process.

2.3 Interpretive ranking process (IRP)

Interpretive ranking process is a new ranking and decision-making technique that merges the analytical logic process and strengths the intuitive procedure of choice selection at elemental level[27]. In this technique, number of interpretations was made to rank the variables to derive dominance in reference to each criterion. Interpretations and dominance relationships are represented as model of interpretive ranking. Despite of using individual method, IRP is holistic approach which combines the characteristics of intuitive judgment and the rational choice process that entail capability to deal with intricacy. Interpretive matrix is a basic tool in interpretive ranking process from where; paired-comparison matrix is derived by conducting pair-wise comparison among the elements[28]. Therefore, the approach is engrained into the strengths of pair-wise comparison approach to diminish the intellectual over-burden on human thinking. Sushil (2009)[29] highlighted that IRP is a novel ranking tool which builds new, logical information while ranking procedure and such new creative knowledge is obliging for future decision building. The use of rational decision models in IRP gets rid on the drawback of pair-wise comparison approach (Saaty[30], meanwhile other MCDM techniques, like AHP, ANP and ISM, do not have this capability[28]. IRP has two sets of variable, one set of variable is to be ranked and the other set that provides the basis for ranking, also known as performance measures. In this research three performance measures and nine CSFs after reliability check were considered for IRP modelling. Seeing the advantages and application of IRP, this technique is adopted to assess and strengthen the results on lean implementation CSFs in accordance with the performance measures after statistical analysis of CSFs in ceramic industries.

2.3.1 Selection of performance measures (PMs)

From the previous literature it can be observed that proper implementation of LM contributes in performance enhancement, responsiveness and analyse the data to predict failure in the manufacturing system. In practice, various performance variables are judged as key indicators to get competitive benefits, improvements and achievements[28]. They have also discussed the number of performance measures and grouped into different clusters such as time, quality, business results, human resource, environmental and safety related. A relationship among two sets of variables (in our study *i.e*. CSFs and PMs) were performed by various authors[31-32]. In this study three performance measures as suggested by industrial and academic experts are discussed below;

Cost (P1): Cost reduction is the major challenge for all firms and is considered as an important performance measures. It includes cost like; manufacturing, operational, and distribution etc.[27,33-34].

Quality (P2): Quality of product or service is key player for organizations for their survival in competitive market[19,28,35].

Time (P3): Time is very vital with the quality to survive the any organization[28,33,36].

2.3.2 Steps for interpretive evaluation process

2.3.2.1 Formulation of cross intersection matrix

In the primary evaluation process relationship among CSFs and performance measures was developed. In this evaluation process, a correlation specified that a CSF affects a performance indicator. Based on individual opinion cross intersection matrix was developed. This cross intersection matrix developed is in binary form *i.e*. 0 and 1. The cell binary digit “1” indicates that the correlation among CSF and performance measure exists, while binary digit “0” indicates that there is no correlation among CSF and performance measures. The formulation of cross intersection matrix is shown in Table 1.

2.3.2.2 Interpreting the relationships among CSFs and performance measures

The above binary matrix (Table 1) has to be converted into an interpretive matrix (Table 2). For this transformation expert plays an important role in interpreting the conceptual relationship[37].

2.3.2.3 Development of dominance interaction matrix

As different CSFs might be having different influences on performances, some may have high significance as compared to others. In such a manner, degree of significance with reference to each performance indicator has to be decided. To indomitable the level of importance of CSFs pairwise comparison has been done. The more vital CSFs are referred as dominating CSF, while the less vital CSFs are called as dominated critical success factors (as shown in Table 1) with respect to each performance indicator. Table 3 summarize the pair-wise comparison among the lean CSFs, this table also gives conceptual knowledge on how a performance indicator is influenced by different CSFs. Further this paired comparison matrix is translated into dominating relationship matrix as demonstrated in Table 4, which

Table 1 — Formulation of cross intersection matrix

	Performance Measures	Cost	Quality	Time
Critical Success Factors		P1	P3	P4
Top management commitment & attitude	CSF1	1	1	1
Organization culture	CSF2	0	1	1
Proper selection of lean tools/techniques	CSF3	1	1	1
Stock/inventory level reduction	CSF4	1	0	0
Customer’s satisfaction	CSF5	1	0	0
Low scrap/rework/elimination of waste	CSF6	1	1	1
Regular training and education for workers	CSF7	1	1	1
Increase in flexibility and market share	CSF8	1	0	1
Balanced workload on different workstation	CSF9	1	0	1

Table 2 — Interpretive matrix of CSFs

	Cost (P1)	Quality (P2)	Time (P3)
Top management commitment & attitude (CSF1)	Top management commitment & attitude ensure the necessary monetary resources for lean accomplishment and arrangements accordingly.	Top management commitment gives a measure of success of quality, and as per regression analysis 42% success of quality accounted for management.	Poor commitment & attitude leads to affect time.
Organization culture (CSF2)		Stronger organization culture directly connected with effectiveness and continuous quality performance.	Joint efforts encourage innovative organization culture and make easy to implement new framework with minimum time.
Proper selection of lean tools/techniques (CSF3)	Correct assortment of lean practices affects manufacturing cost by increasing labour productivity and reducing inventories.	Proper selection lean tool eliminates wastes and improve quality to remain competitive.	Lean tool such as SMED affects the production time.
Stock/inventory level reduction (CSF4)	Reduced inventory directly affects the carrying cost, storage cost and transportation cost.		
Customer's satisfaction (CSF5)	Customer's satisfaction minimizes marketing expenses and increase revenue.		
Lowscrap/rework/elimination of waste (CSF6)	Low scrap/rework/elimination of waste affects the cost of raw material and waste disposal.	This CSF directly affects quality of products and services.	Minimization of scrap/rework affects the delivery time.
Regular training and education for workers (CSF7)	Lean training and education affects the cost.	Regular training and education leads to enhance quality products & production.	Trained workers save time.
Increase in flexibility and market share (CSF8)	Increasing in flexibility and market share affects cost.		Increase in flexibility resulting in shorter lead time.
Balanced workload on different workstation (CSF9)	Balanced workload on different workstation affects cost.		Evenly workload within the workstations affects time.

reflects each dominating, dominated critical success factors and the performance indicators with reference to relationship of dominating relationship.

2.3.2.4 Formation of the dominance matrix

In order to find out the dominating associations among any of the two CSFs, the dominance matrix is generated as represented in Table 5. The matrix is generated by substituting the performance indicator in each grid of dominance relationship by their numbers. Vacant grid shows that there is no dominating relationships and their number by default is '0' (zero). This dominance matrix, which gives the CSFs, dominates others or dominating by others. In this manner, the total number of CSFs being dominated by others is denoted by 'B' and the total number of CSFs dominated to others is denoted by 'D'. Based on net dominance values, ranking of each CSF is determined. The CSF with a highest net dominance is given highest ranking, and the CSF with least net dominance is provided with lowest rank.

2.3.2.5 Ranks validation and development of IRP based model

As shown in last step, the interpretation of relationships among critical success factors and performance indicators has to the paired and further ranking has to be calculated. To check whether, the interpretations and pair-wise comparisons is right/ wrong, a dominance system graph for each performance measures is developed. A paired comparison leads to the ranking of CSFs. In dominance graph, each arrow symbolizes a dominating relationship among CSFs. For validating correct relationship and ranks, the flow of dominance graph ought to be unidirectional and there should be transitive relationship among arrows. It means that arrows should not form close loops and circles, otherwise it makes intransitive relation. The transitive relationships among two CSFs is examined and modified in dominance system graph as well as modification also has been done in pair-wise comparison matrix. Dominating relationship matrix, dominance matrix and new ranks were updated as shown in Table 6 and Table 7. Dominating

Table 3 — The initial pair-wise comparisons of CSFs

CSFs' pair-wise comparison	Dominance holds with performance measures	CSFs' pair-wise comparison	Dominance holds with performance measures
CSF1 dominating CSF2	P1,P2,P3	CSF6 dominating CSF3	P1
CSF1 dominating CSF3	P3	CSF6 dominating CSF4	P1,P2,P3
CSF1 dominating CSF4	P2,P3	CSF6 dominating CSF5	P1,P2,P3
CSF1 dominating CSF5	P1,P2,P3	CSF6 dominating CSF7	P1
CSF1 dominating CSF6	P2,P3	CSF6 dominating CSF8	P1,P2,P3
CSF1 dominating CSF7	P3	CSF6 dominating CSF9	P1,P2
CSF1 dominating CSF8	P2	CSF7 dominating CSF1	P1,P2
CSF1 dominating CSF9	P1,P2	CSF7 dominating CSF2	P1,P2,P3
CSF2 dominating CSF4	P2,P3	CSF7 dominating CSF3	P1
CSF2 dominating CSF5	P2,P3	CSF7 dominating CSF4	P1,P2,P3
CSF2 dominating CSF8	P2,P3	CSF7 dominating CSF5	P1,P2,P3
CSF2 dominating CSF9	P2	CSF7 dominating CSF6	P2,P3
CSF3 dominating CSF1	P1,P2	CSF7 dominating CSF8	P1,P2
CSF3 dominating CSF2	P1,P2,P3	CSF7 dominating CSF9	P1,P2,P3
CSF3 dominating CSF4	P2,P3	CSF8 dominating CSF1	P1,P3
CSF3 dominating CSF5	P1,P2,P3	CSF8 dominating CSF2	P1
CSF3 dominating CSF6	P2,P3	CSF8 dominating CSF3	P1
CSF3 dominating CSF7	P2,P3	CSF8 dominating CSF4	P1,P3
CSF3 dominating CSF8	P2,P3	CSF8 dominating CSF5	P1,P2,P3
CSF3 dominating CSF9	P1,P2	CSF8 dominating CSF7	P3
CSF4 dominating CSF1	P1	CSF8 dominating CSF9	P1
CSF4 dominating CSF2	P1	CSF9 dominating CSF1	P3
CSF4 dominating CSF3	P1	CSF9 dominating CSF2	P1,P3
CSF4 dominating CSF5	P1,P2,P3	CSF9 dominating CSF3	P3
CSF4 dominating CSF8	P2	CSF9 dominating CSF4	P2,P3
CSF4 dominating CSF9	P1	CSF9 dominating CSF5	P1,P2,P3
CSF5 dominating CSF2	P1	CSF9 dominating CSF6	P3
CSF6 dominating CSF1	P1	CSF9 dominating CSF8	P2,P3
CSF6 dominating CSF2	P1,P2,P3		

Table 4 — Initial dominating relationship matrix

Dominating CSFs	Dominated CSFs								
	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
CSF1		P1,P2,P3	P3	P2,P3	P1,P2,P3	P2,P3	P3	P2	P1,P2
CSF2	-		-	P2,P3	P2,P3	-	-	P2,P3	P2
CSF3	P1,P2	P1,P2,P3		P2,P3	P1,P2,P3	P2,P3	P2,P3	P2,P3	P1,P2
CSF4	P1	P1	P1		P1,P2,P3	-	-	P2	P1
CSF5	-	P1	-	-		-	-	-	-
CSF6	P1	P1,P2,P3	P1	P1,P2,P3	P1,P2,P3		P1	P1,P2,P3	P1,P2
CSF7	P1,P2	P1,P2,P3	P1	P1,P2,P3	P1,P2,P3	P2,P3		P1,P2	P1,P2,P3
CSF8	P1,P3	P1	P1	P1,P3	P1,P2,P3	-	P3		P1
CSF9	P3	P1,P3	P3	P2,P3	P1,P2,P3	P3	-	P2,P3	

relationship matrix was used to draw the dominance graphs for each performance measure, as depicted in Fig. 2. Arrows marked in dominance graph shows that, it start with dominating CSF and ends with CSF which is dominated. For an example, the CSF6 (Low scrap/rework/elimination of waste) dominates all remaining eight CSFs in terms of "P1" as mentioned in dominating relationship matrix. So, an arrow that starts with CSF and draws among CSF6 and each of rest CSFs as presented in Fig. 2(a). Likewise, critical success factor 7 (CSF7) dominates rest of seven CSFs *i.e*. CSF8, CSF4, CSF3, CSF2, CSF9, CSF5, CSF1 except CSF6. Similarly, rests of arrows are drawn to symbolize the dominating relationship among the CSFs in term of P1. However, we can see from Fig. 2(c), that there are total three loops denoted by black dotted

Table 5 — Dominance matrix of CSFs

Dominating CSF	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9	No. of dominating (D)	Net dominance (D-B)	Rank dominating
	CSF being dominated											
CSF1		3	1	2	3	2	1	1	2	15	6	IV
CSF2	-		-	2	2	-	-	2	1	7	-10	VIII
CSF3	2	3		2	3	2	2	2	2	18	12	II
CSF4	1	1	1		3	-	-	1	1	8	-8	VII
CSF5	-	1	-	-		-	-	-	-	1	-22	IX
CSF6	1	3	1	3	3		1	3	2	17	10	III
CSF7	2	3	1	3	3	2		2	3	19	14	I
CSF8	2	1	1	2	3	-	1		1	11	-2	VI
CSF9	1	2	1	2	3	1	-	2		12	0	V
No. of being dominated (B)	9	17	6	16	23	7	5	13	12	108	Sum of net dominance =0	

Table 6 — The modified pair-wise comparisons of CSFs

CSFs' pair-wise comparison	Dominance holds with performance measures	CSFs' pair-wise comparison	Dominance holds with performance measures
CSF1 dominating CSF8	P2,P3 (P3 Added)	CSF8 dominating CSF7	(P3 Removed)
CSF8 dominating CSF1	P1(P3 Removed)	CSF9 dominating CSF7	P3 (Added)
CSF7 dominating CSF8	P1,P2, P3 (P3 Added)	CSF7 dominating CSF9	P1,P2 (P3 Removed)

Table 7 — Modified dominance matrix of CSFs.

Dominating CSF	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9	No. of dominating (D)	Net dominance (D-B)	Rank dominating
	CSF being dominated											
CSF1		3	1	2	3	2	1	2	2	16	8	IV
CSF2	-		-	2	2	-	-	2	1	7	-10	VIII
CSF3	2	3		2	3	2	2	2	2	18	12	II
CSF4	1	1	1		3	-	-	1	1	8	-8	VII
CSF5	-	1	-	-		-	-	-	-	1	-22	IX
CSF6	1	3	1	3	3		1	3	2	17	10	III
CSF7	2	3	1	3	3	2		3	2	19	14	I
CSF8	1	1	1	2	3	-	-		1	9	-6	VI
CSF9	1	2	1	2	3	1	1	2		13	2	V
No. of being dominated(B)	8	17	6	16	23	7	5	15	11	108	Sum of net dominance =0	

lines in the dominance system graphs for time (P3). Loops in dominance system graph for time are CSF9- CSF1- CSF3- CSF7- CSF9; CSF7- CSF6- CSF8- CSF7, and CSF1- CSF3- CSF7- CSF6- CSF8- CSF1 which are intransitive and ranks are not valid. To validate the rank, initial pair-wise matrix in Table 4 has to be modified. For this modification process P3 for CSF7 dominating CSF9 is removed from initial pair-wise comparison matrix in Table 4. After that one new pair with respect to performance P3 as CSF9 dominating CSF7 is added as shown in modified pair-wise matrix in Table 6. For second loop (CSF7- CSF6- CSF8- CSF7), CSF8 dominating CSF7 has to be removed from initial paired comparison matrix and CSF7 dominating CSF8 is added in modified matrix. Similarly, third loop of intransitivity is also removed and modified. As per modified ranks as shown in Table 7, IRP based hierarchy model was developed as shown in Fig. 3.

In IRP hierarchy model, all the critical success factors are arranged in ascending order of the ranking. In above modified dominance matrix (Table 7), each row shows the number of dominating CSFs/dominated to others and column shows number

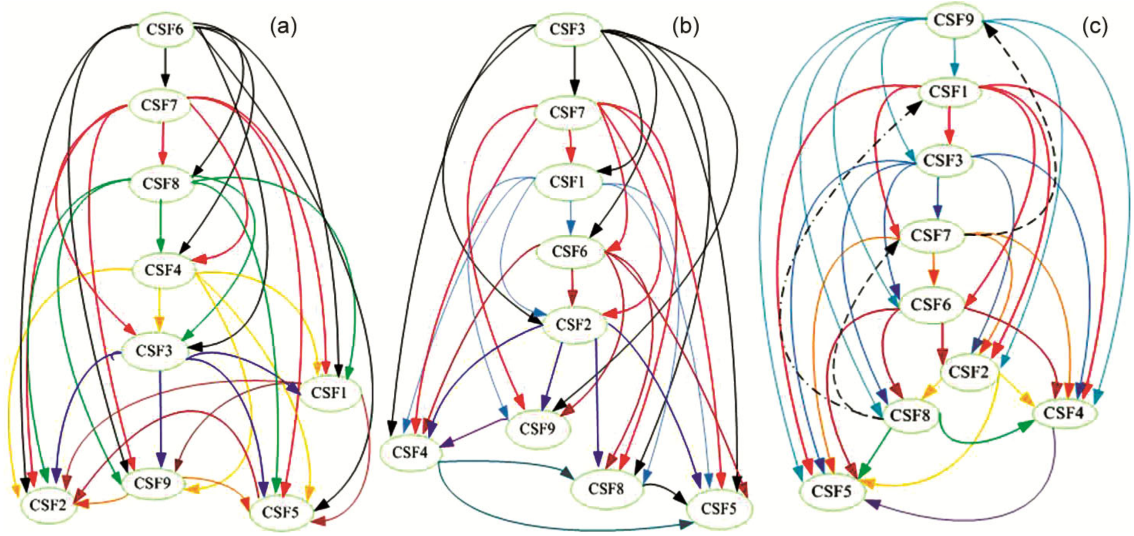

Fig. 2 — Dominance system graphs of performance measures (a) Dominance system graph for cost (P1), (b) Dominance system graph for quality (P2), and (c) Dominance system graph for time (P3).

of being dominated CSFs/got dominated by others, which is also shown in IRP hierarchy model in the small brackets. The arrow shows the dominance relationship among the two CSFs, and also shows the level of significance of each critical success factor with reference of performance indicators. In this manner, IRP based hierarchy model furnishes information regarding significance of CSFs in accomplishing performance evaluation and also helpful for practitioners and researchers.

3 Results and Discussion

The IRP based hierarchy model of selected nine lean CSFs of ceramic industries is shown in the Fig. 3. The indicated rank in model is based on the modified dominance matrix and the highest, medium and least significant CSFs were discussed here. For successful lean implementation management ought to be aware of the CSFs that can encourage the implementation process. The model demonstrates that in hierarchy, regular training and education for workers (CSF7) is observed with highest rank in this study, and dominated eight critical success factors (CSF3, CSF6, CSF1, CSF9, CSF8, CSF4, CSF2, CSF5) and got dominated by four critical success factors (CSF1, CSF3, CSF6, CSF9). The net dominance value (D-B) is 14, which is maximum value and most CSF. Regular training and education for workers leads to improve the organization working culture, operational performance and quality of products. Bhamu and Sangwan[38] in study on ceramic industries mentioned that lack of training is a critical barrier to lean implementation. So, for effective lean manufacturing implementation, training and education is essential and main key driver especially in labour intensive type organization[13]. As we have discussed earlier that SMEs are facing challenges to lean implementation due to wrong selection of lean tools and techniques, therefore SMEs need to train their employees for effective lean implementation. In this study proper selection of lean tools/techniques (CSF3) secured second rank with a good net dominance factor. The proper selection of lean tools and techniques is a prerequisite to drive the organization[7]. The model demonstrates that in hierarchy; low scrap/rework/elimination of waste (CSF6) dominating eight CSFs (CSF1, CSF2, CSF3, CSF4, CSF5, CSF7, CSF8, CSF9) with net dominance 10 occupies place in top three CSFs. Dogra *et al.*[5] mention that Indian SMEs are facing challenges to remain competitive for their survival, like in process inventory which blocks capital, reworks and rejections. Therefore, low scrap/rework/elimination of waste is necessary to drive the organization. In addition, top management commitment & attitude (CSF1) and balanced workload on different workstation (CSF9) are dominating 8 CSFs. The management commitment and attitude have direct impact on manufacturing activities in ceramic industries[18]. The judgment is consistent with earlier research proclaiming that top management commitment is the decisive driver for successful and effective project implementation in Indian manufacturing SMEs. Being a most important critical

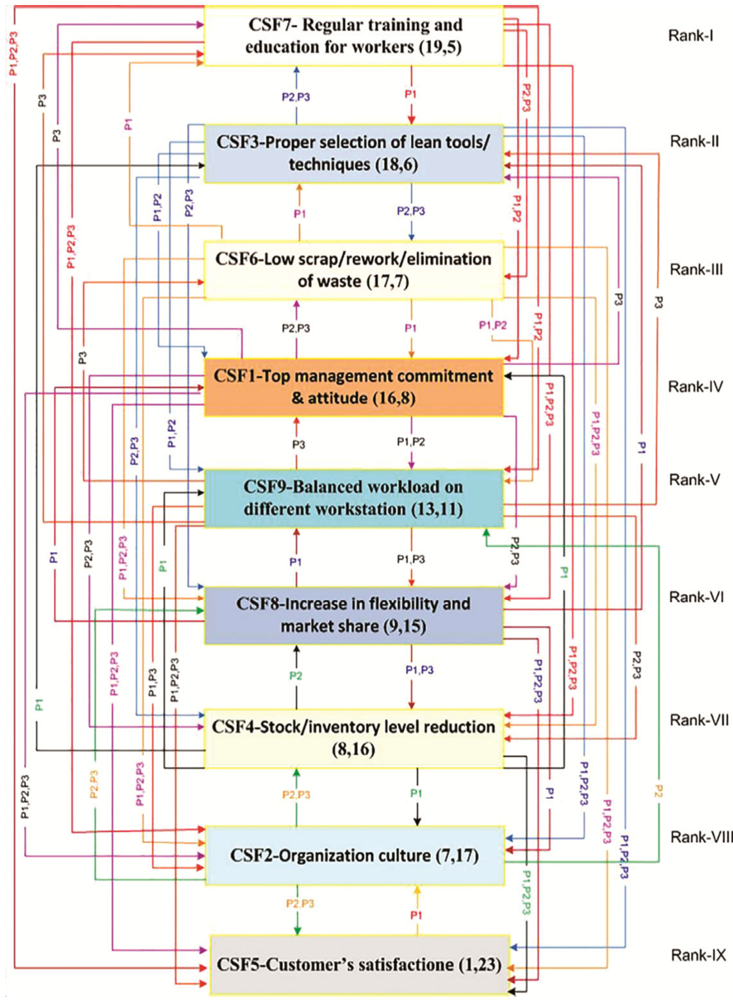

Fig. 3 — IRP based CSFs model.

success factor, it is also dominating other lean CSFs such as organization culture, Regular training and education for workers, Proper selection of lean tools/techniques, Customer's satisfaction etc.[8,28]. Therefore, management needs to pay attention on commitment and attitude for lean implementation. Furthermore, allocation of evenly workload within the workstations leads to optimum efficiency of assembly line, reduced lead time and producing higher outputs[25]. As per previous discussion degree of adoption of lean principles covers flexibility and market share, this evidence also shows that flexibility and market share are also important CSF of lean manufacturing[24]. This CSF also plays a vital role with net dominance (-) 6 in IRP based modelling.

For successful lean implementation, stock/ inventory level reduction CSF (CSF4) is vital for manufacturing organizations and there is huge scope such as kanban, JIT, pull system for inventory reduction with the help of lean production process[7]. In this study stock/inventory level reduction (CSF4) placed at seventh position with net dominance (-8) followed by organization culture (CSF2) and customer's satisfaction (CSF5). These CSFs have least significance level in hierarchy, but supportive culture may guide SMEs towards successful implementation as long term focus, employee involvement and strategic team are critical in the acceptance of any new initiatives. Similarly, lean implementation enhances overall customer contentment in terms of quality, reliability, delivery and response time etc. and minimizes customer grievances and rejections.

4 Conclusion

Primarily, the manufacturing organizations have to concentrate on lean implementation procedure because it provides a way to gain worldwide competitiveness. Nine critical success factors were identified with the help of extensive literature review, expert's inputs and thereafter evaluated with Cronbach's alfa values. These CSFs were compared pair-wise to understand their contextual interrelation. This research study used interpretive ranking process methodology to prioritize essential CSFs and dominance system graphs were drawn for correct results. The CSFs perceived in this research can assist as an agenda that carefully covers conceivable CSFs associated to lean execution, making the way for some additional directions for lean implementation. Behalf of IRP ranking level, the significance level of every CSF can be judged. Normally, due to the lack of sufficient resources, it is not feasible for the management to manage all CSFs at the same time. In this manner, with the ranking of CSFs, the researchers and practitioners can have the capability to understand that on which critical success factors they need to work on the need premise. The results show that regular training and education for workers, proper selection of lean tools/techniques and Low scrap/rework/elimination of waste are three top most CSFs on which the administration must give primary consideration.

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