Abstract

Nowadays, the global competitive scenario plays a critical role in the success of the Indian manufacturing sector. The present study argues that innovation can play a very important role in providing this competitiveness of the Indian manufacturing sector. The study identifies 11 enablers for promotion of innovation in the Indian manufacturing sector. Based on the rigorous literature review, 11 major innovation enablers (IEs) are obtained. The Delphi technique is applied as a potentially valuable tool for the grouping these enablers. The study analyse the impact of innovation enablers (IEs) to enhance the manufacturing competitiveness and categorises into three phases: firstly, identification of innovation enablers, secondly, qualitative analysis of enablers and finally, quantitative analysis of the innovation enablers. The research theme has been categorised into three segments: identifying the enablers from the literature, conducting interviews with directors of different departments and analysis of the manufacturing industries. The study involves 100 manufacturing companies across India and the data is gathered using a 5-point Likert scale. Interpretive Structural Modeling (ISM) has been used to analyse the relationships among these enablers as well as fuzzy MICMAC (Matrixed’ Impact Cross’ Multiplication Applied to a UN Classemment) analysis used to find out driving and the dependence power of enablers. To identify the driving and the dependence power of various IEs, the final outcomes of ISM are used as input to the fuzzy MICMAC analysis. This analysis serves to identify which (IEs) is performing as the most leading one to raise the competitiveness of manufacturing industries. This study plays a vital role in enhancing the competitiveness of manufacturing industries in India.

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Keywords: Innovation Enablers (IEs), Manufacturing, Competitiveness, Delphi technique, Interpretive Structural Modeling (ISM), Fuzzy MICMAC Analysis.

1. Introduction

In the last three decades, most of the literature shows that innovation is the key drivers to enhance the competitiveness of the manufacturing sectors in India (Porter 1966; Burgelman et al., 1988). Thus, in order to sustain the competitiveness in the global marketplace, they need to engage in a continuous improvement of technologies as well as innovation (Johnson et al., 2004). Innovation plays a vital role in today's rapidly-changing business environment (Von, 2007, 2005). Nowadays, most of the literatures support that innovation means "rewiring organizations for creativity and growth" (Balsano et al., 2008; McGregor, 2006). Manufacturing Sector is the main engine of economic growth and wealth creator for a country; it
creates a sustainable economic, encourages investments, creates jobs and builds the nation. "The share of manufacturing sector has been stagnating at a low level of 17% of GDP for over two decades. One of the major reasons for the reduced level of contribution by Manufacturing has been the inability of the country to build and maintain competitiveness needed to meet the global challenges as well as to develop a larger domestic market through low cost production" (National Manufacturing Competitiveness Council, report 2011). Most of the literature shows that the traditional dimensions such as cost, quality, services, flexibility, etc. have not not much sufficient relevant to obtain the competitive performance issues for today’s competitive environment (Liu, 2013; Bierly, 2007). Nowadays, the business environment is rapidly changing because of enhancing global inter-connectivity, growing demand for innovation (Raymond et al., 2014; Lau et al., 2013) and technology (Rahman, 2001; Kleindl, 2000), new product development (Bruch et al., 2014; Schrettle et al., 2014; Sonia and Francisca, 2005). The need of the hour is for innovation (Raymond et al., 2014; Lau et al., 2013; Yam et al., 2011; Rahman, 2001), effective technologies (Liu, 2013), manufacturing flexibility (Hung et al., 2014, Vokurka et al., 2000), and reconfiguration of capabilities on the manufacturing sectors (Chengen, 2000). The future of globalization and manufacturing competitiveness is being driven by new markets for new products. To sustain competitiveness in the global markets an Indian manufacturing sector has a high pressure because of global competition and technologies changing (Mehrabi et al., 2000). Today, Innovation is a key driver for business success because it plays a critical role in creating, improving goods and services, developing market demand, meeting market expectations, and increasing shareholders’ wealth.

This paper is prepared as follows: A literature review focused on the concepts of manufacturing competitiveness in general contexts and identifies the enablers for promotion of innovation in the Indian manufacturing sector. In next section problem description and solution, methodology for the study being presented. In, next section summarizes the findings of the study. The most important factors, different methods, and analyses that relate to manufacturing competitiveness are summarized. Then most relevant issues discussed, including suggestions for future research directions. The final section concludes this paper.

2. Literature Review

2.1 Manufacturing Competitiveness

The manufacturing - strategy study was started in the late sixty’s when Skinner (Skinner, 1969) pronounced that the manufacturing strategy was an important but missing theme. After a relevant development by the academia for more than three decades (Skinner, 1996), there is now a commonly accepted definition of the manufacturing-strategy (Hung et al., 2014):

"Manufacturing strategy is the effective use of manufacturing strengths as a competitive weapon for the achievement of business and corporate goals."

The research on manufacturing competitiveness started debatably with the determining work on the competitiveness of nations by Porter (1996), “who defined national competitiveness as an outcome of a nation’s ability to innovatively achieve, or maintain, an advantageous position over other nations in key industrial sectors”. Competitiveness is also provides the relationship between the productions of goods as well as better quality and services, so that the product and services of the companies is standing in the global market (Newall, 1992, p. 94). Manufacturing competitiveness plays an instrument role in the Indian economy and enhancing the Gross Domestic Product. It has been observed that there are many authors has focused on determining the national competitiveness and other factors of competitiveness that can be affected to manufacturing industries to stabilized in the global market. Over the past three decades, most of the researchers and practitioner described manufacturing competitiveness like cost, quality, delivery, etc. that has given less important now a days but need to be adequately highlighted during the next decade are innovativeness (Raymond et al., 2014; Lau et al., 2013), research and development (Bruch et al., 2014; Lööf et al., 2014) and supply chain coordination (Hugos, 2011; Hilletofth, 2011) etc.

2.2 Innovation

Nowadays Innovation plays an important role to enhance the manufacturing competitiveness in India. Due to the excessive pressure in global markets and regional players, application of technology becomes a more competitive. It has been observed that without major effort for innovation, R&D, marketing and
financial approaches the manufacturing sector lose its competence and its competitiveness in the global market (Raymond et al., 2014; Lau et al., 2013). There is a need for attention to increase an R&D effort based on the adaptation of high technology products, focus on new users, production build up, reducing the cost and delivery time and synchronizing a high level of intelligence and information (Vives, 2008; Hauser, J. et al., 2006).

3. Role of manufacturing in the Indian economy

According, to the National Manufacturing Competitiveness Council, report (2011), the manufacturing sector has been a consistent contributor to the growth of the Indian economy and contributes 15.24 per cent of the country’s Gross Domestic Product (GDP), and provides employment to over 6 million persons. (al., 2007) and Supply Chain Coordination (Hugos, 2011; Hilletofth, 2011) to increase manufacturing competitiveness (NMCC, report 2011).

3.1 Methodology of finding the enablers

In the present study the literature from the year 2000 to 2013 has been reviewed. Further, it has been found that few research papers that are directly associated with the concept of manufacturing sector, therefore, in order to make a comprehensive review of literature, all the research papers related to the concepts of manufacturing competitiveness and innovation, manufacturing capabilities and innovation, competitiveness, competitive manufacturing performance measures and innovation, competitive priorities, and innovation has also been considered. In order to collect the research papers for the review, a rigorous search was carried out using the following databases:
- Scopus
- EBSCO
- Emerald Full Text
- Elsevier
- Taylor and Francis etc.

An advance search, within the preview of present title, was carried out using different combination of words such as, ‘Manufacturing’, ‘Manufacturing Strategy and innovation’, ‘Competitiveness’, ‘Competitive priorities’, along with ‘Manufacturing competitiveness and innovation’ for searching the papers. The research was further extended using keywords such as ‘Manufacturing and Supply Chain Management’ and ‘Manufacturing and Supply Chain Operations’. Still the search resulted in more than 300 research papers. Interestingly, these results also included some un-related research papers, that is, strategic planning, inventory control, sustainable competitive advantage, industrial management, manufacturing competition and so on, and they were excluded from the review process.

3.2 Criteria Used for Final Selection

After the identification of research papers, the criteria for selecting the research papers finally were established. Only the papers appearing in journals were included in the review of literature and articles, represented a higher level of research (Garg et al., 2011; Nord and Nord, 1995). Therefore, dissertations, conference papers, unpublished working papers and textbooks were excluded from the review process. For a better exploration of the field, the references of the remaining papers were also taken into consideration according to the year of their publication. Afterwards, the abstracts of the selected papers were thoroughly studied. Finally, after reading the abstracts of these papers, 50 papers associated with the area, which were published in 50 different journals, were considered in the review of literature.

From, the rigorous literature review 11 key enablers for promotion of innovation in the Indian manufacturing sector have been identified. Only those enablers are considered which emphasized in recent years, particularly after year 2000. Apart from that the Delphi Technique was used to grouping these enablers into proper manner. The Delphi Technique is described below.

3.3 The Delphi Technique

"The Delphi technique is a group process used to survey and collect the opinions of experts on a particular subject. The main components of Delphi techniques include the communication process, a group of experts, and essential feedback" (Yousuf, 2007).

Following steps of the Delphi technique as identified by Brooks (1979), were conducted in the present study:
a. "Identifying the panel of experts.
b. Determining the willingness of individuals to serve on the panel.
c. Gathering individual input on the specific issue and then compiling it into basic statements.
d. Analyzing data from the panel.
e. Compiling information on a new questionnaire and sending to each panel member for review.
f. Analysing the new input and returning to the panel members the distribution of the responses.
g. Asking each panel member to study the data and evaluate their own position based on the responses from the group. When individual responses vary significantly from that of the group norm, the individual is asked to provide a rationale for their differing viewpoint while limitations are placed on the length of the remarks in order to keep responses brief.
h. Analyzing the input, and sharing the minority supporting statements with the panel. Panel members are again asked to review their position and if not within a specified range, to justify the position with a brief statement”.

4 Enablers of Manufacturing Competitiveness for Indian Manufacturing Sector

Most of the Literature survey has focus various kinds of enablers of manufacturing competitiveness for the promotion of innovation in Indian manufacturing sectors. Based on the literature review and discussion with industry experts, researchers and academicians in Delphi analysis, 11 key enablers for promotion of innovation in the Indian manufacturing sector have been identified. All these enablers are discussed in the following sub-sections as shown in the Table 1.

<table>
<thead>
<tr>
<th>Factor of Innovation Enabler (IE)</th>
<th>Sub-factors of Innovation Enablers (IEs)</th>
<th>Literature Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation</td>
<td></td>
<td>Raymond et al. (2014), Lau et al., (2013), Vives, (2008), Hauser, J. et al. (2006).</td>
<td>It has been observed that in today's business environment is unpredictable due to changing competitive environment. Innovation is the most important issues in today’s business environment, especially for steel industries in India.</td>
</tr>
<tr>
<td>New Product Development</td>
<td>Bruch et al. (2014), Schrettle et al. (2014)</td>
<td>New Product Development (NPD) plays a vital role for promotion of innovation. NPD is a dynamic process for design a product in steel industries.</td>
<td></td>
</tr>
<tr>
<td>Development Capabilities</td>
<td>Sharma, (2010), Talluri et al., (2010), Wagner, (2010), McGovern et al. (2006), Davis et al. (2006).</td>
<td>Development Capabilities help to enhance the high technology changes, competitive environment, highly demanding customers, constantly increase in quality levels and cost cutting by competitors.</td>
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<tr>
<td>Technological Opportunities</td>
<td>Geum et al. (2013), Tidd et al. (2003), Becker et al. (2000).</td>
<td>There is an inter linkage between technological opportunities and innovativeness because it enhances the knowledge scientifically as well as give better opportunities for innovation.</td>
<td></td>
</tr>
<tr>
<td>Competitive Pressure</td>
<td>Frésard et al. (2013), Bloom et al. (2011), Vives, (2008), Boone, J. (2000).</td>
<td>Competitive pressure is the key factors in the steel industries to survive in the global market. Due to rapid change in the technological innovations, increase in the demand of the better products and satisfactory services, competitive pressure plays a vital role to to sustain in the global market.</td>
<td></td>
</tr>
<tr>
<td>Continuous Improvement</td>
<td>Singh et al. (2014), McLean et al. (2014), Terziovski et al. (2000).</td>
<td>Continuous Improvement responsible to increase successes and reduce failures” The basic fundamental of CI is the improvement</td>
<td></td>
</tr>
</tbody>
</table>
of quality or process, or both, in order to minimize the waste, shorten the production line and improve quality.

Nowadays integration between manufacturing and R&D is challenging for manufacturing companies. There is a strong internal connectivity between inter-firms cooperative and R&D intensity for information infrastructures.

Top management support is essential for the promotion of innovation of steel industries in terms of providing the necessary financial and technical support together with the employee empowerment.

Information Sharing has focused on the effective and efficient communication based on real-time frame with respect to hardware and software domain to enhance and synchronization of the supply chain.

Supply Chain coordination plays a central role in supply chain management. It is responsible for increased performance, such as a maximum revenue boundaries, increase consumer service performance and more rapidly reaction era.

The objective of long-term strategic goal is to increase customer satisfaction, market share and profits. It also helps in the promotion of innovation.

There are several studies on the relationship between cash cycles, firm liquidity, and firm financial performance of manufacturing sector. It plays an important role in the promotion of innovation for manufacturing competitiveness.

5. Problem description

Over the past decades, The economy of India’s had recorded stunning growth rates. The service sector is one of the most leading areas for immense growth rate, but the current growth rate is dragged down from 6.5 percent to 8.5 percent, which is very low as compared to previous years (NMCC, report 2011). Further, it is a sensational performance as compared to other countries, but it could have been much better. The manufacturing sector of India’s has always suffered from an overburdened innovative product, R&D, infrastructure and supply chain coordinations, etc. The main cause of failure of the manufacturing sector was to rapidly growing population and the mainstream of their raw materials, goods was imported from abroad, resulting in a sharply broadening trade shortage that results in unemployment levels that have risen in the past few years in spite of their rapid economic growth (NMCC report, 2011). The problem selected in the paper is a case of manufacturing company engaged in producing and delivering a big range of products steel, etc. across India. For this research paper 100 steel manufacturing companies are considered out of this 50 companies responded positively. All these companies are located across India. These 50 companies are well-known steel companies which act as the backbone of the Indian market. These companies are producing steel and the manufactured products are distributed in and around the state as well as other states through a distribution network to different engineering industries like power generation and petrochemicals, etc. The study describes the analysis of eleven enablers from the literature as well as industry discussion to enhance the competitiveness of steel industries. The sources and detail descriptions of the eleven enablers of manufacturing competitiveness are shown in Table. 1.
6. Methodology

In the present study, Interpretive Structural Modeling (ISM) used to achieve the objective of the work. Interpretive Structural Modeling (ISM) developed for complex situations, problems and as a communication tool.

7. Interpretive Structural Modeling (ISM)

The Interpretive Structural Modeling (ISM) was first proposed by J. N. Warfield (1973a) to analyze the complex socioeconomic systems. ISM is an interactive computer-assisted learning process into a set of heterogeneous directly related elements are structured into a comprehensive systematic model. ISM also gives the basic ideas to develop a map of the compound associations between the numerous elements concerned in multifaceted circumstances. The most important idea of ISM is to use of practical experience of experts and knowledge to decompose a complicated taxonomy into numerous sub-systems as well as assemble a multi-tiered structural form. Raj et al. (2008) focused on an ISM approach to identify the mutual interaction of the manufacturing competitive enablers that help in the achievement manufacturing sector as well as it also helps to identify the driving and the dependent enablers. Raj et al. (2008) presented the following characteristics of ISM are as follows:

(i) "This methodology is interpretive as the judgment of the group decides whether and how the different elements are related.

(ii) It is structural, too, on the basis of relationship; an overall structure is extracted from the complex set of variables.

(iii) It is a modeling technique, as the specific relationships and overall structure are portrayed in a digraph model.

(iv) It helps to impose order and direction on the complexity of relationships among various elements of a system.

(v) It is primarily intended as a group learning process, but individuals can also use it".

ISM methodology has so many advantages, but apart from that it has a few disadvantages or limitations. The main limitations of ISM are the relationship among the variables are totally depends upon the users' knowledge and their experience within their industries. Therefore, prejudice of the someone who is judging the variables might manipulate the final result. The following steps are concerned with the ISM methodology are (Kannan et al., 2009):

1. Variables (criteria) considered for the system under consideration are listed.

2. From the variables identified in step 1, a contextual relationship is established among the variables in order to identify as to which pairs of variables should be examined.

3. A structural self-interaction matrix (SSIM) is developed for variables, which indicates pairwise relationships among the variables of the system under consideration.

4. Reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

5. The reachability matrix obtained in step 4 is partitioned into different levels.

6. Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

7. The ISM model developed in step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

7.1. Application of ISM

7.1.1. Data collection

The ISM techniques focus on the expert opinions which is based on the various management techniques, brainstorming, nominal technique, etc., which is very helpful for developing the contextual relationship between the various types of variables. In this research paper for identifying the contextual relationships
among the enablers, experts from the industries in steel sector in India and experts from the academia, were consulted.

7.1.2. Structural self-interaction matrix (SSIM)

SSIM is an ISM methodology, which was applied for finding the contextual relationship among the identified enablers using expert’s opinion. The contextual relationship of each variable, the existence of a relation between any two enablers (i and j) and the associated direction of the relation is questioned. In this paper four symbols are used to denote the direction of the relationship between the enablers (i and j):

V: Enablers i will help to achieve enablers j;
A: Enablers j will help to achieve enablers i;
X: Enablers i and j will help to achieve each other; and
O: Enablers i and j are unrelated.

7.1.3. Initial reachability matrix

"Based on the pairwise relationship of the enablers in SSIM (see Table. 2.) is converted into ‘initial reachability matrix’ in a binary digits form (i.e., 1’s and 0’s). This transformation is done with the following rules”:

- If (i, j) entry in SSIM is V, then in the initial reachability matrix (i, j) entry = 1 and (j, i) entry = 0.
- If (i, j) entry in SSIM is A, then in the initial reachability matrix (i, j) entry = 0 and (j, i) entry = 1.
- If (i, j) entry in SSIM is X, then in the initial reachability matrix (i, j) entry = 1 and (j, i) entry = 1.
- If (i, j) entry in SSIM is O, then in the initial reachability matrix (i, j) entry = 0 and (j, i) entry = 0”.

After incorporating the transitivity as mentioned in step 4 in the ISM methodology the final reachability matrix for the enablers is obtained as shown in Table.4.

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<tr>
<th>IEs Code</th>
<th>Name of IEs</th>
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<tbody>
<tr>
<td>IE 1</td>
<td>Top Management Commitment</td>
<td>1</td>
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<tr>
<td>IE 2</td>
<td>Development Capabilities</td>
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<tr>
<td>IE 3</td>
<td>Technological Opportunities</td>
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<td>IE 4</td>
<td>Competitive Pressure</td>
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<td>1</td>
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<td>IE 5</td>
<td>New Product Development</td>
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<td>IE 6</td>
<td>Information Sharing</td>
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<td>IE 7</td>
<td>Supply Chain Coordination</td>
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<tr>
<td>IE 8</td>
<td>Long Term Strategic Goals</td>
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<td>IE 9</td>
<td>Research and Development</td>
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<tr>
<td>IE 10</td>
<td>Continuous Improvement</td>
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Based on the above rules, the initial reachability matrix for the identified enablers as shown in Table. 3. Note that an enabler has an effect on itself.

<table>
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<tr>
<th>IEs Code</th>
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<td>IE 2</td>
<td>Development Capabilities</td>
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<td>1</td>
<td>0</td>
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<td>1</td>
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<td>1</td>
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<tr>
<td>IE 11</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
</tr>
</tbody>
</table>
7.1.4 Level partitions

From the final reachability matrix the reachability and antecedent set for each enabler is obtained (Warfield, 1974). "The reachability set for a particular variable consists of the variable itself and the other variables, which may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same is given the top-level variable in the ISM hierarchy, which would not help achieve any other variable above their own level. After the identification of the top level element, it is discarded from the other remaining variables". (Mathiyazhagan et al., 2013). In this paper elevenblers, along with their reachability set, intersection set and levels, are presented in Table 6. From the Table 6., it can be seen that level of the identification process of these enablers is completed in eleven iterations as well as the failure enablers is found at level I. Thus, weak enablers would be placed at the top of the ISM model. So, the iteration of ISM is continued till the variable are obtained in proper levels in the ISM model. After some iteration, each and every variable have placed in the exact position and identification level support in building the diagraph and final model is coming out.

Table 5. Driving Power and Dependence Calculation Using Indicate transitivity matrix

<table>
<thead>
<tr>
<th>IEs Code</th>
<th>Name of IEs</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>5</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
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<td>Top Management Commitment</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>IE 2</td>
<td>Development Capabilities</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>IE 3</td>
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<tr>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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</tr>
<tr>
<td>IE 11</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

7.1.5 Formation of ISM based model

The relationship among the enablers j and i is shown by an arrow pointing from i and j. So the resulting outcome graph is called a digraph. After removing the transistivities the digraph is finally converted into ISM model.

7.1.6 ISM fuzzy MICMAC analysis

The MICMAC is also known as Matriced’Impacts croises-multipication applique’ and classment (cross-impact matrix multiplication applied to classification). The MICMAC analysis working on the principle of multiplication properties of matrices (Diabat and Govindan, 2011; Kannan et al., 2009). The use of MICMAC
analysis is beneficial to calculate the drive and dependence power of enablers as shown in Table. 5. With the help of key enablers this analysis is done so that drive the structure in different categories. However the relationship between enablers always not equal, some relation may be strong, especially strong and better. To rise above this problem of ISM, fuzzy MICMAC analysis is moved away as per following steps:

### 7.1.7 Binary direct relationship matrix

From the direct examination relationship between the enablers in the ISM a binary direct reachability matrix (BDRM) is obtained and the diagonal entries are converted to zero. After conversion of the diagonal of the Table. 5. the BDRM is shown in Table. 7.

<table>
<thead>
<tr>
<th>IEs Code</th>
<th>Name of IEs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
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<td>Top Management Commitment</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>1</td>
<td>1</td>
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<td>1</td>
</tr>
</tbody>
</table>

### 7.1.8 Binary direct relationship matrix

It has been observed that in the traditional MICMAC analysis the relationship is the only binary type, but in this paper fuzzy set theory (FST) is applied to enhance the responsiveness of MICMAC analysis. To convert from traditional MICMAC analysis to fuzzy MICMAC, a supplementary contribution of option of communication among the enablers is required. The supplementary contribution can be defined by qualitative consideration on 0-1 scale as shown in Table. 8.

Table 8. Possibility of numerical values of the reachability

<table>
<thead>
<tr>
<th>Possibility of reachability</th>
<th>No</th>
<th>0.1</th>
<th>0.3</th>
<th>0.5</th>
<th>0.7</th>
<th>0.9</th>
<th>Complete</th>
</tr>
</thead>
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<td>0.7</td>
<td>0.9</td>
<td>1</td>
</tr>
</tbody>
</table>

### 7.1.9 Fuzzy MICMAC stabilized matrix

After the formation of fuzzy direct relationship matrix (FDRM) as shown in Table. 9. to find the relationship between MCEs, take FDRM as an initial table and further process is starting. Apart from that multiplication of matrix is repeated until the hierarchies of the driving and dependence power constant. Fuzzy matrix multiplication is based on boolean matrix multiplication (Kandasamy et al., 2007). According, to fuzzy set theory, when two fuzzy matrices are multiplied the product matrix is also fuzzy matrix. The following rules of fuzzy matrix are as follows:

\[ C = A, B = \max k[\min (a_{ik}, b_{kj})], \quad \text{where } A = [a_{ik}] \text{, and } B = [b_{kj}] \]

<table>
<thead>
<tr>
<th>IEs Code</th>
<th>Name of IEs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>11</th>
</tr>
</thead>
<tbody>
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<td>IE 1</td>
<td>Top Management Commitment</td>
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<td>0.5</td>
<td>0.7</td>
<td>0.5</td>
<td>0.3</td>
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<td>0.5</td>
<td>0.7</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
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<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>0.7</td>
<td>0</td>
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</tr>
<tr>
<td>IE 3</td>
<td>Technological Opportunities</td>
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<td>0.7</td>
<td>0</td>
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<td>0.5</td>
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<td>0</td>
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</tbody>
</table>

Table 9. Fuzzy direct reachability matrix
After the multiplication of fuzzy matrices a Final Fuzzy MICMAC stabilized matrix is obtained and as shown in Table. 10.

**Table. 10. Final Fuzzy MICMAC stabilized matrix**

<table>
<thead>
<tr>
<th>IEs Code</th>
<th>Name of IEs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>Supply Chain Coordination</td>
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<td>0.5</td>
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<td>0.7</td>
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<td>0</td>
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<tr>
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<td>Research and Development</td>
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</tbody>
</table>

Fig. 1. ISM based model for enablers.
8. Result and Discussion

The manufacturing competitiveness enablers, for promotion of innovation in the Indian manufacturing sector are collected from the literature, industry experts and academicians etc. were placed into ISM to examine relationships among them. Figure 2. shows the dependence and driving power of enablers which is obtained from MICMAC analysis. It gives an insight into the relative importance and interdependencies between these enablers. Some of the major findings of this study have been highlighted here.

(a) First quadrant (Quadrant I): This is an autonomous quadrant. The enablers placed in this quadrant have less driving power and dependents and because they do not have much influence on the system. After the analysis none of the enablers appear in this quadrant. In the present study the absence of enablers in the first quadrant shows that all considered enablers are significant. Therefore, all selected 11 enablers have an important influence to enhance the manufacturing competitiveness.

(b) Second quadrant (Quadrant II): This is a dependent quadrant with low driving power and high dependence. According to the present study, 4 enablers appear in this quadrant.

- **New Product Development (IE 5)** and **Information Sharing (IE 6)** enablers are indicated as an independent and have strong driving power (4) but weak dependence power (9) and appear at the III level in the ISM hierarchy as shown in Fig. 1. New Product Development (MCE 5) enabler is very essential for steel industries to achieve the competitive advantage in the global market. Information Sharing (IE 6) enabler is also playing a vital role for promotion of innovation to enhance the manufacturing competitiveness as well as synchronized the supply chain with respect to hardware and software domain (Lee et al., 2000).

- **Long Term Strategic Goals (IE 8)**, is likewise a considerable enabler for the furtherance of invention to enhance the competitiveness of manufacturing sectors for steel industries. This enabler is capable to increase manufacturing productivity, increase client satisfaction and market share (Tan, 2001). Due to deficiency of proper synchrony between manufacturing productivity and customer satisfaction, this enabler has a weak driver (2) and strong dependence power (10) and placed in the second top level of ISM hierarchy as shown in Fig. 1.

- **Continuous Improvement (IE 10)** is a less important enabler to raise the competitiveness of manufacturing sectors and establish up the relationship between providers and customers in the supply chain (Rungtusanatham, M. et al., 2003). The study shows that due to the lack synchrony, the enabler has a weak driver (1) and strong dependence power (11) and placed in the topmost level of ISM hierarchy as shown in Fig. 1.
Third quadrant (Quadrant III): This quadrant is known as linkage. Enablers with high driving power and high dependence fall in this quadrant. In this study, 2 enablers are classified under linkage category.

- Development Capabilities (IE 2), Research and Development (IE 9) are the enablers who play an important role to enhance the competitiveness of the manufacturing sector in India. These enablers are indicated as a high driving power (6) and high dependence power (7) and appear at IV level in the ISM hierarchy as shown in Fig. 1. Research shows that the integration of Research and Development is challenging for manufacturing companies (Bruch et al., 2014; Liu et al., 2007).

Fourth quadrant (Quadrant IV): This is an independent quadrant which has strong driving power but weak dependence power. According to this study, 5 enablers appear in this quadrant. The enablers are as follows:

- Top Management Commitment (IE 1) is an important enabler for promotion of innovation to enhance the competitiveness of manufacturing sectors. This enabler is indicated as an independent and have very strong driving power (11) but weak dependence power (1) and appears in the fourth quadrant and treated as a "key enabler" as shown in Fig. 2. This enabler is placed in the root level of ISM hierarchy as shown in Fig. 1.

- Supply Chain Coordination (IE 7) and Financial Performance (IE 11) enablers are indicated as an independent and has very strong driving power (10) but weak dependence power (3) and placed in the VI level in the ISM hierarchy as shown in Fig. 1. Supply Chain Coordination plays a central role in supply chain management (Ballou et al. 2000). Financial Performance (MCE 19) enabler is responsible for financial matter because due to financial problem, none of the industries can run and survive in the global market.

- Technological Opportunities (IE 3) and Competitive Pressure (IE 4) are important enablers to enhance the competitiveness of manufacturing sectors. These enablers are indicated as an independent and have strong driving power (8) but weak dependence power (5) and placed in the V level in the ISM hierarchy as shown in Fig. 1. It has been argued that due to rapid changes in technologies, innovation in industries demanding customers, etc. technological opportunities (IE 3), competitive pressure (IE 4) are highly significant to the global market (Bloom et al., 2011).

9. Conclusions

For the achievement of the crucial goal of the modern manufacturing sector in India is to enhance its competitiveness to sustain in the global market. So, due to this reason, it is very essential to identify and analyse the various manufacturing enablers who promote innovation to increase the manufacturing competitiveness in India. In this study ISM methodology has been used to build up the relationship among various enablers and to identify the driving and dependence powers of enablers. The manufacturing competitiveness enablers are iterated in seven levels. The final output of ISM has been used as an input the fuzzy MICMAC analysis to identify the driving and the dependence power of manufacturing competitiveness enablers. From the analysis of this study a structural self-interaction matrix (SSIM) the basis for ISM was formed in which the Continuous Improvement (10) occupied the top most level i.e. first level (I) shown in Fig. 1. The present study shows that the industry feels this enabler are not much significant as compared to others enablers and comparatively to eliminate. Long Term Strategic Goals (8) enabler is occupied in the second level (II) the study shows this enabler is more important as compared to top level enabler. Information Sharing (8) and New Product Development (5) has placed in the third level (III), from the analysis these enablers are a little bit more important as compared to level second level (II) enabler. Development Capability (2) and Research and Development (9) has placed in the fourth level (IV) and shows that these enablers are equally important and gives equal importance to enhance the competitive advantage in the global market. Competitive Pressure (4) and Technical Opportunities (3) are occupied in the fifth level (V), this shows that the industries give more importance to enablers for the promotion of innovation to increase the competitiveness of manufacturing in India. Financial Performance (11) and Supply Chain Coordination (7) are placed in the sixth level (VI), and shows that these enablers are second most important as
compared to other enablers, so industries give more attention. Top Management Commitment (1) is placed in the bottom level, i.e. seventh level (VII), so this enabler plays a key enabler to enhance the competitiveness of steel industries. This is an independent enabler and driving other enablers. This enabler form a relationship among financial support, supply chain coordination and manufacturers for competitive advantage (Kannan et al., 2010). The present study provides significant guidelines for researchers and academicians.

10. Limitations and future scope

The present study shows that 11 enablers have been identified in the promotion of innovation to enhance the competitiveness of manufacturing in India and a model is developed with ISM and fuzzy MICMAC analysis. The enablers are identified from reputed journal and industry experts of steel industry and also discussed with academicians rather than more enablers have not been incorporated and classified. The present study is entirely subjective judgements of few industry experts and academicians. The final result of ISM and fuzzy MICMAC are obtained in the line of the judgement of industry experts and reputed academicians and it is kind of personal judgement and any prejudicing by the individual who is judging the manufacturing competitiveness enablers might manipulate the final conclusion. The future scope of this study expands to identifying most significant enablers which are related to manufacturing competitiveness in different industries of sectors in India or Abroad. Further structural equation modeling (SEM), Multi Criteria Decision Making (MCDM) techniques like (ANP and AHP) also been used for causal relation among the enablers and also find the statistical validation of the developing hypothetical model.

References


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