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Identification and Evaluation of Criteria of Agile Manufacturing Using DEMATEL: A Case from an Indian Metal Fabrication Industry

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ABSTRACT

In metal fabrication industry, assembling department plays the major role since it involves risks in assembling the components. Hence, it is always difficult for the manufacturers to identify the criteria of agile manufacturing in assembling department that effects the assembly of the fabricated metal components. Agile manufacturing is one of the innovative method of manufacturing, which focus on the customer satisfaction and also maintaining the quality and cost of the product. Metal fabrication industries generally struggle to find right criteria for better agile manufacturing process. This study focuses on the selection of suitable criteria for agile manufacturing, which requires an in-depth analysis depending on the influence they possess on the agile manufacturing. The objective of this paper is to analyze and identify the most influencing criteria for the metal manufacturing industry based on the customers' and industrial expert's perspective. Here we have selected ten different criteria based on the literatures available on the agile manufacturing. The criteria are segregated and ranked according to the nature and influence they possess on other criteria using decision making trial and evaluation laboratory (DEMATEL) methodology. This study also helps the metal fabrication industry to identify the most influencing criteria to implement on agile manufacturing and to have high efficiency on the production. The results show that the customer satisfaction seems to be the primary criteria that will have more influence in metal fabrication industry.

INTRODUCTION

In this competitive market environment in any space of manufacturing industry, we must improvise even a minute thing or procedure to compete in the particular sector. One of the most innovative and brilliant improvement in the manufacturing industry is the agile manufacturing process (AM) (Kidd, 1995). Metal fabrication is the production of metal structures by cutting, bending and assemble process (Kalpakjian, 2014). It is one of the highly growing industry in India (Goldar & Kumari, 2003). Now-a-days, the competitiveness of the metal fabrication industry has increased due to the increase in the change of expectations in customer's mind and improvement in advanced manufacturing in the last two decades like incorporation of laser technology, abrasive water jet technology and improvement in the advanced robotic technology (Hill. T & Hill. A, 2009). So, metal fabrication industries should make changes so that it can sustain in this competitive market. The manufacturing companies have possessed the competitive environment by making changes in a faster way according to the customer requirements. In general, customers would like to purchase better quality product at an affordable price (Ismail et al., 2014), which drives industries to adapt new implementation and methodologies in manufacturing technology. In order to avoid the panic situations, manufacturing companies have created separate model to satisfy the modern demands of the customer. These issues are related and interconnected by the model which have been addressed by the practitioners and researchers under the term "Agile Manufacturing" (Gunasekaran et al., 2008). The focus towards agile manufacturing increased the attention of researchers in a larger scale. The researchers are focusing on improving the agile manufacture so that it can be implemented to increase the efficiency of the production in manufacturing department (Kidd, 1995). The agile is also define as the process or the ability to move quickly, effectively and easily. It is the ability to move quickly or to act quickly or answer quickly or to respond quickly to the customer's demand (Kidd, 1995). The agile manufacturing is defined as the manufacturing process or processing of an organization in responding quickly and effectively to the customers call or request to satisfy the customer needs completely and efficiently. In other words, Agile Manufacturing is designed to meet the frequently changing market requirements with relevant partners based on knowledge according to their respective domain, readiness to face the challenges in terms of change and uncertainty, and employing people to manage the unpredictability. Some of the critical issues and questions that are to be addressed to understand how agile manufacturing might be achieved with the clearness of intention, focus and goals.

The main objective of the agile manufacturing is to satisfy the customers. The organization which implements agile manufacturing has to improve itself in the tools, manufacturing, communication, processing and training to respond quickly to the customer needs and satisfaction. The organization which implements agile manufacturing tends to have strong networks with suppliers and related companies along with agreements with suppliers and other partners. The organization should always seek for the changes to improve itself in any way to satisfy the customer. This process helps the organization in knowing the customer needs and analyzing the future trends of the market. This process also helps the organization to share all the necessary design and information related to the product with the marketing department, purchase department and sales department to quickly respond to the customer needs and requirements. This helps the organization to work and produce the product efficiently. Agile manufacturing not only seeks for the customer satisfaction but also to maintain the cost of the product which is appropriate to both customer and organization. This maintains the profits of the organization and also the status in the market. Agile manufacturing also seeks in maintaining the quality of the product according to the customer standards. Agile manufacturing helps the marketing and sales people to communicate with the customer more effectively and efficiently.

Agile manufacturing is generally considered as the innovative step next to lean manufacturing. While lean manufacturing is only concerned on reducing the cost of the product. The lean manufacturing also considering the quality and customer satisfaction can be termed as the agile manufacturing. Lean manufacturing and agile manufacturing can generally be compared as that of between the normal train and bullet train, where the bullet train represents the agile manufacturing.

There are many criteria which influence on the efficiency of the agile manufacturing. In this research, different criteria which influence the agile manufacturing are considered and sorted them depending on the importance it results in the agile manufacturing and influence they project on other criteria. The methodology we used to rank the criteria and find the relation between the criteria is DEMATEL (decision making trial and evolution laboratory) method. This research helps the metal manufacturing industry to understand the criteria which plays an important role in selecting the manufacturing process and procedure in taking the product to the customer to maximize the satisfaction.

LITERATURE REVIEW

The literature on agile manufacturing, criteria that effect the agile manufacturing, methodologies used by earlier researchers on the agile manufacturing are reviewed in this section. The research gap in the agile manufacturing research is also discussed.

Agile manufacturing has been suggested by many researcher (Kidd, 1995; Naylor et al., 1999; Yusuf et al., 1999; Gunasekaran, 1999; Sharifi and Zhang, 2001; Sharp et al., 1999; Brown and Bessant, 2003) Agile manufacturing is currently used by many industries like electronic industries, automobile industry, machine tool industry, aerospace industry, chemical industries casting industry, house hold industry, fabrication industry and so on which improved their production efficiency. Agile manufacturing has a wide scope to apply in all the industries (Thilak et al., 2015). There are many criteria which affect the agile manufacturing. In this paper, the criteria are classified into two subcategories as manufacturing factors and social factors. As shown in table 1, these criteria are categorized based on the nature of the criteria acting on agile manufacturing. The manufacturing factors deals with the criteria that influence the manufacturing aspects like material production and maintenance of the agile manufacturing whereas the social factors deal with the social aspects like sales and marketing of the product which effect on the agile manufacturing process.

There are manufacturing and social factors, which are applicable for any type of industry. These criteria influence one on other. So, the influential criteria are used to rank the criteria in the order of influences. This helps in the manufacturing industry to find priorities that need to be given to the different criteria. The manufacturing factors considered for the analysis are: mounting product requirement (Yamazaki et al., 2009), modern IT tools (Gunasekaran, 1999), concurrent engineering (Clausing, 1998), leagility capabilities (Naylor et al., 1999), reduced lead time (Stevenson et al., 2007) and cost minimization (Beattie et al., 1985). The social factors considered in this study are: competing priorities (Christiansen et al., 2003), data accuracy (Thomes et al., 1997), customer satisfaction (Griffin, 1995), social and cultural factor (Tajfel, 1969).

The methodology used for analysis is DEMATEL. The DEMATEL method ranks the ten criteria, which are effecting on the agile manufacturing (Jia et al., 2015). DEMATEL is an acceptable method to solve industrial related problems over the last two decades. Agile manufacturing was analyzed by other analyzing methods like interpretive structural modelling (Chidambaranathan et al., 2009). Interpretive structural modelling is a methodology used to solve problems by identifying and summarizing relationship among specific variables. Ontology based action planning and verification (Stephen, 2014), is the study based on the study of the domain or area of the properties and relationship between different drives and criteria. Fuzzy agility index (Samantra et al., 2015). DEMATEL involves incorporation of indirect relations in to compressed cause and effect modelling. We have incorporated DEMATEL methodology so that all the criteria can be related which are not directly linked to each other and rank them according to the influence they possess on other criteria.

PROBLEM DESCRIPTION

In general, it would be complex while planning and processing of any product which requires high quality, least price and maintaining customer satisfaction. Most of the literature sources focuses on some limited criteria of agile manufacturing, without the formidable structure for achieving agile manufacturing. In most of the cases, identification and evaluation of the criteria are disconnected for the agile manufacturing for the metal fabrication industry. There are many criteria to be included while selecting the process for the manufacturing. These are the criteria which describes the end product of the organization, which should satisfy the customer needs. The details of the ten criteria considered in this study are presented in table 1

Table - 1

S.no	Detonation	Criteria	Manufacturing Factors (D1)	Social Factors (D2)	Definition	Reference
1.	C1	Mounting Product Requirements	✓		It refers to the changing market scenarios and demand for individual product and services, increase in quality expectation and need to quicker delivery of the products or some of the factors that customer is very much concerned	Gunasekaran, 1998 ;1999
2.	C2	Competing Priorities		✓	Competing priorities is the capability of the firm in the particular sector to produce high quality product at low cost when compared to other firms.	Ward et al., 1998

3.	C3	Modern IT tools	✓		Modern IT tools refers to the modern software and information technology tools that are used by the firm.	Gunasekaran, 1999
4.	C4	Data Accuracy		✓	Data Accuracy refers to the information data values stored or collected for an object or product	Wang and Strong, 1996
5.	C5	Concurrent Engineering	✓		This is a method of designing and developing a product, in which project is subdivided and working on all of it simultaneously	Clausing, 1998
6.	C6	Leagility Capabilities	✓		Ability of the organization to maintain the balance between lean and agile supply chain during the productivity	Krishnamurthy and Yauch, (2007)
7.	C7	Reduced Lead Time	✓		Reducing Lead Time refers to the reduction of time between the initial stage and Execution stage.	Stevenson et al., 2007
8.	C8	Customer Satisfaction		✓	It refers to how the product and service of the supplied by the firm meets a customer expectation.	Anderson et al., 1994
9.	C9	Cost Minimization	✓		It refers to the minimization of final cost of the product as much as possible.	Burgess, 1974
10.	C10	Social and Cultural Factors		✓	Social, Religion, Politics, Law, Language Values and Attitude that effects the firm	Tajfel, 1969

The application areas of DEMATEL methodology is briefly presented in table 2.

Table - 2

S.no	***Application areas of DEMATEL***	***References***
1	Hospital Service Quality	Shieh et al., 2010
2	Supplier Selection Criteria	Chang et al., 2011
3	Green Supply Chain Management	Lin 2013
4	Selection of Managements System	Tsai et al., 2009
5	Risk of Failure	Chang et al., 2011
6	Web Advertising Effect	Wei et al., 2010
7	Restaurant Space Design	Horng et al., 2013
8	Medical Tourism	Chen, 2012
9	E- learning Program	Tzeng et al., 2007
10	Emergency Management	Zhou et al., 2011
11	Healthcare industries	Bhalaji et al., 2019
12	Knowledge Transfer	Sangaiah et al., 2017

DEMATEL Methodology

The DEMATEL methodology is explained through the steps below.

***Step 1**: Calculation of initial average matrix*
In this step, the expert members are asked to indicate the degree of direct influencing parameter that each element *i* maintains on each element *j,* represented by a_{ij} based on the influence scores as shown in Table 3.

Table 3. Linguistic rating

Variable	Influence Criteria
No Influence	0
Very Low Influence	1
Low Influence	2
High Influence	3
Very High Influence	4

The expert members with huge experience are asked to cater their score with the scale provided by DEMATEL. After obtaining the expert members view the required average matrix is formed. The average matrix A is denoted as shown in Eq. (1)

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

***Step 2**: Calculation of initial influence matrix*
The initial influence matrix X= $[\mathrm{x}_{\mathrm{ij}}]_{\mathrm{n}\times\mathrm{n}}$ is obtained by normalizing the average matrix A. Each element in matrix A occupies between zero and one $\left(0 \le x_{ij} < 1\right)$.

***Step 3**: Derivation of full direct/indirect influence matrix*
Using the equation (2) and (3) full direct/indirect influence matrix is determined. The contextual relationship among the characteristics of the system is represented by matrix Y and further it can be converted into realistic structural model. The full direct/indirect influence matrix Y (Lin and Tzeng, 2009) is considered to be the infinite series of direct/indirect effects of each and every aspect get by the matrix operation of Q.
Q = z * A (2)

$$\text{Where} \quad z = \min \left\{ \frac{1}{\max_{1\le i\le n} \sum_{j=1}^{n} a_{ij}}, \frac{1}{\max_{1\le i\le n} \sum_{i=1}^{n} a_{ij}} \right\} \quad (3)$$

And $\lim_{h\to\infty} Q^h = [0]_{n,n}, 0 \le x_{ij} \le 1.$

***Step 4**: Attainment of total influential/relation matrix* Y
The total influence/relation matrix Y is attained using equation (4). Then the total influence/ relation matrix Y is represented as

$$Y=Q(I-Q)^{-1} \quad (4)$$

where I is the identity matrix.

Total influence/relation matrix $Y = [t_{ij}]_{n \times n}$ (5)

Step 5*: Calculation of sum of rows (R) and sum of columns (C) using equations (6) and (7)*

$$R = \left\{ \sum_{j=1}^{n} t_{ij} \right\}_{n \times 1} \quad (6)$$

$$C = \left\{ \sum_{i=1}^{n} t_{ij} \right\}_{1 \times n} \quad (7)$$

Where R represents overall effects of one criteria (i) on the other criteria (j) and C stands the overall effects attained by the criteria (j) due to criteria (i)

Step 6*: To represent the cause and effect diagram with the use of data set mapping (R+C;R-C).*
The data set R+C represents the significance of key criteria of agile manufacturer where as R-C represents the entire the whole effect of the same criteria. If the obtained R-C is positive then the criteria falls in the cause group, in case of R-C is negative then the criteria falls under effect group.

IDENTIFYING AND EVOLUTION OF CRITERIA

For the direct relationship matrix, a team of experts were formed to share their opinion on the criteria and asked them to rank the factors depending on the nature of influence. These experts are the industrial people who are having more than 10 years of experience in the metal fabrication industries. The metal fabrication industries were asked to collect the information and share their perception on the importance of criteria. They are also asked to rate the importance of each criteria based on the nature of the criteria. These experts rated the criteria from 0 – 4 scale (table 3) to form the initial direct relationship matrix. As shown in the table 4. This rating indicates the influence of one criterion on other criteria. Then, the initial direct relationship matrix is normalized with the help of equations 2 and 3. The resultant normalized matrix is tabulated in the table 6. The total influence matrix is formed by substituting the normalized matrix in to the equation 4, and tabulated as shown in the table 7. The prominence vector is represented in the table 8, and the relative vector is represented in the table 9 and 10. These relative vectors are categorized into two categories depending on the sign of the value. The positive sign indicated the cause group and the negative sign indicates the effect group. Also, the averaged DEMATEL methodology has been applied to the subcategories of the manufacturing criteria and the social criteria of metal fabrication industry. The table 11 shows the total influence matrix for the sub categories and in the table 12 prominence and relative vectors of the sub categories has been calculated.

Table 4. Direct Relationship matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	0	3	4	2	1	4	4	1	0	1
C2	4	0	2	4	0	3	3	0	2	2
C3	0	2	0	3	1	3	2	1	4	3
C4	0	3	4	0	3	4	3	0	1	2
C5	3	4	3	2	0	1	3	3	4	3
C6	4	4	3	4	1	0	4	3	4	4
C7	4	3	2	2	3	4	0	4	4	3
C8	4	3	1	4	3	3	4	0	3	1
C9	3	2	1	1	4	4	4	3	0	4
C10	3	1	2	1	3	4	3	1	4	0

Table 5. Initial direct relationship matrix A

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	0.0	3.0	4.0	2.0	1.0	4.0	4.0	1.0	0.0	1.0
C2	4.0	0.0	2.0	4.0	0.0	3.0	3.0	0.0	2.0	2.0

C3	0.0	2.0	0.0	3.0	1.0	3.0	2.0	1.0	4.0	3.0
C4	0.0	3.0	4.0	0.0	3.0	4.0	3.0	0.0	1.0	2.0
C5	3.0	4.0	3.0	2.0	0.0	1.0	3.0	3.0	4.0	3.0
C6	4.0	4.0	3.0	4.0	1.0	0.0	4.0	3.0	4.0	4.0
C7	4.0	3.0	2.0	2.0	3.0	4.0	0.0	4.0	4.0	3.0
C8	4.0	3.0	1.0	4.0	3.0	3.0	4.0	0.0	3.0	1.0
C9	3.0	2.0	1.0	1.0	4.0	4.0	4.0	3.0	0.0	4.0
C10	3.0	1.0	2.0	1.0	3.0	4.0	3.0	1.0	4.0	0.0

Table 6. Normalized direct influence matrix Q

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
C1	0.0000	0.0968	0.1290	0.0645	0.0323	0.1290	0.1290	0.0323	0.0000	0.0323
C2	0.1290	0.0000	0.0645	0.1290	0.0000	0.0968	0.0968	0.0000	0.0645	0.0645
C3	0.0000	0.0645	0.0000	0.0968	0.0323	0.0968	0.0645	0.0323	0.1290	0.0968
C4	0.0000	0.0968	0.1290	0.0000	0.0968	0.1290	0.0968	0.0000	0.0323	0.0645
C5	0.0968	0.1290	0.0968	0.0645	0.0000	0.0323	0.0968	0.0968	0.1290	0.0968
C6	0.1290	0.1290	0.0968	0.1290	0.0323	0.0000	0.1290	0.0968	0.1290	0.1290
C7	0.1290	0.0968	0.0645	0.0645	0.0968	0.1290	0.0000	0.1290	0.1290	0.0968
C8	0.1290	0.0968	0.0323	0.1290	0.0968	0.0968	0.1290	0.0000	0.0968	0.0323
C9	0.0968	0.0645	0.0323	0.0323	0.1290	0.1290	0.1290	0.0968	0.0000	0.1290
C10	0.0968	0.0323	0.0645	0.0323	0.0968	0.1290	0.0968	0.0323	0.1290	0.0000

Table 7. Total influence matrix Y

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
C1	0.2400	0.3300	0.3400	0.2900	0.2100	0.4100	0.4000	0.2000	0.2600	0.2600
C2	0.3500	0.2400	0.2800	0.3300	0.1800	0.3800	0.3700	0.1600	0.3000	0.2900
C3	0.2400	0.2900	0.2100	0.3000	0.2200	0.3700	0.3400	0.1900	0.3600	0.3200
C4	0.2500	0.3300	0.3400	0.2300	0.2700	0.4000	0.3700	0.1700	0.2900	0.3000
C5	0.4000	0.4200	0.3600	0.3400	0.2300	0.4000	0.4500	0.2900	0.4300	0.3800
C6	0.4800	0.4700	0.4100	0.4400	0.3100	0.4400	0.5400	0.3300	0.4800	0.4500
C7	0.4700	0.4300	0.3700	0.3800	0.3500	0.5300	0.4100	0.3500	0.4700	0.4100
C8	0.4300	0.4000	0.3100	0.4000	0.3300	0.4600	0.4900	0.2100	0.4000	0.3300
C9	0.4200	0.3800	0.3200	0.3200	0.3600	0.5000	0.5000	0.3100	0.3300	0.4200
C10	0.3700	0.3100	0.3000	0.2800	0.3000	0.4400	0.4100	0.2300	0.4000	0.2600

Table 8. The prominence vector

Rank	**Criteria**	$r_i + s_i$
1	6	8.6800
2	7	8.4500
3	9	7.5800
4	10	6.7200
5	1	6.5900
6	2	6.4800
7	5	6.4600
8	4	6.2600
9	8	6.2000
10	3	6.0800

Table 9. Relative vector – cause group

Rank	**Cause Group – Criteria**	$r_i - s_i$
1	8	1.3200
2	5	0.9400
3	9	0.1400
4	6	0.0200

Table 10. Relative vector – effect group

Rank	**Effect Group – Criteria**	$r_i - s_i$
1	2	-0.7200
2	1	-0.7100
3	3	-0.4000

4	4	-0.3600
5	10	-0.1200
6	7	-0.1100

Table 11. Total influence matrix for the sub category

Sub Category	D1	D2
D1	0.38	0.35
D2	0.35	0.27

Table 12. Prominence vector and Relative vector

Sub Category	r_i	s_i	$r_i + s_i$	$r_i - s_i$
D1	0.73	0.73	1.46	0
D2	0.62	0.62	1.24	0

RESULTS AND DISCUSSION

In this study, the influential criteria are separated into sub categories. These criteria are separated depending on the nature of influence they project on the metal fabrication. These are manufacturing criteria (**M1**) and social criteria (**M2**). From the results of table 12, casual diagram (Fig. 1) of these sub categories are prepared, it is interesting to note that both manufacturing criteria (**M1**) and social criteria (**M2**) have same influential factors in the agile manufacturing process of metal fabrication, which shows that the agile manufacturing is equally depended on social criteria and as well as the manufacturing criteria in the metal fabrication industry. This shows that, for any company to be highly successful and to compete in the metal fabrication industry, the manufacturing and the social criteria are to be considered equally while planning for the agile manufacturing.

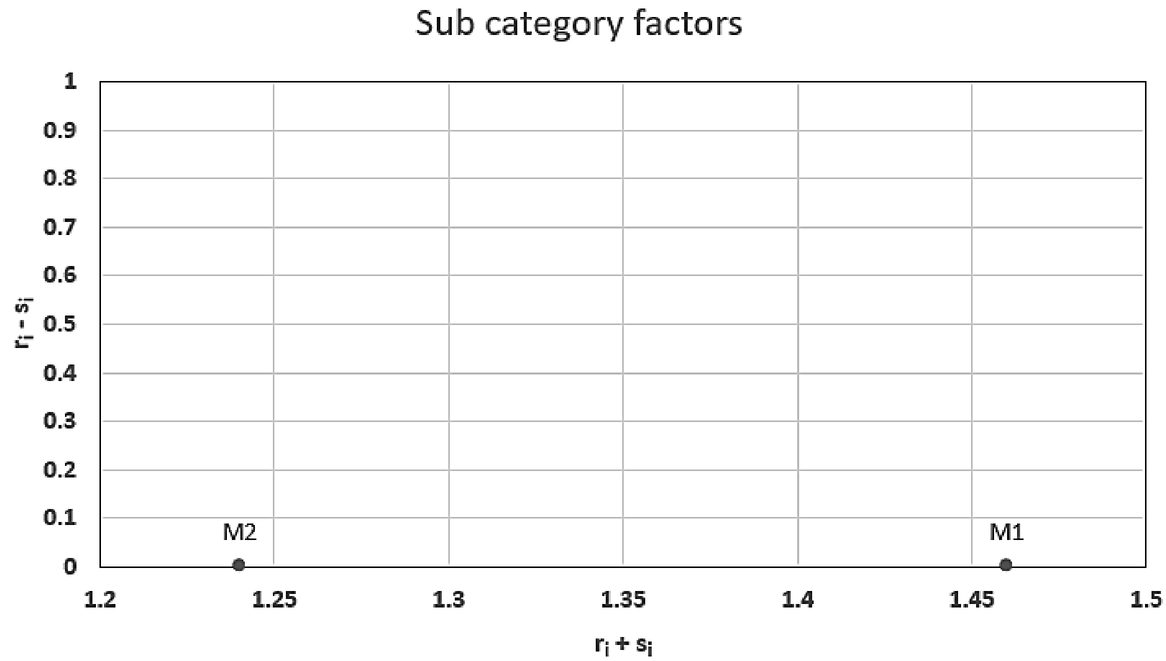

Figure 1 Causal diagram for the sub category factors

To get in-depth analytical information about the criteria of each sub category, each criterion has been identified in-terms of cause and effect group in each sub category. The manufacturing criteria included are: mounting product requirement (C1), Modern IT tools (C3), Concurrent Engineering (C5), Legality capabilities (C6), Reduced lead (C7) and cost minimization (C9). The social criteria considered are:

competing priorities (C2), Data accuracy (C4), Customer satisfaction (C8) and Social and cultural factors (C10). Based on the information obtained from the causal diagram for the manufacturing criteria fig. 2, the manufacturing factors can be sorted as C5 > C9 > C6 > C7 > C3 > C1. From the results obtained from the table 8, 9 and 10. C5, C9 and C6 are spotted in the cause group criteria and C7, C3 and C1 are spotted in the effect group criteria. Depending on the relative vector of each criteria, the criteria is divided into two stages, the positive values are the cause group criteria and the negative values are the effect group criteria. This shows that the cause group are having driving potential. These criteria are the one influencing criteria of the effect group. Here the effect group is having driven power. The criteria on the cause group effects the criteria on the effect group. If we consider C5 (concurrent engineering), it is having the highest influential criteria among the manufacturing criteria. Concurrent engineering, the process in which the product design and development is divided and worked out simultaneously, is the primary factor in the agile manufacturing. Concurrent engineering is used to reduce the product development time and lead time. This concurrent engineering factors drives all the other criteria in the manufacturing criteria of the agile manufacturing in metal fabrication industry. So, the concurrent engineering is given the highest priorities while considering the agile manufacturing. The next criteria in the order is for C9 (cost minimization), that means the total cost to be invested in the design, development and the manufacturing should be as minimum as possible, because this influence the product selling price. If the cost of the product is reduced the product will have high influence on the customer's mind. Here it can be noted from the fig 2, that the concurrent engineering drives the cost minimization so, concurrent engineering is the driver and the cost minimization is the driven criterion. Then, similarly the next position is for C6 (legality capabilities), here the lean ability and agility of the manufacturing is considered. Next in the order is for C7 (reduction lead time), where the time taken for the product from the initiation stage to the completion of the production should be minimum. Here the product should be manufactured as soon as possible to get perfect result of the agile manufacturing. Next position in the order is for C3 (modern IT tools), means that the modern IT tools like the latest software, latest software equipment are having less influence on the agile manufacturing when compared to other criteria. The least priority is to be given for C1 (mounting product requirements), thus means C1 is having little influence on the agile manufacturing.

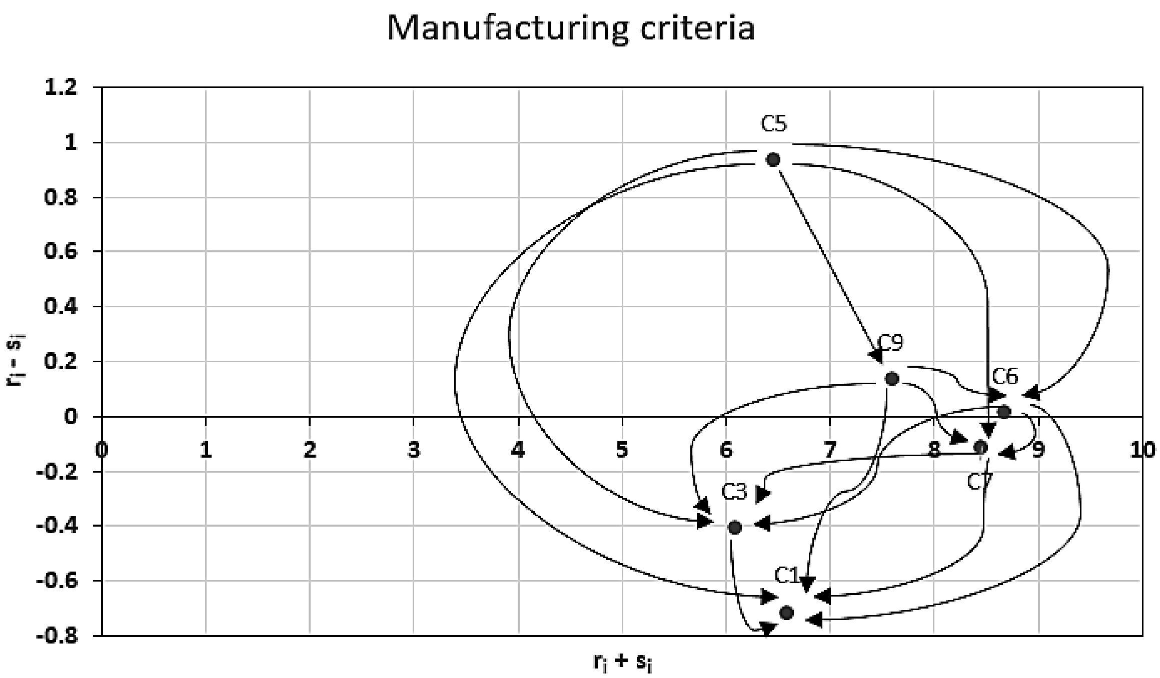

Figure 2 Casual diagram for the manufacturing criteria

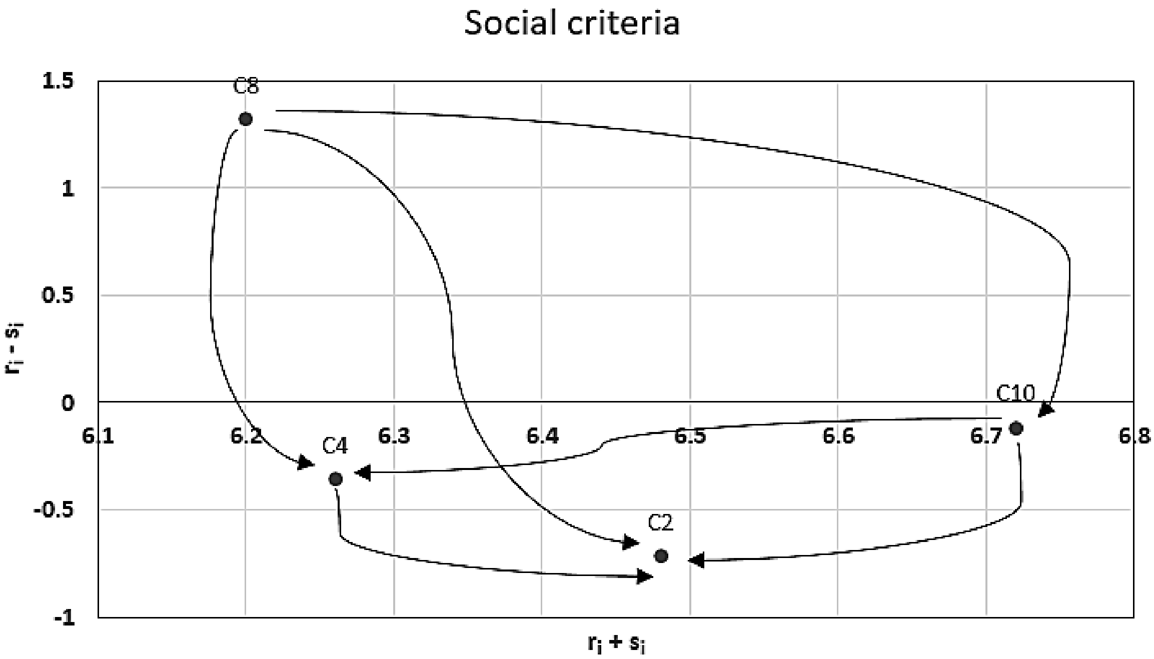

Figure 3 Casual diagram for the social criteria

Based on the information from figure 3, the social criteria can be sorted as C8 > C10 > C4 > C2. Similar to the manufacturing criteria, customer satisfaction (C8) is spotted in cause group criteria. Then, C10, C4 and C2 are spotter in the effect group criteria. The most influencing criteria among the social criteria is C8 (customer satisfaction). Generally, customer satisfaction is the highest criteria when considering the social criteria of agile manufacturing in metal fabrication. Customer feedback, customer usage and customer satisfaction are the most effecting criteria because the product must be user friendly and useful to the customer so, before taking any product, it must be tested with surveys so that it can have high impact on the end customer. Next position is given to the C10 (cultural factors). And the least priority is given to the C4 (Data accuracy) and C2 (competing priorities) when compared to the other criteria in the social criteria.

From the figure 4 showing the casual diagram for the overall criteria, C8 (Customer satisfaction) and C5 (Concurrent Engineering) are the top two influential criteria and C2 (Competing priorities) and C1 (mounting product requirement) are the least two influential criteria. So, for any metal fabrication industry to be successful in the market and have high growth of the product, these are the important criteria to be considered in the agile manufacturing of metal fabrication industry.

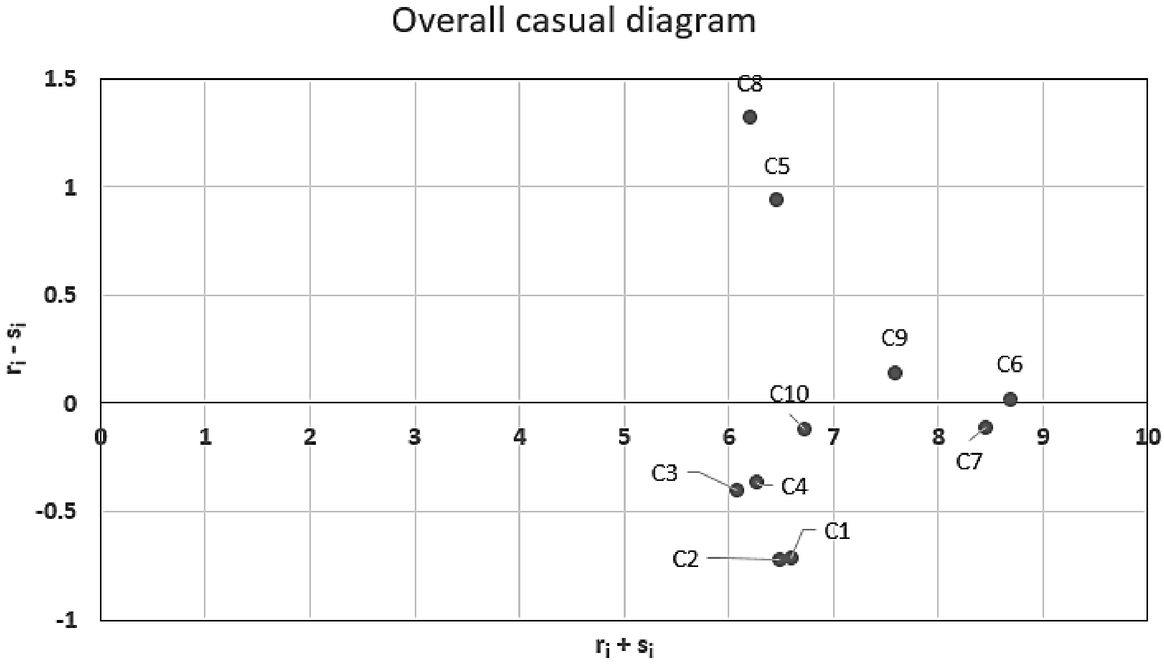

Figure 4 Casual diagram for the overall criteria

Managerial implication

The results from the analysis of criteria in the agile manufacturing of the metal fabrication industry shows that both manufacturing factors and social factors have same major level of influence on the agile manufacturing. This results obtained are useful for the metal fabrication industry to improve itself in the market to achieve high customer satisfaction. This research is helpful for the metal fabrication industry in finding the crucial criteria while considering the agile manufacturing. The ranking of the criteria helps the industry in agile manufacturing to process effectively and efficiently. The results shows the ranking of the criteria which helps the industry to prioritize the criteria so that it can gain competing strength in the sector. The result shows that the customer satisfaction and concurrent engineering are the top most influencing criteria in the agile manufacturing. So, if the metal fabrication industry is to have high profile, then it must always include the customer satisfaction and concurrent engineering as the top most priorities than any other criteria. This research helps the metal fabrication industry in improving or maintaining the standard of the organization in the market sector in manufactures and customer's perspective.

CONCLUSIONS

From this study, it is observed that the criteria in the agile manufacturing places an important role in this competitive world, where companies are looking for new methods and innovative techniques to improve itself and compete in the industry and to be the best in the metal fabrication industry sector. Similarly, when a company is seeking for the customer's standards and high profile in the space of manufacturing industry, there are certain criteria that should be considered like customer feedback, which helps the company to make a product to satisfy a customers of metal fabrication industry.

The analysis of the criteria effecting the agile manufacturing in the metal fabrication industry using DEMATEL has not been attempted in any of the literatures provided to the best of our knowledge. This study had mainly focused on the criteria that are effecting the agile manufacturing in the metal fabrication industry. This analysis helps in providing the information about what criteria should be considered in agile manufacturing. Available literature only results in finding the criteria on agile manufacturing, but there was no study on ranking and prioritizing the criteria in the metal fabrication industry. To overcome this, DEMATEL methodology is used to identify the influence of criteria on agile manufacturing in metal fabrication industry. As discussed in the result section, both the manufacturing criteria and social criteria have same influence on the agile manufacturing when analyzed with the application of DEMATEL methodology. But if we consider all the ten criteria in the DEMATEL analysis, it is observed that the customer satisfaction and the concurrent engineering are the highest influencing criteria in the agile manufacturing process of metal fabrication industry. When it comes to the least influencing criteria mounting product requirements and the competing priorities are the least influencing criteria when compared to the other criteria of agile manufacturing of the metal fabrication industry. So, for any metal fabrication industry to have high success rate they must consider these priorities of the criteria while selecting agile manufacturing. This research helps the metal fabrication industry to have knowledge in prioritizing criteria that could be helping the product to have high growth rate in the market.

This research also have some limitation, since it only addresses the ten selected criteria which we have considered from the literatures. But in the real system there might be more criteria which effect the agile manufacturing. These criteria are only based on metal fabrication industry so, these are not applicable for any other industry. In addition, this research open opportunities for future research in the metal fabrication industry including the supply chain management, customer services, quality check of the product, machine durability and so on. Finally, this research helps the metal fabrication industry in selection of the criteria and the criteria that most effect the agile manufacturing and prioritize these criteria so that they can be applicable in the metal fabrication industry.

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