International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 06 | June -2017 www.irjet.net p-ISSN: 2395-0072

# Agility Assessment for Enhancing Agility: a Case study in Food Manufacturing Industry

**Nitha K N[1], Sunil D T[2]**

[1]*Mtech Student, Government Engineering College, Thrissur, Kerala, India*
[2]*Assistant Professor, Government Engineering College Thrissur, Kerala, India*

---

**Abstract -** *The food industries of India marked its own place in world food trade by its huge growth and contribution in every year. In India, the food sector has emerged as a high-growth and high-profit sector due to its immense potential for value addition, particularly within the food processing industry. The food industry, which is currently valued at US$ 39.71 billion!, is expected to grow at a Compounded Annual Growth Rate (CAGR) of 11 per cent to US$ 65.4 billion by 2018.Today with globalization and technological development the food from any part of the world can be made available to everyone. The need and expectation of customer is increasing also in food industry like other .In order to survive in existing condition like Increased product variety and continuously changing market condition an organization needs to be agile. In this paper assessment of agile in food industry is carried out using fuzzy logic. For assessment twenty criteria's model was used. The assessment was conducted as a case study in an Indian food organization. The key enabler and obstacles are found out using this method and a plan of action was also given for improving the agility of the organisation.*

***Key Words***: **Agile Manufacturing, malcom bridge award, fuzzy logic, Fuzzy agility index**

## 1. INTRODUCTION

Manufacturing field of this time faces competition in its all functional areas. The developments in the field of manufacturing as well as information technology made the competition tougher. Today the customer is expecting wide variety of products at low cost. For a company needed to be successful in this competition it is needed to flexible, innovative, and responsive to the dynamic to market. Such capability of a company is known as agility. An agile company can only able to exist in today' as well as tomorrow's market. Others fail to reach to frontier stages in today's market. Agility means rapid response to changing conditions. A company who intend to attain through a slow pace can never be a winner because their competitor may be quicker in meeting market changes. In order to survive a company need to assess their agility level and need to concentrate in the areas where more money and attention need to invest for attaining agility at faster rate. This paper deals with assessment of agility index of a food manufacturing company and finding its obstacles and suggesting methods to improve. In this paper agile assessment is done using a twenty criteria model. Firstly an agile potential company is selected from a group of companies using Malcolm Bridge Award Method. Then agility index of the company is calculated using fuzzy logic. Finally obstacles are identified and improvement measures are suggested.

## 2. LITERATURE REVIEW

Gunasekaran (1998) have give about idea of agile manufacturing and about its enablers and proposed a frame work implementation. Zhang and Sharifi (2000) gives a tool to determine need of company to implement AM p or not, and also a tool for measuring the agility level. They also proposed the neural network to determine the required agile capabilities and the providers. Gunasekaran et al. (2002) measure AM work in aerospace manufacturing firm .This paper used a questionnaire method for assessing the firm's agility. Yang and Li (2002) proposed a method to assess agility using a multi-grade fuzzy approach. They identified the ranges in a scale of 2 to 10 to indicate the company's agility. The paper proves fuzzy logic which is better than conventional scoring approach to reduce the vagueness. Chang Torng Lin ,Hero Chiu ,Yi-Hong Tseng (2006) article related to assessing agility index in supply chain management of automotive industry using fuzzy logic. This paper uses drivers and enablers of agile manufacturing for assessment .The paper measures the agility level and identified the obstacles and gives suggestions for improving the agility level. R Devadasan (2007) agility assessment carried out in Indian pump industries using the scoring approach. Vinodh *et al.* (2008) have contributed a method for measuring agility in an electronics Company using 20 criteria agility assessment model This article deals with quantification agility level of the firm using scoring approach.Vinod et al. (2010) did their agility assessment using combined scoring and multi grade fuzzy logic method and provide suggestions for improve. Vinod et al. (2014) uses forty criteria method for assessing agility.
Hence from the literature review, it was found that so many studies are conducted in assessing agility in various manufacturing sector. Hence in this paper an attempt is made to assess agility in food manufacturing industries.

## 3. RESEARCH METHODOLOGY

The methodology followed in the paper is shown in the figure.1 .In the first phase, from the literature review criteria agile model is selected from which 5 enablers,20 criteria's,

78 attributes are selected. In the second phase a company with agile potential is needed to selected .For selection National Quality Malcom bridge award is used. From preliminary analysis a company is selected for case study. There after agility index of the organization is estimated followed by identification of obstacles and suggestions for improvement.

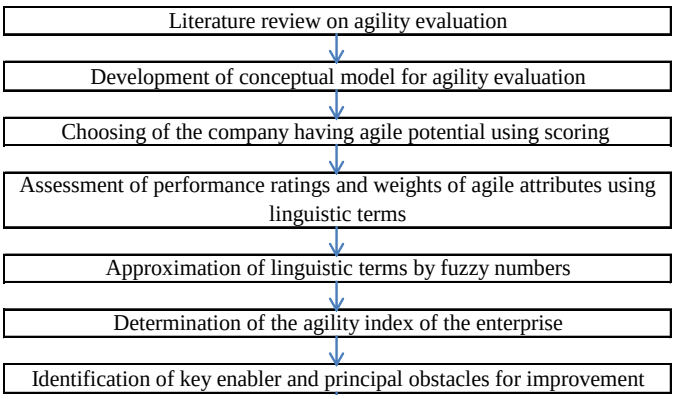


**Fig -1**: Research Methodology

**Table- 1**: Conceptual model for agility evaluation

### 3.1 Design of agility evaluation system

The agility evaluation system has been designed by referring to the 20 criteria agile model (Vinod et al. 2010). The agility evaluation system is shown in Table 1. This system consists of three levels:

- First level index represents five agility enablers.
- Second level index represents 20 agile criteria.
- Third level index represents various agile attributes.

The corresponding indices are placed as shown in Table 1. The agility evaluation system represents a comprehensive overview of agility from various perspectives such as management responsibility, manufacturing management, workforce, and technology and manufacturing strategy.

### 3.2 Preliminary Analysis

In the preliminary analysis from a group of companies a company is needed to select for assessing agility index. For primary selection Malcolm Bridge National Quality Award (MBQNA) model is found suitable. In this model 20 criteria's are grouped under 5 enablers Vinod (2008).

| Sl NO | Agile enabler (level 1 index) | Agile criteria (level 2 index) | Agile attributes (level 3index) |
|---|---|---|---|
| 1 | Management responsibility agility ($AC_1$) | Organizational structure ($AC_{11}$) | Flattened organizational structure ($AC_{111}$) |
| | | | Smooth information flow ($AC_{112}$) |
| | | Devolution of authority ($AC_{12}$) | Team management for decision making($AC_{113}$) |
| | | | Interchangeability of personnel ($AC_{114}$) |
| | | | Clear definition of personnel's responsibility and authority ($AC_{121}$) |
| | | | Education and training to create the self-managed teams ($AC_{122}$) |
| | | Nature of management ($AC_{13}$) | Participative management style ($AC_{131}$) |
| | | | Clearly known management goal ($AC_{132}$) |
| | | | Management involvement ($AC_{133}$) |
| | | | Profit motivation coupled with humanitarian approach ($AC_{134}$) |
| | | | Transparency in information sharing ($AC_{135}$) |
| | | | Regular conduct of management–employees meetings ($AC_{136}$) |

**Table- 1**: (continues)

| Sl NO | Agile enabler (level 1 index) | Agile criteria (level 2 index) | Agile attributes (level 3index) |
|---|---|---|---|
| | | | Rapid evaluation and implementation of employee suggestions ($AC_{137}$) |
| 2 | Manufacturing management agility ($AC_2$) | Customer response adoption ($AC_{21}$) | Prevalence of continuous improvement culture ($AC_{211}$)<br>Communication media to collect the customer responses ($AC_{212}$)<br>Incorporation of customer's feedback into products ($AC_{213}$)<br>Empowerment of personnel to resolve customer problems ($AC_{214}$)<br>Efficient information system ($AC_{215}$) |
| | | Change in business and technical processes ($AC_{22}$) | Flexible business system ($AC_{221}$)<br>Application of BPR for reinventing and reengineering the organization ($AC_{222}$)<br>Employee's attitude tuned to accept the changes ($AC_{223}$)<br>Conduct of pilot study on new production business processes ($AC_{224}$) |
| | | Outsourcing ($AC_{23}$) | Adoption of SCM concepts for enhancing the outsourcing efficiency ($AC_{231}$)<br>Exploitation of IT utilities in managing the supply chain ($AC_{232}$)<br>Involvement of suppliers in product development ($AC_{233}$)<br>Working towards a smaller number of qualified suppliers ($AC_{234}$) |
| 3 | Workforce agility ($AC_3$) | Employee status ($AC_{31}$) | Flexible workforce to accept the adoption of new technologies ($AC_{311}$)<br>Implementation of job rotation system ($AC_{312}$)<br>Education and cross-training imparted to all the existing and new employees ($AC_{313}$) |
| | | Employee involvement ($AC_{32}$) | Strong employee spirit and cooperation ($AC_{321}$)<br>Employee empowerment ($AC_{322}$)<br>Institution of employee suggestion schemes ($AC_{323}$) |

**Table- 1**: (continues)

| Sl NO | Agile enabler (level 1 index) | Agile criteria (level 2 index) | Agile attributes (level 3index) |
|---|---|---|---|
| 4 | Technology agility ($AC_4$) | Manufacturing setups ($AC_{41}$) | Flexible manufacturing setups ($AC_{411}$)<br>Less time for changing the machine setups ($AC_{412}$)<br>Upgradation and retrofitting of machines ($AC_{413}$)<br>Usage of collapsible setups, jigs and fixtures ($AC_{414}$) |
| | | Product life cycle ($AC_{42}$) | Specification of product life to the customer ($AC_{421}$)<br>Company encouragement to the customer for switching over to new product ($AC_{422}$) |
| | | Product service ($AC_{43}$) | Products designed for easy serviceability ($AC_{431}$)<br>Products incorporated with modular design ($AC_{432}$)<br>Service centers well equipped with spares ($AC_{433}$)<br>Minimum time required to restore the defective product ($AC_{434}$) |
| | | Design improvement ($AC_{44}$) | Management's interest towards evolving new models ($AC_{441}$)<br>Training of design personnel in all aspects of design ($AC_{442}$)<br>Cross-functional teams towards running development ($AC_{443}$)<br>Preparedness of the management to invest on latest design techniques like RP and CAD/CAM ($AC_{444}$)<br>Usage of DFMA concepts, axioms and guidelines ($AC_{445}$) |
| | | Production methodology ($AC_{45}$) | Fully automated inspection systems ($AC_{451}$)<br>Management's interest towards evolving new models concepts ($AC_{452}$)<br>Application of lean manufacturing principles for waste elimination ($AC_{453}$)<br>Development of products whose components are all outsourced and assembled in-house ($AC_{454}$) |

**Table- 1**: (continues)

| Sl NO | Agile enabler (level 1 index) | Agile criteria (level 2 index) | Agile attributes (level 3index) |
|---|---|---|---|
| | | Manufacturing planning ($AC_{46}$) | Execution of short range planning ($AC_{461}$)<br>Company's procurement policy based on time schedule ($AC_{462}$) |
| | | Automation type ($AC_{47}$) | Flexible system ($AC_{463}$)<br>Company having automated systems ($AC_{471}$) |
| | | IT integration ($AC_{48}$) | Flexible automation ($AC_{472}$)<br>IT utilities incorporated with reengineered pattern of working ($AC_{481}$)<br>IT application to eliminate paper work ($AC_{482}$) |
| | ($AC_5$) | ($AC_{51}$) | Incorporation of new ideas into products ($AC_{511}$)<br>Conduct of survey/studies to ensure quality status ($AC_{512}$)<br>Usage of TQM tools ($AC_{513}$)<br>Inculcation of innovation into product design ($AC_{514}$) |
| | | Status of productivity ($AC_{52}$) | Productivity improvement in all functions ($AC_{521}$)<br>Productivity linked to the personnel prosperity($AC_{522}$)<br>Reduction of non-value-adding costs ($AC_{523}$)<br>Quality is not infused at the cost of productivity ($AC_{524}$)<br>Application of totality concepts in achieving productivity ($AC_{525}$) |
| | | Cost management ($AC_{53}$) | Activity-based method of product pricing ($AC_{531}$)<br>Costing system focusing on the identification and non-value adding activities ($AC_{532}$)<br>Costing system enabling the evaluation of future resource consumption ($AC_{533}$)<br>Product cost fixed based on customer's pricing ($AC_{534}$) |
| | | Time management ($AC_{54}$) | Scheduled activities ($AC_{541}$)<br>Training programmers on time management concepts ($AC_{542}$)<br>Adoption of time compression technologies ($AC_{543}$) |

Adopted for checking agile potential. The distribution of score for each enabler's and criteria's are shown in the Table 2 and Table 3.

**Table- 2**: Enabler Scoring

| Enabler | Mark |
|---|---|
| 1.Management responsibility enabler | 500 |
| 2.Manufacturing management enabler | 150 |
| 3.Employee enabler | 130 |
| 4.Technology enabler | 120 |
| 5.Manufacturing strategy enabler | 100 |

A company scoring more than 500 marks can be said that it have potential to acquire agility. A company score anywhere between 500 and 800 would be indicative of a favorable sign in the direction of acquiring agility. The companies scoring marks between 800 and 900 can be said to be almost nearing the acquirement of agility. It goes without saying that only very little efforts are required to propel these companies towards acquiring full-fledged agility. The company scoring marks more than 900 is said to have acquired agility to a remarkable extent. Such companies can confidently afford to continue its current practices for acquiring agility to the maximum extent.

For the preliminary analysis the questionnaire was prepared and distributed among different food manufacturing industries and response was collected . Company C1 which has got highest score was used for further analysis.

## 4. CASE STUDY

From the discussion above , we have found out that the company C1 has scored highest among others and chosen for further assessment. Company attained score of 855.5 out 0f 1000 In order to conceal the identity of the food manufacturing industry from hereby it is referred as ABC.ABC is located in Kerala, one of the famous brand among the food manufacturer. It is classified as Non-government Company. Its authorized share capital is Rs. 10,000,000 and its paid up capital is Rs. 7,750,000. The number of employees currently working at ABC is 400 the company is ISO certified with six sigma implemented. The current study is conducted among heads of different sections of the company.

**Table -3**: Mark Distribution for criteria

| Criterion number | Criterion | Marks |
|---|---|---|
| 1 | Organizational structure | 50 |
| 2 | Devolution of authority | 150 |
| 3 | Manufacturing set-ups | 10 |
| 4 | Status of quality | 50 |
| 5 | Status of productivity | 10 |
| 6 | Employees' status | 30 |
| 7 | Employee involvement | 100 |
| 8 | Nature of management | 300 |
| 9 | Customer response adoption | 100 |
| 10 | Product life cycle | 20 |
| 11 | Product service life | 10 |
| 12 | Design improvement | 20 |
| 13 | Production methodology | 10 |
| 14 | Manufacturing planning | 10 |
| 15 | Cost management | 20 |
| 16 | Automation type | 20 |
| 17 | Information technology integration | 25 |
| 18 | Change in business and technical processes | 25 |
| 19 | Time management | 20 |
| 20 | Outsourcing | 20 |
| | Total marks | 1,000 |

### 4.1 Determination of the appropriate linguistic scale for assessing the performance ratings and importance weights of agility attributes

For assessing the performance rating and important weightage of agile attribute linguistic variables are used .The linguistic variables used for performance ratings of agile capabilities are {excellent(E), very good (VG), good (G), fair (F), poor (P), very poor (VP), worst (W)} and for importance weightage are {very high (VH), high (H), fairly high (FH), medium (M), fairly low (FL), low (L), very low (VL)} are used. These variables are accepted by the experts shown in Table 4

**Table -4**: Fuzzy numbers for approximating linguistic variable values

| Linguistic Variable | Fuzzy Number |
|---|---|
| W | 0, 0.5, 1.5 |
| VP | 1, 2, 3 |
| P | 2, 3.5, 5 |
| F | 3, 5, 7 |
| G | 5, 6.5, 8 |
| VG | 7, 8, 9 |
| E | 8.5, 9.5, 10 |
| VL | 0, 0.05, 0.15 |
| L | 0.1, 0.2, 0.3 |
| FL | 0.2, 0.35, 0.5 |
| M | 0.3, 0.5, 0.7 |
| FH | 0.5, 0.65, 0.8 |
| H | 0.7, 0.8, 0.9 |
| VH | 0.85, 0.95, 1.0 |

### 4.2 Measurement of performance ratings and importance weightage using linguistic variables

After selecting the appropriate linguistic variables questionnaire was prepared. For measurement of importance weightage of the agile criteria's and enablers, the questionnaires were given among different. The weightages were given by the expert's .Similarly in order to assess the performance rating and importance weightage of the company ABC, the questionnaire were given to the heads of different departments. The response from the company is shown in Table 5

**Table- 5**: Aggregated performance rating and weight of agility attributes

| Aci | Acij | Acijk | Wi | Wij | Wijk | Rijk |
|---|---|---|---|---|---|---|
| $AC_1$ | $AC_{11}$ | $AC_{111}$ | VH | H | H | VG |
| | | $AC_{112}$ | | | H | VG |
| | | $AC_{113}$ | | | FH | VG |
| | | $AC_{114}$ | | | H | VG |
| | $AC_{12}$ | $AC_{121}$ | | FH | FH | VG |
| | | $AC_{122}$ | | | H | VG |
| | $AC_{13}$ | $AC_{131}$ | | H | H | VG |
| | | $AC_{132}$ | | | FH | VG |
| | | $AC_{133}$ | | | H | VG |
| | | $AC_{134}$ | | | H | VG |
| | | $AC_{135}$ | | | H | VG |
| | | $AC_{136}$ | | | H | VG |
| | | $AC_{137}$ | | | FH | VG |
| $AC_2$ | $AC_{21}$ | $AC_{211}$ | H | VH | H | VG |
| | | $AC_{212}$ | | | VH | E |
| | | $AC_{213}$ | | | H | VG |
| | | $AC_{214}$ | | | H | VG |
| | | $AC_{215}$ | | | H | E |
| | $AC_{22}$ | $AC_{221}$ | | H | H | G |
| | | $AC_{222}$ | | | H | G |
| | | $AC_{223}$ | | | H | VG |
| | | $AC_{224}$ | | | H | VG |
| | $AC_{23}$ | $AC_{231}$ | | FH | M | G |
| | | $AC_{232}$ | | | FH | G |
| | | $AC_{233}$ | | | FH | G |
| | | $AC_{233}$ | | | FH | G |
| $AC_3$ | $AC_{31}$ | $AC_{311}$ | H | H | H | G |
| | | $AC_{313}$ | | | M | G |
| | | $AC_{314}$ | | | H | VG |
| | $AC_{32}$ | $AC_{321}$ | | H | FH | G |
| | | $AC_{322}$ | | | H | VG |
| | | $AC_{323}$ | | | VH | E |
| $AC_4$ | $AC_{41}$ | $AC_{411}$ | VH | H | FH | G |
| | | $AC_{412}$ | | | H | VG |
| | | $AC_{413}$ | | | H | G |
| | | $AC_{414}$ | | | H | VG |
| | | $AC_{415}$ | | | M | G |
| | | $AC_{416}$ | | | H | VG |
| | $AC_{42}$ | $AC_{421}$ | | VH | VH | E |
| | | $AC_{422}$ | | | H | VG |
| | $AC_{43}$ | $AC_{431}$ | | H | H | G |
| | | $AC_{432}$ | | | H | VG |
| | | $AC_{433}$ | | | H | G |
| | | $AC_{434}$ | | | H | VG |
| | $AC_{44}$ | $AC_{441}$ | | VH | FH | VG |
| | | $AC_{442}$ | | | FH | VG |
| | | $AC_{443}$ | | | FH | VG |
| | | $AC_{444}$ | | | H | VG |
| | | $AC_{445}$ | | | M | G |
| | $AC_{45}$ | $AC_{451}$ | | H | M | G |

**Table -5:** (continued)

**Table -5** (continued)

| Aci | Acij | Acijk | Wi | Wij | Wijk | Rijk |
|---|---|---|---|---|---|---|
| | | $AC_{452}$ | | | H | VG |
| | | $AC_{453}$ | | | H | G |
| | | $AC_{454}$ | | | H | G |
| | $AC_{46}$ | $AC4_{61}$ | | H | FH | G |
| | | $AC_{462}$ | | | H | VG |
| | | $AC_{463}$ | | | FH | G |
| | $AC_{47}$ | $AC_{471}$ | | H | H | G |
| | | $AC_{472}$ | | | FH | G |
| | $AC_{48}$ | $AC_{481}$ | | H | H | VG |
| | | $AC_{482}$ | | | H | VG |
| $AC_5$ | | $AC_{483}$ | | | H | VG |
| | $AC_{51}$ | $AC_{511}$ | H | FH | H | VG |
| | | $AC_{512}$ | | | H | VG |
| | | $AC_{513}$ | | | FH | VG |
| | | $AC_{514}$ | | | FH | G |
| | | $AC_{515}$ | | | H | G |
| | $AC_{52}$ | $AC_{521}$ | | H | H | G |
| | | $AC_{522}$ | | | H | G |
| | | $AC_{523}$ | | | FH | VG |
| | | $AC_{524}$ | | | H | VG |
| | | $AC_{525}$ | | | H | G |
| | $AC_{53}$ | $AC_{531}$ | | H | FH | G |
| | | $AC_{532}$ | | | FH | G |
| | | $AC_{533}$ | | | H | VG |
| | | $AC_{534}$ | | | H | G |
| | $AC_{54}$ | $AC_{541}$ | | VH | FH | G |
| | | $AC_{543}$ | | | FH | G |
| | | $AC_{544}$ | | | H | VG |

### 4.3 Approximation of the linguistic terms by fuzzy numbers

Using the concept of fuzzy theory, the linguistic variables can be approximated by a fuzzy number Lin et al(2006). In the application of the relation between linguistic terms and fuzzy numbers, the linguistic terms are transferred into fuzzy numbers are shown in Table 6

### 4.4 Determination of fuzzy agility index FAI

FAI gives the overall agility level of a company. The calculation starts from the lower level. First the fuzzy index of the criteria has been calculated using the weightage and the performance rating of the attributes. It can be calculated by the formula

$$AC_{ij} = {}_{k=1}\Sigma^{n} ( R_{ijk} \times \Sigma W_{ijk} ) / {}_{K=1}\Sigma^{n} W_{ijk}$$

Where $AC_{ijk}$ represent performance rating and Wijk represent fuzzy importance weight of the agile attribute

Fuzzy index of organizational structure =

$AC_{11}$ =[ (.7,.8,.9) × (7,8,9) + (.7,.8,.9)× (7,8,9) + ( 5,6.5,8) × (7,8,9) + (.7,.8,.9) × (7,8,9)] / [ (.7,.8,.9) +(.7,.8,.9) + (5,6.5,8) +(.7,.8,.9)]

= (7, 8, 9 )

Similarly Fuzzy index of enablers can be calculated

Finally Fuzzy Agility Index=

FAI=[(7,8,9)×(.85,.95,1)+(6.43,7.59,8.69)×(.7,.8,.9)+(6.47,7.62,8.71)×
(.7,.8,.9)+(6.32,7.49,8.02)×(.85,.95,1)+(5.81,7.09,8.39)×(.7,.8,.9)]/[(.85,.95,1) +(.7,.8,.9) +(.7,.8,.9)+ (.85,.95,1) +(.7,.8,.9)]

FAI= (6.43, 7.58, 8.56)

### 4.4 Determination of Euclidean distance to match FAI with approximate agility level

From the above calculation we get a fuzzy agility index which cannot able to say directly how much agile the company is .So it is needed to match with appropriate agility level .Once FAI obtained it can be match with linguistic variable. From the literature survey Euclidean distance method seen as widely used as well as most reliable method for matching the membership functions with linguistic variable. The advantage of Euclidean distance method is the most intuitive form of human perception of proximity Chang Torng et al(2006).For matching the FAI a natural level expression set taken for AL=

**Table 6**: Linguistic variables approximated by fuzzy numbers

| ACi | ACij | ACijk | Wi | Wij | Wijk | Rijk | Rij |
|---|---|---|---|---|---|---|---|
| $AC_1$ | $AC_{11}$ | $AC_{111}$ | (0.85,0.95,1.00) | (0.7,0.8,0.9) | (.7,.8,.9) | (7,8,9) | (7,8,9) |
| | | $AC_{112}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{113}$ | | | (.5,.65,.8) | (7,8,9) | |
| | | $AC_{114}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{12}$ | $AC_{121}$ | | (0.50,0.65,0.80) | (.5,.65,.8) | (7,8,9) | (7,8,9) |
| | | $AC_{122}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{13}$ | $AC_{131}$ | | (0.7,0.8,0.9) | (.7,.8,.9) | (7,8,9) | (7,8,9) |
| | | $AC_{132}$ | | | (.5,.65,.8) | (7,8,9) | |
| | | $AC_{133}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{134}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{135}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{136}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{137}$ | | | (.5,.65,.8) | (7,8,9) | |
| $AC_2$ | $AC_{21}$ | $AC_{211}$ | (0.7,0.8,0.9) | (0.85,0.95,1.00) | (.7,.8,.9) | (7,8,9) | (7.64,8.63,9.41) |
| | | $AC_{212}$ | | | (.85,.95,10) | (8.5,9.5,10) | |
| | | $AC_{213}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{214}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{215}$ | | | (.7,.8,.9) | (8.5,9.5,10) | |
| | $AC_{22}$ | $AC_{221}$ | | (0.7,0.8,0.9) | (.7,.8,.9) | (5,6.5,8) | (6,7.25,8.5) |
| | | $AC_{222}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | | $AC_{223}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{224}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{23}$ | $AC_{231}$ | | (0.50,0.65,0.80) | (.3,.5,.7) | (5,6.5,8) | (5,6.5,8) |
| | | $AC_{232}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | | $AC_{233}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | | $AC_{233}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| $AC_3$ | $AC_{31}$ | $AC_{311}$ | (0.7,0.8,0.9) | (0.7,0.8,0.9) | (.7,.8,.9) | (5,6.5,8) | (5.82,7.07,8.36) |
| | | $AC_{313}$ | | | (.3,.5,.7) | (5,6.5,8) | |
| | | $AC_{314}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{32}$ | $AC_{321}$ | | (0.7,0.8,0.9) | (.5,.65,.8) | (5,6.5,8) | (7.13,8.18,9.07) |
| | | $AC_{322}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{323}$ | | | (.85,.95,10) | (8.5,9.5,10) | |
| $AC_4$ | $AC_{41}$ | $AC_{411}$ | (0.85,0.95,1.00) | (0.7,0.8,0.9) | (.5,.65,.8) | (5,6.5,8) | (6.16,7.32,8.53) |

**Table 6:** (Continues)

| ACi | ACij | ACijk | Wi | Wij | Wijk | Rijk | Rij |
|---|---|---|---|---|---|---|---|
| | | $AC_{413}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | | $AC_{414}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{415}$ | | | (.3,.5,.7) | (5,6.5,8) | |
| | | $AC_{416}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{42}$ | $AC_{421}$ | | (0.85,0.95,1.00) | (.85,.95,10) | (8.5,9.5,10) | (7.82,8.81,9.53) |
| | | $AC_{422}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{43}$ | $AC_{431}$ | | (0.7,0.8,0.9) | (.7,.8,.9) | (5,6.5,8) | (6,7.25,8.5) |
| | | $AC_{432}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{433}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | | $AC_{434}$ | | | (.7,.8,.9) | (7,8,9) | |
| | $AC_{44}$ | $AC_{441}$ | | (0.85,0.95,1.00) | (.5,.65,.8) | (7,8,9) | (6.76,7.77,8.83) |
| | | $AC_{442}$ | | | (.5,.65,.8) | (7,8,9) | |
| | | $AC_{443}$ | | | (.5,.65,.8) | (7,8,9) | |
| | | $AC_{444}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{445}$ | | | (.3,.5,.7) | (5,6.5,8) | |
| | $AC_{45}$ | $AC_{451}$ | | (0.7,0.8,0.9) | (.3,.5,.7) | (5,6.5,8) | (5.58,6.91,3.23) |
| | | $AC_{452}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{453}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | | $AC_{454}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | $AC_{46}$ | $AC_{461}$ | | (0.7,0.8,0.9) | (.5,.65,.8) | (5,6.5,8) | (5.82,7.07,8.36) |
| | | $AC_{462}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{463}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | $AC_{47}$ | $AC_{471}$ | | (0.7,0.8,0.9) | (.7,.8,.9) | (5,6.5,8) | (5,6.5,8) |
| | | $AC_{472}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | $AC_{48}$ | $AC_{481}$ | | (0.7,0.8,0.9) | (.7,.8,.9) | (7,8,9) | (7,8,9) |
| | | $AC_{482}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{483}$ | | | (.7,.8,.9) | (7,8,9) | |
| $AC_5$ | $AC_{51}$ | $AC_{511}$ | (0.7,0.8,0.9) | (0.50,0.65,0.80) | (.7,.8,.9) | (7,8,9) | (6.23,7.41,8.60) |
| | | $AC_{512}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{513}$ | | | (.5,.65,.8) | (7,8,9) | |
| | | $AC_{514}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | | $AC_{515}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | $AC_{52}$ | $AC_{521}$ | | (0.7,0.8,0.9) | (.7,.8,.9) | (5,6.5,8) | (5.72,7.06,8.39) |
| | | $AC_{523}$ | | | (.5,.65,.8) | (7,8,9) | |
| | | $AC_{524}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{525}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | $AC_{53}$ | $AC_{531}$ | | (0.7,0.8,0.9) | (.5,.65,.8) | (5,6.5,8) | (5.83,6.91,8.26) |
| | | $AC_{532}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | | $AC_{533}$ | | | (.7,.8,.9) | (7,8,9) | |
| | | $AC_{534}$ | | | (.7,.8,.9) | (5,6.5,8) | |
| | $AC_{54}$ | $AC_{541}$ | | (0.85,0.95,1.00) | (.5,.65,.8) | (5,6.5,8) | (5.82,7.07,8.36) |
| | | $AC_{543}$ | | | (.5,.65,.8) | (5,6.5,8) | |
| | | $AC_{544}$ | | | (.7,.8,.9) | (7,8,9) | |

{Extremely agile (EA), very agile (VA), agile (A), fairly (F), slowly (S)}.Fuzzy Number used for AL is shown below

Extremely Agile [EA] = (7, 8.5, 10).

Very Agile [VA] = (5.5, 7, 8.5).

Satisfactorily AGILE [A] = (3.5, 5, 6.5).

Fairly Agile [F] = (1.5, 3, 4. 5).

Slowly Becoming Agile [S] = (0, 1.5, 3)

In this method a distance d is calculated From FAI to each member set of AL. For calculating the distance d following equation is used

$$d(FAI, Ali) = \sqrt{\{_{x\varepsilon p}\Sigma(f FAI(x) - f ALi(x))}$$

Where p={x0, x1, x2…xm }⊆[0,10]

Distance calculated from FAI to EA

$$d(FAI,EA) = ((6.43-7)^2 + (7.58-8.5)^2 + (8.56-8.5)^2)^{1/2}$$
$$= 2.93$$

Similarly Euclidean distance calculated for all other linguistic terms are

d (FAI, EA) = 2.93
d (FAI, VA) = 1.57
d (FAI, F) = 13.57
d (FAI, S) = 18.07
d (FAI, A) = 7.57

By matching a linguistic label with the minimum d, the agility index has been identified as 'very agile'.

### 4.5 Identification and analysis of obstacles for improvement

Next step of evaluation is to identify obstacles for improvement. For identify the obstacles. Fuzzy Performance Importance Index (FPII) is calculated. Higher the value of FPII, higher its contribution. FPII can be calculated using the following equation

$$FPII = W'_{ijk} \times AC_{ijk}$$

$$W'_{ijk} = (1, 1, 1) - W_{ijk}$$

FPII of flattened organizational structure is calculated as follows

$$FPII_{111} = (.1, .2, .3) \times (7, 8, 9)$$
$$= (.7, 1.6, \text{and } 2.7)$$

For finding the critical obstacles FPII indices need to be ranked. Ranking of fuzzy number can be done using Vinod S et al (2012) using the equation

$$\text{Ranking Score} = (a + 4b + c)/6$$

Where a, b and c are the lower, middle and upper values of triangular fuzzy number

Ranking Score for flattened organizational structure
$$= (.7 + 4\times 1.6 + 2.7)/6$$

$$= 1.63$$

Similarly rank score can be calculated for other attributes .Rank score are given in Table 7.To identify the obstacles, value 1.5 Vinod et al.(2008) has been set as management threshold to distinguish the critical obstacles

**Table-7**: Fuzzy performance importance indexes of agility attributes

| Agile attributes | FPII | Rank |
|---|---|---|
| $AC_{111}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{112}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{113}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{114}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{121}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{122}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{131}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{132}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{133}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{134}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{135}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{136}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{137}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{211}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{212}$ | (0,0.48,1.5) | 0.62 |
| $AC_{213}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{214}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{215}$ | (0.85,1.90,3) | 1.9 |
| $AC_{221}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{222}$ | (0.5,1.30,2.4) | 1.65 |
| $AC_{223}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{224}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{231}$ | (1.5,3.25,5.6) | 3.48 |
| $AC_{232}$ | (1,2.28,4) | 2.37 |
| $AC_{233}$ | (1,2.28,4) | 2.37 |
| $AC_{234}$ | (1,2.28,4) | 2.37 |
| $AC_{311}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{312}$ | (1.5,3.25,5.6) | 3.48 |

**Table-7 :**( Continues)

| Agile attributes | FPII | Rank |
|---|---|---|
| $AC_{321}$ | (1,2.28,4) | 2.37 |
| $AC_{322}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{323}$ | (0,0.48,1.5) | 1.62 |
| $AC_{412}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{413}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{414}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{415}$ | (1.5,3.25,5.6) | 3.48 |
| $AC_{416}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{421}$ | (0,0.48,1.5) | 0.62 |
| $AC_{422}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{431}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{432}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{433}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{434}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{441}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{442}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{443}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{444}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{445}$ | (1.5,3.25,5.6) | 3.48 |
| $AC_{451}$ | (1.5,3.25,5.6) | 3.48 |
| $AC_{452}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{453}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{454}$ | (0.5,1.30,2.4) | 1.65 |
| $AC_{461}$ | (1,2.28,4) | 2.37 |
| $AC_{462}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{463}$ | (1,2.28,4) | 2.37 |
| $AC_{471}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{472}$ | (1,2.28,4) | 2.37 |
| $AC_{481}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{482}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{483}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{511}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{512}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{513}$ | (1.4,2.8,4.5) | 2.87 |
| $AC_{514}$ | (1,2.28,4) | 2.37 |
| $AC_{515}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{521}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{522}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{523}$ | (1.4,2.80,4.5) | 2.87 |
| $AC_{525}$ | (0.5,1.30,2.4) | 1.35 |
| $AC_{531}$ | (1,2.28,4) | 2.37 |
| $AC_{533}$ | (0.7,1.6,2.7) | 1.63 |
| $AC_{534}$ | (0.5,1.30,2.4) | 1.65 |
| $AC_{541}$ | (1,2.28,4) | 2.37 |
| $AC_{542}$ | (1,2.28,4) | 2.37 |
| $AC_{543}$ | (0.7,1.6,2.7) | 1.63 |

**Table-7 :**( Continues)

### 4.6 Result and Discussion

From the computation we can see that the company is very agile. Still it is need to work on some the areas to attain extreme agility .From our 20 criteria assessment we identified mainly 14 attribute as obstacles.

1. Communication media to collect the customer responses
2. Flexible business system
3. Application of BPR for reinventing and reengineering the organization
4. Flexible workforce to accept the adoption of new technologies
5. Upgradation and retrofitting of machines
6. Specification of product life to the customer
7. Products designed for easy serviceability
8. Service centers well equipped with spares
9. Application of lean manufacturing principles for waste elimination
10. Company having automated systems
11. Inculcation of innovation into product design
12. Productivity improvement in all functions
13. Productivity linked to the personnel prosperity
14. Application of totality concepts in achieving productivity

## 5. CONCLUSION

Today due to globalization competition are increasing .The knowledge and the information are available to everyone in their finger tips. In such a situation a manufacturing company needs to very dynamic to exist in a competition .For this company needs to be agile. In this paper a method to assess agility is done using fuzzy logic approach and suggested some methods for improving obstacles. Fuzzy

logic approach gives good result in imprecise and vague conditions. The company studied for this assessment is in very agile conditions. Some more efforts on the obstacles can improve the company to extreme agility at fast rate

**REFERENCE**

[1] S Vinod, S Aravindhraj (2015) Benchmark agility assessment approaches: A Case Study. International Journal Vol 22, No 1, pp-2-17

[2] Maryam Lofti, Mohmoud Houshmad (2015) Agility evaluation using Fuzzy logic in a Supply chain Management Company. Engineering Management Research Vol 4.

[3] Manivel muralidaran V (2015) agile manufacturing –An overview .International Journal Science & Engineering Application Vol 4, Issue 3

[4] Sakthivel Aravind Raj ,S Vinodh (2014) Forty criteria based agility assessment using scoring approach in Indian relays manufacturing organizations. Journal Engineering Design & Technology Vol 12.No 4,pp-506-517

[5] S Vinodh ,S R Devadasan ,Deepak Kumar (2013)Design of agile supply chain assessment model & its case study in an Indian automation components manufacturing organization .Journal Manufacturing systems , Vol 32, pp-620-631

[6] Swagitika Mishra, Saurav Dalta, S S Mahapatia (2012) Interrelationship of drivers for agile manufacturing: An Indian experience. International Journal Service & Operations Management, Vol 11, No 1

[7] C G Sreenivasa, S R Devadasan (2012) thirty criteria based assessment of agility in a pneumatic enabling products manufacturing company. International Journal Services & Operations Management, Vol 11, No 2

[8] S Vinodh, V U day Kumar, R Jeya Girubha (2012) thirty criteria based agility assessment: A case study in an Indian manufacturing pump organization. International Journal Advanced Manufacturing Technology 63, pp-915-929

[9] Ameya S Erande, Alok K Verma (2011) Measuring agility of organizations –A comprehensive agility measurement tool. International Journal Applied Management & Technology Vol 6

[10] S Vinodh, O Kuttanlingam (2011) Computer aided design & engineering as enablers of agile manufacturing: A case study in an Indian Manufacturing organization. International Journal Manufacturing Technology Management, Vol 22, 3, pp-405-418

[11] S Vinodh & Suresh Kumar Chinsha (2011) Application of Fuzzy QFD for enabling agility in a manufacturing organization: A case study.TQM Journal Vol 23, No 3, pp-343-357

[12] Yi-Hong Tseng, Cheng-Tornlin (2011) Enhancing enterprise agility by deploying agile drivers, capabilities & providers. Journal of Information Sciences pp-3693-3708

[13] Vinodh S, Vimal KEK (2012) thirty criteria based leanness assessment using fuzzy logic approach. International Journal of Advanced Manufacturing Technology; 60: 1185–95.

[14] S Vinod, S R Devadasan (2010) twenty criteria based agility assessment using fuzzy logic approach. International Journal Advanced Manufacturing Technology 54, pp-1219-1231

[15]S Vinod, S R Devadasan, B Vasudeva Reddy, Kusuma Ravichand (2010) Agility Index measurement using multi grade fuzzy logic approach integrated in a 20 criteria agile model. International Journal Production Research, Vol 48,pp-7159-7176

[16] Eleonora Bottani (2010) Profile & Enablers of agile companies: An empirical investigation. International Journal Production Economics 125,pp-251-261

[17] S Vinodh, G Sundaraj , S R Devadasan ,Rajanayagam (2008) Quantification of Agile: An experimentation in an electronics switches manufacturing companies .Journal Engineering design and technology ,Vol 6,pp-44-48

[18] G Ramesh, S R Devadasn (2007) Literature Review on Agile manufacturing criteria. International Journal Manufacturing Technology Management, Vol 18, No- 2,pp-182-201

[19]Daniel Vanquez Bastelo, Lucia Avella & Estebon Fernandez (2007) Agility Drivers, enablers and outcomes empirical test of an integrated agile manufacturing model. International Journal Operations and Production Management, Vol 27, No 12, pp-1303-1330G

[20] Ramesh, S R Devadasan (2007) Agility assessment through quantification and qualification tools: A case studying an Indian pump manufacturing company .International Journal Mass Customization Vol 2

[21] Chang Torng Lin ,Hero Chiu ,Yi-Hong Tseng (2006)Agility Evaluation using Fuzzy Logic .International Journal Production Economics,pp-353