Comparison of Agility in Process Industries using Agility Attributes: A Case Study

Nedhish Somanath, Sabu K, K. V. Krishnankutty
Department of Mechanical Engineering
College of Engineering
nedhishsomanath@cet.ac.in
sabu@cet.ac.in
drkrishnankuttykv@gmail.com

Abstract— **In recent years, demand pattern of customers are changing rapidly due to requirement of customized products in wide ranges and varieties. In order to meet this volatility in demand patterns, the industries must be agile enough to respond to these changes quickly. Agility is the approach that can be applied to deal with these challenges of volatility in the modern market conditions successfully. The main aim of agility is to achieve organizational flexibility during changing situations and opportunities and thus organization can withstand and handle the external or internal turbulent conditions. Agility of organizations depends upon certain attributes or factors called agility attributes that are difficult to describe because of its multidimensionality and vagueness of its concept. In this work, ten agility attributes are considered based on which, a questionnaire is prepared and survey is conducted in two process industries. Based on the responses, agility attributes are ranked using its mean value calculated for both process industries separately. The agility of two process industries are also compared using mean values of agility attributes calculated and found out to be similar in both industries. Finally the least agile attributes are pointed out for both process industries and thus industries can improve its agility by concentrating on these least agile areas.**

Keywords—agility; attributes; vagueness

I. INTRODUCTION

In this 21st century business environment, the ability to adapt to unexpected and unpredicted changes is a key to achieve success for an organization. These rapid and turbulent changes in the business environment are mainly due to the increased rate of innovative and technological developments, fragmentation of markets and elevated customer expectations of products. The solution for adapting to these uncertain and unpredictable changes has led to evolution of one of the latest and predominant concepts in business strategies referred to as agility. The term agility was initially introduced by the Iacocca Institute in 1991.

Agility is fast becoming a key business driver for all organizations as well as a crucial factor to a firm's ability to survive and thrive in uncertain and turbulent markets [1]. This concept was proposed to explain a new approach in manufacturing and enterprise management to achieve success in this modern dynamically changing market. Being agile means "having a quick resourceful and adaptable character", so it is basically being adaptive, able to adjust to changing situation [2].

Agility, since its inception in 1991, has been the Buzzword for all the industries in today's globally competitive dynamic market. Companies try hard to achieve an upper edge over competitors in this continuously changing and unpredictable market. The needs to measure agility of an organization were:

- Agility is very important to stay competitive in the market.

- Measurement of agility gives organization measure of its competitiveness and readiness for changes in the market.

- Measuring agility identifies "less agile" areas in an enterprise and thus it can plan for improvements [3].

Agility is the approach that can be applied to deal with the challenges of volatility in the modern market situations successfully as it no longer emphasis on the idea of product focused manufacturing organizations. However this does not consider the use of previous experiences to anticipate change and act pro-actively [4]. Goldman identified four key dimensions of agility: delivering value to the customer; being ready for change; valuing human knowledge and skills; and forming virtual partnerships [5].

There are a large number of opinions concerning the understanding of agility. One of the approaches is a very broad notion that encompasses all definitions and descriptions of

various practices and technologies that have been implemented in industry during the last two decades. Agile manufacturing is neither lean, flexible manufacturing, nor computer integrated manufacturing. Agility has found to be the perfect solution for organizations as it allows to gain competitive advantage and to be productive. With regard to the dynamics of today's environment and the necessity of adapting to the environmental changes and the more important, the speed of this adaptation in gaining competitive advantage, the agility is inevitable. The organization can gain a consistent competitive advantage when that is faster and more flexible in decision-making, management and processes [6].

Because of globalization, technology, and outsourcing contributing to uncertainty and unpredictability in all sectors, the ability of an organization to adapt to unexpected changes is critical to achieving and maintaining a competitive advantage [1]. There has been lots of research activities in recent years focusing on the benefits to manufacturing in an agile production process.

II. LITERATURE REVIEW

The word agility in the dictionary means fast and agile move and quick ability of thinking with a smart approach. The term agility was first coined by the Iacocca Institute, Lehigh University in 1991. Agility means quick adaptability to the changing market environment. The researchers have identified the three main phases of agility as agility drivers, agility capabilities and agility providers. Various research works has been done in which agility and attaining agility is defined, expressed in different ways. Some of definitions of agility were shown in TABLE 1.

Different approaches are used in order to measure agility of organizations by the researchers. The determination of agility of an organization is important because by exploring its least agile areas and by improving agility lacking areas, organizations would be able to achieve its competitive advantage in the market. The main aim of this work is to compare agility in process industries and also to explore how agility attributes affecting agility in the organization and how to control these factors so as to improve the agility of process industries.

Ameya S Erande and Alok K Verma (2008) explained about Comprehensive Agility Measurement Tool (CAMT) which is used to measure agility on the scale of 1-5, 1 being least agile and 5 being highly agile. This tool captures agility using 10 agility enablers and also points out agility lacking areas. These are Takt time, plant capacity, inventory, problem solving, e-manufacturing, continuous improvement, operational flexibility, SMED/quick changeover, internal customer satisfaction and human resource management. This paper describes methodology used to develop CAMT which can be used to measure agility of an enterprise independent of the industry it is operating in. This tool is repeatable, provides guidelines to achieve agile status that goes hands in hands with company's goals, and accommodates all levels and functions of an organisation.

James E. Bartlett II et al. (2001) describes the procedures for determining sample size for continuous and categorical variables using Cochran's (1977) formula. A discussion and illustration of sample size formula, and the formula for adjusting the sample size for smaller populations are provided. Procedures for determining the appropriate sample size and common issues in sample size determination are explained in detail. The above method seems to be suitable to adopt in this paper for sample size determination of the population.

Bodhana Sherehiy et al. (2007) explains about enterprise agility, considering global characteristics of agility which can be applied to different levels of enterprise. They also identified some attributes that are believed to be associated with work force agility such as speed, responsiveness, flexibility, culture of change, integration & low complexity, high quality & customised products and mobilisation of core competencies based on empirical research on workforce. The

TABLE 1. Definitions of Agility

Sl No.	Authors	Definitions of Agility
1	Kidd, 1994	Agility is a rapid and proactive adaptation of enterprise elements to unexpected and unpredicted changes.
2	Goldnan et al., 1995	Agility is defined as "capability of an organization to operate profitably in a competitive environment comprised of continually changing customer habits".
3	Nelson and Harvey, 1995	Agility is defined as "organizations capacity to respond rapidly and effectively to unanticipated opportunities and to proactively develop solutions for potential needs".
4	Cho et al., 1996	Agility is defined as "capability to survive and prosper in a competitive environment or continuous and unpredictable changes by reacting quickly and effectively to changing markets, designed by customer designed products and services".
5	Gunasekaran, 1999	Agility is defined as "the capability of surviving and prospering in the competitive environment of continuous and unpredictable change by reacting quickly and effectively to chosen markets, driven by customer-designed products and services".
6	Menor et al., 2001	Agility is defined as "the ability of a firm to excel simultaneously on operations capabilities of quality, delivery, flexibility and cost in a coordinated fashion"
7	Sambamurthy et al., 2003	Agility is defined as "the ability of a firm to redesign their existing processes rapidly and create new processes in a timely fashion in order to be able to take advantage and thrive of the unpredictable and highly dynamic market conditions".
8	Overby et al., 2006	The agility of an organization lies in its ability to sense unforeseen changes in the business environment and respond readily to adapt to those changes.
9	Ganguly et al., 2009	Agility is fast becoming a key business driver for all organizations as well as a crucial factor to a firm's ability to survive and thrive in uncertain and turbulent markets.

authors have considered only workforce agility but a comprehensive study is needed to be done in order to evaluate and improve agility of an entire organization.

Eleonora Bottani (2010) in his study, he did an empirical investigation of enablers of agile companies. He identified the characteristics of agile companies operating in different marketing field and discussed about the tools used by the companies to achieve agility. The work done is based on conducting survey using questionnaires. The responses are collected using 5 point scale from 189 valid individuals. The analysis of work are based on descriptive statistics, cluster analysis, discriminant analysis and principal component analysis. All the agile enablers and attributes affecting agility of companies in different market fields are evaluated and analysed. The main limitation of his work is that he has considered only marketing field but agility of an organization is not confined to marketing field only.

Mohd. Asif Hasan et al. (2012) explained the importance of agility for an organisation which can be improved while integrating many design dimensions, operations infrastructure and capacity in production flow and suggestions for the improvement of production planning layouts for attaining agility. Their work focussed on significant impact of layout design on the performance of manufacturing industry and uses artificial neural network which captures different criteria's of production flow layouts in complex agile manufacturing environment. They introduced a strategic decision model to help manufacturing managers strategically implement agility in their organization by selecting the most appropriate production layout.

Ahmad Jafarnejad et al. (2013) explained that about the concept of agility and agility factors affecting organizational agility. The factors considered are inner complexity, suppliers, competition, customer needs, market, technology and social factors. These factors are then ranked in terms of importance and their influence by Multi Criteria Decision Making (MCDM). A questionnaire is prepared as agility indicator tables based on their importance and effect on organizational agility and gave to some responders. Based on the scores, the rate of effect of each indicator on organizational agility is measured using a qualitative range. Then, apply clock range and weighting factors using Shannon entropy technique and also using weighted simple average technique, TOPSIS method and Analytical Hierarchy (AHP) method among decision methods with multi-criteria, to prioritize the criteria and merged using Cope Land method. Copeland method is used to integrate ranking of different methods, by finding difference between wins and loss of each option the agility factors were ranked.

The above reviews indicates that agility of industries also depend on its production layout which can be measured using agility attributes. So this study is focused based on process layout and its agility attributes are measured. Process layout is chosen because most of the daily products are manufacturing by this process and so it must be agile enough to meet the customised demands of the customers. In this work, the agility of two process industries (say A and B) are measured using some agility attributes and then evaluated. Also agility in process industries A and B are compared using agility attributes.

A. Hypothesis Statement

Null Hypothesis, H_0: there is no significant difference in agility between two process industries.

Alternate Hypothesis, H_a: there is a significant difference in agility between two process industries.

III. METHODOLOGY

A. Agility Attributes

Most of the organizations are concerned with change, uncertainty and unpredictability within their business environment, so they require a set of distinguishing agility attributes or capabilities to respond quickly. Agility attributes are the elements which constitute the underlying structure of an agile organization [7]. Agility attributes have been selected from the journals reviewed in section 2. These were Takt time, Additional capacity, Inventory turnover ratio, Critical problem faced & solved, E- manufacturing, Skill development programs, Operational flexibility, Customer satisfaction, Attrition and Profit increase.

B. Data Collection Tool

The data used for any research can be obtained either from primary data or secondary data and both. Primary data is the first-hand data collected directly from the source, from interviews, through questionnaires and by direct observations. The secondary data is the data collected by the other researchers i.e. available (journal papers, articles, reports etc.) already and used in a study to save time, money, increase the quality of the available data. Here data was gathered using responses from middle management level of both process industries through questionnaires. The selected ten attributes were used to prepare the questionnaires for measuring the agility of process industries. A five point Likert scale was used to measure the agility of process industries, where 1 being least agile and 5 being highly agile. This data was then tabulated and analysed using cronbach's alpha for measuring internal consistency (reliability) of scale. The cronbach's alpha value based on data of process industries A and B were found to be 0.634 and 0.658 respectively. The Cronbach's alpha value between 0.6 and 0.7 indicates that internal consistency of scale in acceptable level [8, 9].

C. Sample Size Determination and Sampling Method

A common goal of survey research is to collect data representative of a population. Cochran's formula uses two key factors: margin of error and the alpha level. The general rule relative to acceptable margins of error in educational and social research is as follows: for categorical data, 5% margin of error is acceptable, and, for continuous data, 3% margin of error is acceptable. The alpha level used in determining sample size in most educational research studies is either 0.05 or 0.01 [10].

Sample size required for this study was calculated using Cochran's formula for determining sample size for continuous data [10].

Cochran's sample size formula:

$$n = (t^2 \times s^2) / d^2 \qquad (1)$$

Level of significance, α = 0.05 (assume)

Acceptable margin of error, = 3% or 0.03

where t = value for selected alpha level of 0.025 in each tail (1.96)

s = estimate of standard deviation in the population

Estimate of standard deviation in the population, s = (no. of points on the scale) / (no. of standard deviations)

d = acceptable margin of error for mean being estimated

= no. of points on primary scale × acceptable margin of error.

If sample size exceeds 5% of population, use Cochran's correction formula to calculate the final sample size,

$$N = n / (1+ n/P) \qquad (2)$$

where P = size of the population

Using Cochran's formula, the final calculated sample size for both industries A and B was found to be 65 and 55 respectively. Based on the final sample size calculated, questionnaire survey was conducted among middle management employees in both process industries. A simple random sampling technique was used for selecting responders from process industries A and B.

D. Analysis

Based on data collected from process industries A and B, descriptive statistics of agility attributes were calculated. In descriptive statistics, the following were calculated using Statistical Package for the Social Sciences (SPSS): Total score, mean & mode (measures of central tendency) and standard deviation. Based on the mean value, the agility attributes in process industries A and B were ranked separately. The least agility lacking areas can be identified based on mean value, i.e. the mean value less than 3 in this case. Also this mean value of each agility attributes were used to compare the agility in both process industries using independent samples t test.

IV. RESULTS

A. Descriptive Statistics

Data was processed to calculate its total score, mean value, mode value and standard deviation for ten agility attributes in process industries A and B were shown in table 2 and 3 respectively. The total score was calculated by adding all responses. The mean value was obtained by dividing the total score of each attribute by number of responses. The mode value indicates the response more often chosen by respondents and also standard deviation of responses were also calculated.

TABLE 2. Descriptive statistics of agility attributes in Process industry A

Sl No	Agility Attributes	Total Score	Mean	Mode	Standard Deviation	Rank
1	Takt time	313	4.8154	5	0.6822	I
2	Additional capacity	72	1.1077	1	0.4718	VIII
3	Inventory turnover ratio	310	4.7692	5	0.8248	II
4	Critical problems faced & solved	310	4.7692	5	0.5235	II
5	E-manufacturing	229	3.5231	4	0.562	VI
6	Operational flexibility	287	4.4154	5	0.7047	III
7	Customer satisfaction	268	4.1231	4	0.48437	IV
8	Skill development programs	242	3.7231	4	0.5156	V
9	Attrition	117	1.8	2	0.6892	VII
10	Profit increase	71	1.0923	1	0.5221	IX

Based on the result obtained from descriptive statistics for agility attributes, Takt time got highest mean value in both process industries i.e. 4.8154 in A and 4.8545 in B. Also profit increase got lowest mean value for both process industries i.e. 1.0923 in A and 1.0545 in B. The ranking was done based on the mean value of each attribute, so the Takt time and Profit increase were ranked highest and lowest respectively in both process industries, A and B. Also standard deviation of responses were less than 1 for all attributes in both process industries. A comparison between mean values of agility attributes in process industries A and B was shown below in fig. 1.

TABLE 3. Descriptive statistics of agility attributes in Process industry B

| Sl No	Agility Attributes	Total Score	Mean	Mode	Standard Deviation	Rank
1	Takt time	267	4.8545	5	0.5906	I
2	Additional capacity	60	1.0909	1	0.2901	IX
3	Inventory turnover ratio	237	4.3091	5	0.9204	III
4	Critical problems faced & solved	265	4.8182	5	0.4342	II
5	E-manufacturing	175	3.1818	3	0.8626	VII
6	Operational flexibility	219	3.9818	4	0.8275	VI
7	Customer satisfaction	231	4.2	4	0.5235	IV
8	Skill development programs	223	4.0545	4	0.5906	V
9	Attrition	120	2.1818	2	0.8838	VIII
10	Profit increase	58	1.0545	1	0.4045	X
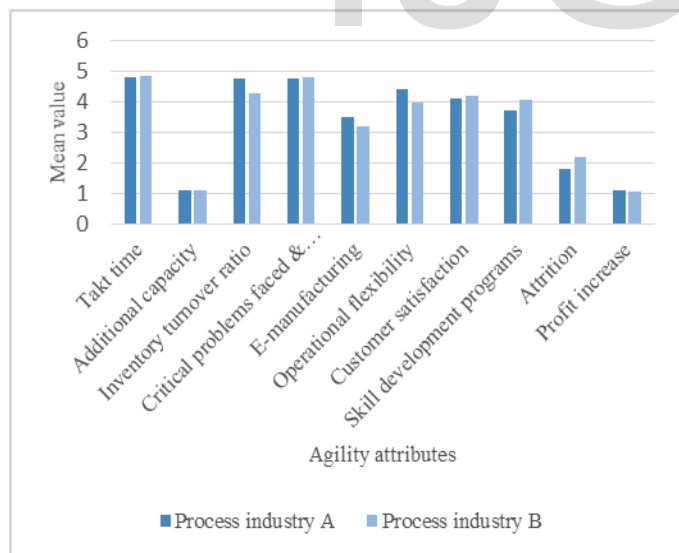
Fig. 1 Comparison between mean values of agility attributes in process industries A and B

B. Independent Samples t Test

A test is a statistic that checks if two means or averages are reliably different from each other. The t test is an inferential statistics that helps to make inferences about the population under the study. By observing mean values of attributes in both process industries, A and B, shows a small difference but it can't be sure if that was a reliable difference. So an independent samples t test was performed to compare the agility of two process industries A and B using SPSS. Here t-test was performed by considering process industries A and B as two groups and data points were the mean value of agility attributes calculated from the descriptive statistics. The t statistics value was found to be 0.062 and t critical value from t distribution table for 18 degrees of freedom and level of significance, 0.05 was 2.101. Since t statistics value was less than t critical value, the null hypothesis was failed to reject.

V. CONCLUSIONS

Based on the study conducted in two process industries, agility attributes are measured. In this work, it is found that the least agile attributes in the process industries, A and B are profit increase, additional capacity and attrition. Profit increase can be enhanced to an extend either by expanding capacity of the plant or by appointing skilled and efficient employees, based on the results obtained. Thus by concentrating on improvement in these less agile areas and other intermediate areas like agility attributes having mean value less than 3, helps to increase agility of both process industries to a certain extend. The t-test proves that the agility in both process industries A and B are similar. This may be due to industries possessing similar manufacturing layout and have a common effect of agility attributes in maintaining agility.

This work is conducted in two process industries as a case, so there is a difficulty in generalizing the result. This work is limited to ten agility attributes but it can be extended by incorporating other relevant attributes. Also in this study only process layout is considered, but in further studies various layouts and comparison between different layouts can be performed. This agility measurement tool can be applied as a common instrument to any industries to explore its agility lacking areas. Thus by focusing industries effort into these less agile areas, enables to increase its responsiveness towards changes in customer demands without compromising cost and quality.

References

[1] Anirban Ganguly, Roshanak Nilchiani, John V. Farr, "Evaluating agility in corporate enterprise", International journal of Production Economics, vol. 118, pp. 410-423, 2009.

[2] Agnieszka Stachowiak and Marek Fertsch, "The data used in agile facility layout design procedure", Proceedings of the Fifth Asia Pacific Industrial Engineering and Management Systems Conference, in press.

[3] Ameya S Erande and Alok K Verma, "Measuring agility of organizations – A Comprehensive Agility Measurement Tool (CAMT)", the International Journal of Applied Management and Technology, Vol. 6, no. 3, pp. 31-44, 2008.

[4] Arteta, B.M. and Giachetti, R.E., "A measure of agility as the complexity of the enterprise system", Robotics and Computer-Integrated Manufacturing, vol. 20, pp: 495-503, 2004.

[5] C. D. W. Lomas, J. Wilkinson, P.G. Maropoulos and P. C. Matthews, "Measuring design process agility for the single company product development process", International journal of agile manufacturing, vol. 9 , no. 2, pp: 105-112, 2006.

[6] Ahmad Jafarnejad, Sayyed Mohammad Reza Davoodi and Abolfazl Sherafat, "Applying multi-criteria decision-making techniques to prioritize Agility Drivers", International Journal of Academic Research in Business and Social Sciences, vol.3, no. 7, pp. 296-305, 2013.

[7] Ren, J., Yusuf, Y., & Burns, D., "The effects of agile attributes on competitive priorities: a neural network approach", Integrated Manufacturing Systems, vol. 14, no. 3, pp. 489-497, 2003.

[8] George, D., & Mallery, P., SPSS for Windows step by step: A simple guide and reference. 11.0 update, 4th ed., Boston: Allyn & Bacon, 2003.

[9] Kline, P., The handbook of psychological testing, 2nd ed., London: Routledge, 2000, pp. 13.

[10] James E. Bartlett II, Joe W. Kotrlik and Chadwick C. Higgins, "Organizational Research: Determining appropriate sample size in survey research", Information Technology, Learning and Performance Journal, vol. 19, no. 1, pp. 43-50, 2001.

[11] Bohdana Sherehiy, Waldemar Karwowski, John K. Layer, "A review of enterprise agility: Concepts, frameworks, and attributes", International Journal of Industrial Ergonomics, vol. 37, pp. 445–460, 2007.

[12] Eleonora Bottani, "Profile and enablers of agile companies: An empirical investigation", International Journal of Production Economics, vol. 125, pp. 251–261, 2010.

[13] Mohd. Asif Hasan, Joseph Sarkis and Ravi Shankar, "Agility and production flow layouts: An analytical decision analysis", Computers & Industrial Engineering, vol. 62, pp. 898–907, 2012.