

## A Review on Measurement of Agility

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### Abstract

Shifting paradigms gave rise to agile manufacturing. The concept which was later applied at a broader level to organizations, workforce, and enterprise as well as supply chains. As trend of agility is being recognized as a necessary step to compete in the highly turbulent environment it becomes necessary to evaluate the agility of systems. As agility has no exact definition and subjected to individuals perception the evaluation of a system's agility has been attempted with diverse approaches. This paper reviews various agility evaluation methods proposed and attempts to provide a holistic view of every method and draws out their advantages and limitations, in order to help in further research in this field.

**Keywords:** Agile manufacturing; Manufacturing system; Manufacturing Supply Chain (MSC); Fuzzy logic; Fuzzy

### Introduction

21<sup>st</sup> century has witnessed humongous technological advances which has laid foundations for highly dynamic structure of today's business environment. This tendency is increasing day by day due to rising competitions. Globalization has resulted in blurring the demographic differences increasing accessibility for both customers and suppliers. This has empowered the customers to demand best products at better price, lesser time, more customization and arbitrary quantity, thus increasing problems for enterprises who want to maintain their market share. This is because they have to deal with a highly unpredictable, dynamic and turbulent environment. Many different solutions have been put forward such as networking, reengineering, modular organizations, virtual corporations, high performing organizations, employee empowerment, flexible manufacturing, Just-In-Time (JIT), etc. However the most prominent of the approaches is the use of agility.

The term 'agility' was first introduced in the Iacocca Institute, describing it as one key to future competition. They defined agility as manufacturing system with capabilities to meet the rapidly changing needs of the marketplace. Kidd [1] defined agility as a rapid and proactive adaptation of enterprise elements to unexpected and unpredicted changes. Goldman et al. [2] state agility as being a comprehensive response to challenges posed by a business environment dominated by change and uncertainty. According to Gunasekaran [3], Agile Manufacturing (AM) is the ability of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-defined products and services. Yusuf et al. [4] proposed that agility is the successful application of competitive bases such as speed, flexibility, innovation, and quality by the means of the integration of reconfigurable resources and best practices of knowledge-rich environment to provide customer-driven products and services in a fast changing environment. Although the definitions differ from each other most of them discuss common characteristics of agility namely-time, flexibility of the system, and the ability to response (responsiveness). From these definitions we can infer that organizations which are able to react and respond to an environment that frequently pressure the firm to change while continuing to satisfy customers and achieve business objectives can be considered agile. Agility is based on several capabilities found in three main enterprise dimensions: manufacturing, product and market dimensions. Jackson and Johansson [5] divided agility capabilities into four main dimensions: product - related change

capabilities, change competency within operations, internal and external co-operation and people, knowledge, and creativity.

A holistic framework was proposed by Sherehiy et al. [6]. They proposed four main aspects of AM: agility drivers, strategic abilities, agility providers, and agility capabilities. The agility drivers represent factors of the external business environment creating turbulence and unpredictability of the changes which drive an organization to adapt agility. Strategic abilities determined through factors such as responsiveness, competency, quickness, and flexibility are considered as main attributes of the agile organization that allow adaptation to changes. The agility capabilities could be achieved by the means of agility providers. Agility providers can be derived from four manufacturing areas: organization, technology, people, and innovation. They argued that only by integrating these criteria's agility could be achieved.

Tsourveloudis et al. [7] propose a knowledge-based framework for the measurement and assessment of manufacturing agility. In order to calculate overall agility of an enterprise, a set of quantitatively defined agility parameters is proposed and grouped into production, market, people and information infrastructures.

Ismail et al. [8] propose an agility strategic framework combining external parameters and indicators for the enterprise's agile capability. The model consists of a business environmental audit with a number of environmental turbulence indicators and agility capability indicators covering product, process, operation, people, and organization.

As there is no definite method of achieving agility, defining a holistic model for it is difficult. The literature on the subject suggests various framework, models and correlations for agility measurement that can be implemented by organization to adapt to current business conditions. However assessment of organization's agility creates a problem due to inexact boundary in which the agility is defined. This

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is the reason various different methodology have been used to assess agility. Some measure the agility of the structure of organization, some focus on agility as purely a competitive outcome, indirect methods such as measuring complexity have also been used to measure agility of the organization. In this paper we discuss these methods of assessment and analyze them for their advantages and their shortcomings.

### Recent Work on Measurement of Agility

A lot of research in the field of developing an agile model has been carried out but assessment of agility of such organization isn't extensively researched. This can be attributed to the fact that the metrics of agility is difficult to design due to the vagueness with which it is defined. The term agility is understood in a broader perspective and is influenced by many characteristics which may or may not be same for all types of organizations. Accounting to this the models developed are diverse and focus on certain areas. Many of the initial models developed were empirical but later more extensive and flexible models developed using broader techniques integrating organization and workplace.

Sherehiy et al. [6] laid out a framework which consisted of various steps for implementing agility in various organizations. The first step is consists of determining the nature of environment the organization. The next step was the assessment of the company itself in terms of agility. Then a gap analysis presents the plan of action .The last step uses a set of viable tools, agility providers to attain agility, by which capabilities of the organization can be achieved. A case study was conducted by them to verify the model. A similar framework for agility assessment was developed by Jackson and Johansson [5] in which they mentioned a three step approach for evaluation. First being evaluating the market trends, second being analysis of the strategic objectives in order to find out whether flexibility competency is a long term objective and the areas of potential development, the final part of the analysis is to find out the capabilities that needs to be focused on. Hoek et al. [9] also proposed an empirical model based on five characteristics of agility – customer sensitivity, virtual integration, process integration, network integration and measurement. The managers need to mark their organization based on these characteristics based on 5 point Likert's scale and the overall agility is measured average of individual characteristics.

Ren et al. [10] proposed agility assessment based on AHP. Decision makers first apply pair wise comparisons to evaluate the agility capabilities of a company. Combining the judgments against capabilities fetched the overall agility of the organization. Pair wise comparisons are particularly useful when direct comparison of capabilities is difficult. It is an intuitive method of comparing and gives better estimates compared to direct rating methods.

Yang et al. [11] proposed a multi graded fuzzy approach which was used to evaluate the agility of Mass Customizable (MC) organization. This model uses weights and ratings matrices from experts who evaluate the organization based on crisp numbers. It evaluates agility using weighted rating matrices of various agility attributes. Some process-based approaches to assessing agility concentrate on a single type of process, such as software development or product development. Sanchez et al. [12] for example, measure responsiveness of companies relative to the product development cycle time. A quantitative agility metric is developed that provides the desired time-based performance rating which reflects the agility of a manufacturer during product development.

Arteta et al. [13] adopted an indirect approach to measure agility.

They proposed to use complexity as a surrogate measure for agility. The hypothesis supporting this proposition mentioned was that a less complex enterprise in terms of systems and processes is easier to change and consequently more agile.

Costantino et al. [14] presented a technique for the strategic management of the chain addressing supply planning and allowing the improvement of the Manufacturing Supply Chain (MSC) agility in terms of ability in reconfiguration to meet performance.

Another different approach was proposed by Yauch [15]. They proposed a quantitative index of agility, based on a conceptualization of agility as a performance outcome, which captures both the success of an organization and the turbulence of its business environment. This model integrates operational measures and external parameters to determine the agility of the any type of manufacturing organization.

These methods are relatively easy to understand and implement. However, these scoring methods are frequently criticized, the main reasons for it are the evaluator's subjective judgment as well as the multi-possibility and the ambiguity associated with assigning a number to the attributes. To overcome this problem several fuzzy based models were proposed. Research in the field of fuzzy logic has been extensive and it proves to be a capable tool in handling the vagueness and imprecision of the situation Klir et al. [16]. Use of fuzzy concept enables the evaluators/experts to use linguistic terms to assess indicators related to natural language expressions, and each linguistic term is respectively associated with appropriate membership function. Several methods have been proposed which utilize fuzzy logic in measuring organizational agility. One of the first such models was the IF- THEN approach proposed by Tsourveloudis et al. [7] which was an outgrowth based on their previous work. The key idea of this approach is to combine all infrastructures namely-production infrastructure, market infrastructure, people infrastructure, and information infrastructure as agile characteristics and their corresponding operational parameters, to determine the overall agility. Another model based on fuzzy logic approach was proposed by Yang et al. [11]. It uses a supply chain agility evaluation model based on fuzzy logic and the Multi-Criteria Decision-Making (MCDM) to provide a means for both measuring supply chain agility and also identifying the major obstacles to improving agility levels. The model introduces a Fuzzy Agility Index (FAI) which tells about the agility of an organization. Ganguly et al. [17] defined three metrics to measure responsiveness, market share and cost effectiveness which would help in measuring a company's agility. They proposed the use of their method along with fuzzy logic approach proposed by Yang et al. [11] in order to arrive at a conclusion regarding the level of agility of any corporate enterprise.

Jain et al. [18], proposed a model which along with Fuzzy Logic uses Algorithms of Association Rule Mining (FARM) which derives associations to support decision makers by enhancing the flexibility in making decisions for evaluating agility with both quantitative and qualitative attributes. It has been used for evaluation agility in supply chains in a real time practical environment. In the model large fuzzy frameworks and effective association rules for agility evaluation are determined by fuzzy support and fuzzy confidence, minimum value of which is given by the decision makers. In the algorithm adopted, fuzzy association rules scans a database containing both quantitative and qualitative attributes for agility and applies Boolean operators (AND, OR, XOR) to produce large fuzzy support frameworks which are then used to generate fuzzy association rules. The methodology is a useful and practical method to make the fuzzy association rules from the available database.

Authors	Description	Advantages	Disadvantages
Sherehiy [6]	The model's framework consists of -determining agility need, assessing current position, determining capabilities required for agility, and adopting relevant practices which could bring about the recognized capabilities.	<ul style="list-style-type: none"> <li>Familiarizes with concept of agility</li> <li>Provides a holistic view of agility</li> <li>Ease of computation</li> <li>Provides tools for achieving agility</li> </ul>	<ul style="list-style-type: none"> <li>Evaluation based on crisp values</li> <li>A quantifiable index is not proposed</li> </ul>
Jackson and Johansson et al. [5]	The model's a three step approach for evaluation- First is evaluating the market trends, second is the analysis of the strategic objectives to find out flexibility competency as a long term objective, the final part is finding out the capabilities that needs to be focused on.	<ul style="list-style-type: none"> <li>Ease of computation</li> <li>Identifies capabilities needing focus to increase agility</li> </ul>	<ul style="list-style-type: none"> <li>Evaluation based on crisp values</li> <li>A quantifiable index is not proposed</li> </ul>
Van Hoek et al. [9]	The model accesses five characteristics for agility – customer sensitivity, virtual integration, process integration, network integration and measurement. The organization is marked based on these characteristics on 5 point Likert's scale and the overall agility is measured average of individual characteristics.	<ul style="list-style-type: none"> <li>Ease of computation</li> </ul>	<ul style="list-style-type: none"> <li>Evaluation based on crisp values</li> <li>Comprehensiveness of The model needs to be improved</li> </ul>
Ren et al. [4]	The model uses Analytical hierarchy process (AHP) to determine agility capabilities which is used with the judgments of organization performance the agility index is calculated.	<ul style="list-style-type: none"> <li>Increases the ease and intuitiveness in calculating agility capabilities</li> </ul>	<ul style="list-style-type: none"> <li>Assessment based on crisp numbers</li> <li>Numerous pair wise comparison is required depending on no. of</li> </ul>
Yang and Li [11]	The model is specific to mass customized manufacturing organization. The model utilizes multi grade fuzzy approach to calculate agility. A three grade evaluation index is used to measure agility which is orderly calculated as a weighted sum of companies rating against agility capabilities mentioned in the framework.	<ul style="list-style-type: none"> <li>Ease of computation and implementation</li> <li>Reduces fuzziness of evaluation</li> </ul>	<ul style="list-style-type: none"> <li>Framework specific for a MC organization</li> <li>Evaluation based on crisp values</li> <li>Doesn't take into account any external factors</li> <li>Less no. of capabilities are considered</li> </ul>
Arteta and Giachetti [13]	The model determines complexity and consequently agility owing to the inverse relationship between them. It uses Petri Nets, which represents two elements needed to measure process complexity - resources in the process and the interconnection between those resources, to find the state space probabilities needed for the complexity measure.	<ul style="list-style-type: none"> <li>Determines complexity of the organization</li> </ul>	<ul style="list-style-type: none"> <li>The model doesn't propose methods improve agility</li> <li>Measurement of ease of change is difficult</li> <li>The model in complex</li> </ul>
Yauch [15]	This model conceptualizes agility as performance outcome of an organization in turbulent environment. Turbulence score and organization success is calculated using empirical correlation which in turn is used to calculate agility.	<ul style="list-style-type: none"> <li>Applicable to any type of industry</li> <li>Includes external factors</li> <li>Assessment is dynamic</li> <li>Approach is holistic</li> </ul>	<ul style="list-style-type: none"> <li>The model doesn't propose methods improve agility</li> </ul>
Tsourveloudis et al. [7]	This model combines all infrastructures -production, market, people, and information using the knowledge that is included in simple IF-THEN rules, as agile characteristics and their corresponding operational parameters. Based on company's performance overall agility is determined.	<ul style="list-style-type: none"> <li>Uses fuzzy logic to determine agility</li> </ul>	<ul style="list-style-type: none"> <li>The method suffers with inflexibility since IF-THEN rules must be redesigned to fit the new situation</li> <li>Model is complex</li> </ul>
Lin et al. [11]	The model introduces a fuzzy agility index (FAI) which is calculated as a weighted average of performance rating of various agility attributes and their relative importance. Fuzzy performance importance index (FPII) is used to identify attributes that need to ameliorate.	<ul style="list-style-type: none"> <li>Uses fuzzy logic to deal with ambiguity</li> <li>Identifies attributes that need improvement</li> </ul>	<ul style="list-style-type: none"> <li>Comprehensiveness of the model need to improve</li> <li>Does not take external factors into account</li> </ul>
Jain et al. [18]	The model proposed uses Fuzzy Association Rule Mining (FARM) .The model with the help of quantitative and qualitative relational databases derives association rules for evaluating agility.	<ul style="list-style-type: none"> <li>Provides flexibility in agility assessments</li> <li>Evaluation in real time practical environment</li> </ul>	<ul style="list-style-type: none"> <li>Model is complex</li> <li>Equal weight age is provided to all attributes</li> </ul>

Table 1: Advantage and Disadvantage of different Agility Measurement Methods.

### Highlight of Evaluation Methods

As discussed the methods vary in their approaches of evaluating agility. Hence a direct comparison of each methods based on a common metric would be incorrect. Therefore each of the method has been separately analyzed drawing out their advantages and limitations in Table 1.

### Conclusion

As discussed the method of agility evaluation has taken different approaches. Their focus has been diverse and directed to different aspects. Some models Jackson and Johansson [5], Sherehiy et al. [6], Van Hoek et al. [9] have proposed a framework within which agility is calculated. While these models are simple in their approaches more extensive and accurate models were developed. Models using AHP, Ren et al. [10], multigrade fuzzy approach , Yang et al. [11], Jain et al. [18] employ more extensive approaches. Tsourveloudis et al. [7], Yang

et al. [11] used fuzzy logic along with previously developed methods to reduce vagueness in rating hence providing a more accurate result. One of the most thorough evaluation methods developed was by Yauch [15] which measured the performance outcome as a measure of agility. Certain indirect methods such as measurement of complexity, Arteta et al. [13], were also proposed. A problem related with all these model is lack of sufficient data from different organization to set a reference. Although models have covered various aspects varying from organization structure to performance outcome to measure agility need for a universal index is needed in order to set a reference point and to check the validity of models in varied field of applications. Thus due to this shortcoming it is very difficult to choose the most appropriate model for agility evaluation.

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