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A SCIENTIFIC APPROACH TO THE DESIGN AND DEVELOPMENT OF A MODEL TO IMPROVE THE ASSESSMENT LEVEL BY FUZZY LOGIC

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ABSTRACT

Today, Increased competition forces Manufacturing Organizations (such as FIEL) to adopt new Manufacturing Paradigms for producing products, as customer demands are Dynamic in Nature. This situation resulted in the evolution of a new manufacturing paradigm called “Agile Manufacturing.” Incorporating more efficient and contemporary supply chains (a major component) which have acquired agile characteristics is a must. In this regard, the quantification of Supply Chain Agility gains extreme importance as it indicates the Strategic Agile Position of an Organization from the supply chain perspective. This project begins with the development of a Supply Chain Agility Assessment Model. The model is comprehensive in nature as it includes Five Enablers and Twenty Two different Agile Supply Chain Criteria and various Agile Supply Chain Attributes. The Fuzzy logic approach is used to compute the Supply Chain Agility. The output of the Project will include the Supply Chain Agility Index, Fuzzy Performance Important Index of Various Agile Supply Chain Attributes and Identification of Principal Obstacles. The improvements for supply chain agility improvement are derived from within the company. The implementations of the results lead to enhancement of profitability and increase in customer domain of the organization.

Keywords: Agile Manufacturing, Supply Chain Management, Agile Supply Chain Enablers and Criteria’s, and Fuzzy Logic Approach.

INTRODUCTION
Fuzzy Logic Introduction

“Change” seems to be one of enterprise’s major characteristics in this new competitive era. The increasing competition has been forcing the manufacturing organizations to develop various manufacturing paradigms for satisfying the requirements of the customers. The demand conditions of markets are fluctuating due to varied customers’ requirements. Thus to achieve a competitive edge in the rapidly changing business environment, companies must align with suppliers and customers to streamline operations as well as working together to achieve a level of agility beyond individual companies. This situation has marked the emergence of a new manufacturing paradigm called Agile Manufacturing (AM). AM enables an organization to produce a variety of products within a short period of time in a cost effective manner. Supply chain management (SCM) is one of the managerial enablers of AM. The contemporary supply chains have acquired agile attributes such as high product variety, high profit margin and short product life cycle. In this context, the quantification of supply chain agility gains importance as it is an indicator of strategic agile position of an organization from supply chain perspective. So, this Publication is basically concerned with

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the assessment of supply chain agility of a manufacturing industry using Fuzzy logic approach which comes in handy to apply as it can help us to decide on several aspects which are characterized by ambiguity and multi possibility (people having different opinions) and where the conventional assessment approaches cannot suitably nor effectively handle such measurement.

Fuzzy Logic Application

Fuzzy Logic enables computerized devices to reason more like humans. Fuzzy-logic technology has created a paradigm shift evident through many scientific and industrial applications. Interestingly, fuzzy science started in the questioning minds of philosophers. Confused and inquisitive, from Buddha, to Aristotle, to Plato, these ancient philosophers were constantly searching for a "rule of law" beyond true or false. Observing that computer logic was incapable of representing subjective ideas such as "very hot" or "very cold," in 1965, Zadeh published his ideas of fuzzy set theory that made it possible for computers to distinguish between different shades of gray, similar to the process of human reasoning. He described fuzzy mathematics, devising precise rules for combining vague expressions such as "somewhat fast," "very hot," and "usually wrong," which are particularly useful for controlling robots, machine tools, and various electronic systems. Prof. Terano was inspired by Zadeh's work and introduced fuzzy logic to the Japanese scientific community in 1972.

As Bart Kosko, a Zadeh protégé and a professor of electrical engineering at the University of Southern California said: "Fuzziness begins where Western logic ends." Japan embraced the technology and adapted it to physical control systems. In 1980, F.L. Smidth & Co. of Copenhagen began marketing the first commercial fuzzy expert system: a computer program that controlled the fuel intake rate and gas flow of a rotating kiln used to make cement.

From Hitachi's subway system, to Nissan's fuzzy auto transmission and antiskid braking systems, to Yamaichi Security's fuzzy stock market investment program for signaling shifts in market sentiment, to Matsushita's fuzzy automobile-traffic controller, Japan has been taking the lead in fuzzy-logic research and development and transforming the technology into industrial applications. Some say that the Japanese cultural environment plays a significant role by embracing fuzzy logic. For these companies, fuzzy logic is a paradigm to introduce human subjectivity into objective science and a method to model and use human knowledge and senses as they are, without complicating abstraction.

LITERATURE REVIEW

Agile Supply Chains

Iskanius **[2.1]** has mentioned virtual enterprise/organisation, outsourcing, collaborative relationships, Production planning, Product design & service, Customer focus, Customer and market sensitivity as the characteristics of agile supply chain. In this study, the case network has been undergoing a shift towards project-oriented business, where quick responses are the priority and agility is recognised as the facilitating factor. Using a constructive approach, an agile supply chain for a steel product network, Steel Net system, is developed. In this study, qualitative methods such as interviews, observations, questionnaires and documents are used as data collection methods. Christopher et al [**4.1]** have discussed about Market sensitivity, Process integration, Networking and Cycle time reduction as the characteristics of agile supply chain and has successfully delivered a wide range of products to those markets where cost is the primary order winning criteria. This has led to the emergence of the agile paradigm characterized by 'quick response' and similar initiatives.

Chopra et al **[7.1]** have explained aspects related to inventory management, supplier relationship management, enterprise wide relationship management, supply chain partner selection and internal supply chain management as the characteristics of agile supply chain. Paneerselvam **[7.2]** has mentioned time management and nature of management as the characteristics of agile supply chain.

Lou et al **[5.1]** have defined agile supply chain as a network from the topologic structure which is composed of autonomous or semi-autonomous enterprises. All enterprises work together for procurement, production and delivery. An important factor to the agility in manufacturing enterprises is flexibility among firms so that they can react to changes effectively, driven by customer designed products and production capacity to rapid new product launch.

Canidar **[4.2]** observed issues related to inventory management cost, warehousing, materials handling cost, transportation management cost, supply/demand planning cost and sourcing/procurement Processes (Excluding Purchases of Goods Cost). Lin and Chiu **[1.1]** has defined agile supply chain and discussed about the characteristics of volatile markets. Volatile markets mean the supply chain is capable of reading and responding to real demand. One of the keys to achieve agile response to fast-changing markets lies upstream of the organization in the quality of supplier relationships. Often it is the lead-time of in-bound suppliers that limits the ability of a manufacturer to respond rapidly to customer requirements. Equally new product introduction time can be dramatically reduced through the involvement of suppliers in the innovation process.

Waddington **[6.1]** has mentioned the design aspects of agile supply chain; Supply chain management is moving away from traditional processes to agile capability to realize operations on actual demand, where information is instantly available through information sharing and exchange and organizations are designed for maximum efficiency during the integration processes.

Viharos et al **[4.3]** have discussed about the integration of the production, quality and process monitoring for enabling agile manufacturing. In this paper, a parametric manufacturing knowledge representation model was proposed to address the issue of product configuration variation and manufacturing agility to facilitate agile manufacturing. Variation product configuration (VPC) model has been proposed for modeling of manufacturing facility and process, respectively. The concepts of manufacturing capability for facility and process, as well as the mechanism for matching them, were also introduced in the proposed model. With these models, the knowledge of manufacturing facility and process for products with wide variations can be concisely represented for agile manufacturing.

Pswaffor et al **[6.2]** have suggested a supply chain agility model and discussed about the concepts of that model. This study proposes related constructs and a model of supply chain agility. Supply chain agility is defined as a measure of the supply chains ability to efficiently adapt to a rapidly changing global competitive environment to provide products and services.

They have hypothesized that supply chain agility is determined by four flexibility components; product development flexibility, sourcing flexibility, manufacturing flexibility, and logistics flexibility. Each flexibility is composed of two dimensions namely range and adaptability. They also conceived that an organization's information technology flexibility and global competitive environment influence its level of supply chain agility. To study the effects of supply chain agility on performance, two additional constructs called supply chain performance and competitive performance are included in the model.

Brim **[4.4]** has proposed the theory about logistics transformation for supply chain, characteristics of dynamic logistics demand and relative forecasting methods. In order to enhance the forecasting efficiency and precision, extended filter is applied to training artificial neural network, which serves as the agile forecasting algorithm.

Some dynamic influencing factors are taken into consideration and further quantified in agile forecasting. Swarm simulation is used to demonstrate the forecasting results. Comparison analysis shows that the forecasting method has better reliability for agile forecasting of dynamic logistics demand.

Supply Chain Agility Assessment

Lin et al **[1.1]** have utilized fuzzy logic approach for assessing supply chain agility of manufacturing organization. They have mentioned that a supply chain must possess a number of distinguishing enable-attributes such as distribution networks, Manufacturing capabilities, Interchange-ability of personnel and Learning organization, Yusuf et al **[2.2]**. Due to the qualitative and ambiguous attributes linked to agility assessment, most measures are described subjectively using linguistic terms, and cannot be handled effectively using conventional assessment approaches.

However, fuzzy logic provides an effective means of dealing with problems involving imprecise and vague phenomena. The survey aims to understand the information that will be considered in assessing agility-enabler-attributes. Assessments thus are frequently measured linguistically rather than numerically. Many methods can be adopted to aggregate the assessments of multiple decision-makers, such as arithmetic mean, median, and mode. Since the average operation is the most widespread aggregation method, this study uses the arithmetic mean to pool the opinions of experts.

Elmuti et al **[2.3]** posits the longitudinal approach for assessment of supply chain agility. The purpose of this article is to investigate the impact of integrated supply chain management on productivity, efficiency, and performance of participants in the system, in an industrial field. Actual organizational data from the survey firm was used. Follow-up interviews were conducted with key managers in the manufacturing facility.

The results show positive and substantial improvements in overall performance as a result of integration and coordination of the internal functions within the firm and effectively linking them with their external suppliers. The results also support the claims that an integrated supply chain involves aligning outsourcing activities to achieve the organizational goal of responding positively to the needs of consumers. Several factors were identified as key contributors to supply chain program success in this firm. These included sharing information through new technologies, established partnerships with key suppliers, and constant communication with employees.

Research Gap

This exploratory empirical study provides insight into the effectiveness of implementing an integrated supply chain management approach for increasing the probability of success in the supply chain management approach and identifies areas that need further investigation.

Based on the literature review, it has been inferred that researchers have contributed various characteristics of agile supply chains. Few researches have been reported on the investigation of supply chain agility of manufacturing organization. In this context, this project is focused on the assessment of the supply chain agility of a typical manufacturing organization.

METHODOLOGY

Fuzzy Logic Algorithm

The framework of the fuzzy agility evaluation method (FAEM), as shown, comprises three main parts. The first part involves examining business operation environments, measuring agility drivers and identifying of agile supply chain capabilities. Through this evaluation, the agility level needed by a supply chain can be determined and the agile-enabled attributes can be identified for measuring agility. The second part of the framework assesses the agile-enabled attributes and synthesizes fuzzy ratings and weights to obtain the fuzzy agility index (FAI) of a supply chain and the fuzzy performance importance index for each agile supply chain attribute (ASCA). Moreover,

The third part of the framework matches the FAI with an appropriate linguistic term to identify the supply chain agility level, and selects major barriers to enable managers may proactively implement appropriate improving measures. A stepwise description is presented below:

- Form a self-assessment committee, determine the required agility level and select agile-enabled attributes for assessment.
- Collect and survey data or information.
- Determine the appropriate preference scale for assessing the ratings and weights of the agile enable-attributes.
- Measure the agile-enabled-attributes' ratings and weight using linguistic terms.
- Approximate the linguistic ratings and weights with fuzzy numbers.
- Aggregate fuzzy ratings and fuzzy weights into the FAI of a supply chain.
- Translate the FAI into an appropriate linguistic level.
- Analyze gaps and identify barriers to agility.

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Framework To Measure Industry's Agility

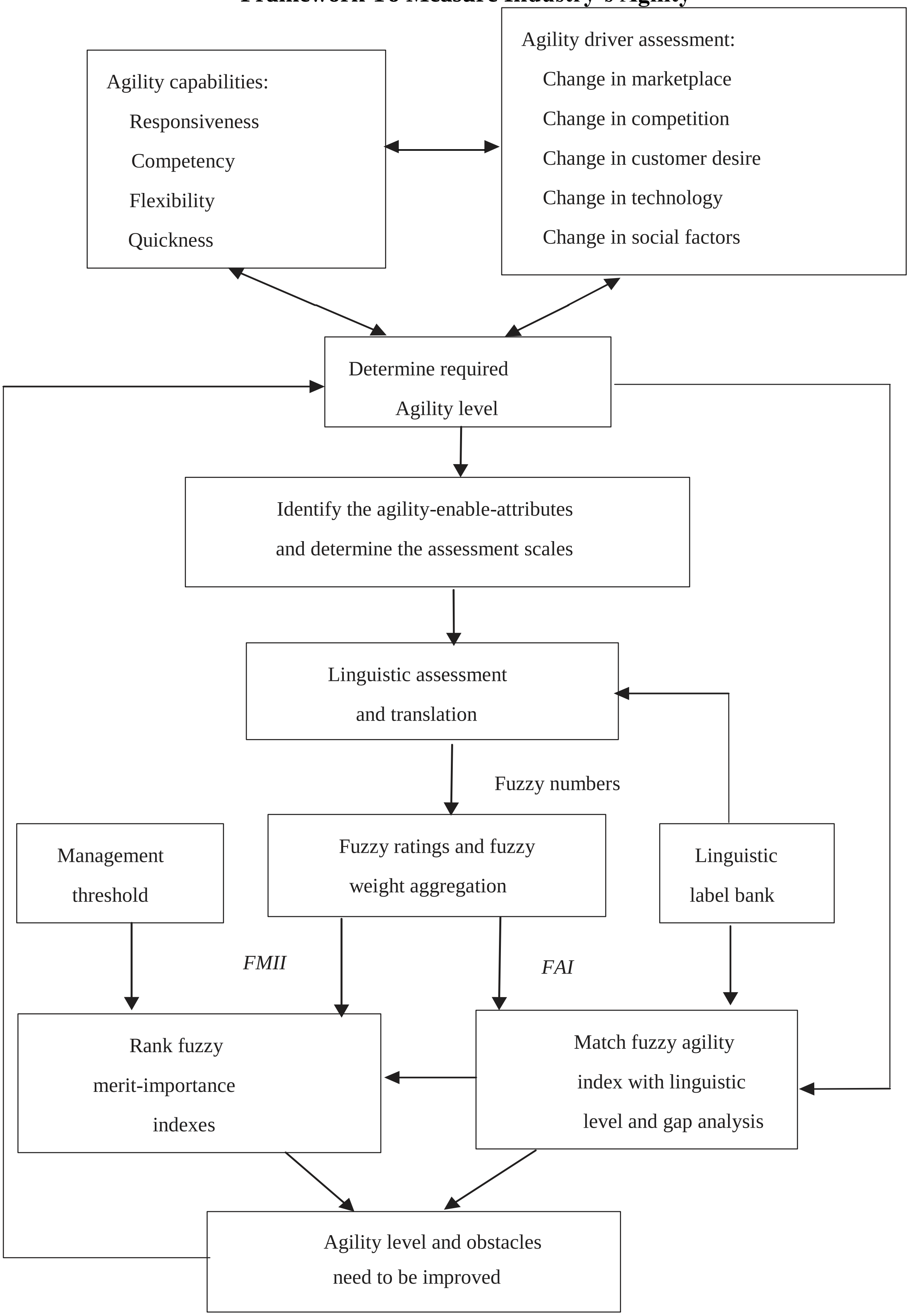

Figure – 1 :- Industrial Agility Framework

Selected Enablers And Their Respective Criteria's

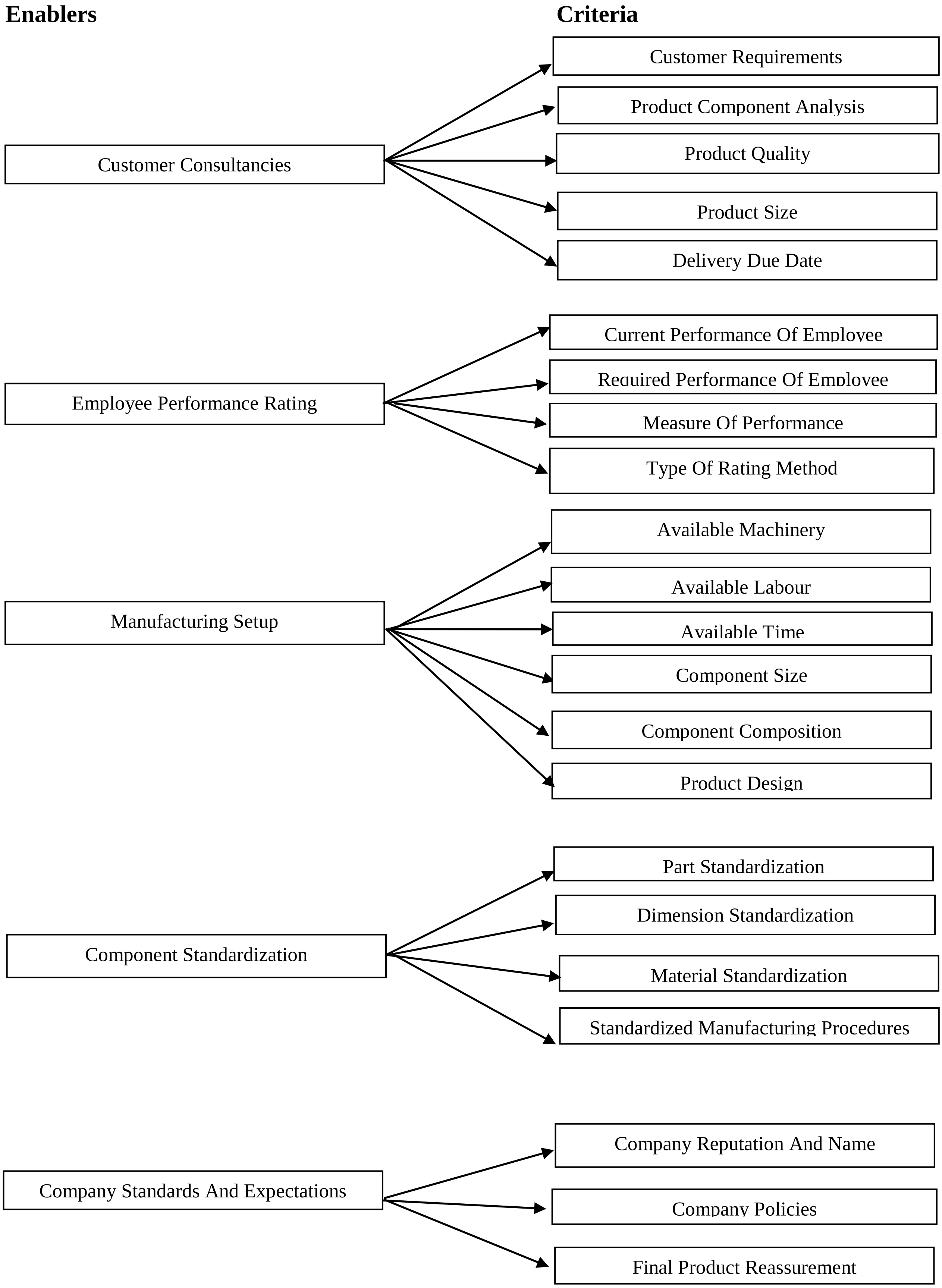

Figure – 2 :- Selected Enablers And Criteria's

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Determination Of Approximate Linguistic Terms For Assessing Performance Rating And Important Weights Of Agile Attributes

The linguistic terms are used to assess the performance rating and important weights of agile attributes. In order to assist in assigning the performance rating of agile attributes, the linguistic variables (Excellent (E), Very Good (VG), Good (G), Fair (F), Poor (P), Very Poor (VP) and Worst (W)) are used. In order to assess the importance weights of agile attributes, the linguistic variables (Very High (VH), High (H), Fairly High (FH), Medium (M), Fairly Low (FL), Low (L), and Very Low (VL)) are used. The linguistic variables and fuzzy numbers used in this project are shown in the Table.

Table - 1: - Linguistic Variables And Fuzzy Number Used

Linguistic Variable	**Fuzzy Number**	**Linguistic Variable**	**Fuzzy Number**
Worst (W)	(0, 0.5, 1.5)	Very Low (VL)	(0, 0.05, 0.15)
Very Poor (VP)	(1, 2, 3)	Low (L)	(0.1, 0.2, 0.3)
Poor (P)	(2, 3.5, 5)	Fairly Low (FL)	(0.2, 0.35, 0.5)
Fair (F)	(3, 5, 7)	Medium (M)	(0.3, 0.5, 0.7)
Good (G)	(5, 6.5, 8)	Fairly High (FH)	(0.5, 0.65, 0.8)
Very Good (VG)	(7, 8, 9)	High (H)	(0.7, 0.8, 0.9)
Excellent (E)	(8.5, 9.5, 10)	Very High (VH)	(0.85, 0.95, 1.0)

Data Collection Sample Table

Excerpt Of Supply Chain Agility Assessment Data Sheet

Table -2:- Sample Data Sheet

Name :
Designation :
Company :
Date :

S. No	**Enablers**	**Criteria**	**Attributes**	**Expert Rating**	**Expert Weight**

Current Characteristics Of Agile Supply Chain At FEIL

Table -3:- Current Characteristics Of The Agile Supply Chain

Serial Number	**Agile Supply Chain Attributes**	**Current Characteristic Of Agile Supply Chain**

Supply Chain Agility Evaluation Model

Table – 4:- Tabulation Of The Initial Supply Chain Agility Evaluation Model

Serial Number	**Agile Supply Chain Enablers**	**Agile Supply Chain Criteria**	**Agile Supply Chain Attributes**

The linguistic variables for assessing the performance ratings, importance weights are gathered from 5 executives of FEIL

Fuzzy Logic Data Analysis

Aggregation Of Fuzzy Rating And Fuzzy Weights Of Agile Supply Chain

The average fuzzy ratings is given by R_j and average performance weights is given by W_j

$$R_j = (a_j, b_j, c_j) = (R_{j1}(+)R_{j2}(+)......(+)R_{jm})/m \qquad \textbf{(1.1)}$$

$$W_j = (x_j, y_j, z_j) = (W_{j1}(+)W_{j2}(+)W_{jm})/m \qquad \textbf{(1.2)}$$

Consolidated fuzzy rating and fuzzy weights are used to determine the supply chain agility level.

Fuzzy Agility Index (FAI)

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$$FAI = \sum_{j=1}^{n}(w_j(.)R_j) \Big/ \sum_{j=1}^{n} w_j \quad \textbf{(1.3)}$$

As a sample, the average fuzzy rating and average fuzzy weight of Agile Supply Chain attribute “Incorporation of IT utilities in SCM” has been shown as follows:-

$ASCA_{1,1}$ = [E+VG+F+G+G] / 5 **From Equation (1.1)**
[(8.5, 9.5, 10) + (7, 8, 9) + (3, 5, 7) + (5, 6.5, 8) + (5, 6.5, 8)] / 5
$ASCA_{11}$ = (5.7, 7.1, 8.4)

$ASCA_{12}$ = [E + VG + G+ G +F] / 5
[(8.5, 9.5, 10) + (7, 8, 9) + (5, 6.5, 8) + (5, 6.5, 8) + (3, 5, 7)] / 5
$ASCA_{12}$= (5.7, 7.1, 8.4)

$ASCA_{13}$= [VG + VG + G +VG + VG]/ 5
[(7, 8, 9) + (7, 8, 9) + (5, 6.5, 8) + (7, 8, 9) + (7, 8, 9)] / 5
$ASCA_{13}$= (6.6, 7.7, 8.8)
$ASCA_{11}$ = [VH+FH+FL+H+FH] / 5 **From Equation (1.2)**
[(0.85,0.95,1.0) + (0.5,0.65,0.8) + (0.2,0.35,0.5) + (0.7,0.8,0.9) + (0.5,0.65,0.8)]/5
$ASCA_{11}$= (0.55, 0.68, 0.8)

$ASCA_{12}$ = [VH+FH+FH+H+H] / 5
[(0.85,0.95,1.0) + (0.5,0.65,0.8) + (0.5,0.65,0.8) + (0.7,0.8,0.9) + (0.7,0.8,0.9)]/5
$ASCA_{12}$= (0.65, 0.77, 0.88)

$ASCA_{13}$= [VH+FH+FH+H+H] / 5
[(0.85,0.95,1.0) + (0.5,0.65,0.8) + (0.5,0.65,0.8) + (0.7,0.8,0.9) + (0.7,0.8,0.9)]/5
$ASCA_{13}$= (0.65, 0.77, 0.88)

The aggregated fuzzy ratings and fuzzy weights of main and sub criteria were similarly calculated.
The aggregated fuzzy ratings of main criteria ‘outsourcing’ has been calculated as
$ASCA_1$= [(5.7, 7.1, 8.4) (*) (0.55, 0.68, 0.80) + (5.7, 7.1, 8.4) (*) (0.65, 0.77, 0.88) + (6.6, 7.7, 8.8) (*) (0.65, 0.77, 0.88)] / [(0.55, 0.68, 0.80) + (0.65, 0.77, 0.88) + (0.65, 0.77, 0.88)]
$ASCA_1$= (6.02, 7.31, 8.54) **From Equation (1.3)**
Other aggregated fuzzy ratings are calculated in a similar manner. After applying the equation (1.3)

THE FUZZY AGILITY INDEX (FAI) OF FEIL IS (5.29, 6.66, 7.99)

<u>Determination Of Euclidean Distance To Match Fai With Approximate Agility Level</u>

Once the FAI has been obtained, it can be matched with linguistic level. Euclidean distance method is the most widely used method for matching the membership function with linguistic term. In THIS project, the agility level (AL) has been set as (Extremely Agile [EA], Very Agile [VA], Agile [A], Fairly [F], Slowly [S]) has been selected for labelling. Euclidean distance has been used to find the distance between FAI and AL.

- Extremely Agile [EA] = (7,8.5,10)
- Very Agile [VA] = (5.5,7,8.5)
- Agile [A] = (3.5,5,6.5)
- Fairly [F] = (1.5,3,4.5)

- Slowly [S] = (0,1.5,3)

The membership function used for calculating FAI is given by,

$$f_A(x) = \begin{cases} (x-a)/(b-a), & a \le x \le b, \\ (x-c)/(c-b), & b \le x \le c, \\ 0, & otherwise \end{cases} \quad \textbf{(1.4)}$$

For FAI,

$$f_A(x) = \begin{cases} (x - 5.29)\ /\ 1.37, & 5.29 \le x \le 6.66 \\ (x - 7.99)\ /\ 1.33, & 6.66 \le x \le 7.99 \\ 0, & otherwise \end{cases}$$

$$d(FAI, AL_i) = \left\{ \sum_{x \in p} \left(f_{FAI}(x) - f_{AL_i}(x) \right)^2 \right\}^{1/2}$$

(1.5)

Table 5:- Tabulated Values Of FAI And VA.

X	FAI	VA	FAI-VA	$(\text{FAI-VA})^2$
0	0	0	0	0
0.5	0	0	0	0
1	0	0	0	0
1.5	0	0	0	0
2	0	0	0	0
2.5	0	0	0	0
3	0	0	0	0
3.5	0	0	0	0
4	0	0	0	0
4.5	0	0	0	0
5	0	0	0	0
5.5	0.153284672	0	0.153284672	0.023496191
6	0.518248175	0.333333333	0.184914842	0.034193499
6.5	0.883211679	0.666666667	0.216545012	0.046891742
7	-0.744360902	1	-1.744360902	3.042794957
7.5	-0.368421053	-0.666666667	0.298245614	0.088950446
8	0	-0.333333333	0.333333333	0.111111111
8.5	0	0	0	0
9	0	0	0	0
9.5	0	0	0	0
10	0	0	0	0

			Sum Of $(FAI\text{-}VA)^2$	3.347437946
			Square Root Of $(FAI\text{-}VA)^2$	1.829600488

Similarly, the Minimum "D" Values are Tabulated for All the Values as Follows:-

D (FAI, EA) = 1.870
D (FAI, VA) = 1.829
D (FAI, A) = 1.736
D (FAI, F) = 1.736
D (FAI, S) = 1.736

By matching a linguistic label with minimum D, the agility level of **FEIL** has been identified as "**Very Agile**".

Identification Of Importance Index Of Various Attributes

Fuzzy performance cannot be stopped with determination of performance level; it must identify the principle obstacles for improvement by calculating Fuzzy Performance Importance Index (FPII).

$$FPII_{ijk} = W'_{ijk} \otimes R_{ijk} \quad \textbf{(1.6)}$$

where,

$$W'_{ijk} = (1.0, 1.0, 1.0) - W_{ijk}$$

W_{ijk} is the fuzzy importance weight of the flexibility element capability ijk.
The FPIIs of each flexibility element capability are obtained and defuzzified by applying the following equation,

Ranking Score = (l + 2m + u)/4 **(1.7)**

As above, total score of attribute "CUSTOMER SPECIFICATIONS" is found to be 2.3660.

Similarly, scores have been computed for all 86 agile supply chain attributes

The following points are made a note off:-

- Indicates the score less than the Management Threshold Value of **1.75.**
- Management threshold has been fixed at **1.75.**
- Agile supply chain attributes with score less than **1.75** are found to be improvement areas.

RESULTS

The computation of FAI and Euclidean Distance has indicated that FEIL comes under the **'Very Agile'** Category. This inference very much coincided with the practical culture prevailing in the organization. After the computation of FAI, FPII and ranking of Agile Supply Chain Attributes, the agile supply chain attributes which require significant improvement has been identified. Based on consultation with the executives, proposal for improvement of supply chain agility at Naveen Industry has been found and are presented in Table 1.

Identification Of Proposals For Supply Chain Agility Improvement At Feil

The major factors affecting the efficiency of the supply chain agility have been identified and proposals for supply chain agility improvement at **FEIL** have been suggested as follows:-

Table – 6:- Proposals for Supply Chain Agility improvement

SERIAL NUMBER	AGILE SUPPLY CHAIN ATTRIBUTES	RANKING SCORE	PROPOSALS FOR SUPPLY CHAIN AGILITY IMPROVEMENT
1	COMPONENT REQUIREMENTS	1.7225	Reinforced scheduling must be implemented within FEIL to ensure that the correct quantity of Components required are ordered at the right time so as not to halt or delay the machining and assembly processes in the Assembly By area.
2	EMPLOYEE SKILL LEVEL	1.6925	The skill levels of the employees within the company is good as many of the employees have been in the company for a very long period of time (Some of them more than Fifteen years), but still they are not able to meet the demand requirements as the workers work at a very relaxed pace which overshadows their high skill levels. Hence, the company should take measures to utilize the skill levels of their employees to their full potential.
3	COMPONENT ANALYSIS	1.5110	The components procured by the Supply Chain Team should be thoroughly checked to make sure that the right quality of materials required are procured and maintained.
4	EMPLOYEE AGE	1.3950	Most of the employees within FEIL are near their retirement ages, and hence, the company should hire new employees who should be properly trained by the existing employees to ensure that they are able to continue working at the same pace or a higher pace once the existing employees retire.

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SERIAL NUMBER	AGILE SUPPLY CHAIN ATTRIBUTES	RANKING SCORE	PROPOSALS FOR SUPPLY CHAIN AGILITY IMPROVEMENT
5	PERFORMANCE STANDARDS	1.6500	The performance standards followed within eh company shows that most of the employees are highly talented but they are not adequately motivated. This results in less than par performance standards being set rather than the required performance standards.
6	SKILL LEVEL REQUIREMENTS	1.2810	The required skill levels of the overall company functioning are not on par with the requirements. Hence, emphasis has to be put on developing the skill sets of various employees within various departments of the company to bring overall efficiency improvements.
7	MATERIAL USAGE	1.2125	The material and castings procured must be handled very carefully and utilized with minimal wastages so as to not over utilize or underutilize the available material as it may increase costs in the long run.
8	COMPONENT PROPERTIES	1.6095	The components and castings procured should be utilized and handled in such a manner that the physical and chemical properties of the components do not get altered during machining or assembly activities or testing procedures.
9	DESIGN PARAMETERS	0.5285	The design parameters currently under consideration are good, but as time moves forward, enhancements should also take place and designs should be able to incorporate these enhancements and improve over them if possible. The company is currently working in this direction.
10	DESIGN LANGUAGE	0.9790	The design language used within the company has an extremely lengthy procedure, involves a lot of clearances and high levels of clear communication within the various departments. This procedure should be improved so as to reduce time needed and improve the overall design of the final component.
11	DESIGN FEASIBILITY	0.8085	The overall feasibility of the design is based on the customer requirements and the available machinery equipment within the company. Once these two areas are clearly taken into consideration by the employees, the design becomes highly feasible.
12	NUMBER OF STANDARDIZED	1.4150	The number of standardized components for a particular product within the company depends on the design of the product and the size of the

SERIAL NUMBER	AGILE SUPPLY CHAIN ATTRIBUTES	RANKING SCORE	PROPOSALS FOR SUPPLY CHAIN AGILITY IMPROVEMENT
	PARTS FOR A PRODUCT		product. As these products are "Make To Order", there should be an optimal number of standardized parts designed for a product irrespective of its size.
13	DIMENTIONAL ACCURACY	0.8895	The levels of dimensional accuracy of the products produced are highly depended on the tolerance limits of the various components. Understanding these tolerance limits will help improve the overall dimensional accuracy of the finished product.
14	TOLERANCE LIMITS	1.0100	Tolerance limits vary for different components of the final product and this can lead to dimensional changes in the final product. Establishing a common tolerance limit for all the various components results in more accurately finished products over time.
15	DEFECTS	1.3355	Defects are present in every industry and FEIL is no exception. However, precautions are being taken to reduce the number of defects produced within the company.
16	MATERIAL QUALITY	1.2595	Good quality materials are procured by the Supply Chain Department of FEIL which are sufficient for product manufacturing and assembly purposes. But, better materials are slowly emerging in the market and the company should look at these new materials to make sure they have a better quality products produced over time.
17	DISPATCH AND PAYMENT POLICIES	1.3950	Dispatch of the final product depends on the payments received by FEIL from their customers. When payments are delayed, dispatches are also delayed and this causes problems for the company. As a result of which the dispatch and payment policies of the company have to be properly framed to ensure that there are no delays and if delays persist at either end, fines or price increments or reductions are enforced.
18	CUSTOMER LOYALTY DEVELOPEMENT	1.5060	Customer loyalty development plays a major role for a company such as FEIL as they have been sustaining in the market for over fifty years. As time progresses, the company became known for their reliability and quality, but they can improve in the other areas such as number of orders and reduction in subcontracting.

DISCUSSION

The findings with regards to the agility improvement of the current Supply Chain using the Fuzzy Logic technique has led to basically FIVE main enablers containing TWENTY TWO Criteria's having SIXTY SEVEN Attributes. These factors were determined using the Framework to Measure Industry's Agility, the Selection of Enablers model, the Conceptual Model for Supply Chain Agility Evaluation, the Supply Chain Agility Evaluation Model, the Excerpt of Supply Chain Agility Assessment Data Sheet and the table of Current Characteristics of the Agile Supply Chain. These factors act as the basis for the identification of the importance index for various attributes and the ranking score. We find that there are Eighteen Factors which need to be improved upon for high beneficial levels of the company in the future.

CONCLUSIONS

The manufacturing organizations such as FEIL are facing the pressure to transform their manufacturing paradigm. Agile manufacturing is a modern manufacturing paradigm which enables the organizations to survive in the competitive dynamic environment.

Supply chain management is essential constituent of agile manufacturing. The quantification of supply chain agility gains an importance in the modern industrial scenario.

This project has been carried out for assessing the supply chain agility of FEIL. After determining the supply chain agility level, the importance index of various agile supply chain attributes has been found. This is followed by the derivation of various proposals for supply chain agility improvement

Limitations

As fuzzy logic uses approximation, it cannot be used in organization where there is requirement of extreme precise results and figures.

Another limiting factor is the inability of fuzzy logic to solve problems when no one knows the solution. Experts must exist who know how to create the rule sets needed to make a fuzzy logic system work. It was a very difficult task to make the executives understand each term while taking the performance ratings and weightage of agile attributes.

There is no systematic approach to fuzzy system designing. Instead, empirical ad-hoc approaches are used.

Future Scope Of The Project

The experiences and the results gained as a result of conducting this case study is practical and feasible. In future, numerous case studies on supply chain agility assessment could be carried out for different departments with specific emphases on the major function of that particular department and what role it plays in FEIL, as well as across varied sectors to further enhance and refine the developed supply chain agility assessment model. Reiteration can be carried out in the same organization for overall improvement.

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