National Seminar
On
"Management Challenges in The New Milieu –The Road Ahead"

Understanding Performance Criterions for Leagile Supply Chain using Fuzzy AHP

Presented by

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Outline

- **What is Lean, Agile and Leagile Supply Chain**
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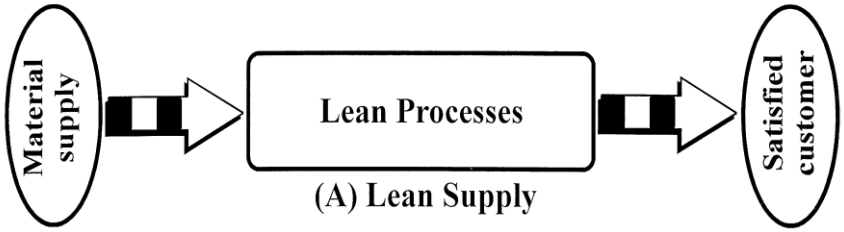
Lean Supply chain

- **Lean supply chain is a systematic approach to identifying and eliminating waste (non-value added activity)**
- **Identifies an opportunity to improve the product quality**
- **Reduces risk and introduces a continuous learning and improvement**
- **Lean adopted where demand is stable and to ensure level schedule**

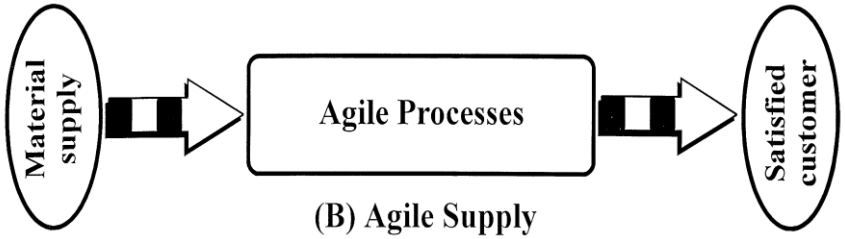
Agile Supply chain

- **Agile supply chain is an operational strategy focused on inducing speed and flexibility in the supply chain.**
- **It must posses the following characteristics: Market sensitive, virtual supply chain, process integration, network based**
- **Agile adopted where demand is volatile**

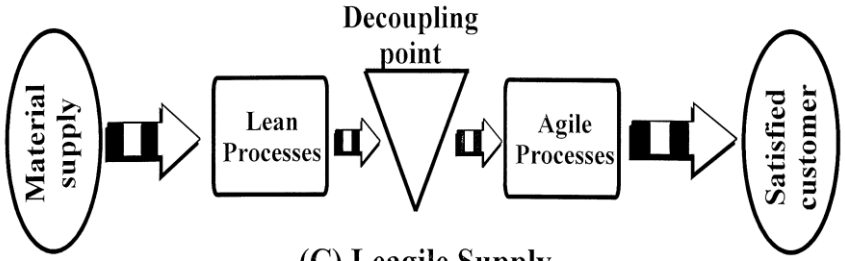
Leagile supply chain



(A) Lean Supply



(B) Agile Supply



(C) Leagile Supply

- **Leagile is the combination of the lean and agile within a total supply chain strategy by positioning the decoupling point.**
- **Combined to take the advantage of both in single unit**
- **Because there is always need to response to volatile demand in down stream and provide level schedule in upstream from marketplace**

Literature Review

S. N.	Authors	Journals/Proceedings/ Books	Findings
1.	Naylor et al. (1999)	Int. J. Production Economics	Compared the lean and agile principle highlighting the similarities and differences and combined with a total supply chain considering market knowledge and decoupling point
2.	Mason-Jones et al. (2000a)	Int. J. of Agile Management Systems	Integrated the lean production and agile supply in total supply chain, that approach ensure that customer service levels are improved at the same time lead times and costs are reduced
3.	Mason-Jones et al. (2000b)	Int. J. Production Research	Classified the SC design and operations according to the Lean, Agile and Leagile paradigms
4.	Agrawal et al. (2006)	European Journal of Operational Research	Presented a framework which summarize the market sensitiveness, process integration, information driver and flexibility measures of SC perform

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S. N.	*Authors*	*Journals/Proceedings/ Books*	*Findings*
5.	Narasimhan et al. (2006)	Journal of Operations Management	Attempted an empirical study to determine whether lean and agile forms occur with any degree of uniformity in manufacturing plants
6.	Sylwia Konecka (2010)	Electronic Scientific Journal of Logistics	Emphasizes the importance of the risk management in supply chains strategy such as lean, agile and leagile
7.	Naimn and Gosling (2011)	Int. J. Production Economics	Presented that there have been extensive exploitation and robust testing of the leagile supply chain model and associated definitions
8.	Prince and Kay (2003)	Int. J. Production Economics	Describe the circumstances on which, a manufacturing organisations require an integrated agile and lean characteristic in their manufacturing organisations

Problem Formulation

- **The concept of Leagility has gained vital consciousness to all manufacturing sectors, their supply chains and hence a logical measurement index system is indeed required in implementing Leagility in practice**
- **That can help the enterprises to assess their existing Leagility level and to compare different industries**
- **The present work exhibits an efficient Fuzzy based leagile performance framework using Fuzzy AHP method with Triangular Fuzzy Numbers set. The methodology described here has fruitful while applying for a particular industry**

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- **A manufacturing industries have been chosen**
- **A committee of five decision makers DM_1, DM_2, DM_3, DM_4, DM_5 has been formed**
- **Each main criteria is evaluated based on different Leagile sub criterions**

Leagile Entities

Goal	Main Criteria	Sub Criterions	Main Criteria	Sub Criterions
Leagility	Market Knowledge (C_1)	Product Demand Variability (C_{11})	Service (C_5)	Customer Support (C_{51})
		Product Variety(C_{12})		Product Service(C_{52})
		Product Differentiation(C_{13})		Product Support(C_{53})
		Lead Time Requirements(C_{14})		Flexibility to Meet Demands (C_{54})
	Supply Chain Design(C_2)	Supply Chain Material Flow(C_{21})		Flexibility to Meet Market Changes(C_{55})
		Supply Chain Information Flow(C_{22})	Cost (C_6)	Design and Engineering(C_{61})
		Strategic Positioning of The Decoupling Point (C_{23})		Quality Assurance (C_{62})
		Lead Time Compression(C_{24})		Distribution (C_{63})
	Optimisation for Leanness agility (C_3)	Eliminate All Waste(C_{31})		Administration(C_{64})
		Maximise Flexibility Without Additional Waste (C_{32})		Inventory (C_{65})
		Design For Total Flexibility (C_{33})		Materials(C_{66})
		Minimise Waste Without Restricting Flexibility (C_{34})	Lead time (C_7)	Time to Market(C_{71})
	Quality(C_4)	Meeting Customer Requirements(C_{41})		Response to Market Forces(C_{72})
		Fitness For Use(C_{42})		Design, Conversion and Engg(C_{73})
		Process Integrity(C_{43})		Inventory(C_{74})
		Minimum Variance(C_{44})		Materials(C_{75})
		Elimination Of Waste(C_{45})		Delivery(C_{76})
		Continuous Improvement(C_{46})		

Methodology

Fuzzy Analytic Hierarchy Process

- **It is a systematic decision making method which includes both qualitative and quantitative techniques**
- **In which a set of comparison matrixes are made for attributes or alternatives**
- **When the number of attribute or alternatives increases. A consistency check are performed for comparison matrixes.**
- **And carried out the test until they are consistent**

Procedural Steps

Step I : Determination of the linguistic variable and fuzzy importance scale for both main and sub criterions

Linguistic terms	Triangular Fuzzy number	Triangular Fuzzy reciprocal number
Equally important	(1,1,1)	(1,1,1)
Moderately important	(2/3,1,3/2)	(2/3,1,3/2)
Strongly important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly important	(5/2,3,7/2)	(2/7,1/3,2/5)
Extremely important	(7/2,4,9/2)	(2/9,1/4,2/7)

Step II: Formation of hierarchy pair-wise comparison matrices for main and sub criterions and assign the linguistic terms

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Fuzzy Pair-wise Comparison matrix at Main Criteria level

Criterions	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	(1,1,1)	(2/7,1/3,2/5)	(3/2,2,5/2)	(2/7,1/3,2/5)	(2/9,1/4,2/7)	(7/2,4,9/2)	(5/2,3,7/2)
C_2	(5/2,3,7/2)	(1,1,1)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(5/2,3,7/2)	(2/5,1/2,2/3)	(2/9,1/4,2/7)
C_3	(2/5,1/2,2/3)	(5/2,3,7/2)	(1,1,1)	(2/3,1,3/2)	(2/5,1/2,2/3)	(7/2,4,9/2)	(1,1,1)
C_4	(5/2,3,7/2)	(3/2,2,5/2)	(2/3,1/2,3/2)	(1,1,1)	(2/7,1/3,2/5)	(5/2,3,7/2)	(7/2,4,9/2)
C_5	(7/2,4,9/2)	(2/7,1/3,2/5)	(3/2,2,5/2)	(5/2,3,7/2)	(1,1,1)	(2/9,1/4,2/7)	(3/2,2,5/2)
C_6	(2/9,1/4,2/7)	(3/2,2,5/2)	(2/9,1/4,2/7)	(2/7,1/3,2/5)	(7/2,4,9/2)	(1,1,1)	(2/7,1/3,2/5)
C_7	(2/7,1/3,2/5)	(7/2,4,9/2)	(1,1,1)	(2/9,1/4,2/7)	(2/5,1/2,2/3)	(5/2,3,7/2)	(1,1,1)

Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_1)

Sub-criteria	C_{11}	C_{12}	C_{13}	C_{14}
C_{11}	(1,1,1)	(7/2,4,9/2)	(3/2,2,5/2)	(2/7,1/3,2/5)
C_{12}	(2/9,1/4,2/7)	(1,1,1)	(2/9,1/4,2/7)	(3/2,2,5/2)
C_{13}	(2/5,1/2,2/3)	(7/2,4,9/2)	(1,1,1)	(2/7,1/3,2/5)
C_{14}	(5/2,3,7/2)	(2/5,1/2,2/3)	(5/2,3,7/2)	(1,1,1)

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Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_2)

Sub-criteria	C_{21}	C_{22}	C_{23}	C_{24}
C_{21}	(1,1,1)	(2/7,1/3,2/5)	(2/9,1/4,2/7)	(3/2,2,5/2)
C_{22}	(5/2,3,7/2)	(1,1,1)	(2/5,1/2,2/3)	(2/3,1,3/2)
C_{23}	(7/2,4,9/2)	(3/2,2,5/2)	(1,1,1)	(2/7,1/3,2/5)
C_{24}	(2/5,1/2,2/3)	(2/3,1,3/2)	(5/2,3,7/2)	(1,1,1)

Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_3)

Sub-criteria	C_{31}	C_{32}	C_{33}	C_{34}
C_{31}	(1,1,1)	(7/2,4,9/2)	(2/3,1,3/2)	(2/7,1/3,2/5)
C_{32}	(2/9,1/4,2/7)	(1,1,1)	(5/2,3,7/2)	(1,1,1)
C_{33}	(2/3,1,3/2)	(2/7,1/3,2/5)	(1,1,1)	(3/2,2,5/2)
C_{34}	(5/2,3,7/2)	(1,1,1)	(2/5,1/2,2/3)	(1,1,1)

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Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_4)

Sub-criteria	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
C_{41}	(1,1,1)	(3/2,2,5/2)	(5/2,3,7/2)	(2/7,1/3,2/5)	(3/2,2,5/2)	(2/9,1/4,2/7)
C_{42}	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,3/2)	(2/7,1/3,2/5)	(5/2,3,7/2)	(2/3,1,3/2)
C_{43}	(2/7,1/3,2/5)	(2/3,1,3/2)	(1,1,1)	(7/2,4,9/2)	(5/2,3,7/2)	(2/5,1/2,2/3)
C_{44}	(5/2,3,7/2)	(5/2,3,7/2)	(2/9,1/4,2/7)	(1,1,1)	(2/7,1/3,2/5)	(2/7,1/3,2/5)
C_{45}	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(2/7,1/3,2/5)	(5/2,3,7/2)	(1,1,1)	(5/2,3,7/2)
C_{46}	(7/2,4,9/2)	(2/3,1,3/2)	(3/2,2,5/2)	(5/2,3,7/2)	(2/7,1/3,2/5)	(1,1,1)

Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_5)

Sub-criteria	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}
C_{51}	(1,1,1)	(2/9,1/4,2/7)	(3/2,2,5/2)	(2/7,1/3,2/5)	(5/2,3,7/2)
C_{52}	(7/2,4,9/2)	(1,1,1)	(2/5,1/2,2/3)	(2/9,1/4,2/7)	(3/2,2,5/2)
C_{53}	(2/5,1/2,2/3)	(3/2,2,5/2)	(1,1,1)	(5/2,3,7/2)	(2/7,1/3,2/5)
C_{54}	(5/2,3,7/2)	(7/2,4,9/2)	(2/7,1/3,2/5)	(1,1,1)	(2/9,1/4,2/7)
C_{55}	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(5/2,3,7/2)	(7/2,4,9/2)	(1,1,1)

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Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_6)

Sub-criteria	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	C_{66}
C_{61}	(1,1,1)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(5/2,3,7/2)	(2/9,1/4,2/7)	(5/2,3,7/2)
C_{62}	(5/2,3,7/2)	(1,1,1)	(2/3,1,3/2)	(2/7,1/3,2/5)	(2/3,1,3/2)	(3/2,2,5/2)
C_{63}	(3/2,2,5/2)	(2/3,1,3/2)	(1,1,1)	(2/5,1/2,2/3)	(3/2,2,5/2)	(2/9,1/4,2/7)
C_{64}	(2/7,1/3,2/5)	(5/2,3,7/2)	(3/2,2,5/2)	(1,1,1)	(2/7,1/3,2/5)	(2/3,1,3/2)
C_{65}	(7/2,4,9/2)	(2/3,1,3/2)	(2/5,1/2,2/3)	(5/2,3,7/2)	(1,1,1)	(2/7,1/3,2/5)
C_{66}	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(7/2,4,9/2)	(2/3,1,3/2)	(5/2,3,7/2)	(1,1,1)

Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C_7)

Sub-criteria	C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}
C_{71}	(1,1,1)	(2/9,1/4,2/7)	(5/2,3,7/2)	(2/3,1,3/2)	(3/2,2,5/2)	(2/7,1/3,2/5)
C_{72}	(7/2,4,9/2)	(1,1,1)	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(5/2,3,7/2)	(2/3,1,3/2)
C_{73}	(2/7,1/3,2/5)	(3/2,2,5/2)	(1,1,1)	(2/9,1/4,2/7)	(3/2,2,5/2)	(7/2,4,9/2)
C_{74}	(2/3,1,3/2)	(5/2,3,7/2)	(7/2,4,9/2)	(1,1,1)	(2/3,1,3/2)	(2/7,1/3,2/5)
C_{75}	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(2/3,1,3/2)	(1,1,1)	(3/2,2,5/2)
C_{76}	(5/2,3,7/2)	(2/3,1,3/2)	(2/9,1/4,2/7)	(5/2,3,7/2)	(2/5,1/2,2/3)	(1,1,1)

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Step III: **By using the chang's extent analysis find the value of fuzzy synthesis extent**

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}$$

M = Set of criteria's

Step IV: **Determined the degree of similarity between two Triangular fuzzy number**

$M_1 = (l_1, m_1, u_1)$, $M_2 = (l_2, m_2, u_2)$

$$V(M_2 \geq M_1) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise}, \end{cases}$$

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Step V: Determination of Normalized weight vector or priority weight

$$NW_i = \frac{W_i}{\sum W_i}$$

W = weight vector

Step VI: Checked the Consistency of pair wise comparison matrices

$$CI_n = \frac{\lambda_{max} - n}{n-1}$$

CI = Consistency index
λ_{max} = Principle Eigen value
n = Order of matrix

Consistency Ratio: $CR = \frac{CI}{RI}$

* In practical decision situations consistency is "acceptable" if CR< 0.1

Step VII: Finally find the overall priority weight and ranked the criteria and sub criterions

Results and Discussion

- **According to the methodology described above the calculation has done and shown below in the tables**
- **Consistency ratio test has done and found to the acceptable level**
- **Finally ranked the criterions on the basis of over all priority weight**

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Priority weight and over all priority weight of criteria and sub criterions

Goal	Main Criteria	Priority Weight for MC	Sub Criteria	Priority Weight for SC	Over all Priority Weight	Ranking	CR
Leagility	Market Knowledge (C_1)	0.15	(C_{11})	0.38	0.057	4	0.065
			(C_{12})	0.00	0.000	26	
			(C_{13})	0.22	0.033	13	
			(C_{14})	0.40	0.060	2	
	Supply Chain Design(C_2)	0.05	(C_{21})	0.14	0.007	22	
			(C_{22})	0.36	0.018	19	
			(C_{23})	0.15	0.008	21	
			(C_{24})	0.36	0.018	19	
	Optimisation for Leanness agility(C_3)	0.16	(C_{31})	0.35	0.056	5	
			(C_{32})	0.23	0.037	11	
			(C_{33})	0.15	0.024	17	
			(C_{34})	0.26	0.042	9	
	Quality(C_4)	0.28	(C_{41})	0.16	0.046	7	
			(C_{42})	0.09	0.025	16	
			(C_{43})	0.21	0.060	2	
			(C_{44})	0.12	0.034	12	
			(C_{45})	0.14	0.039	10	
			(C_{46})	0.27	0.078	1	

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Priority weight and over all priority weight of criteria and sub criterions

Goal	Main Criteria	Priority Weight for MC	Sub Criteria	Priority Weight for SC	Over all Priority Weight	Ranking	CR
Leagility	Service(C_5)	0.22	(C_{51})	0.13	0.029	14	0.065
			(C_{52})	0.20	0.045	8	
			(C_{53})	0.15	0.033	13	
			(C_{54})	0.25	0.055	6	
			(C_{55})	0.26	0.058	3	
	Cost(C_6)	0.02	(C_{61})	0.15	0.003	24	
			(C_{62})	0.17	0.003	24	
			(C_{63})	0.11	0.002	25	
			(C_{64})	0.14	0.003	24	
			(C_{65})	0.21	0.004	23	
			(C_{66})	0.21	0.004	23	
	Lead time(C_7)	0.11	(C_{71})	0.08	0.009	20	
			(C_{72})	0.24	0.027	15	
			(C_{73})	0.21	0.024	17	
			(C_{74})	0.24	0.027	15	
			(C_{75})	0.03	0.004	23	
			(C_{76})	0.19	0.020	18	

Conclusions

- **The research aimed to develop a quantitative analysis framework and a simulation methodology to evaluate the effectiveness of leagility in practices by exploring the concept of Triangular Fuzzy Numbers**
- **The procedural hierarchy presented here could help the industries to assess their existing leagile performance.**
- **The results obtained by the proposed Fuzzy AHP method are found an appropriate for ranking the criteria.**
- **This work will be very help full to the management while implementing leagile supply chain in any organization.**

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Thank You