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A Grey-based Approach for Integration of Lean and Agile Supply Chain

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ABSTRACT

Leanness in a supply chain maximizes profits through cost reduction while agility maximizes profit through providing exactly what the customer requires. The leagile supply chain enables the upstream part of the chain to be cost-effective and the downstream part to achieve high service levels in a volatile marketplace. As was studied in the literature there are many models to select the appropriate supply chain that each one has different criteria for decision making regarding the selection of supply chain. In presented model based on the gray theory were able modeling preferences and criteria for decision makers. It should be noted that this model consider criteria in two dimensions that include flexibility and sensitivity of market. The present model used the opinions of expert to make decisions in the real world. This model was studied in the automotive industry as a case study. The results of model with industry experts and managers were reviewed and the results were confirmed.

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1. Introduction

A key feature of present day business is the idea that it is supply chains (SC) that compete, not companies (Christopher and Towill, 2001), and the success or failure of supply chains is ultimately determined in the marketplace by the end consumer. Getting the right product, at the right time to the consumer is not only the linchpin to competitive success, but also the key to survival. Hence, customer satisfaction and market place understanding are critical elements for consideration when attempting to establish a new SC strategy. Significant interest has been shown in recent years in the idea of ‘‘lean manufacturing’’, and the wider concepts of the ‘‘lean enterprises’’. The focus of the lean approach has essentially been on the elimination of waste or muda. The upsurge of interest in lean manufacturing can be traced to the Toyota Production Systems with its focus on the reduction and elimination of waste. Lean is about doing more with less. Lean concepts work well where demand is relatively stable and hence predictable and where variety is low. Agility is a business-wide capability that embraces organizational structures, information systems, logistics processes and in particular, mindsets (Power et al., 2001; Katayama and Bennett, 1999). Agility is being defined as the ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety (Christopher, 2000). The lean and agile paradigms, though distinctly different, can be and have been combined within successfully designed and operated total supply chains (Mason-Jones and Towill, 1999). leagile is the combination of the lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream yet providing level scheduling upstream from the market place (van Hoek et al., 2001). The decoupling point is in the material flow streams to which the customer orders penetrates (Mason-Jones et al., 2000a,b; Prince and Kay, 2003).

2. Grey relational analysis

A grey system is defined as a system containing uncertain information presented by a grey number and grey variables. Let X is the universal set. Then a grey set *G* of *X* is defined by its two mappings:

$\overline{\mu}_G(x) : x \to [0,1]$, $\underline{\mu}_G(x) : x \to [0,1]$
$\overline{\mu}_G(x)$: Upper membership functions
$\overline{\mu}_G(x)$: Lower membership functions
$x \in X$, X=R.

The grey number can be defined as a number with uncertain information. For example, the ratings of attributes are described by the linguistic variables; there will be a numerical interval expressing it. This numerical interval will contain uncertain information. Generally, grey number is written as

$$\otimes G = G|_{\underline{\mu}}^{\overline{\mu}} \quad (1)$$

The lower and upper limits of G can be estimated and G is defined as an interval grey number.

$$\otimes G = [\underline{G}, \overline{G}] \quad (2)$$

Basic operation laws of grey numbers:

$$\otimes G_1 \pm \otimes G_2 = [\underline{G}_1 \pm \underline{G}_2, \overline{G}_1 \pm \overline{G}_2] \quad (3)$$

$$\otimes G_1 \times \otimes G_2 = [\text{Min}(\underline{G}_1 \underline{G}_2, \underline{G}_1 \overline{G}_2, \overline{G}_1 \underline{G}_2, \overline{G}_1 \overline{G}_2), \text{Max}(\underline{G}_1 \underline{G}_2, \underline{G}_1 \overline{G}_2, \overline{G}_1 \underline{G}_2, \overline{G}_1 \overline{G}_2)] \quad (4)$$

$$\otimes G_1 \div \otimes G_2 = [\underline{G}_1, \overline{G}_1] \times \left[\frac{1}{\underline{G}_2}, \frac{1}{\overline{G}_2}\right]. \quad (5)$$

The length of grey number G is defined as:

$$L(\otimes G) = [\overline{G} - \underline{G}]. \quad (6)$$

The possibility degree of $\otimes$G1≤$\otimes$G2 can be expressed as follows:

$$P\{\otimes \text{G1} \leq \otimes G_2\} = \frac{\text{Max}(0, L^* - \text{Max}(0, \overline{G}_1 - \underline{G}_2))}{L^*} \quad (7)$$

Where $L^* = L(\otimes \text{G1}) + L(\otimes G(2))$ (8)

3. Proposed Methodology

As mentioned, according to Purvis (2014) and Agarwal (2006), selection criteria were classified into the following divisions which can be seen in Table 1. In the current article, Market sensitiveness and Flexibility criteria is evaluated by GRA.. The case study for the same model is conducted in the real environment in an automotive manufacturing unit, and the company's managers were provided with the results for decision-making. In each dimensions (Market sensitiveness and Flexibility criteria), the following steps should be done.

Table 1. Market sensitiveness and Flexibility criteria

Market sensitiveness	Flexibility
Delivery Speed (DS)	Source flexibility(SF)
New product introduction (NPI)	Make flexibility(MF)
Customer responsiveness(CR)	Delivery flexibility(DF)

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3.1 Evaluation of the Alternatives Using GRA:

3.1.1. At first, weight of each of the criteria was mentioned according to the linguistic variables. Linguistic variables are determined based on a grey number as follows:

$\otimes W_i=[\overline{w_i}, \underline{w_i}]$ (9)

$$W_i = \frac{1}{K}\left[W_i^1 + W_i^2 + \cdots + W_i^k\right] \quad (10)$$
$1 \le i \le m$

In which K, the decision maker of each criteria of i, using linguistics variables and mentions self-weights. The respective weight of each criterion is worked out from the weight average related to the decision makers. The scale of criteria may be considered according to the Table 2.

Table 2. The scale of criteria weights

Scale	$\otimes W$
Very low (VL)	[0.0, 0.1]
Low (L)	[0.1, 0.3]
Medium low (ML)	[0.3, 0.4]
Medium (M)	[0.4, 0.5]
Medium high (MH)	[0.5, 0.6]
High (H)	[0.6, 0.9]
Very high (VH)	[0.9, 1.0]

3.1.2. For each of the alternatives, the decision makers present their scores using the linguistic variables. The weight average is used in order to calculate the final weight: Where G_{ij}^k is rank of alternative j at the criteria i in the Kith decision maker's view.

$$G_{ij}=\frac{1}{K}\left[G_{ij}^1 + G_{ij}^2 + \cdots + G_{ij}^k\right] \quad (11)$$
$1 \le i \le m$
$1 \le j \le n$

The decision-making matrix is as follows:

$$D = \begin{bmatrix} G_{11} & \cdots & G_{1m} \\ \vdots & \ddots & \vdots \\ G_{n1} & \cdots & G_{nm} \end{bmatrix} \quad (12)$$

The table of linguistic variables to score the alternatives is as follows (see Table 3).

Table 3. Linguistic variables to score the alternatives

Scale	$\otimes G$
Very poor (VP)	[0, 1]
Poor (P)	[1, 3]
Medium poor (MP)	[3, 4]
Fair (F)	[4, 5]
Medium good (MG)	[5, 6]
Good (G)	[6, 9]
Very good (VG)	[9,10]

3.1.3 The acquired matrix must be normalized

$$D = \begin{bmatrix} \otimes {G^*}_{11} & \cdots & \otimes {G^*}_{1m} \\ \vdots & \ddots & \vdots \\ \otimes {G^*}_{n1} & \cdots & \otimes {G^*}_{nm} \end{bmatrix} \quad (13)$$

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$$\otimes G^*_{ij} = \left[\frac{\underline{G_{ij}}}{G_j^{max}}, \frac{\overline{G_{ij}}}{G_j^{max}}\right]$$

$G_j^{max} = \max\left[\overline{Gij}\right]\ 1 \le i \le m \qquad 1 \le j \le n$.

For a cost criterion

$$\otimes G^*_{ij} = \left[\frac{G_j^{min}}{\overline{G_{ij}}}, \frac{G_j^{min}}{\underline{G_{ij}}}\right]$$

3.1.4. The grey decision-making matrix is result of normalized grey decision-making matrix multiplied by factor weights

$$D = \begin{bmatrix} \otimes V_{11} & \cdots & \otimes V_{1m} \\ \vdots & \ddots & \vdots \\ \otimes V_{n1} & \cdots & \otimes V_{nm} \end{bmatrix} \qquad (14)$$

$\otimes V_{ij} = \otimes G^*_{ij} \times \otimes W_j$.

3.1.5. In order to compare and rank the options (alternatives), the ideal option is worked out according to the following items:

$S^{max} = \{\otimes G_1^{max}, \otimes G_2^{max}, \ldots., \otimes G_n^{max}\}$. (15)

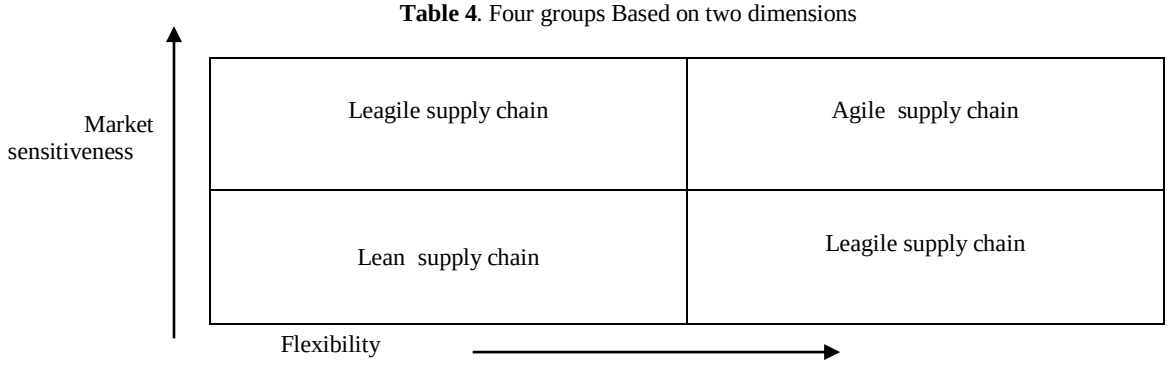
3.1.6. The grey possibility degree between compared alternatives is calculated.

$P\{S_i \le S^{max}\} = \frac{1}{n}\sum_{j=1}^{n} P\{\otimes V_{ij} \le \otimes G_j^{max}\}$. (16)

The less grey possibility degree is, the better, and ordering is done based on the same.

3.1.7. The solutions can be divided into four following groups as shown Table 4.

Table 4. Four groups Based on two dimensions



4-Adaptation of the Model to Select Alternatives in the Automotive Company:

The above model was reviewed in Zamyad Company (an automotive company). This company, according to the type of industry and varied supplied parts, uses a large number of alternatives, and the company's managers admitted the need for a model for decision-making. In this regard, some alternatives are selected for assessment. In order to acquire weights pertinent to the criteria and their assessment, at first, a number of check lists were employed for which the senior managers were responsible, and the scoring was carried according to Tables 5 and the results in the following table were obtained. (See Tables 6 to 11).

Table 5. Criteria weights based on four Decision makers' ranking

Market sensitiveness	Manager 1	Manager 2	Manager 3	Manager 4	w_i	
					$\underline{w}_i$	$\overline{w}_i$
Delivery Speed (DS)	VH	MH	MH	VH	0.7	0.8
New product introduction (NPI)	H	H	H	H	0.6	0.9
Customer responsiveness(CR)	MH	MH	MH	MH	0. 5	0.6
Flexibility criteria	Manager 1	Manager 2	Manager 3	Manager 4	$\underline{w}_i$	$\overline{w}_i$
Source flexibility(SF)	MH	MH	VH	VH	0.7	0.8
Make flexibility(MF)	H	MH	H	MH	0.55	0.75
Delivery flexibility(DF)	MH	MH	H	H	0.55	0.70

Table 6. Criteria rating values for alternative based on four Decision makers' ranking according to Equation (11)

Flexibility criteria		Manager 1	Manager 2	Manager 3	Manager 4	G_{ij}	
						$\underline{G_{ij}}$	$\overline{G_{ij}}$
Source flexibility(SF)	A1	VP	P	P	VP	*0.5*	*2*
	A2	MP	MP	MP	MP	*3*	*4*
	A3	F	F	F	F	*4*	*5*
	A4	G	G	G	G	*6*	*9*
Make flexibility(MF)	A1	VP	P	P	VP	*0.5*	*2*
	A2	G	G	G	G	*6*	*9*
	A3	MP	MP	MP	MP	*3*	*4*
	A4	MG	MG	MG	MG	*5*	*6*
Delivery flexibility(DF)	A1	VP	P	P	VP	*0.5*	*2*
	A2	MG	F	F	MG	*4.5*	*5.5*
	A3	G	MG	MG	G	*5.5*	*7.5*
	A4	G	G	VG	VG	*7.5*	*9.5*

Table 7. Criteria rating values for alternative based on four Decision makers' ranking according to Equation (11)

Market sensitiveness		Manager 1	Manager 2	Manager 3	Manager 4	G_{ij}	
						$\underline{G_{ij}}$	$\overline{G_{ij}}$
Delivery Speed (DS)	A1	G	G	G	G	*6*	*9*
	A2	MG	MG	MG	MG	*5*	*6*
	A3	MG	MG	MG	MG	*5*	*6*
	A4	G	G	MG	MG	*5.5*	*7.5*
New product introduction (NPI)	A1	MG	MG	MG	MG	*5*	*6*
	A2	G	G	G	G	*6*	*9*
	A3	G	G	G	G	*6*	*9*
	A4	VG	VG	VG	VG	*9*	*10*
Customer responsiveness(CR)	A1	G	G	MG	MG	*5.5*	*7.5*
	A2	G	G	MG	MG	*5.5*	*7.5*

	A3	G	G	G	G	*6*	*9*
	A4	G	G	G	G	*6*	*9*

Table 8. Grey normalized table according to Equation (13) for Flexibility criteria

Flexibility criteria		A1	A2	A3	A4
Source flexibility(SF)	$\frac{\underline{G_{1j}}}{G_j^{max}}$	*0.222*	*0.444*	*0.556*	*1.000*
	$\frac{\overline{G_{1j}}}{G_j^{max}}$	*0.056*	*0.333*	*0.444*	*0.667*
Make flexibility(MF)	$\frac{\underline{G_{2j}}}{G_j^{max}}$	*0.222*	*1.000*	*0.444*	*0.667*
	$\frac{\overline{G_{2j}}}{G_j^{max}}$	*0.056*	*0.667*	*0.333*	*0.556*
Delivery flexibility(DF)	$\frac{\underline{G_{3j}}}{G_j^{max}}$	*0.211*	*0.579*	*0.789*	*1.000*
	$\frac{\overline{G_{3j}}}{G_j^{max}}$	*0.053*	*0.474*	*0.579*	*0.789*

Table 9. Grey normalized table according to Equation (13) for Market sensitiveness criteria

Market sensitiveness		A1	A2	A3	A4
Delivery Speed (DS)	$\frac{\underline{G_{1j}}}{G_j^{max}}$	*1.000*	*0.667*	*0.667*	*0.833*
	$\frac{\overline{G_{1j}}}{G_j^{max}}$	*0.667*	*0.556*	*0.556*	*0.611*
New product introduction (NPI)	$\frac{\underline{G_{2j}}}{G_j^{max}}$	*0.600*	*0.900*	*0.900*	*1.000*
	$\frac{\overline{G_{2j}}}{G_j^{max}}$	*0.500*	*0.600*	*0.600*	*0.900*
Customer responsiveness(CR)	$\frac{\underline{G_{3j}}}{G_j^{max}}$	*0.833*	*0.833*	*1.000*	*1.000*
	$\frac{\overline{G_{3j}}}{G_j^{max}}$	*0.611*	*0.611*	*0.667*	*0.667*

Table 10. Weighted normalized grey according to Equation (14)

Flexibility criteria		A1	A2	A3	A4
Source flexibility(SF)	$\underline{V_{1j}}$	*0.039*	*0.233*	*0.311*	*0.467*
	$\overline{V}_{1j}$	*0.178*	*0.355*	*0.445*	*0.800*
Make flexibility(MF)	$\underline{V_{2j}}$	*0.031*	*0.367*	*0.183*	*0.306*
	$\overline{V}_{2j}$	*0.166*	*0.75*	*0.333*	*0.500*

Delivery flexibility(DF)	$\underline{V}_{3j}$	*0.029*	*0.261*	*0.318*	*0.434*
	$\overline{V}_{3j}$	*0.148*	*0.405*	*0.552*	*0.700*
Market sensitiveness criteria		A1	A2	A3	A4
Delivery Speed (DS)	$\underline{V}_{4j}$	*0.467*	*0.389*	*0.389*	*0.428*
	$\overline{V}_{4j}$	*0.800*	*0.534*	*0.534*	*0.666*
New product introduction (NPI)	$\underline{V}_{5j}$	*0.300*	*0.360*	*0.360*	*0.540*
	$\overline{V}_{5j}$	*0.540*	*0.810*	*0.810*	*0.900*
Customer responsiveness(CR)	$\underline{V}_{6j}$	*0.306*	*0.306*	*0.334*	*0.334*
	$\overline{V}_{6j}$	*0.500*	*0.500*	*0.600*	*0.600*

Table 11. S^{max} for alternatives according to Equation (15)

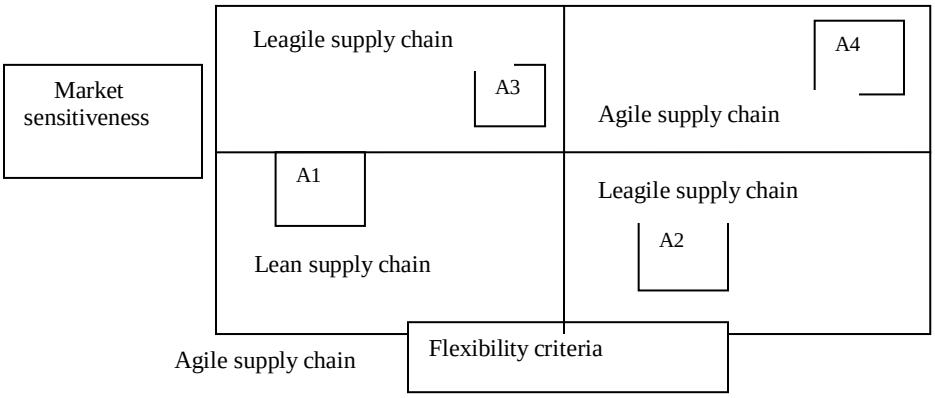
Flexibility criteria	S^{max}
Source flexibility(SF)	*0.467*
	0.800
Make flexibility(MF)	*0.367*
	0.500
Delivery flexibility(DF)	*0.434*
	0.700
Market sensitiveness criteria	S^{max}
Delivery Speed (DS)	*0.467*
	0.800
New product introduction (NPI)	*0.540*
	0.900
Customer responsiveness(CR)	*0.334*
	0.600

Table 12. Grey possibility degree according to Equation (16)

	Grey possibility degree	1- (Grey possibility degree)	Ranking of alternatives
Flexibility criteria	P (A_1<=SMAX) =*1* P (A_2<=SMAX) = *0.7525* P (A_3<=SMAX) = *0.9213* P (A_4<=SMAX) =*0.5311*	1-P (A_1<=SMAX) =*0* *1-P (A_2<=SMAX) = 0.2475* *1-P (A_3<=SMAX) =0.07687* *1-P (A_4<=SMAX) =0.4689*	$A_1 \leq A_3 \leq A_2 \leq A_4$
Market sensitiveness criteria	P (A_1<=SMAX) = *0.7130* P (A_2<=SMAX) = *0.7219* P (A_3<=SMAX) = *0.6755* P (A_4<=SMAX) = *0.5504*	1-P (A_1<=SMAX) = *0.287* 1-P (A_2<=SMAX) =0*.2781* 1-P (A_3<=SMAX) = *0.3245* 1-P (A_4<=SMAX) = *0.4496*	$A_2 \leq A_1 \leq A_3 \leq A_4$

The less grey possibility degree, the better this criteria's result is. As it is shown in Table13, the alternatives can be shown in two dimensions. The alternatives are shown based on the probability value in column 2. The fourth Alternative is at the agile condition, so has the highest value of column 2 and the lowest value of column 1. The third Alternative is in a good condition based on market sensitiveness, but it is weak in flexibility criteria dimension and etc.

Figure 1: Positions of alternatives based on two dimensions



The final responses were made available to commercial and procurement managers, and the mentioned individuals approved majority of the responses.

5. Conclusions

Improved supply chain performance implies that a supply chain is capable of quickly responding to the variations in the customer demand with effective cost reduction. Leanness in a supply chain maximizes profits through cost reduction while agility maximizes profit through providing exactly what the customer requires. The leagile supply chain enables the upstream part of the

chain to be cost-effective and the downstream part to achieve high service levels in a volatile marketplace. As was studied in the literature there are many models to select the appropriate supply chain that each one has different criteria for decision making regarding the selection of supply chain. In presented model based on the gray theory were able modeling preferences and criteria for decision makers. It should be noted that this model consider criteria in two dimensions that include flexibility and sensitivity of market. The present model used the opinions of expert to make decisions in the real world. This model was studied in the automotive industry as a case study. The results of model with industry experts and managers were reviewed and the results were confirmed.

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