Prioritization of Robust Strategies for Resilient Supply Chain

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Abstract— In order to survive in the present era of competitive environment, organizations need to mitigate risk by creating resilient supply chain. This paper aims to study various aspects of resilient supply chain and their relations. It also studies the various robust strategies which can be implemented to supply chain activities, these strategies are grouped on the basis of similarity of their ultimate effect on supply chain by using the Delphi method. Among the group's best one is selected by using the AHP method. The uniqueness of the work is that it will help managers to select the most adequate strategies depending on their organization goal. So, it minimizes the cost, unproductive time and human resource required for implementing the strategies.

Key words: Supply Chain Management, Electrical Energy, Resilient supply chain, Robust Design

I. INTRODUCTION

Supply chain constitutes enormous number of activities and each activity has some inherent shortcomings, due to which disruptions may takes place. Due to global rich of the supply chain, shorter product life cycles, increased number of competitor and higher customer expectation indicates that any disruption to the supply chains causes undesirable impact on overall performance of the organization. Disruptions such as the loss of a supplier, a disturbance at the key manufacturing unit, economic crisis, terrorist attack, natural calamity, labor strike, computer virus, etc., can all be the causes of supply chain disruption and delay (Berger et al., 2004; Christopher and Lee, 2004; Norman and jansson, 2004; Tang, 2006a; Serhiy Y. ponomarov & Mary C.Holcomb., 2009), these disruption has capacity to affect both revenue and cost. They can lead to lost sales, market share, increased cost (Serhiy Y. Ponomarov & Mary C.

Holcomb), sometime these disruptions lead to complete failure of the firm.

To reduce this risk and its adverse impact, supply chain must be multidimensional and multidisciplinary and it should be designed to incorporate event readiness, capability to adapt to regain its initial state before disruptions or even better state, etc.

The concept of supply chain resilience (SCR) proposed in this paper shows multidimensional phenomenon of supply chain and is based on the assumption that risk causing events are the inherent parts of the supply chain. Thus resilience can be incorporated into it. In other words, there are certain features that if engineered into a supply chain, it can impart resiliency in supply chain. Classifying those features, finding strategies which strengthen these features and the scope of improvement is a challenge attempted in this paper.

Available research on SCR and strategies provides only theoretical view and is qualitative in nature. But the work on selection of specific strategies which suits the organization has not been attempted so far and still need to be addressed. Thus motivation for this research was to propose a quantitative measure of selection of strategies for incorporating required level of resilience in the supply chain and finding the scope of improvements of the result.

The main objectives of this paper can be summarized as follows:

1) To identify various component which makes supply chain resilient?
2) To identify various robust strategies which helps to achieve resilient supply chain?
3) To classify the strategies into three major groups.
4) To select best group of strategies.

II. SUPPLY CHAIN RESILIENCE

According to Canadian ecologist Holling (1973), the system has two distinct properties: resilience and stability. Resilience is the ability of the system to absorb changes without affecting the actual performance of the system, and stability is the capacity of systems to return to an equilibrium state after a temporary disturbance. Higher is the returning capacity higher is the stability of the system. Supply chain resilience is defined as, "The capability of the supply chain to prepare for the unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function (Ponomarov and Holcomb).

Important aspect of supply chain resilience:

- Agility.
- Supply chain collaboration.
- Supply chain re-engineering.
- Supply chain risk management culture.

III. ROBUST SUPPLY CHAIN STRATEGY

In the present highly vulnerable business environment condition, we see many of the organizations are running efficiently and effectively, where as many of the organizations unable to deal with these conditions and they are either in loss or some time complete failure of the organization takes place. The reason behind success of the Nokia, Li and Fung and Dell supply chain is that they are having established robust supply chain strategies (Bellington and Johnson, 2002). Supply chain related issues can be mainly grouped into two major groups: supply management and demand management. Supply management issues include selection of appropriate supplier, relationship between them, supply planning, transportation realated activities and logistics, etc. While demand management include designing of products, their pricing, product line management, development of new product, demand and promotion planning, etc.,(C. S. Tang). According to Christopher S. Tang there are nine robust supply chain strategies, which can be implemented to improve the capability of supply chain members to sustain its operations when major disruptions takes place. In Table 1, objectives and benefits of these strategies are summarized (C. S. Tang). The strategies are:

1) Postponement
2) Strategic stock
3) Flexible supply base
4) Make-and-buy
5) Economic supply incentives
6) Flexible transportation
7) Revenue management
8) Dynamic assortment planning
9) Silent product rollover

As the implementation of all the above nine strategies altogether are not feasible. Therefore paper research work is done to group these nine robust strategies into three. Delphi method was used among the industrial experts and academic professionals for grouping these nine strategies into three alternatives A, B&C. for selecting the best among the three alternative's AHP method was used. For solving the AHP the priority weights are collected for the attributes and sub-attributes are obtained from the survey of 73 experts and academic personals of the supply chain.

Robust supply chain strategy	Main objective	Benefit(s) under normal circumstances	Benefit(s) after major disruption
Postponement	Increases product flexibility	Develops Ability to manage supply	Allows a firm to change the configurations of different products quickly
Strategic stock	Increases product availability	Develops Ability to manage supply	Allows a firm to react to market demand quickly during a major disruption
Make-and-buy	Increases supply flexibility	Develops Ability to manage supply	Allows a firm to shift production between in-house production facility and supplier rapidly
Economic incentives	Increases product availability	Increases the Ability to manage supply	Allows a firm to regulate order quantities hurriedly
Flexible transportation	Increases flexibility in transportation	Increases the Ability to manage supply	Allows a firm to manage the mode of transportation quickly
Revenue management	Increases control of product demand	Increases the Ability to manage demand	Allows a firm to influence the s election of product by the customer
Silent product rollover	Increase control of product exposure to customers	Increases the ability to manage supply and demand	Allows a firm to influence the demands of different products swiftly
Dynamic assortment planning	Increase control of product demand	Increases the ability to manage demand	Allows a firm to influence the demands of different products quickly

Table 1: Robust supply chain strategies

The three groups of the strategies are named as three alternatives:

1) Alternative A
   - Strategic stock
   - Economic supply incentives
   - Flexible transportation
2) Alternative B
   - Flexible supply base
   - Make and buy
   - Postponement
3) Alternative C
   - Revenue management
   - Dynamic assortment planning
   - Silent product roll over

IV. METHOD USED: ANALYTICAL HIERARCHY APPROACH

The analytic hierarchy process (AHP) is a hierarchically structured technique used for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been widely studied and cultured since then. It is widely used in group decision making, and is used around the world in almost all field, such as public administration, corporate sector, healthcare unit, manufacturing unit and educational institutions. AHP helps the decision maker to select the best possible alternatives which suits their goal. It provides a broad and balanced framework for structuring a decision problem, for demonstrating and computing its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

The procedure for using the AHP can be summarized as:

A. Determine the Goal

Select the factor affecting the goal, their sub factors and available alternatives.

B. Design the Questionnaire.

C. Collect the Expert's Opinion.

- Test the consistency of the collected data.
- Compute the vector of criteria weight. Compute the matrix of option scores. Rank the options.

In our case, goal is to make the supply chain resilient and the factor responsible for the resilient supply chain and various available alternatives are as stated above in section 2 and 3. The AHP chart is as shown below in fig1.

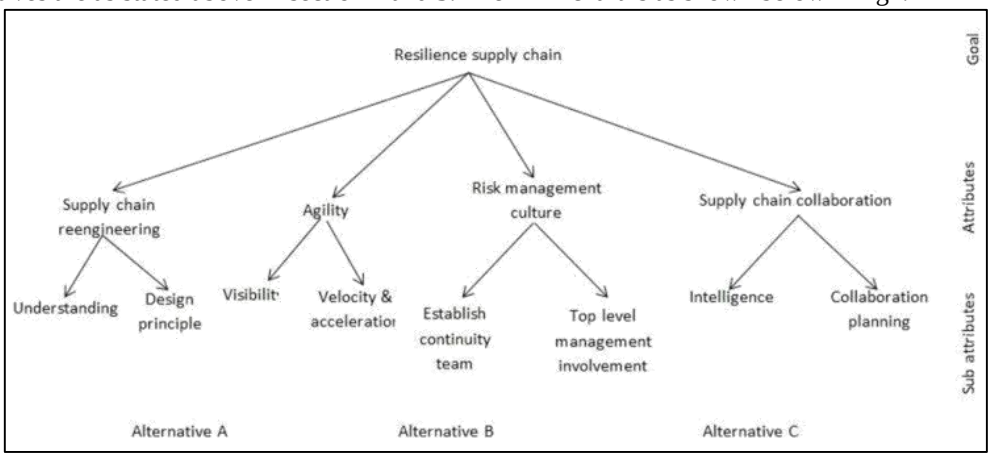

Fig. 1: Decision hierarchy for resilient supply chain alternative

Questionnaire will be provided on the demand of the viewer. The various pair wise comparison of the attributes, sub-attributes and available alternatives with respect to the goal is as shown in the following tables. To check the consistency of the collected data, Saaty (1980) defined the consistency index (CI) as follows

Where is the maximum eigenvalue of the matrix of the importance ratios and n is the number of factors. Constitency Ratio (CR) as defined by the Saaty (1980) is as follows:

According to Saaty (1980), the Random Index (RI), is as shown in Table 1(b). If the value of the consistency ratio (CR) is less than or equal to 0.1, the questionnaire is considered to be acceptable. If the CR is greater than 0.1, the questionnaire is not acceptable.

n	1	2	3	4	5
RI	0.00	0.00	0.58	0.90	1.12
n	6	7	8	9	10
RI	1.24	1.32	1.41	1.45	1.49

Table 2: Value

V. CALCULATION

The questionnaire is filled up by the professors, research scholars and the students of the master's degree in industrial management belongs to reputed colleges and also by the some of the experts of supply chain. The pair wise comparisons and the priority weights of the attributes of resilient supply chain are as shown in the Table 2 and the pair wise comparison of the sub attributes with respect to the attributes are shown in Table 2.1 to Table 2.4. Normalized matrix of the matrices of the Table 2 to Table 2.4 is as shown in the Table 3 to Table 3.4. Similarly normalized matrices for all the available alternatives (Robust strategies) with respect to the sub-attributes and the attributes are as shown in the Table 4.1 to Table 4.8.

	Supply Chain Re-Engineering	Agility	Risk Management Culture	Supply Chain Collaboration	Priority Weight
Supply chain re-engineering	1	3.777	9.310	4.78	0.508
Agility	0.265	1	4.146	4.25	0.287
Management culture	0.302	0.241	1	2.54	0.133

Supply Chain collaboration	0.209	0.235	0.394	1	0.072

Table 2: Matrix of paired comparison results for attributes with respect to goal: Resilient supply chain

Matrix of paired comparison results for sub-attributes with respect to attributes:

	Understanding	Design principles
Understanding	1	3.703
Design principles	0.270	1

Table 2.1: Supply chain re-engineering

	Visibility	Velocity and acceleration
Visibility	1	4.150
Velocity and acceleration	0.235	1

Table 2.2: Agility

	Establish continuity team	Board level responsibility and leadership
Establish continuity team	1	2.722
Board level responsibility and leadership	0.367	1

Table 2.3: Risk management culture

	Intelligence	Collaboration planning
Intelligence	1	4.333
Collaboration planning	0.231	1

Table 2.4: Supply chain collaboration

	Supply chain reengineering	Agility	Risk management culture	Supply chain collaboration	Priority weights
Supply chain reengineering	0.563	0.374	0.374	0.380	0.508
Agility	0.149	0.468	0.468	0.338	0.287
Risk management culture	0.170	0.113	0.133	0.202	0.133
Supply chain Collaboration	0.118	0.045	0.045	0.080	0.072

Table 3: Normalized matrix and priority weights for attributes with respect to goal:

Normalized matrix and priority weights of sub-attributes with respect to attributes:

	Understanding	Design principles	Priority weight
Understanding	0.787	0.787	0.787
Design principles	0.213	0.213	0.213

Table 3.1: Supply chain (re)engineering

	Visibility	Velocity and acceleration	Priority weight
Visibility	0.809	0.809	0.809
Velocity and answer	0.191	0.191	0.191

Table 3.2: Agility

	Establish continuity team	Board level responsibility and leadership	Priority weight
Establish continuity team	0.732	0.732	0.732
Board level responsibility and leadership	0.268	0.268	0.268

Table 3.3: Risk management culture

	Intelligence	Collaboration planning	Priority weight
Intelligence	0.812	0.812	0.812
Collaboration planning	0.188	0.188	0.188

Table 3.4: Supply chain collaboration

Normalized matrix and priority weights for alternatives with respect to sub-attributes:

	Alternate A	Alternate B	Alternate C	Priority weight	Consistency ratio(CR)
Alternate A	0.684	0.738	9.594	0.672	0.042
Alternate B	0.164	0.177	0.274	0.205	
Alternate C	0.152	0.085	0.132	0.123	

Table 4.1: Supply chain understanding

	A	B	C	Priority weight	C.R.
A	0.341	0.337	0.356	0.345	0.0025
B	0.526	0.520	0.505	0.517	
C	0.133	0.143	0.139	0.138	

Table 4.2: Design Principles

	A	B	C	Priority weight	C.
A	0.608	0714	0416	0.579	0.10
B	0.185	0.217	0.443	0.282	
C	0.207	0.069	0.141	0.139	

Table 4.3: Visibility

	A	B	C	Priority weight	C.R
A	0.719	0.779	0.540	0.686	0.110
B	0.138	0.154	0.353	0.215	
C	0.143	0.047	0.107	0.099	

Table 4.4: Velocity and acceleration

	A	B	C	Priority	C.R.
A	0.621	0.681	0.483	0.595	0.068
B	0.224	0.245	0.398	0.289	
C	0.155	0.074	0.119	0.116	

Table 4.5: Establish continuity team

	A	B	C	Priority	C.R.
A	0.648	0.755	0.369	0.591	0.330
B	0.176	0.206	0.531	0.304	
C	0.176	0.039	0.100	0.105	

Table 4.6: Board level responsibility and leadership:

	A	B	C	Priority	C.R.
A	0.638	0.655	0.622	0.638	0.008
B	0.167	0.172	0.188	0.176	
C	0.195	0.174	0.190	0.186	

Table 4.7: Collaboration planning

	A	B	C	Priority	C.R.
A	0.551	0.643	0.536	0.536	0.088
B	0.384	0.247	0.287	0.287	
C	0.434	0.110	0.176	0.176	

Table 4.8: Intelligence

Summary of priority weight labeled as sub-attribute weight, Evaluation Rating and Weighted Evaluations with respect to Attributes: In the following table from Table 5.1 to Table 5.4, the priority weights of each of the individual alternatives with respect to the attributes on the basis of sub-attributes are as shown:

	Intelligence	Collaborative planning	Priority weight
Attribute weight	0.188	0.812	
A	0.536	0.638	0.619
B	0.287	0.176	0.194
C	0.176	0.186	0.184

Table 5.1: Supply chain collaboration

	Establish continuity	Top management	Priority weight
Attribute weight	0.732	0.268	
A	0.595	0.591	0.594
B	0.289	0.304	0.293
C	0.116	0.105	0.113

Table 5.2: Risk management culture

	Visibility	Velocity & acceleration	Priority weight
Attribute weight	0.810	0.190	
A	0.579	0.686	0.599
B	0.282	0.215	0.269
C	0.139	0.099	0.132

Table 5.3: Agility

	Understanding	Design principles	Priority weight
Attribute weight	0.787	0.214	
A	0.672	0.345	0.603
B	0.205	0.517	0.272
C	0.123	0.138	0.125

Table 5.4: Supply chain (re)engineering

Summary combination of priority weights for sub-attributes, attributes, and alternatives to determine priority weights for Resilient Supply Chain:

	S.C.R	Agility	R.M.C	S.C.C	Alternative Priority Weight
Attribute Weight	0.508	0.287	0.133	0.072	
A	0.603	0.599	0.594	0.619	0.602
B	0.272	0.269	0.293	0.197	0.269
C	0.125	0.132	0.112	0.184	0.130

Table 5.5: Resilient Supply Chain

VI. RESULT

From above Analytical Hierarchy process matrices we find that the attribute supply chain reengineering, agility, risk management culture and supply chain collaboration are having weightage of 0.508, 0.287, 0.133 and 0.072 respectively for achieving the goal of resilient supply chain. Therefore it is required to pay more attention on the supply chain re-engineering then as compared to agility, risk management culture, and supply chain collaboration. From the Alternative Weight calculation we find that alternative A which consists of Strategic stock, Economic supply incentives and Flexible transportation facility is having priority weight of 0.602, alternative B which consists of Flexible supply base, Make and Buy, and Postponement strategies is having priority weight of 0.269, and alternative C which consists of Revenue Management, Dynamic Assortment Planning and Silent Product Rollover strategies is having priority weight of 0.130.

VII. CONCLUSION

From above result we conclude that Supply Chain Re-engineering is having maximum weightage among the resilient supply chain attributes and therefore it is important to give more importance to supply chain re-engineering as compared to other attributes in order to achieve the goal of resilient supply chain. And also from priority weight calculation we find that alternative A which consists of strategic stock, Economic supply incentive and flexible transportation strategies is having maximum priority weight of 0.602. Thus selection of alternative A is best choice for achieving the goal of Resilient Supply Chain.

The above result so obtained is completely based on the view and perspective of the Professors, research scholars and students of the master degree in industrial management and fewer numbers of experts from the real field. Therefore in order to have better results one needs to take the view and perspective of the experienced manager and the people working in the actual field.

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