ANALYSIS OF SUPPLY CHAIN RISK MITIGATION USING GRAPH THEORY, MATRIX DETERMINANT METHOD AND C PROGRAMMING

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Abstract

In today's world of globalization many apparel retailers are building strong supply chains to gain advantage over their competitors by offering the best value to their customers. The supply-chain management (SCM) has become very critical to manage risk, dynamism, and complexities of global sourcing. A totally integrated supply chain is required for the company to gain the maximum benefits. The objectives of the supply chain and the performance measurements need to be understood in order to build the most effective supply chain. Performance measurements provide an approach to identify the success and potential of supply management strategies. One major aspect of the SCM is to select the right sources of supply in the global business environment that can support corporate strategy. The purpose of this paper is to emphasize the importance of mitigation of risk in the supply-chain management. It presents a framework, based on the analytical hierarchy process (AHP), matrix method and graph theory that an apparel company can use to select its suppliers based on minimum risk, and creates a strategy for supplier relationship management (SRM). The framework of the performance measurement is based on the quantitative and qualitative measurements of Risk Mitigation Environment (RME) which is done by using C programming.

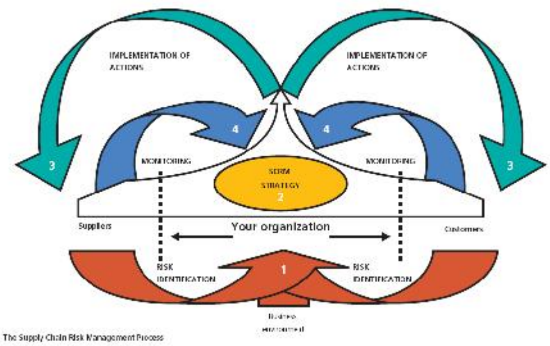
Keywords: *SCRM, risk, graph theory, matrix determinant method, AHP, Risk Mitigation Environment (RME), C Programming*

Introduction and Literature Survey

Supply Chain Management (SCM)

A supply chain is characterized by the flow of goods, services, money, and information both within and among business entities including suppliers, manufacturers, and customers. The ultimate goal of SCM is to meet customers' demand more efficiently by providing the right product, in the right quantity, at the right location, on the right time and in the right condition[10].

Figure 1



As Figure 1 Shows, SCM aims four major goals:

- Waste reduction
- Time compression
- Flexible response and
- Unit cost reduction.

These goals have been articulated in several contexts associated with SCM, emphasizing the importance of both intra- and inter-firm coordination [5].

Supply Chain Management Framework Firms practicing SCM seek to reduce waste throughout the supply chain by minimizing duplication, harmonizing operations and systems, and enhancing quality. When production and logistics processes are accomplished in less time, all entities in the supply chain are able to operate more efficiently, and primary result is the reduced inventories throughout the system. Flexible response is in order handling, including how orders are handled, product variety, order configuration, order size, and several other dimensions means that a customer's unique requirements can be met in a cost-effective manner[4].

Effective SCM in the new competition suggests seeking close relationships in the long term with less number of partners. Considering the rapidly changing market conditions and customer seeking the best value, long-term relationships with the vendors became very critical in the apparel industry. Therefore the apparel retailers are looking for the vendors who can provide the best cost in the fastest way. Such a relationship is regarded as partnership since it includes activities such as information sharing, joint product design, or sharing storage spaces.

Performance Measurement in the Apparel Industry

The aim of supply chain management is to gain an advantage in terms of customer service and cost over competitors.

Traditionally, performance measurement is defined as the process of quantifying the effectiveness and efficiency of action. It plays a critical role in monitoring performance, enhancing motivation and communication, and diagnosing problems. Furthermore, performance measurement helps identifying the success and potential of management strategies, and facilitating the understanding of the situation [18].

Performance measures are categorized into two groups; qualitative and quantitative. These measures involve customer satisfaction and responsiveness, flexibility, supplier performance, and costs. There are three types of measures: resources, output, and flexibility. A framework for measuring the strategic, tactical and operational level of performance in a supply chain, which deals mainly with supplier, delivery, customer service, and inventory, and logistics costs, exists [12].

Customer satisfaction level is an indication of the required standard of service level of a particular company, which is closely related to the whole performance of its supply chain. For different industries, customers look at different measures, such as delivery service, where time is no doubt their major concern; whereas for parts manufacturing, the accuracy of specification may be the most importance consideration. Thus, the weighting of each performance measurement can be different for each industry.

Variables Affecting SCM in Apparel industry

The following are the Variables affecting SCM in Apparel Industries:

A1: Information sharing

A2: Supply chain agility

A3: Aligning incentives

A4: Knowledge about risk in a supply chain

A5: Risk sharing in a supply chain
A6: Trust among supply chain partners
A7: Collaborative relationships
A8: Corporate social responsibility
A9: Continual risk assessment and analysis
A10: Loss assessment metrics for the supply chain.

Di-Graph Representation of Variables Affecting SCM

Table 2-Scale For Diagonal Values

The value that has been surveyed and gathered from the industry by means of questioners form from the 10 suppliers is:

S. No	Risks In Textile Industry	Supplier									
		1	2	3	4	5	6	7	8	9	10
1.	Information sharing	.9	.8	.9	.8	.8	.8	.6	.7	.5	.5
2.	Supply chain agility	.9	.7	.8	.7	.9	.8	.7	.6	.4	.5
3.	Aligning incentives and revenue sharing policies in a supply chain	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
4.	Knowledge about risks in a supply chain	.7	.7	.6	.6	.7	.6	.6	.1	.1	.1
5.	Risk sharing in a supply chain	.8	.8	.7	.9	.7	.7	.8	.5	.5	.4
6.	Trust among supply chain partners	.9	.8	.9	.8	.7	.6	.5	.5	.6	.7
7.	Collaborative relationships among supply chain partners	.9	.8	.6	.8	.7	.9	.8	.3	.6	.5
8.	corporate social responsibility	.8	.8	.8	.8	.8	.8	.8	.8	.8	.8
9.	Continual risk assessment and analysis	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3
10.	Loss assessment metrics for the supply chain	.8	.9	.8	.7	.6	.5	.4	.6	.8	.5

Table 3 Diagonal Values Substituting these Values the Permanent Matrix becomes

$$\begin{bmatrix} 1 & 1 & 3 & 1 & 1 & 3 & 3 & 1 & 1 & 1 \\ 1 & 1 & 2 & 2 & 2 & 2 & 2 & 1 & 2 & 2 \\ .33 & .5 & 1 & 1 & 1 & 2 & 2 & 2 & 3 & 2 \\ 1 & .5 & 1 & 1 & 1 & 2 & 2 & 1 & 3 & 2 \\ 1 & .5 & 1 & 1 & 1 & 2 & 2 & 1 & 2 & 2 \\ .33 & .5 & .5 & .5 & .5 & 1 & 3 & 4 & 1 & 3 \\ .33 & .5 & .5 & .5 & .5 & .3 & 1 & 1 & 1 & 3 \\ 1 & 1 & .5 & 1 & 1 & .25 & 1 & 1 & 2 & 2 \\ 1 & .5 & .33 & .33 & .5 & 1 & 1 & .5 & 1 & 1 \\ 1 & .5 & .5 & .5 & .5 & .33 & .33 & .5 & 1 & 1 \end{bmatrix}$$

Table 4 Permanent Matrix

Calculation of Consistency

The C.I. and R.I. values are found to be

$$C.I = \frac{\lambda - n}{n-1} = \frac{11.05 - 10}{10 - 1} = 0.116858$$

where λ is the Principle Eigen value of the Matrix (Table 4) and n is the number of risk variables in SCM[15]

$$C.R = . \frac{C.I.}{R.I.} = \frac{0.116258}{1.49} = 7.8\%$$

Here the Calculated C.R. value is found to be less than 10%. So our judgment is consistent and acceptable[10].

Permanent Function

The permanent is a standard matrix function and is used in combinatorial mathematics the permanent function is obtained in a similar manner as the determinant but unlike in a determinant where a negative sign appears in the calculation, in a variable permanent function positive signs replace these negative signs[17]. Quantitative RME evaluation of a supply chain is obtained from VPF-RME by substituting numerical values of the Ri's and Rij's which can be obtained analytically or by comparing to ideal cases. This single numerical index is the representation of a typical risks mitigation environment in quantitative terms. The VPF-RME expression corresponding to any factors is given by[13]

$$\begin{aligned} per(\hat{R}) = & \sum_{i=1}^{M} R_i + \sum_{i,j,\ldots,M} (R_{ij}R_{ji}) R_k R_l \ldots R_M + \sum_{i,j,\ldots,M} (R_{ij}R_{jk}R_{ki} + R_{ik}R_{kj}R_{ji}) R_l R_m \ldots R_M \\ & + \left\{ \sum_{i,j\ldots M} (R_{ij}R_{ji})(R_{kl}R_{lk}) R_m R_n \ldots R_M + \sum_{i,j\ldots M} (R_{ij}R_{jk}R_{kl}R_{li} + R_{il}R_{lk}R_{kj}R_{ji}) R_m R_n \ldots R_M \right\} \\ & + \left[\begin{array}{l} \sum_{i,j\ldots M} (R_{ij}R_{ji}) R_{kl}R_{lm}R_{mk} + R_{km}R_{ml}R_{lk}) R_n R_o \ldots R_M \\ + \sum_{i,j\ldots M} (R_{ij}R_{jk}R_{kl}R_{lm}R_{mi} + R_{im}R_{ml}R_{lk}R_{kj}R_{ji}) R_n R_o \ldots R_M + \end{array} \right] \ldots \end{aligned}$$

The evaluation of this permanent function is done using a c program.

C-Programming

To identify the Index of the Risk mitigation Matrix for different combinations of Qualitative and Quantitative value of Risk variables, the C programming is used [15]. The final Risk Index will be compared with the ideal risk value.

The result obtained from running the C Programme [15] for various values are tabulated as:

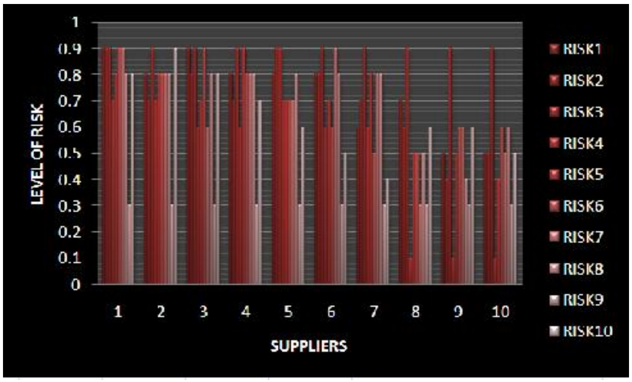
Supplier	Numerical Values Index
1.	8670589.566
2.	8383204.041
3.	8180677.867
4.	8323466.372

5.	8115313.151
6.	8001568.152
7.	8123546.166
8.	6838976.50
9.	6955364.162
10.	6758382.739

Table 5-Numarical Index

From this index values it is known that out of all the 10 suppliers only 3 suppliers have minimum index values compared to others and it also found out the reason behind this decrease in index values and the corrective actions are carried out. This will enhance the Objective of this Paper. The fallowing graph gives a clear idea regarding this.

Fig4 Conclusion Graph



Conclusion

Thus the whole Business environment make all the supply chain member become more interdependent and complex and as the result supply chain becomes more vulnerable to risk. Any disruption happens or affects one player of supply, could disrupt the whole network. Therefore there is a need to manage risk in supply chain to avoid minor and major lost.

- A methodology based on Graph theory, matrix determinant and C – Programming approach is suggested which helps in identifying the various risks in Business environment and which is a simple tool by which supply chain managers can easily analyze the variables responsible for risk mitigation in a supply chain.
- The proposed method is a general method and can consider any number of qualitative and quantitative risk variables from a supply chain perspective with a continuous monitoring by using a single numerical index identified from a supply chain

References

1. Kulkarni, S. (2005) 'Graph theory and matrix approach for performance evaluation of TQM in Indian industries', *The TQM Magazine*, Vol. 17, No. 6, pp.509–526.
2. Alessandri, T.M., Ford, D.N., (2004) 'Managing risks and uncertainty in complex capital projects', *The Quarterly Review of Economics and Finance*, Vol. 44, No. 5, pp.751–767.

3. Christopher, M. and Towill, D.R. (2001) 'An integrated model for the design of agile supply chains', *International Journal of Physical Distribution and Logistics Management*, Vol. 31, No. 4, pp.235–246.
4. Deo, N. (2000) *Graph Theory with application to Engineering and Computer Science*, New Delhi: Prentice Hall.Faisal, M.N., Banwet, D.K. and Shankar, R. (2006) 'Mapping supply chains on risk and customer sensitivity dimensions', *Industrial Management and Data Systems*, Vol. 106, No. 6, pp.878–895.
5. Grover, S., Agrawal, V.P. and Khan, I.A. (2004) 'A digraph approach to TQM evaluation of an industry', *International Journal of Production Research*, Vol. 42, No. 19,dpp. 4031
6. Chopra, S. and Sodhi, M.S. (2004) 'Managing risks to avoid supply chain breakdown', *Sloan Management Review*, Vol. 46, No. 1, pp.53–61.
7. Gunasekaran, G., Patel, C. and McGaughey, R.E. (2004) 'A framework for supply chain performance measurement', *International Journal of Production Economics*, Vol. 87.
8. Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V.M. and Tuominen, M. (2004) 'Risks management processes in supplier networks', *International Journal of Production Economics*,Vol. 90, No. 1, pp.47–58.
9. Jense, J.B. and Gutin, G. (2000) *Digraph Theory, Algorithms and Organisations*, London: Springer.Jüttner, U. (2005) 'Supply chain risk management: understanding the business requirements from a practitioner perspective', *The International Journal of Logistics Management*, Vol. 16, No. 1, pp.120–141.
10. Lee, H.L. (2002) 'Aligning supply chain strategies with product uncertainties', *California Management Review*, Vol. 44, No. 3, pp.105–120.
11. Nagurney, A., Cruz, J., Dong, J. and Zhang, D. (2005) 'Supply chain networks, electronic commerce, and supply side and demand side risk', *European Journal of Operational Research*, Vol. 164, No. 1, pp.120–142.
12. Narayanan, V.G. and Raman, A. (2004) 'Aligning incentives in supply chains', *Harvard Business Review*, Vol. 82, No. 11, pp.94–103.
13. Faisal, M.N., Banwet, D.K.and Shankar, R. (2007) 'Quantification of risk mitigation environment of supply chains using graph theory and matrix methods', European J. Industrial Engineering, Vol. 1, No. 1, pp.22–39.
14. Norrman, A. and Jansson, U. (2004) 'Ericsson's proactive supply chain risks management approach after a serious subsupplier accident', *International Journal of Physical Distribution and Logistics Management*, Vol. 34, No. 5, pp.434–456.
15. C.Krishnaraj(2009)'Analysis of supplay chain risk mitigation using graph theory, Matrix detemination method and C Programming', Naval R&D Journal, Vol 231 PP.318-327.
16. Ojala, M. and Hallikas, J. (2006) 'Investment decision-making in supplier networks: management of risk', *International Journal of Production Economics*, Vol. 104, pp.201.
17. Rao, R.V. and Padmanabhan, K.K. (2006) 'Selection, identification and comparison of industrial robots using digraph and matrix methods', *Robotics and Computer-Integrated Manufacturing*,Vol. 22, No. 4, pp.373–383.

18. R.E. and Lomax, R.G. (1996) *A Beginner's Guide to Structural Equation Modelling*,Pittsburgh: Lawrence Erlbaum Associates.Sinha, P.R., Whitman, L.E. and Malzahn, D. (2004) 'Methodology to mitigate supplier risks in an aerospace supply chain', *Supply Chain Management: An International Journal*, Vol. 9, No. 2,pp.154–168.
19. Sodhi, M.S. (2005) 'Managing demand risk in tactical supply chain planning for a global consumer electronics company', *Production and Operations Management*, Vol. 14, pp.69.
20. Speckman, R.E. and Davis, E.W. (2004) 'Risky business: expanding the discussion on risks and the extended enterprise', *International Journal of Physical Distribution and Logistics management*, Vol. 34, No. 5, pp.414–433.