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EVALUATING BULLWHIP EFFECT MITIGATION: AN ANALYTICAL NETWORK PROCESS (ANP) APPLICATION

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Abstract: ***This paper aims at proposing best possible solution to a very common problem in managing supply chains called bullwhip effect. The results obtained may help the practitioners in improving the competitiveness of the supply chains operating in India by reducing the bullwhip effect effectively. A framework involving analytical network process is established for reducing bullwhip effect after consulting experts from industry and academia both. The methodology consists of pair wise comparisons of attributes and checking for their interdependencies. After the calculations the results have been verified by consulting the experts again.***
The analytical network process technique has been found effective and systematic methodology to deal with real practical problems. Bullwhip effect reduction weighted indices obtained from the research suggest that vendor managed inventory has been most favorable solution for reducing bullwhip effect but as per the expert's opinion electronic data interchange and every day low pricing approaches can not be ignored. The proposed model has been developed for Indian FMCG sector. The results may not be generalized for other sectors. However after some modifications the model may be used for other sectors and for other countries.

Keywords: **Analytical network process; Bullwhip effect; Electronic data interchange (EDI); Every day low pricing (EDLP); Supply chain management (SCM); Vendor managed inventory (VMI)**

1. INTRODUCTION

Organizations operating in globalized environment, have realized significance of managing supply chains (SCs) in last decade to achieve competitive advantage. They are gearing up for competing with rival supply chains. Providing right product/services of right quality to right customer at right time and in right quantity has been area of concern for SC managers while formulating supply chain strategies. Excessive inventory and stock outs appears as extra costs in a SC. Alternative cycles of excessive inventory and stock outs appear in a very common problem experienced by the

practitioners, termed as bullwhip effect (BWE) which is all about increase in variance while going upstream in a SC (Lee et al, 1997a,b). We have identified important factors affecting the phenomenon of BWE after reviewing concerned literature and getting opinions from experts. Based upon this we have proposed an analytical network process (ANP) framework to critically evaluate three alternative approaches to mitigate BWE in fast moving consumer goods (FMCG) sector. These alternatives are: EDLP, EDI and VMI. ANP methodology seems to provide effective framework for analyzing and prioritizing these alternatives.

1.1 Objectives of the paper

Main objective of present paper has been to evaluate different alternatives for reducing BWE and to propose the best possible solution to the SCM managers to counteract BWE. We have tried to achieve this objective by identifying different factors (from literature review and through expert opinion) affecting appearance / reduction of BWE, which have been further clubbed into four groups (dimensions) that are: demand assessment (DA), cost (C), supply chain integration (SCI), and order processing (OP). To analyze in a comprehensive manner three attributes have been put in the hierarchy under each dimension. These attributes are checked for their interdependencies, which is a highlight of ANP approach.

1.2 Scope of the paper

The proposed ANP framework is specific to the Indian condition. It deals with the fast moving consumer goods (FMCG) sector of India. Retail sector has been growing very fast and some of the observations of the experts may not be that much mature. This may be applied globally with little modifications as Indian retailers are also growing same way as their global counter part in FMCG sector. The result obtained cannot be generalized for the sector like infrastructure etc. However with some modifications the model can be adopted for other sectors.

2. BULLWHIP EFFECT: COMMON PROBLEM IN MANAGING SUPPLY CHAIN

Managing supply chain is considered very important in the researches carried out in the last decade. One problem often troubles the supply chain managers, which is bullwhip effect. It has emerged as an important area for research nationally and internationally. 'Increasing variance' while moving upstream in an SC from customer end to manufacturer side may identify the phenomenon of BWE. First empirical evidence of existence of BWE with system dynamics viewpoint in SCM has been presented (Forrester, 1961). A game (MIT beer distribution game) has been created to confirm BWE existence (Sterman, 1989). It was proposed to play beer distribution game with the use of internet (Jacobs, 2000).

It has been vital to mention here the causes of BWE for better insight of the problem for the clarity about the phenomenon. Important drivers of BWE identified are (Simchi-Levi David et al., 2006; Goran Svenson, 2003; Lee et al 1997; Cooper M.C. et al, 1997; Edifice, 2000; Chen et al, 2000; Xicolongzhang, 2004; Carlson Christer and Fuller Robert, 1999-2000; Carlson Christer and Fuller Robert, 2001, Kenneth Gilbert, 2005). Beer game simulation of four-member supply chain has been done with complete information sharing at all levels and without information sharing at all levels. Lead-time and customer demand variance have been taken constant in the experimental set up (Haleem Abid, Kaushik Avnish and Kumar Sanjay,

2007; Kumar Sanjay and Haleem Abid, 2006; Haleem Abid and Kumar Sanjay, 2007; Kumar Sanjay and Haleem Abid, 2008; Kumar Sanjay and Haleem Abid, 2008).

- Demand signal processing: demand uncertainty, demand fluctuation, unavailability of forecasting tools, updating forecast, supplier uncertainty and unavailability;
- Rationing game: manufacturing capacity insufficiency, fear of shortage, rational decision making process;
- Order batching: batch size, order cost, different ordering policies of SC members, order cycle,;
- Price fluctuations: price fluctuation of raw material, price fluctuation of final product;
- Other factors which include government policies, lack of coordination and cooperation, lack of information sharing etc.

The problems associated with bullwhip effect are (Carlsson C and Fuller R., 1999-2000, Lee H., Padmanabham V, Whang, 1997b).:

- Excessive inventory investment needed throughout SC: demand predicted by different supply chain member is more than the actual as a result of rational decision to mitigate the demand uncertainties. Thus the phenomenon of bullwhip effect leads to more investments on inventory throughout SC;
- Poor customer services because of shortages: bullwhip effect is identified with alternate cycles of shortages and high inventories at the upstream member levels. The shortages caused by bullwhip effect leads to the poor customer services;
- Lost revenue due to shortages: as mentioned above shortages at different point of time are followed by high inventory then the required. Poor customer services due to shortages may lead to detachment of unsatisfied customers. Both the situations of customers (at the time of stock outs) and high inventories are nothing but lost revenues;
- Poor productivity of invested capital: different members of supply chain experience repeated cycles of shortages and high inventories than required resulting into substandard productivity of the capital invested;
- Plans of capacity enhancement: shortages may misguide the members involved in supply chain and may give this impression that to meet the increased false demand they should increase the capacity of the plant which is not the case in reality;
- Sub optimal transportation schemes: it becomes very difficult to optimize the transportation strategy due to the uncertainties involved;
- Missed production schedules: increased production requirements, production schedules also get disturbed as because of bullwhip effect. The good items are either over produced or under produced and may lead to understanding increased production requirements.

For competitiveness of supply chain, managing information effectively has drawn a lot of attention in recent years. To deal with BWE information sharing among SC members has been given due importance by many researchers. Kahn 1987 showed that BWE mitigates if: retailers follow optimal inventory model; period wise demand is serially correlated; excess demand backlogging is allowable (Carlsson C. and Fuller R., 1999-2000)

3. BWE REDUCTION: SOLUTIONS?

EDLP, EDI and VMI approaches as alternative solutions for BWE reduction have been identified from available literature.

Customer demand variability reduction may contribute towards BWE reduction and we may decrease variability in demand of customers through utilization of EDLP. The product is offered consistently at low price. Retailer using price promotions' estimations may be able to eliminate many of dramatic demand shifts which appear with promotions; and hence, EDLP may lead to less variable/additional stable demand patterns (Simchi-Levi David et al., 2006).
Information 'lead time' (LT) may be decreased considerably by usage of EDI as LT involve two components: information LT and order LT (Simchi-Levi David et al., 2006). Researchers have been involved to estimate and analyze importance of EDI towards BWE reduction substantially at different stages of SC. Most significant limitation in implementation of EDI has increasingly been implementation cost (Machuca J.A.D. and Barajas R.P., 2004).
VMI may be recognized among those important strategies in which manufacturer attempts to manage products' inventory at retailer's outlet. Also, manufacturer needs not to rely upon order placed by retailer and hence avoiding the possibility of occurrence of BWE completely (Simchi-Levi David et al., 2006). Because of Wal-Mart' success VMI has been increasingly acceptable in grocery sector in last few decades (Andel, 1996; Stalk et al., 1992; Disney S.M. and Towill D.R., 2003).
Vendor selection is a complicated process. Decision criteria used for vendor selection can be different depending on the size of a buyer organization. The main objective of the paper is to rate vendors (large scale, medium scale and small scale) with respect to various criteria. Here we found, through our analysis of MCDM problem of vendor selection, that Reliability of the Vendor (RV), Quality of the Product (QP) and the Experience of the Vendor in the same field (EV) are top three in the vendor selection problem (Kumar Sanjay, Parashar Neeraj and Haleem Abid, 2009). Benefits of implementation of vendor managed inventory concept to different members have been provided followed by challenges being faced by supply chain members (Khatri T., Duhan M., Kumar S., and Haleem A., 2015).

4. THE ANP FRAMEWORK FOR REDUCING BULLWHIP EFFECT

For selection of best alternative solution for reducing Bullwhip Effect, we have used analytical ANP technique. ANP has been selected for following important facts:
ANP is comprehensive approach allowing consideration of all important criteria and interdependencies;
Analytical hierarchy process (AHP) has been comparable to ANP; however, AHP has not been able to consider interdependencies (Meade et al., 1997; Meade and Sarkis, 1999);
ANP considers complex relationships among attributes and decision levels because of relatively rlexible hierarchical structure (Ravi V. et al, 2005);
ANP methodology can be adopted while making decision – qualitative and quantitative nature. Limitations of ANP are: ANP approach application needs rigorous calculations as compared to AHP. Because of the subjectivity involved, the accuracy of results depends upon expertise of decision maker (Ravi V. et al, 2005). AHP may be one among most frequently utilized MCDM approaches because of ease of handling multi criteria (Drake P.R., 1998). It is relevant to mention here that the base of AHP is propositions delimiting problem environment scope (Saaty, 1986). AHP has been based upon well defined hierarchical structure of matrices consistent in nature and ability of concerned eigenvector to evaluate weights (exact/approximate) (Merkin, 1979; Saaty 1980, 1994) suggested by experts of field

relevant to the problem. AHP approach compares criteria, alternatives with reference to criterion, in pair wise manner.

AHP makes the selection process very transparent. AHP (Analytical Hierarchy Process) is one of the most extensively used MCDM methods because of ease with which it handles the multi criteria. The AHP uses a fundamental scale of absolute numbers that has been proven in practice and validated by physical and decision problem experiments (Kumar Sanjay, Parashar Neeraj and Haleem Abid, 2009). Some extended application of analytic hierarchy process (AHP) approach has been introduced and proposed, which uses fundamentals of important and established technique that is analytic hierarchy process (Kumar S., 2014a). Based on the ratings obtained during workshop by experts, matrix is formed and the priorities are synthesized using the methodology of AHP. In AHP approach, all pair comparisons have been made on the basis on the experts' opinions (Kumar, S., Luthra, S., Garg, D. and Haleem, A., 2014).

Graphical summary of the ANP framework to deal with the problem of reducing BWE has been developed by taking opinions of experts and review of related literature as presented in figure 1. Objective of ANP framework is to reduce bullwhip effect that can be measured by amplification ratio. We have considered three determinants, which are oscillation, amplification and phase lag (Jose et al, 2004).

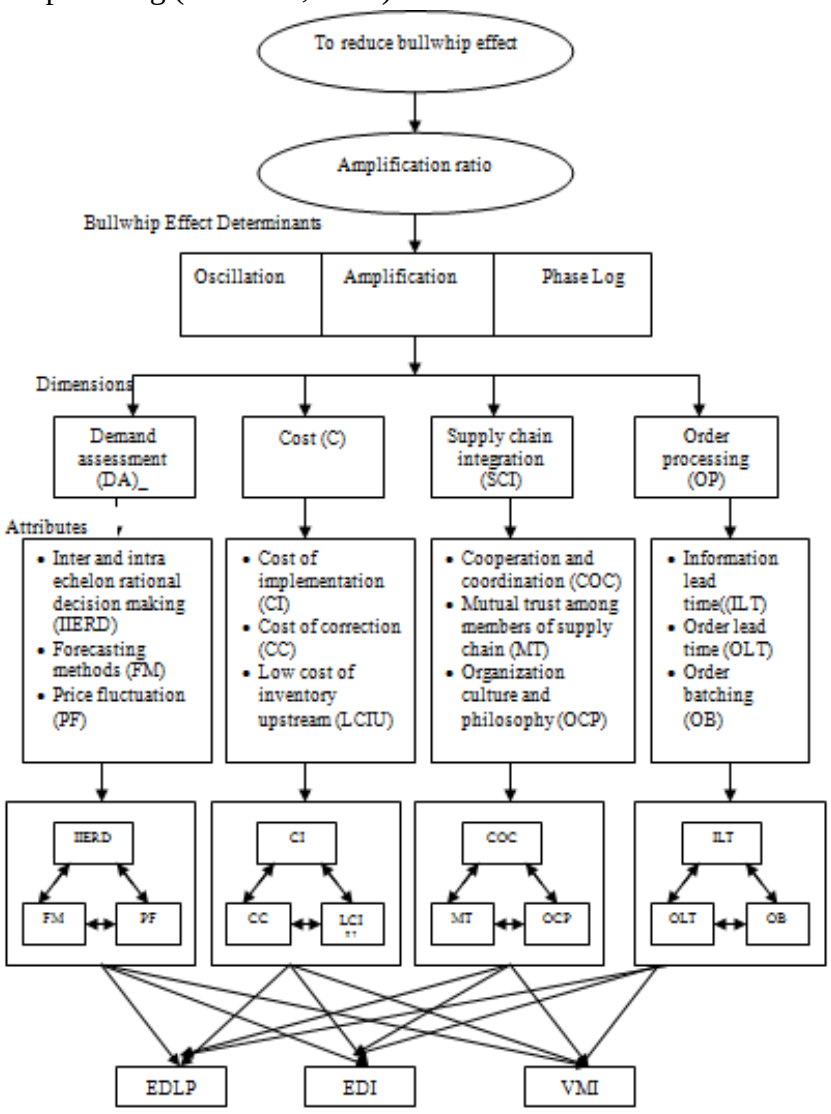

Figure 1 ANP Based Framework

Figure 1 ANP Based Framework

Demand assessment (DA), cost (C), supply chain integration (SCI) and order processing (OP) have been chosen carefully as dimensions. Each of the dimensions has its attributes. Inter and intra echelon rational decision-making (IIERD), forecasting methods (FM) and price fluctuations (PF) have been considered as the attributes of demand assessment. Similarly cost of implementation (CI), cost of correction (CC) and low cost of inventory upstream (LCIU) have been taken as attributes of cost. Cooperation and coordination (COC), mutual trust among members of SC (MT) and organization culture and philosophy (OCP) play important role in supply chain integration so considered as its attributes. Order batching (OB) and lead time (lead time includes information lead time (ILT) and order lead time (OLT)) have been researched upon from reduction of BWE perspective (Simchi-Levi David, Kaminsky P., Simchi- Levi E. 2006). So ILT, OLT and OB have been taken as attributes of order processing. The ANP framework has been applied to select best suitable alternative out of EDLP, EDI and VMI considering fast moving consumer goods (FMCG) sector as discussed earlier.

5. ANP FRAMEWORK APPLICATION

ANP technique has been applied to achieve the objective of reducing bullwhip effect in very simple and systematic six steps procedure as under:

Step 1: Construction of model and structuring of problem:

Model has been constructed as shown in figure 1 after identification of determinants, dimensions and attributes for the overall objective that is to reduce bullwhip effect, where hierarchy's top most elements (determinants) are fragmented into dimensions and attributes. Objective of the hierarchy is to identify the best suitable alternative out of EDLP, EDI and VMI for reducing BWE.

Step 2: Pair wise comparison matrices (PCMs) between component/ attribute levels:

Decision maker is asked to assess to a number of pair wise comparisons (on a scale of 1 to 9) with respect to an upper level "control" criterion. The pair wise comparison in the form of matrices is deduced in the form of weighted priority. Table 1 shows PCM utilized to estimate relative importance of oscillation, amplification and phase lag. The e-vector thus calculated is highest for amplification, which is 0.68. Phase lag and oscillation come second and third with 0.234 and 0.078 e-vectors.

Table 1 PCM for Demand Assessment

Phase Lag				
	IIERD	FM	PF	Priority Matrix
IIERD	1	2	1/6	0.179
FM	1/2	1	¼	0.129
PF	6	4	1	0.692

Step 3: Interdependencies' PCMs

PCMs for interdependencies are key feature of ANP approach, which makes ANP different from AHP. For example we have been shown (table 3) comparison between FM and PF under phase log, DA and IIERD, which indicates 0.125 and 0.875 as e-vectors for FM and PF

respectively. Likewise e-vectors for other enablers have been calculated considering interdependencies.

Table 2 PCM for enablers under Phase Lag, DA, and IIERD

	FM	PF	Priority Matrix
FM	1	1/7	0.125
PF	7	1	0.875

Step 4: Super matrix (SM) development

Super matrices three in number were developed one for each BWE determinants i.e., oscillation, amplification and phase log. Table 4 illustrates the super matrices for phase log. All super matrices have been converged, for example super matrix for phase log got converged to a power of 42 as presented in Table 5.

Table 3 *SM* for Phase Lag before Convergence

	IIERD	FM	PF	CI	COC	LCIU	CC	MT	OCP	ILT	OLT	OB
IIERD	0	0.167	0.75									
FM	0.125	0	0.25									
PF	0.875	.833	0									
CI				0	0.857	0.75						
COC				0.75	0	0.25						
LCIU				0.25	0.143	0						
CC							0	0.667	0.667			
MT							0.667	0	0.333			
OCP							0.333	0.333	0			
ILT										0	0.857	0.667
OLT										0.857	0	0.333
OB										0.143	0.143	0

Table 4 *SM* for Phase Lag after Convergence (M^{42})

	IIERD	FM	PF	CI	COC	LCIU	CC	MT	OCP	ILT	OLT	OB
IIERD	0.38	0.38	0.38									
FM	0.16	0.16	0.16									
PF	0.46	0.46	0.46									
CI				0.45	0.45	0.45						
COC				0.38	0.38	0.38						
LCIU				0.17	0.17	0.17						
CC							0.40	0.40	0.40			
MT							0.35	0.35	0.35			
OCP							0.25	0.25	0.25			
ILT										0.45	0.45	0.45
OLT										0.43	0.43	0.43
OB										0.12	0.12	0.12

Step 5: Best alternative selection

Desirability index D for alternatives and determinant may be represented as (Meade and Sarkis, 1999):

$$D_{ia} = \sum_{j=1}^{J} \sum_{k=1}^{Kja} P_{ja} A^{D}_{kja} A^{I}_{kja} S_{ikja}$$

Symbols' description is as follows:

P_{ja}- relative importance weight (RIW) of dimension;

A^{D}_{kja}- RIW for attribute k, dimension j and determinant 'a';

A^{I}_{kja}- Stabilized RIW for attribute k, dimension in the determinant 'a' for interdependencies (I) relationships within the attribute enabler's component level;

S_{ikja}- relative influence of SC alternative paradigm I on SCP enabler k of dimension of SCP j;

K_{ja}- index set of attributes for dimension j of determinant 'a';

J- Index set for dimension j.

Evaluation for desirability index for phase log for alternatives for reducing BWE are presented in table 6.

Column wise description of the table 6 is as follows:

Column 1: Dimensions
Column 2: Relative impact of dimension on phase log determinant.
Column 3: Attributes
Column 4: PCM for relative impact of attributes on dimensions
Column 5: Attributes' stable interdependent weights of obtained by SM convergence.
Column 6, 7, 8: Alternatives' relative weights for dimensions obtained after comparing three alternatives for every dimension of BWE
Column 9, 10, 11: Desirability index of each alternative for attributes.

Final Row of table gives the summation of column 9, 10 and 11.The result from table 6 has been used to calculate BWERWI.

Table5 Bullwhip Effect Reduction Desirability Index for Phase Lag

Dim.	P_{ja}	Attribute	A^{D}_{kja}	A^{I}_{kja}	S1	S2	S3	EDLP	EDI	VMI
DA	0.120	IIERD	0.179	0.38	0.07	0.235	0.695	0.0005714	0.0019182	0.00567287
	0.120	FM	0.129	0.16	0.185	0.204	0.611	0.0004582	0.0005053	0.00151332
	0.120	PF	0.692	0.46	0.07	0.206	0.724	0.0026739	0.0078689	0.02765564
C	0.171	CI	0.685	0.45	0.22	0.067	0.713	0.0115964	0.0035316	0.03758276
	0.171	COC	0.136	0.38	0.128	0.277	0.595	0.0011312	0.0024479	0.00525818
	0.171	LCIU	0.179	0.17	0.143	0.286	0.571	0.0007441	0.0014882	0.00297122
SCI	0.259	CC	0.525	0.40	0.164	0.297	0.539	0.0089238	0.0161538	0.02931621
	0.259	MT	0.334	0.35	0.122	0.23	0.648	0.0036938	0.0069637	0.01961956
	0.259	DCP	0.141	0.25	0.172	0.478	0.35	0.0015703	0.0043664	0.00319541
OP	0.45	ILT	0.581	0.45	0.187	0.567	0.246	0.0220001	0.0667099	0.02894252
	0.45	OLT	0.309	0.43	0.190	0.224	0.586	0.0113604	0.0133933	0.03503782
	0.45	OB	0.11	0.12	0.143	0.286	0.571	0.0008494	0.0016988	0.00339174
								0.0655727	0.1270427	0.20015725

Step 6: Calculation of Bullwhip Effect Reduction Weighted Index (BWERWI)

BWERWI concerning to a particular alternative may be multiplication of relative importance of the determinants (C) of BWE and desirability indices (D). Table 6 shows PCM utilized to

estimate relative importance of determinants: oscillation, amplification and phase lag. The e-vector thus calculated is highest for amplification, which is 0.68. Phase lag and oscillation come second and third with 0.234 and 0.078 e-vectors respectively.

Table 6 Determinants' relative importance

	Oscillation	Amplification	Phase Lag	Priority Matrix
Oscillation	1	1/7	¼	0.078
Amplification	7	1	4	0.688
Phase Lag	4	¼	1	0.234

These relative weights of determinants calculated have been used for further calculations in table 7, which indicates that BWERWI for VMI, EDI and EDLP are 0.2253, 0.1122 and 0.0601 respectively

Table 7 Bullwhip Effect Reduction Weighted Index (BWERWI) for Various Alternatives

	Oscillation	Amplification	Phase Lag	Bullwhip Effect Reduction Weighted Index (BWERWI)	Normalized Weights of BWERWI	Ranking
Weights	0.078	0.688	0.234			
EDLP	0.055	0.059	0.065	0.0601	0.151	III
EDI	0.105	0.108	0.127	0.1122	0.282	II
VMI	0.275	0.229	0.2	0.2253	0.567	I
Total				0.3976	1.000	

6. Findings

An ANP framework has been developed for reducing BWE in Indian FMCG sector. ANP has been found an appropriate technique to deal with MCDM problem. ANP is one of the most powerful techniques, which quantifies qualitative variables to create objectivity in the real world problems.

Important findings after applying the suitable ANP technique to the problem are:

- Out of three determinants of BWE amplification (0.668) has been found highest weighted as compared to phase lag (0.234) and oscillation (0.078).
- VMI is being suggested the most effective approach to reduce BWE if we consider amplification, phase lag and oscillation individually. EDI and EDLP come afterwards in order.
- BWERWI calculation estimating effect of each alternative indicates that most important alternative towards BWE reduction may be VMI followed by EDI and EDLP. It is evident from the normalized value of BWERWI for different alternatives, the difference is significant. So even if some difference is there in perception of experts there may not be any significant variations in results.

Experts were again consulted to verify the outcomes of the calculations after applying ANP methodology to the problem. Taking expert's opinion at every stage of problem solving process is very useful towards getting authentic results. Although, VMI has been indicated as the best solution to the problem of reducing BWE, but importance of EDI and EDLP cannot

be ignored: as suggested by experts, rather EDI and EDLP help in effective implementation of VMI and reducing BWE to the minimum possible level.

7. DISCUSSIONS AND CONCLUDING REMARKS

Various alternatives effective in reducing bullwhip effect have been obtained from contemporary literature review and experts perception. ANP approach has been found suitable for transforming qualitative evaluation into quantified values of preference for three solutions, which are EDLP; EDI and VMI. These solutions can be taken up in isolation or in combinations. An ANP framework has been developed by making pair wise comparisons of attributes and checking for interdependencies leading to calculation of bullwhip effect reduction weighted index for each alternative. It is found that VMI is the best alternative solution and EDI comes at second priority followed by EDLP. It has being suggested that VMI and EDI to be used to reduce bullwhip effect when applied in combination. Also it has being further suggested that EDLP cannot be ignored.

7.1 Limitations

The main limitations and ways to overcome these limitations have been as follows:

- ***Limitation 1-*** The opinions of experts that are subjective in nature may be observed as biased. Some times the results so obtained by using various qualitative approaches such ass ANP are treated as invalidated and ignored.
  Way out- Results need to be appropriately validated using some case studies, or by using questionnaire based survey technique and statistically validating the survey findings towards validating the findings of this study.
- ***Limitation I1-*** Findings presented in this study are sector specific.
  Way out- Need to be applied with some modifications for applications to other sectors.

7.2 Future scope of study

Future scope of study may be as follows:

In our research, we have evaluated three alternatives to reduce/mitigate bullwhip effect in FMCG sector of India. Similar studies may be carried out with different relevant alternatives towards reducing bullwhip effect.

Modeling of enablers for implementing the alternatives (EDLP, EDI and VMI) using modeling technique such as Interpretive Structural Modeling (ISM) that may be found very useful in analyzing interactions among the enablers/alternatives/combinations of alternatives (Parashar Neeraj, Singh Rachna, Kumar Sanjay and Haleem Abid, 2007; Kumar Naveen, Kumar Sanjay, Haleem Abid, Gahlot Pardeep, 2013; Kumar, S., Luthra, S., Haleem, A., Garg, D. and Singh, S., 2014; Kumar S., 2015; Luthra S., Kumar V., Kumar S., Haleem A., 2011; Luthra S., Garg D., Kumar S., Haleem A., 2012).

The interactions may be further rated and critical path of interactions may be identified by utilizing contextual interactions analytic hierarchy process approach (CIAHP) suggested by Kumar S. (2014b).

A structured model for another/allied industry (as lean manufacturing first conceived and applied in automotive sector; however, it has been repeatedly reported about its applicability in various sectors other than automobile, appropriate barriers may be deleted or/and added. To validate the existing model, structural equation modeling may be further applied.

REFERENCES

[01] Andel T. (1996) Manage Inventory Own Information, *Transport and Distribution*, Vol. 37, No. 5, pp. 54-58.

[02] Carlson Christer and Fuller Robert (1999-2000) Soft Computing & Bullwhip Effect, *Economics & Complexity*, Vol. 2, No. 3, Winter, pp. 1-26.

[03] Carlson Christer and Fuller Robert (2001) Reducing the Bullwhip Effect by means of Intelligent, *Soft Computing Methods*, Proceedings of 34th Hawaii International Conference on System Sciences, pp. 1-10.

[04] Chen et al. (2000) Quantifying the bullwhip effect in a supply chain: the impact of FC, lead times and information, *Management Science*, Vol. 46, No. 3, pp. 436-443.

[05] Cooper, M.C., D.M Lambert, J.D Pagh (1997) Supply Chain Management: More than a new name for logistics, *International Journal of Logistics Management*, Vol. 8, No. 1.

[06] Disney S.M. and Towill D.R. (2003) The Effects of Vendor Managed Inventory (VMI) Dynamics on the Bullwhip Effect in Supply Chains, *International Journal of Production Economics*, Vol. 85, pp. 199-215.

[07] Drake, P.R. (1998) "Using the Analytical Hierarchy Process in Engineering Education", *International Journal of Engineering Education*, Vol. 14, No. 3, pp. 191-196.

[08] Edifice. (2000) Forecast & Inventory Management, *Business and Information Model Guideline*, No. 1.

[09] Forester. J. (1961) Industrial Dynamics, MIT Press, Cambridge, MA.

[10] Gilbert, K., (2005) An ARIMA Supply Chain Model, *Management Science*, Vol. 51, No. 2, pp. 305–310.

[11] Goran Svenson, (2003) The bullwhip effect in intra organizational echelons, *International Journal of physical distribution and logistics management*, Vol. 33, No. 2, pp. 103-132.

[12] Haleem Abid, Kaushik Avnish and Kumar Sanjay, (2007) Modeling Bullwhip Effect and Understanding the Role of Information Sharing, *Flexibility with Business Excellence in Knowledge Economy, Proceedings of 7th Global Conference on Flexible Systems Management, GloGIFT*, Noida, pp. 386-397.

[13] Haleem Abid and Kumar Sanjay, (2007) Effective Information Sharing for Reducing Bullwhip Effect: A Simulation Based Study, *International Journal of Computer Science and System Analysis*, Vol. 1, No. 2, pp. 111-128.

[14] Jacobs, F.R. (2000) Playing the distribution game over the internet, *Production and Operation Management*, Vol. 9, No. 1, pp. 31-39.

[15] Jose A. D. Machuca, Rafael P. Barajas (2004) The impact of electronic data inter change on reducing bullwhip effect and supply chain inventory costs, *Transportation research*, part E Vol. 40, pp. 209-228.

[16] Kahn, J. (1987) Inventories and the volatility of production, *America Economic Review*, Vol. 77, pp. 667-679.

[17] Khatri T., Duhan M., Kumar S., and Haleem A. (2015) Vendor Managed Inventory (VMI): Benefits, Challenges and Essentials in Implementation, *Data Mining and Knowledge Engineering*, Vol. 7, No. 3, pp. 248-252.

[18] Kumar Naveen, Kumar Sanjay, Haleem Abid, Gahlot Pardeep, (2013) Implementing Lean Manufacturing System: ISM Approach, *Journal of Industrial Engineering and Management (JIEM)*, Vol. 6, No. 4, pp. 996-1012.

[19] Kumar, S., Luthra, S., Haleem, A., Garg, D. and Singh, S. (2014) Understanding requisites of product innovation management: An ISM approach, *11th World Congress of Academy for Global Business Advancement (AGBA), Indian Institute of Technology, Delhi, India on November 21-23, 2014*.

[20] Kumar S. (2015) Brief About Applications of Interpretive Structural Modeling, *Data Mining and Knowledge Engineering*, Vol. 7, No. 3, pp. 108-110.

[21] Kumar S. (2014a) Some Application of Analytic Hierarchy Process, *Data Mining and Knowledge Engineering*, Vol. 6, No. 9, pp. 382-384.

[22] Kumar, S., Luthra, S., Garg, D. and Haleem, A. (2014) Lean six sigma implementation: An analytic hierarchy process approach, *NITIE-POMS Conference 2014 Manufacturing Excellence: Imperatives for Emerging Economies at National Institute of Industrial Engineering, Vihar Lake, Mumbaion December 18-21, 2014*.

[23] Kumar Sanjay and Haleem Abid, (2006) Bullwhip Effect: Effect on Supply Chain Performance, Proceedings of *National Conference on Emerging Trends in Technology and Management* , Feb 18-19, GLAITM, Mathura, pp. 98-105.

[24] Kumar Sanjay and Haleem Abid, (2008) Bullwhip Effect: A Brief Review, *International Review of Mechanical Engineering*, Vol. 2, No. 1, pp. 20-26.

[25] Kumar Sanjay and Haleem Abid, (2008) Understanding Bullwhip Effect: A Literature Review Approach, *Invertis Journal. of Science and Technology*, Vol. 1, No. 4, pp. 231-240.

[26] Kumar Sanjay, Parashar Neeraj and Haleem Abid, (2009) Analytical Hierarchy Process Applied to Vendor Selection Problem: Small Scale, Medium Scale and Large Scale Industries, *Business Intelligence Journal*, Vol. 2, No. 2 pp. 355-362.

[27] Kumar Sanjay (2014b) Contextual Interactions Analytic Hierarchy Process (CIAHP): Introduction and Application to Analyze Interactions among Knowledge Management Implementation Capability (KMIC) Factors, *International Journal of Knowledge and Learning*, Vol. 9, No. 3, pp. 242-263, (Inderscience Publishers).

[28] Lee H.L. Padmanabhan P, Whang S. (1997a) Information distortion in a supply chain, the bullwhip effect, *Management science*, Vol. 43, pp. 543-558.

[29] Lee H.L. Padmanabhan P, Whang S. (1997b) The bullwhip effect in a supply chain, *Sloan management review*, Vol. 38, no. 3, pp. 93-102.

[30] Luthra S., Kumar V., Kumar S., Haleem A. (2011) Barriers to Implement Green Supply Chain Management in Automobile Industry using Interpretive Structural Modeling Technique-An Indian Perspective, *Journal of Industrial Engineering and Management*, Vol. 4, No. 2, pp. 231-257. doi:10.3926/jiem.2011.v4n2.p231-257

[31] Luthra S., Garg D., Kumar S., Haleem A. (July, 2012) Implementation of The Green Supply Chain Management in Manufacturing Industry in India using Interpretive Structural Modeling Technique, *BPR Technologia: A Journal of Science, Technology & Management*, Vol. 1, No. 1, pp. 1-17, ISSN: 2278-8387.

[32] Machuca J.A.D. and Barajas R.P. (2004) The Impact of Electronic Data Interchange on Reducing Bullwhip Effect and Supply Chain Inventory Cost, *Transportation Research*, Part E 40, pp. 209-228.

[33] Meade L.M. and Sarkis J. (1999) Analyzing Organizational Project Alternatives for Agile Manufacturing Process: An Analytical Network Approach, International *Journal of Production Research*, Vol. 37, No. 2, pp. 241-261.

[34] Meade L.M., Liles D.H. and Sarkis J. (1997) Justifying Strategic Alliances and Partnering: A Prerequisite for Virtual Enterprising, *Omega*, Vol. 25, No. 1, pp. 29-42.
[35] Merkin, B. G. (1979) Group Choice, *John Wiley & Sons*, NY.
[36] Parashar Neeraj, Singh Rachna, Kumar Sanjay and Haleem Abid, (2007) Developing Plant Layout: An ISM Analysis, *GPM Journal of Technology and Management*, Vol. 1, No. 1, pp 33-39.
[37] Saaty, T. L. (1980) The Analytic Hierarchy Process, *McGraw-Hill Book Co.*, N.Y.
[38] Saaty, T. L. (1986) Axiomatic Foundation of the Analytic Hierarchy Process, *Management Science*, 32, pp. 841-855.
[39] Saaty, T. L. (1994a) How to Make a Decision: The Analytic Hierarchy Process, *Interfaces*, Vol. 24, pp. 19-43.
[40] Saaty, T. L. (1994b) Fundamentals of Decision Making, *RWS Publications*, Pittsburgh, PA
[41] Simchi-Levi David, Kaminsky P., Simchi- Levi E. (2006) Designing and Managing the Supply Chain, *Tata McGraw Hill Publishing Company Limited*, pp. 101-110.
[42] Stalk G., Evans P, Shulman L.E. (1992) Competing on Capabilities: The New Rules of Corporate Strategy, *Harvard Business Review*, and Vol. 70, No. 2, pp. 57-70.
[43] Sterman, J. (1989) Misperceptions of Feedback in Dynamic Decision Making, *Organizational Behavior and Human Decision Processes*, Vol. 43, No. 3, pp. 301-335.
[44] V Ravi, Shankar Ravi and Tiwari M.K. (2005) Analyzing Alternatives in Reverse Logistics for End- of – life Computers: ANP and Balanced Scorecard Approach, *Computers and Industrial Engineering*, Vol. 48, No. 2, pp. 327-356.
[45] Xicolongchang (2004) Effects of FC methods on bullwhip effect, *International Journal of production economics*, Vol. 88, pp. 15-27.

