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Modelling of the factors influencing the phenomenon of bullwhip effect in the seasonal products using ISM technique

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ABSTRACT

Bullwhip effect is a phenomenon of increase in variation of demand as one move up the supply chain. Bullwhip effect has adverse effects on the sustainable growth of the industries. Bullwhip effect is very predominant in case of seasonal products. In this paper author has identified the major factors that affects the Bullwhip effect, and has derived a Multi-level model of these factors, on the basis of their contextual relationship, using Interpretive Structural Modelling (ISM) technique.

Introduction

The Bullwhip effect is not a recent field of work for management experts but it has been keep on influencing the market from past many decades. It (Bullwhip effect) is having a phenomenal ability to derive the reasons for the excess inventory within the supply chain. The demand and supply are the two poles of the supply chain, if one gets unbalanced, the other will automatically get affected in the one way or other. Bullwhip effect mainly comes into scene due to the amplification of the variation in demand in the supply chain. (Octavio Carranza Torres ,2010)

The variation in the demand increases as one move up i.e. towards the source, in supply chain. When a supply chain is struck by Bullwhip effect, the production planning as well as the inventory planning gets shattered as the bulking of stocks gets intensified, in parallel with the reduction in sales. Bullwhip is a predominant phenomenon in the case of Seasonal products such as, winter equipments like heaters, woollen cloths; rainy season products like umbrella etc. Also the automobile and IT sector is plagued by this phenomenon. In the recent past the companies such as Hewlett-Packard, Compaq, Ford etc had also severely hampered by Bullwhip effect. (LIU Hong & WANG Ping ,2007)

The main objective of this study is to analyse the various factors that affect, directly or indirectly, the Bullwhip effect in the seasonal products and to draw a conclusion based on some mathematical tools so as to curb this effect. This study is to provide an interactive model having different levels, on to which the factors are arranged.

The profit margin in the seasonal products can be extended appreciably to a large scale by systematically analysing and treating the determined factors. This study helps in optimizing the production methodology, so as to increasing the gain.

Literature review:

The Bullwhip effect is not a newly originated topic but it is an age old phenomenon. In the early 1960s Professor Forrest studied and illustrated the existence of Bullwhip effect by a series of case studies. Professor Sterman of MIT gave his theory on the existence of the Bullwhip effect, in an experiment of "Beer Distribution Game".(LIU Hong & WANG Ping ,2007)

The Bullwhip effect was critically and systematically studied by Professor Lee and his co-operators. They established a Bullwhip effect theory model.

Chen et al. (2000), Simchi-Levi et al.(2000) and Shen(2001) found that, independent local optimisation choices of each manager without global vision, was one of the cause to originate Bullwhip effect. This is one of the most important factor causing Bullwhip effect. Bolton and Katok (2005) studied and analysed the relationship between the inventory conditions and the inventory or stocks.(Robert J. Bloomfield et al. ,2007)

Many innovative works had also been done in Interpretive Structural Modelling technique earlier. Rituraj Chandraker & Rajesh Kumar (2013) used ISM methodology to analyse the practice for implementation of Green Supply Chain Management in Chhattisgarh Manufacturing Industries (India).

Methodology:

The methodology used in this study is based on a systematic and planned approach to draw a mathematical environment to achieve the contextual relationship between the parameters.

The major steps involved in ISM methodology:

1) Problem Selection: In this study the author has taken upon the phenomenon of Bullwhip effect in the seasonal products under consideration. As the level of uncertainty is very high, seasonal products are very much liable to the Bullwhip effect.

2) Factor Identification: After carefully studying and examining the problem the important factors affecting the

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problem are carefully chosen. For factor selection the advice of experts from the relevant field can be taken.(Rituraj Chandraker et al. , 2013)

3) Contextual Relationship: After examining the factors their relationship is identified. Once the relationship is identified a structural self-interaction matrix (SSIM) is prepared. Four symbols are used to denote the direction of relationship between the factors in both the directions i and j:

F- Factor i will cause factor j;
S- Factor j will cause factor i;
B- Factor i and j both affect each other;
N- Factors i and j are unrelated

4) Initial Reachability Matrix: The SSIM is transformed into a matrix of binary type consisting of 1 and 0, called the initial reachability matrix by replacing the symbols F,S,B and N, by 1 and 0 as per the case. The rules for the replacement of 1's and 0's are:

• If the symbol at any position (i, j) in the SSIM is F, then the position (i, j) in the reachability matrix becomes 1, and the corresponding (j, i) position becomes 0.

• If the symbol at any position (i, j) in the SSIM is S, then the position (i, j) in the reachability matrix becomes 0, and the corresponding (j, i) position becomes 1.

• If the symbol at any position (i, j) in the SSIM is B, then both the positions (i, j) and (j, i) in the reachability matrix becomes 1.

• If the symbol at any position (i, j) in the SSIM is N, then both the positions (i, j) and (j, i) in the reachability matrix becomes 0.

5) Final Reachabilty Matrix: The initial reachability matrix obtained in step 4 is converted into the final reachabilty matrix by checking it for transitivity.

The transitivity of the contextual relation is a mathematical law, which states that " if element A is related to B and B is related to C, then A is also related to C".

The driving power and dependence power of the factors are determined, they shows the nature of the factor.

6) Level Determination: The final reachability matrix obtained in Step 5 is grouped into different levels on the basis of the dominance of factors in the problem.

7) Development of ISM model: In the model the factors are arranged according to their level, factor of first level is placed at the top and the further levels are arranged in the descending order.

8) MICMAC Interpretation: The MICMAC analysis is done for showing driving and dependence power, it is represented in a graphical format.

Result:

Factor Identification:

After critically examining and reviewing the literature on Bullwhip effect and also taking the advice from experts, the following factors are considered that affect the Bullwhip effect in the seasonal products.

Structured Self Intersection Matrix:

For determining the relationship among the factors and also to identify the nature of contextual relationships among the factors, various industrial experts, managers and academia were consulted. Various symbols are used in designing the SSIM, which explains the relationships of the factors in i and j. (Sunil Luthra et al. 2011) (Rituraj chandraker et al. 2013)

• F- Factor i will cause factor j;
• S- Factor j will cause factor i;
• B- Factor i and j both affect each other;
• N- Factors i and j are unrelated

Table 1: Factors affecting Bullwhip effect

S.No.	Factors	Description
1	Demand forecast updating	Delayed updating the forecast of demands
2	Order batching	Grouping or collection of orders
3	Price fluctuation	Demand variation with price
4	Misperception of feedback	Wrong interpretation of feedback
5	Local optimization without global vision	Sudden modification of product without proper analysis at global level
6	False ordering	False order placement at different levels of supply chain
7	Operational obstacles	Technical, managerial and other administrative obstacles
8	Prolong lead time (Lead time variability)	Lengthening of lead time
9	Lack of communication in supply chain	Lack of proper communication within the supply chain
10	Delayed information and material flow	Slow information and material transfer rate

Table 2: Structured Self Intersection Matrix (SSIM) to analyse the effects of the factors on the Bullwhip effect in the seasonal products

S.No.	Factors	10	9	8	7	6	5	4	3	2	1
1	Demand forecast updating	S	S	N	F	S	N	S	N	F	
2	Order batching	S	S	S	S	S	N	S	F		
3	Price fluctuation	S	N	N	N	N	S	N			
4	Misperception of feedback	F	N	F	B	N	N				
5	Local optimization without global vision	N	F	S	S	N					
6	False ordering	N	F	N	N						
7	Operational obstacles	B	S	F							
8	Prolong lead time	S	S								
9	Lack of communication in supply chain	B									
10	Delayed information and material flow										

Table 2 is created on the basis of the relationship between the factors. From the table, factor 10 i.e. Delayed information and material flow, leads to Delay in Demand forecast updating i.e. factor 1, so the block (1, 10) is filled with 'S'. Also Misperception of feedback leads to Operational obstacles, and the vice-versa is also true so block (4, 7) is filled with 'B'.

Reachability Matrix:

Reachability Matrix is a binary matrix in which the symbols F,S,B and N are replaced by 0 and 1, on the basis of following rule:

• If the symbol at any position (i, j) in the SSIM is F, then the position (i, j) in the reachability matrix becomes 1, and the corresponding (j, i) position becomes 0; for F(1, 7) in SSIM, '1' is given in block (1, 7) and '0' is given in block (7, 1) , in reachability matrix.

• If the symbol at any position (i, j) in the SSIM is S, then the position (i, j) in the reachability matrix becomes 0, and the corresponding (j, i) position becomes 1; for S(2, 10) in SSIM, ‘1’ is given in block (10, 2) and ‘0’ is given in block (2, 10) , in reachability matrix.

• If the symbol at any position (i, j) in the SSIM is B, then both the positions (i, j) and (j, i) in the reachability matrix becomes 1; for B(4, 7) in SSIM, ‘1’ is given in block (4, 7) and block (7, 4) both , in reachability matrix.

• If the symbol at any position (i, j) in the SSIM is N, then both the positions (i, j) and (j, i) in the reachability matrix becomes 0; for N(6, 8) in SSIM, ‘0’ is given in block (6, 8) and block (8, 6) both, in reachability matrix.

Table 3: Initial Reachability Matrix for factors affecting Bullwhip effect in the seasonal products

S.No	Factors	1	2	3	4	5	6	7	8	9	10
1	1	1	1	0	0	0	0	1	0	0	0
2	2	0	1	1	0	0	0	0	0	0	0
3	3	0	0	1	0	0	0	0	0	0	0
4	4	1	1	0	1	0	0	1	1	0	1
5	5	0	0	1	0	1	0	0	0	1	0
6	6	1	1	0	0	0	1	0	0	1	0
7	7	0	1	0	1	1	0	1	1	0	1
8	8	0	1	0	0	1	0	0	1	0	0
9	9	1	1	0	0	0	0	1	1	1	1
10	10	1	1	1	0	0	0	1	1	1	1

Final reachability matrix is obtained by applying transitivity in the Initial reachability matrix. According to transitivity law, “If A is related to B, and B is related to C, then A is also related to C”.

After suitably applying transitivity, the 1’s are calculated along i and j, and the driving and driven power of the factor are calculated.

Level determination:

Reachability set and Attendance set are formed by examining the driving and driven power respectively. Then their intersection is obtained , and finally the level is decided.

After suitably determining the reachability and attendance sets the levels are decided. All the factors are grouped in 5 levels, having factor 3 (Price fluctuation) at the top.

ISM modelling:

Once all the levels are determined, they are depicted in Table 6, as per their levels.

Now an inter-connected model of all the factors is created, using rectangular boxes and then connecting them using arrows.

From the model we can easily state that, price fluctuation is the most predominant factor in causing the Bullwhip effect. Similarly order batching or collection of orders is also another important factor, along with prolong lead time (or Lead time variability) which plays equally important role in the Bullwhip effect in seasonal products. (Figure: 1)

Bullwhip effect in seasonal products

MICMAC Analysis:

MICMAC Analysis is one of the important management tools which generally used along with the ISM technique to analyze the driving power and the dependence power of the variables or factors.

In this tool the factors are divided into four groups or clusters (Sunil Luthra et al. 2011) (Rituraj Chandraka et al. 2013)

The factors are classified into four clusters:

• The first cluster consists of autonomous variables that have weak driver power and weak dependence power, there are no factors in this cluster.

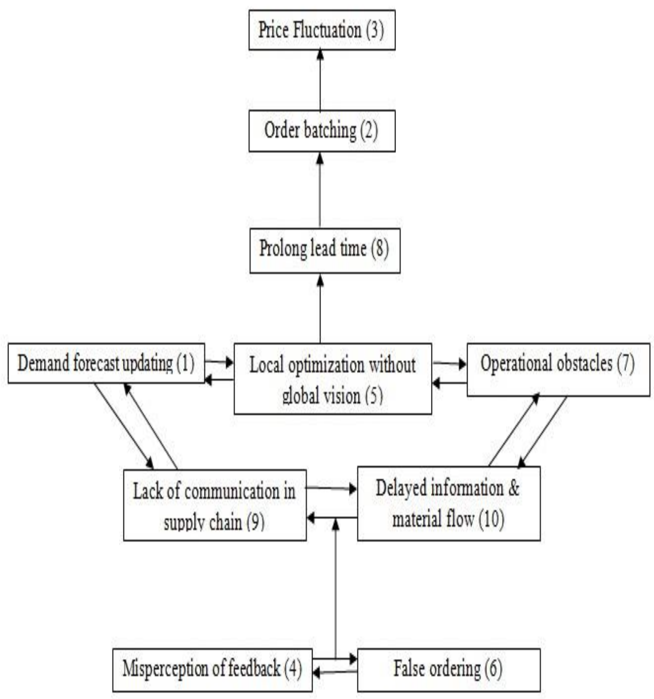

Figure 1: ISM based Model for the factors affecting the

• The second cluster consists of the dependent variable that have weak driver power but strong dependence power, factors 2,3 and 8 are dependent variables. These factors depends on the other factors for their occurrence.

• The third cluster has the linkage variables that have strong driving power and also strong dependence power, factors 1,5,7,9 and 10 are linkage variables with high degree of driving and dependence powers.

• The fourth cluster includes the independent variables having strong driving power but weak dependence power, factor 4 falls in this cluster.

The graph between dependence power and driving power for the factors affecting Bullwhip effect in seasonal products is shown in Figure 2.

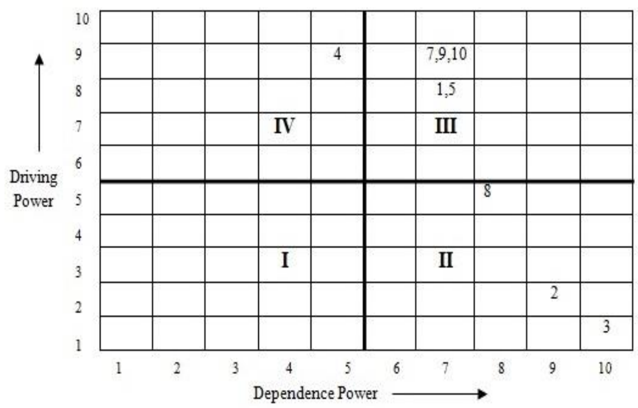

Figure 2: Cluster of factors that affect the Bullwhip effect in the seasonal products

Conclusion:

The main aim of this study is to determine the order in which various factors affects the Bullwhip effect in the seasonal products. The factors were chosen on the basis of their relative importance and interdependence.

After critically examining all the factors and identifying their relationship, a model is created containing different levels.

Table 4: Final Reachability Matrix for factors affecting Bullwhip effect in the seasonal products

S.No.	Factors	1	2	3	4	5	6	7	8	9	10	Driving Power
1	1	1	1	1^t	1^t	1^t	0	1	1^t	0	1^t	8
2	2	0	1	1	0	0	0	0	0	0	0	2
3	3	0	0	1	0	0	0	0	0	0	0	1
4	4	1	1	1^t	1	1^t	0	1	1	1^t	1	9
5	5	1^t	1^t	1	0	1	0	1^t	1^t	1	1^t	8
6	6	1	1	1^t	0	0	1	1^t	1^t	1	1^t	8
7	7	1^t	1	1^t	1	1	0	1	1	1^t	1	9
8	8	0	1	1^t	0	1	0	0	1	1^t	0	5
9	9	1	1	1^t	1^t	1^t	0	1	1	1	1	9
10	10	1	1	1	1^t	1^t	0	1	1	1	1	9
	Dependence Power	7	9	10	5	7	1	7	8	7	7	

Table 5: Iteration to find Levels of factors that affects Bullwhip effect in the seasonal products

S.No.	Reachability Set	Attendance Set	Intersection	Level
1	1,2,3,5,6,8	1,4,5,6,7,9,10	1,5,6	4
2	2,3	1,2,4,5,6,7,8,9,10	2	2
3	3	1,2,3,4,5,6,7,8,9,10	3	1
4	1,2,3,4,5,6,7,8,9,10	4,6	4,6	5
5	1,2,3,5,6,8	1,4,5,6,7,9,10	1,5,6	4
6	1,2,3,5,6,8	6	6	5
7	1,2,3,4,5,6,7,8,9,10	1,4,5,6,7,9,10	1,4,5,6,7,9,10	4
8	2,3,8	1,4,5,6,7,8,9,10	8	3
9	1,2,3,4,5,6,7,8,9,10	1,4,5,6,7,9,10	1,4,5,6,7,9,10	4
10	1,2,3,4,5,6,7,8,9,10	1,4,5,6,7,9,10	1,4,5,6,7,9,10	4

Table 6: Various levels of factors that affect Bullwhip effect in seasonal products

S.No.	Level	Factors that affect Bullwhip effect
1	1	Price fluctuation (3)
2	2	Order batching (2)
3	3	Prolong lead time (8)
4	4	Demand forecast updating (1), Local optimization without global vision (5) Operational obstacles (7), Lack of communication in supply chain (9), Delayed information & material flow (10)
5	5	Misperception of feedback (4), False ordering (6)

All the factors are arranged in this model on the basis of their relative importance.

This model gives a self-explanatory structure of the order of factors. If these factors or causes are resolved, starting from the first level, it will greatly help in curbing the Bullwhip effect in seasonal products.

From the model it is clear that Price fluctuation is the major phenomenon that must be taken care of to control the Bullwhip effect. It is followed by Order Batching which is yet another important factor.

Thus in order to restrict the Bullwhip effect in seasonal products it is very essential to control the price fluctuation of the products, along with reducing the phenomenon of false ordering & operational obstacles. Also it is important to have a good feedback system and enhanced communication and information transfer system so to have a control over Bullwhip effect.

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