

BULLWHIP Effect Minimization Strategy Formulation: Keys to Enhancing Competitiveness and Performance

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ABSTRACT

Bullwhip effect (BWE) is the lack of Supply Chain (SC) coordination and distortion of information. Variations in orders increase BWE as they move up from the downstream stage to the upstream stage of the SC. To be successful in competition and rapidly changing marketplace, industries must generate plans to provide proper information throughout the SC. This study makes a dual contribution. On the one hand, it finds out the main causes that create bullwhip causes and aggregate all other causes under two main causes' operational causes and behavioral causes which have low to high impact on BWE. On the other hand, it develops relationships among these causes and finds out a significant analysis of Bullwhip causes on SC fitness by using Linear Structural Relations (LISREL) analysis. This analysis found statistically significant & positive relationship of operational causes & behavioral causes with BWE. Decreasing number of echelons, incentives, price, discount and policies variation, and increasing trust issues among participators of the SC can eliminate BWE in a significant manner.

Keywords: BWE, Operational causes, Behavioral causes, Statistical analysis.

1. Introduction

Increasing global competition, swiftly changing markets, and strategies and high complexity and uncertainty are creating a new competitive market environment. To cope up with this highly competitive market environment, Supply chain (SC) stability is one of the most important things. Bullwhip effect (BWE) is the main reason for this SC instability. Production and distribution is the center core process of many manufacturing industries. The occurrence of the BWE is first realized and studied decades ago by Forrester (1961) [1]. In the research of Handfield (2002), he said that the term "bullwhip" originated by the logistics executives of the Procter & Gamble [2]. Bhattacharya (2011) gave some examples of industries where BWE is common, such as grocery, retail, telecommunication manufacturing, computer components manufacturing, electronics industry, furniture industry, automotive industry, food, and beverage industry, apparel and so on [3]. Forrester (1961) found out that factory production rates often fluctuate more extensively than does the actual customer purchase rate and a small disturbance of information that occurred at the retail level, highly manipulate the information generated at the higher stage or manufacture level of the SC. This type of information distortion is known as BWE. The retailer provides order to a wholesaler based on the consumer demand and like this, the downstream stages place an order to its upstream stage according to the demand. The manufacturer delivered the manufactured product to the end consumer following the same chain in the opposite direction as shown in Fig. 1. Lee et al. (1997) and Chen et al. (2000) defined the Bullwhip effect as BWE has the tendency for variability to increase at each level of a SC as one moves from customer sales to production [4].

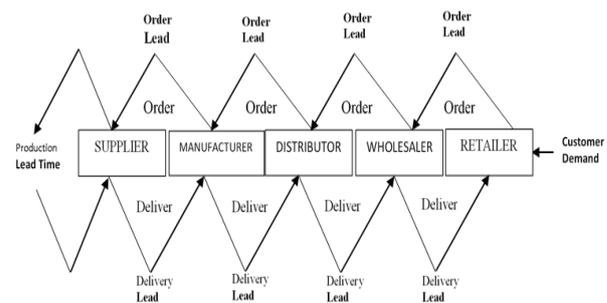


Fig. 1 A Typical SC

Sterman (2006) stated that people have some difficulties to take into account the impacts of their ordering decisions on the system because of the complexity of the system and the time lags between ordering and receiving goods [5]. Forrester (1958, 1961) named these two causes as operational causes and behavioral causes [6]. Croson et al. (2005) used found out that only downstream information sharing could significantly minimize the order fluctuations throughout the SC through beer distribution game [7]. According to Zajak (1989) strategy is the broad way in which an organization seeks to maintain or improve its performance [8]. Information enrichment and production lead time reduction significantly reduce the BWE and control system, time compression, Information transparency, Echelon elimination principles also reduces the BWE (McCullen and Towill, 2001) [9]. Machuta (2004) said the use of Electronic Data Interchange (EDI) provides substantial savings for each of the separate stages in the SC [10]. Sterman (2006) indicated in his research that, appropriate training of managers is required to get rid of the BWE.

Hossain et al. (2019) found out a gap where more “systematic” approach is needed to understand and manage any sort of unwanted consequences coming from complex supply chain network. To solve this gap, they propose a comprehensive model based on Bayesian network theory that addresses the risk and uncertainty associated with OGSC (Oil and Gas Supply Chain) and this Bayesian network is an analytical tool that demonstrates all the causal relationships among the different qualitative and quantitative variables and allows practitioners to understand the relative importance of independent variable(s) on a particular dependent variable for a given set of conditions. [11]. Strategy Formulation is an analytical process of selection of the best suitable course of action to meet the organizational objectives and vision.

A hypothesis is proposed for the statistical relationship between the two data sets, and this is compared as an alternative. According to N.U.I Hossain [2020], analysis that entails environmental factors and supplier responsiveness are imperative to port disruption and supply chain performance and for these kind of analysis sensitivity analysis is required [12]. Regression validation and significance analysis of BWE can be used to experimenting with the fitness of the SC. This study investigates some research questions based on different causes that occur BWE on the SC. To test these causes and research questions, organization level study in a large sample has been completed. Reliable and valid measures of operational causes, behavioral causes and relation of them with BWE are manifested from these data. Likert scale (1932) is used for analyzing the research questionnaire [13]. LISREL is used to examine the structural model that addresses these research questions. The proposed Research model of this study is given below.

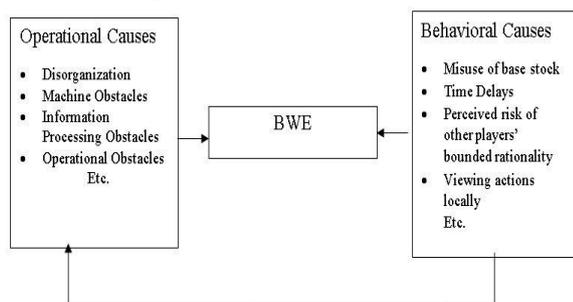


Fig. 2 Research Model of BWE

This research proceeded towards focusing the problems-order redundancy and supply shortage throughout the SC stages from the suppliers to retailers. It finds out that during festivals and occasions, outbreak and government regulation change shows extensive price variation, discount and behavioral and operational changes from both end which lead to BWE in SC. The main objectives of this research are

1. Development of relationship diagram among the causes related to SC performance by showing their effect on its performance.
2. Aggregation of sub-causes and determine their impact on SC performance by linear structural equation analysis (LISREL).

It will develop a Hypothesis model to analyze the impact of information sharing strategies on the magnification of demand fluctuations as orders move up the SC and identify the most important causes of the BWE.

2. Methodology

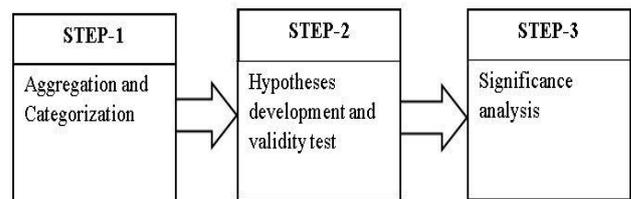


Fig. 3 Steps of the research process

The research steps are described below:

Step 1: Aggregation and Categorization of the causes of the BWE

This research identify and aggregate the causes of the BWE in Table 1 by literature review. This research will help to find out the bullwhip causes that are hinder to reach 100% success. These reasons will be categorized according to their causes and sub causes will also be found out.

Step 2: Hypotheses development among these causes and their validity test

A correlation and regression analysis will be performed among the causes and sub-causes according to their category. p-value, t-value and R-value will be analyzed and used to find out the proper result

Step 3: Significance analysis of Bullwhip causes on SC fitness

Finally, this research will develop a Hypothesis model of strategy formulation on the BWE by statistical analysis by using software SPSS®. According to Lawrence et al. (2019) a mixed-method research approach is the best fit approach to collect and analyze data consisting of qualitative and quantitative methods. [25]. Likert scale can serve this purpose to analyze the collected qualitative data will be used with range 1 to 5 to analyze the questions. From the model, it will be easy to identify the more effective and less effective causes of the BWE and aggregated the causes and develop linear structural relations.

2.1 Aggregation and Categorization of Bullwhip Factors

Aggregated bullwhip causes and its sub causes are shown in Table 1. Since it is necessary to aggregate all the items for each cause for their strategy formulation and signification analysis to enhancing competitiveness and loss minimization.

Table 1 Aggregation and Categorization of Bullwhip causes

Bullwhip causes	Main Causes	Operational Sub Causes	References	Main Causes	Behavioral Sub Causes	References		
Operational Causes	Disorganization (DO)		Prostean, G., & Badea, A. (2016) [14].	Behavioral Causes	Policies Obstacles (PLO)	Sunil, C., & Peter, M. (2013).		
	Number of Echelons (NOE)		Habibur et al. (2014) [15]				Bhattacharya, R., & Bandyopadhyay, S. (2011).	
	Workloads (WL)		Habibur et al. (2014)				Jakšič, M., & Rusjan, B. (2008) [19].	
	Machine Obstacles (MC)	MC1	Habibur et al. (2014)					Dolgui, A., & Proth, J. M. (2010) [20].
		MC2	Moyaux et al. (2007) [16]					
	Incentives Obstacles (IO)	IO1	Sunil, C., & Peter, M. (2013) [17].					
		IO2	Sunil et al. (2013).					
	Information Processing Obstacles (IPO)	IPO1	Sunil et al. (2013).					
		IPO2	Sunil, C., & Peter, M. (2013).					
		IPO3	Wang, H., & He, B. (2011) [18].					
		IPO4	Rachel Croson and Karen Donohue (2006)					
	Pricing Obstacles (PO)	PO1	Sunil, C., & Peter, M. (2013).					
		PO2	Sunil, C., & Peter, M. (2013).					
	Operational Obstacles (OO)	OO1	Sunil, C., & Peter, M. (2013).					
OO2		Sunil, C., & Peter, M. (2013).						

2.2 Hypotheses Proposition among Bullwhip Factors

Physical and Institutional structure is referred to as Operational causes. John D. Sterman (2006) said that Physical structure encircles the inventories' placement throughout the suppliers and customer network and production time delays, the fulfillment of an order, transportation, etc. The institutional structure includes the competition among and within firms, the degree of horizontal and vertical coordination, information availability to every organization and department and decision maker's incentives. For example, the bullwhip can arise from the causes if there are quantity discounts that encourage bulk purchases. Therefore

H1. The BWE is affected by operational causes.

Behavioral causes in the BWE are mainly descriptive, linking the difference between optimal adjustments to human biases. These biases are linked to the appearance of the BWE and observed in empirical data (Udenio et al., 2015) [23]. From this behavior, it has understood that decision-makers do not perform under the illustration of complete logicity (Su, 2008) [24]. Udenio found out through extensive numerical experiments that the performance of the system depends on the combination of the behavioral biases and demand stream structure. People make mistakes and it is shown that psychological biases affect decisions, which causes the BWE. Therefore,

H2. The BWE is affected by behavioral causes.

Experimental studies from Sterman (2006) show clearly that SC instability remains even after all operational causes such as quantity discounts are eliminated. There is no single cause for the failure to account for feedback, time delays, and the supply line. A range of factors, from information available to individual incentives, all contribute. But behind these apparent causes lies a deeper set of behavioral causes, causes rooted in our imperfect mental models and poor inquiry skills. Therefore,

H3. Operational causes are affected by behavioral causes.

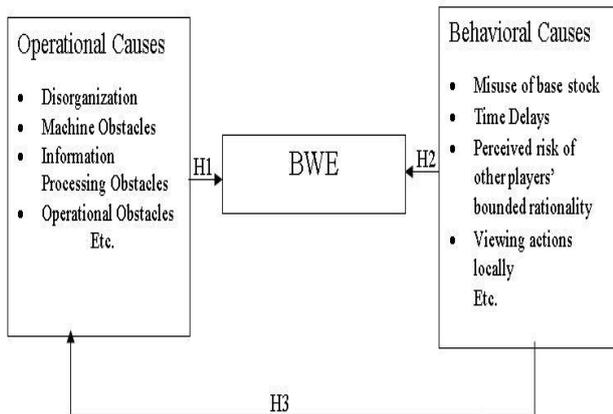


Fig. 4 Proposed Hypotheses Model of bullwhip effect

2.2.1 Scale Development

Table 2 shows the results of purifications using CITCs and Cronbach’s alpha (1951) for operational causes (OC) and Behavioral causes (BC) [26]. Items with the CITC’s value less than 0.5 is dropped. After dropping, among 19 OC there are 9 severe cause and for BC the severe cause’s number is 4. Cronbach’s alpha value and KMO value also showed in table 2. These two values were used to check the validity. The KMO value of OC is 0.696 and for BC it is 0.809. Both the value is above 0.5 which indicates that the factor analysis was appropriate. Loadings below 0.5 are not reported. Eigen value of OC is 5.764 and BC is 3.649. As both value is above 2.00 which indicates a positive analysis.

Table 2 OC and BC items with analytical values

Causes	Items	Sub items	CITCs	Cronbach’s α	KMO
Operational Causes	NOE		0.886	0.919	0.696
	IO	IO1	0.874		
		IO2	0.625		
	IPO	IPO1	0.788		
		IPO2	0.619		
	PO	PO1	0.600		
		PO2	0.619		
Behavioral Causes	OO	OO1	0.780	0.950	0.809
	PLO	PLO2	0.725		
		PLO3			
	PR		0.951		
	AV		0.958		
LOL		0.903			
	BO		0.878		

2.3 LISREL analysis and Structural modeling

LISREL is preferable to perform the regression, path analysis and/or correlation and it is also becoming popular with researchers as it can test casual models. LISREL is capable of simultaneously evaluating the measuring and causal parts of not simple and advanced models [27].

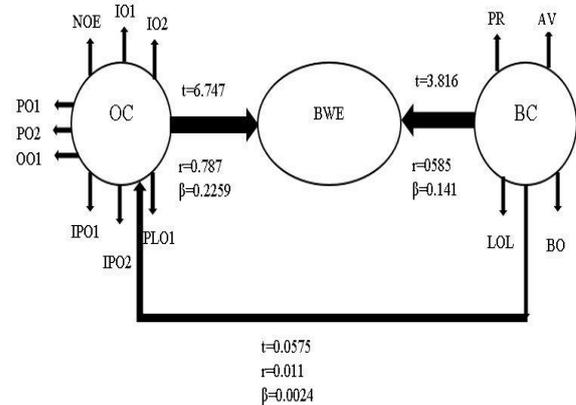


Fig. 5 BWE minimization Strategy formulation and relation with each other

Fig. 5 displays the relationship which is tested with structural equation modeling. The items preserved from scale development are used as the noticeable indicators of the exogenous latent variables, OC and BC. As the BWE mainly dependent on these two causes, there is no specific endogenous latent variable.

If the t-value is above 2.00 at ($\alpha=0.05$), then the statistical significance of the indicators are acceptable. [27]. From Table 3, LISREL analysis shows t- value

and p-value for OC to BWE and BC to BWE is above 2.00 and significant. So, Hypotheses 1 and 2 are both

Table 3 Summary of LISREL generated result

Relationship	t- value	P value	β value	Significant
(Test of Hypotheses 1,2 and 3)				
OC to BWE	6.747352	P<0.01	0.225864	YES
BC to BWE	3.816428	p<0.01	0.140644	YES
BC to OC	0.057486	p>0.10	0.002384	NO

accepted because a considerable positive relationship is represented between Operational Causes and BWE and between Behavioral causes and BWE. High price variation, Quantity discount on a large lot, a large number of echelons, providing sales force incentive by higher stages of the SC for selling high amount of product, etc. cause BWE. Lack of learning from previous action or problem, blaming others for information distortion, high action views and high player rationality also have a high effect to cause BWE. But as the t value is below 2.00 at ($\alpha=0.05$) for BC to OC it indicates that there is no significant relationship between Operational causes and behavioral causes. So hypotheses 3 is not considerable and there is no direct relationship between them.

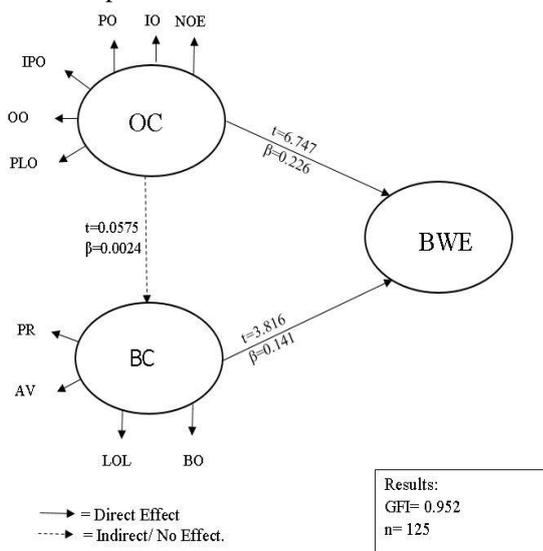


Fig. 6 Examining the relationship between OC, BC and BWE.

The GFI of 0.952 which is above 0.5 indicates a good model for data fit [28]. The final relationship of OC, BC and BWE is shown by **Fig. 6**. The Solid lines indicate the direct relation and the dotted line shows indirect relationship.

3. Results and Discussion

The primary objective of this research is to aggregate bullwhip causes and to develop a LISREL among these causes in the SC. In previous, the BWE causes were not aggregated as this and their significance analysis with each other was also not studied. Nine factors have been found out as the sub causes of operational causes and

four items in have emerged as a sub causes of behavioral causes shown in Table 2. The instruments used for analyzing are one-dimensional with sturdy proof of convergent, discriminant, and prognostic validity. Food and beverage companies in Bangladesh have helped this research for obtaining organization level survey and analysis of a large sample. Manufacturing firms were accustomed to develop the instruments and testing the research questions. Table 2 shows that among twenty- eight Bullwhip causes, nine operational causes and four behavioral causes are most important. The CITC value (above 0.5), Chronbach's alpha value (above 0.5), KMO and Eigen value (above 0.5), all are justified this result. To find out the significant analysis t-value and P value is used and GFI value indicates model fitness. So, the results of structural equation model testing expressly indicate that there is a positive relationship between Operation causes and BWE and behavioral causes and BWE (t-value is over 2.00) and model is also good fitted with GFI=0.952.

As BWE is enhanced by both OC and BC so this finding indicates that improving operational performance and designing proper product rationing plans can dampen information distortion. In addition, the BWE can reduce by designing pricing strategies that emboldened retailers to order in smaller lots and minimizing forward buying. The BWE can be reduced by minimizing the gap between the two parties. Assessing the value of the relationship, devising proper conflict resolution strategies.

4. Conclusion and Implication

The purpose of the study is to aggregate the causes of the BWE and developing a linear structural relationship among the causes. Three hypotheses were made initially to find out the relationship among operational causes, behavioral causes and BWE. After drawing up a precise definition of research objectives, the measurement scale for the constructs is validated and the set of hypotheses proposed was examined using structural equation modeling. After testing, from the three hypotheses, two of them were found out positive. The results of the unidimensional model with convergent and predictive validity show that operational causes have more and high impact on BWE than behavioral causes and between operational and behavioral causes there is no relationship.

As there are numerous causes that are the reason behind the BWE, solving all problem is both difficult and consume high cost. This research will be beneficial for any organization to take a close look at the most severe causes of BWE that are found out in this research to get the optimum result. Industries can produce exact amount of goods that is demanded so it will not cause any wastage problem. This research can also serve the academic purposes as it aggregate all kinds of causes from low to high that need to be considered to minimize BWE and optimizing organizations' supply chain efficiency.

In spite of its contribution, the research has some limitations that represent challenges for further research. The consideration of the economic recession on bullwhip, Multidimensional factors at a time and qualitative analysis is the future area of improvement of this research.

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