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# Fuzzy Logic Assessment for Bullwhip Effect in Supply Chain

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**ABSTRACT**

Having an efficient supply chain has always been a challenge for managers. One of the most important factors affecting the efficiency of the supply chain is the bullwhip effect. This effect influences the whole profitability of the supply chain and the first step to control the bullwhip effect is to measure it. Researchers have referred to different methods to measure the bullwhip effect, but if the data is incomplete, inconsistent, uncertain or unclear, then it is impossible to use them. In this paper, we create a model which uses Fuzzy Inference System (FIS). The flexibility of the proposed model allow managers to estimate the bullwhip effect which enable them to take action reduce this effect.

**KEYWORDS:** Bullwhip Effect, Fuzzy Inference System (FIS), Supply Chain

## 1. INTRODUCTION

Concurrent with the start of the 21st century, the success and survival of organizations have become more difficult. These are resulting from the period in which changes are inevitable. The constant changes in the business environment have forced organizations to think about a mechanism to face the environmental changes in the best possible ways. Having such an attitude, the topics related to the supply chain have found important positions.

Today there is no existence of competition among companies, but a competition among supply chains [1]. Supply chain is a network of organizations that are directly or indirectly involved in fulfilling the customer requirement [2]. The primary aim of each supply chain is to maximize the overall value generated. Success criteria of a generic supply chain should be measured for the overall chain profit, not at any specific level of the chain, because sticking to a portion of the chain not only makes no commitment to maximizing overall chain profit but also reduces the whole supply chain profitability [3]. One of the most important issues which have an impact on the whole supply chin profitability is the bullwhip effect. The bullwhip effect refers to the phenomenon of demand variability amplification along a supply chain while moving upstream.

The bullwhip effect increases the supply chain costs and decreases the customer service level by moving performance level of the chain away from the efficiency frontier, and this will result in more decrease in profitability. The bullwhip effect results in an increase in all costs in the supply chain including: manufacturing costs, inventory costs, transportation costs, and labor costs [3].The main challenge in managing the bullwhip effect is to reduce inefficiencies and attenuate its propagation throughout the supply chain, so that optimization of resources used in different levels becomes possible. To attain that, managers must single out what are the causes of the bullwhip effect in a supply chain and learn how to measure its intensity [4].

Quantitative and qualitative studies to attenuate this effect have been proposed but remain unsolved in many situations due to the complex nature of the bullwhip effect. One reason for that is the incomplete, inconsistent, uncertain or unclear data. In this situation, the bullwhip quantification is the most significant activities which could be done by us [5]. Because, this quantification enables the managers of the supply chain to forecast and afterwards, they can take necessary measures to prevent from the increase of this effect.

In this paper, a measure of bullwhip effect will be developed. The novelty of this work is combination of existing reasons in the literature and fuzzy inference system (FIS) for prediction bullwhip effect. Therefore, this paper is organized as follow. Firstly, section 2 review the literature on bullwhip effect in supply chain .Section 3 presents a conceptual model. In section 4 a fuzzy inference system is developed to evaluate bullwhip effect in supply chain. Section 5 evaluates the proposed model with a numerical example. Section 6 examines the validity of our fuzzy system. Finally, the conclusions are provided.

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## 2. LITERATURE SURVEY

The researchers made in the area of the bullwhip effect can be studied from two dimensions.

### 2.1. **Dimension 1:** Causes of the bullwhip effect

In general, two categories of causes are recognized which has become the standard in the literature. The first category focuses on operational causes. Operational cases refer to the physical and institutional structure. Physical structure includes the placement of inventories throughout the network of suppliers and customers and time delays in production, order fulfillment, transportation and so on. The institutional structure includes the degree of horizontal and vertical coordination and competition among and within firms, the availability of information to each organization and department and the incentives faced by each decision maker [6].These causes have been documented in practice, and techniques to eliminate them are now an important part of the tool kit for supply chain design [7].

The second category focuses on behavioral causes. Behavioral causes encompass the mental models of the decision makers, including their attitudes about other actors and the heuristics and routines they use to interpret the information they have and to make decisions such as production, capacity [6]. In the other hand, the behavioral causes emphasize the bounded rationality of decision makers, particularly the failure to adequately account for feedback effects and time delays [8].

### 2.2. **Dimension 2**: The tools which have been used for quantification

The researchers can be divided in four main categories:

Conceptual framework **-** Conceptual framework is a theoretical structure of assumption, principles and rules. Researchers use a conceptual framework to guide their data collection and analysis. In other words, conceptual framework is a written or visual presentation that explains either graphically, or in narrative form, the main things to be studied – the key factors, concepts or variables and presumed relation among them[9].

Analytical framework – In the analytical framework, the mathematical models such as probability, statistics, algebra and calculus are used..

The choice of this type of modeling draws on a number of assumptions regarding the mathematical robustness of the model [10].

Simulation framework – Simulation is a powerful framework for designing and analyzing systems. Simulation modeling provides the flexibility to model processes and events to the desired level of complexity, in a risk free, dynamic and stochastic environment. The simulation methodology provides a means by which decision makers can obtain accurate result, given the model is valid, that take into account the uncertainty, dynamism and distributed nature of supply chain [11].

Heuristic framework – Heuristic refer to experience-based techniques for investing time and problem solving. In this framework use the rules that called as knowledge structures. These rules are learned and stored then used to finding a solution.

## 3. Conceptual Model

We have used operational causes and behavioral causes as the basis of our conceptual model. In other words, they are the attributes of the research model. After that to select sub-attributes of model, we were gathered information from various references and designed questionnaire to select more effective sub-attribute which are presented in the table 1 along with respective sources references.

We have constructed the influence diagram. Influence diagram shows the relation between attributes and sub-attributes that has been shown in figure1.

Table 1. Attributes and sub-attributes of conceptual model

| Attribute | Sub-Attribute | Reference List |
|---|---|---|
| **Operational Causes** | Demand Forecasting | Lee et al. 1997, Chen et al. 2000 |
| | Order Batching | Lee et al. 1997, Riddal and Bennet 2001, Holland and Sodhi 2004 |
| | Price Fluctuation | Lee et al. 1997, Makui et al |
| | Gaming | Lee et al. 1997 |
| | Number of Echelon | Chandra and Grabis 2005 , Paik and Bagchi 2006 |
| | Capacity limits | Alony and Munoz 2007 |
| **Behavioral Causes** | Lack of Learning | Yan and Katok2006 |
| | Fear of Empty Stock | Croson and Donohue 2009, Steckel et al. 2004 |

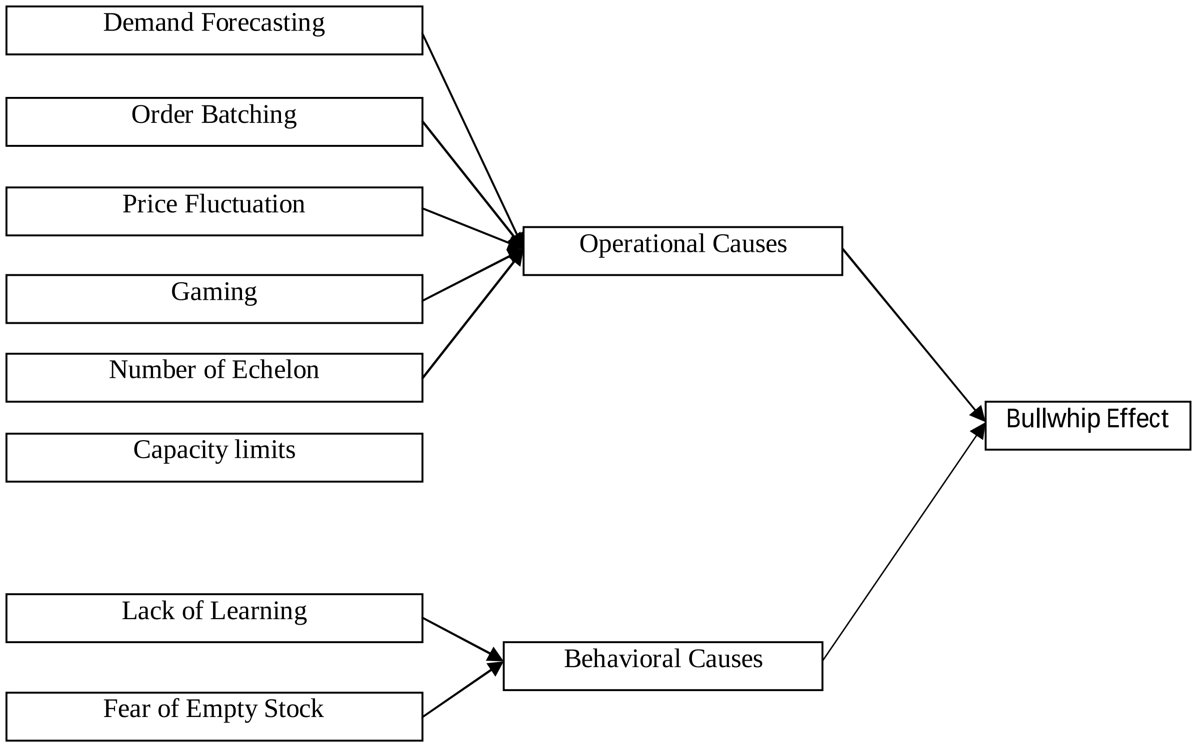


Figure1. Conceptual model

## 4. Fuzzy Model

In this paper a fuzzy model based on Fuzzy Inference System (FIS) is introduced for measuring the bullwhip effect by considering all the above- mentioned two attitude and their sub- attitude. A fuzzy inference system is a rule based system, with fuzzy set theory and fuzzy logic. The systems are mapping from an input space to an output space; therefore, they allow constructing structures which can be used to generate responses (outputs) to certain simulations (inputs) based on store knowledge on how the responses and simulations related. The knowledge is stored in form in of rule base, a set of rules that express the relation between inputs of system and expected outputs [12].

The first step to construct a fuzzy model is to select a membership function. A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1[13]. In this paper, membership functions are used to calculate the degree of fuzzy bullwhip effect in different values expressed by linguistic term such as low, low to medium, medium, medium to high and high. We have triangular membership function.

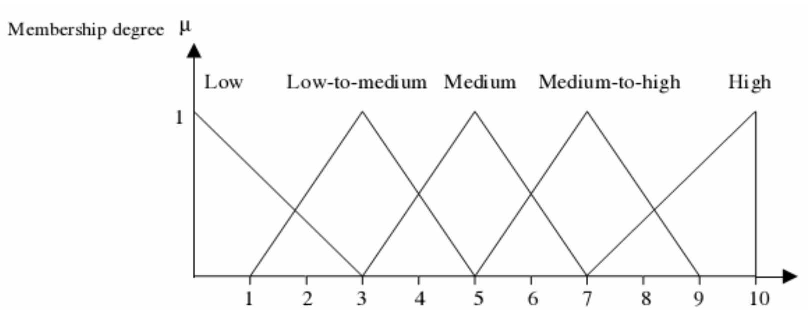


Figure2. Membership function

Next step is to create a rule base. All uncertainties, nonlinear relationships, or model complications are included in the descriptive fuzzy inference procedure in the form of IF-THEN statements. In general, a fuzzy IF-THEN rule has to constitutes; first the IF part and the second the THEN part; which are called premise and consequent, respectively. The general form of a fuzzy IF-THEN rule is IF z is A THEN f is B [14]. To do this step, a committee of expert who have proper experience and knowledge about attributes and sub-attributes was formed. The verbal options of these experts regarding the effect of different factor gathered and processed for generating a rule base. Some of rules are shown in table2.

Table 2. Some of the rules that use in rule base

| | |
|---|---|
| **1** | **If operational causes is low and behavioral causes is low then bullwhip effect is low** |
| 2 | If operational causes is low and behavioral causes is low to medium then bullwhip effect is low |
| 3 | If operational causes is low to medium and behavioral causes is low then bullwhip effect is low to medium |
| 4 | If operational causes is low and behavioral causes is medium then bullwhip effect is low to medium |
| 5 | If operational causes is medium and behavioral causes is medium to high then bullwhip effect is medium |

In the last step, we need an algorithm to aggregate the rules to reduce size of rule base. We use the technique that looks for rules that IF part (premise) is similar the THEN part (consequent) should adjust. This technique compares the rules in pairs and at the end, we got a rule base with less rules but a more effective one.

## 5. Case Study

The proposed model has been applied to an Iranian manufacturing company to evaluate the bullwhip effect. This company produces seven types of productions. It represents a seven-product and four-stage supply chain with end customers, five retailers and one manufacturer. In consist of three main rule blocks and eight inputs, two intermediates (operational causes and behavioural causes) and the output of fuzzy inference system is the bullwhip effect in supply chain.

We use MATLAB software to drive final aggregated result by Mamdani (Max/Min) inference method, and also to find a crisp value for the aggregated output, we have chosen the centre of gravity, the most prevalent and physically appealing of all the Defuzzification methods. Then we have mentioned in proposed method, the bullwhip effect in this company is evaluating 1.32. It can be labelled low bullwhip effect.

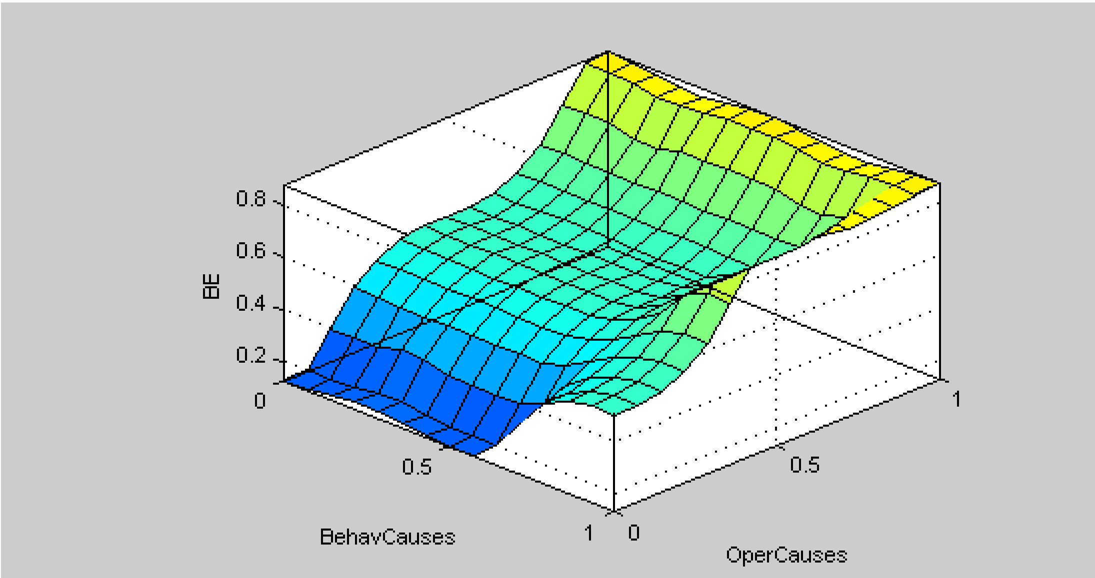


Figure3. Output surface

## 6. Validation

In this stage, we have studied the validity of our constructed fuzzy system. For this propose, we provided two series of information. The first series is the output of our system (BE1) and the second series is the bullwhip effect being qualified by using the previous prevailing method.

We chose Kruskal-Wallis test. This test can be applied in the one factor ANOVA case. It is a non-parametric test for the situation where the samples are not from normal distribution/population or the variances are heterogeneous [15].

The hypothesis test is as follow:

$H_0 : \mu_1 = \mu_2$

$H_1 : \mu_1 \neq \mu_2$

Test statistic:H= $\frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{R_I}{n_i} - 3(n+1)$ (1)

Significance level: typically set 0.05

For testing this hypothesis, Pvalue is calculated 0.416. $H_0$ cannot be rejected because the test statistic is not in the critical region and there is no significant difference between two mentioned data in table.3. It means that we cannot find a significant difference between system behavior and the previous prevailing method.

Table.3. system output (1) and the previous prevailing method (2)

| BE1 | BE2 |
|---|---|
| **2** | 1.42 |
| **1.5** | 1.3 |
| **1.71** | 1.52 |
| **1.9** | 2.02 |
| **1.06** | 1.2 |
| **1.3** | 1.11 |

## 7. Conclusion

The bullwhip effect is an important phenomenon in supply chains. The two sources for bullwhip effect are recognized in the literature: operational causes and behavioral causes Therefore, a model is which helps manager quantify and view all the above- mentioned. The fuzzy logic in quantifying the bullwhip effect in a supply chain has been described in this paper. The unique feature of this system is in adopting a fuzzy inference system to deal with bullwhip effect, and in particular predicting bullwhip effect when vague and inaccurate data is exist. The fuzzy rule based system is more useful in modeling some complex systems that can be observed by humans because they make use of linguistic variables as fuzzy rule base.

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