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A Study on Bullwhip Effect on Various Stages of Supply Chain

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Abstract: The purpose of the present study was to investigate bullwhip effect on various stages of supply chain and changing inventory control parameters. The results were investigated step by step. To this end, four variants of the main supply chain model were explored and the obtained results were put in bullwhip effect. In the study, we employed a combination of Arena high-level simulation tool and Java programming language to simulate the model. As we observed, bullwhip effect and lead time, periodic review and safety time were directly 58.19, 120.7 and 1498.57%, respectively. Forecast window was the only variation which had a good effect (14.98%, reversely). Regulating these parameters can lead to promising results regarding bullwhip effect and identify the best combination of parameters which lead to the least change in order.

Key words: Java, bullwhip, chain model, arena, order

INTRODUCTION

Gradually, supply chains have been changed into a dominant paradigm in business world. Forrester, the founder of supply chains discussion, claimed that management is exposed to a change which makes organizations' success dependent on effective interaction of information flow, materials, capital, human resources and equipments. He established an idea which is today, an undeniable theory in various businesses domain (Mentzer, 2004). Perhaps, nowadays, no organization can be imagined without considering its place in a supply change. Developing the concept of supply chain is in such a way that some scholars believe currently, competition has been transferred from companies to chains. In fact, supply chain concept has been mainly developed in the two last decades such that many big international organizations have benefited from it gradually. Chopra and Meindl (2007) consider supply chain as all members who are directly and indirectly involved to meet a customer's need. Usually, a supply chain includes five stages of customers, retailers, wholesalers/distributor, producers and ingredients suppliers.

Successful direction of each supply chain involves wide managerial efforts and adopting various policies. Management facilitates the main streams of each chain including materials, capital and information. The issue of demand forecast is highly important in supply chains management. According to the definition of supply chain, the main purpose of each chain is to meet customers' needs. Therefore, knowing about future needs is necessary for supply chains. Forecasting, in fact is a base for supply chain planning. In a common classification there are four methods of forecasting: qualitative methods, time series, causal methods and simulation. Each of these methods is employed in various situations and has their own advantages and disadvantages. One the important management issues in supply chain management is bullwhip effect. Briefly, bullwhip effect refers that demand fluctuations of the last level of customers in supply chain is increased as moving along supply chain stages (Rui *et al*., 2007). For the 1st time, this effect was proposed by Forrester in the book of "industrial dynamicity". Forrester introduced this effect due to the change in organizations' behavior (Forrester, 1961). Such effect causes improper planning, the increase of inventory level, the decrease of benefit, the decrease of service level and other harmful consequences for organizations. Accordingly, many studies have been performed on this issue. Researchers have introduced various factors leading to this effect including demand forecasting, cluster orders, price fluctuations, rationing decisions, time lags and incongruity in chain structure. Lee *et al*. (1997) have introduced four basic factors to create bullwhip effect including demand forecasting, cluster order, price fluctuations, rationing and shortage. Also, Paik and Baghchi (2007) have considered updating demand forecasting, cluster order, ingredients lags, information lag, purchasing lag and the number of chain levels as the effective factors in bullwhip effect. In Iran, a wide range of studies have been performed on supply chain management as well as the effect of bullwhip. For example, we can refer to the study by

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Movahedi in which the role of financial factors in bullwhip effect was investigated in a two-level supply chain. Zanvar and Mahnaj (2011a, b) also studied the effect of turbulent demand forecasting system on bullwhip effect in supply chain. Further, Nazari and Aghayi (2012) evaluated bullwhip effect phenomenon in three-level supply chain with more than one product.

As observed, one of the factors influencing bullwhip effect creation is demand forecasting. The reason of such impact can be found in beer game established by Sterman (1989). This game, indeed, consists of a four-level chain. In the game, each level adopts its ordering decisions independently from other level. Principally, decision makers of these four levels regulate their ordering policy without considering other levels. Accordingly, dispersion of orders is always increased from the lowest level of chain to its highest level. This game, in fact, confirms the effect of forecasting methods due to bullwhip effect. Identifying the effect of forecasting effect due to bullwhip effect causes to conduct various studies to investigate this effect. The purpose of the paper is to investigate and compare various forecasting methods on bullwhip effect in a three-leve chain.

LITERATURE REVIEW

Increasing growth of supply chains in various business domains has been faced with different challenges and considered by researchers and mangers. One of the issues considered by researchers in supply chains is bullwhip effect and its influencing factors. Bhattacharya and Bandyopadhyay (2011) reviewed factors influencing bullwhip effect. Chatfield *et al.* (2004) investigated the effect of random preparation times, information sharing and shared information quality on bullwhip effect. Machuca and Barajas (2004) investigated the effect of electronic exchange of data on the decrease of bullwhip effect as well as inventory average cost using internet simulation software. Kelepouris *et al.* (2008) analyzed the way of influencing supply parameters and information sharing on bullwhip effect. Jaksic and Rusjan (2008) studied the effect of supply policies on this effect. Sengupta and Shanker (2009) evaluated the effect of preparation time on supply policies of this effect. Bray and Mendelson (2012) investigated the effect of information exchange between supply chain levels due to bullwhip effect. One of the factors which highly influence bullwhip effect as scholars believe is to use various forecasting methods by supply chain rigs. In this regard, many studies have been conducted on the effect of forecasting methods on bullwhip effect. For example, Chen *et al.* (2000a, b) investigated and compared the effect of exponential smoothing and moving average methods on bullwhip effect in a simple two-level supply chain including a retailer and a producer. Chen *et al.* (2000a, b) also studied the effect of demand forecasting and order providing time on bullwhip effect in a two-level supply chain and generalized its results to multi-level chains. Zhang (2004) explored the effect of forecasting methods on bullwhip effect in a simple inventory supply system. He concluded that forecasting methods influences bullwhip effect. Carbonneau *et al.* (2008) investigated the effect of learning methods such as neural networks, regressive neural networks and backup vector machines for forecasting due to bullwhip effect. They then compared them with traditional methods such as moving average and linear regression. Bayraktar *et al.* (2008) studied the effect of exponential smoothing method due to bullwhip effect in electronic supply chain management. They developed a simulation program to select the best exponential smoothing parameters in the chain. Barlas and Gunduz (2011) introduced one of the structural roots of bullwhip effect in supply chain as incongruous use of various chain levels of forecasting methods. Najafi and Farahani also studied and compared the effect of moving average forecasting methods, exponential smoothing and linear regression due to bullwhip effect in a four-level chain in two states of constant and linear. They assumed that all the members of the chain use similar methods to forecast their demand. Abadi *et al.* (2007) investigated the effect of X+Y ordering pattern on the decrease of bullwhip effect in supply chain. Zanvar and Manhaj (2011a) designed a combinational framework of turbulent demand forecasting and predictive pattern control to minimize bullwhip effect. Esmaeili compared the effect of various forecasting methods on bullwhip effect in supply chain. They primarily investigated the role of moving average and exponential smoothing methods to create or intensify bullwhip effect in a part of a real two-level supply chain including a supplier and four retailers. Considering eight different patterns for retailers' demand they computed the value of bullwhip effect in two forecasting methods in various periods through various correlation coefficients.

THE PROPOSED MODEL

This study attempted to investigate the effect of bullwhip on various stages of supply chain to explain the effects of changing inventory control parameters. The obtained results including variance and order increase were investigated step by step. Accordingly, four variants of the main supply chain model were explored and the obtained results were put in bullwhip effect. As we stated earlier, inventory control plays an important role in supply chain management. Inventory control can determine the extent and time of order. When forecasting is entered into the process of order, bullwhip effect appears in supply chain. It is only due to the fact that forecasting is based on occurring statistics. Stock-to-demand policy creates better results on bullwhip effect compared to min-max inventory policy. Regardless of the fact that whether customer has shared demand related information or not, stock-to-demand model will have always better performance. Accordingly, it is the best choice to allow inventory management in central model is based on stock-to-demand policy. This policy is a type of periodic review model in which:

- Inventory level will be reviewed at any predetermined interval (in the research model, every week)
- In each review, an order is created to take back up at a certain level of inventory

Supply chain model: In this study, the general form of the central model is discussed. Since, there are many variations of supply chain models, the main model is considered as the central model and its other variations are allocated name and number to be identified. The research model includes a four-stage supply chain with a structure similar to beer distribution game. This model entails a retailer, wholesaler, distributor and factory (Fig. 1). This structure is widely used placed in the middle of simple two-stage supply chains and complex supply networks.

Bullwhip effect: All the inventories in the four stages act under stock-to-demand policy. Due to stock-to-demand policy order of each stage is put in a predetermined review period for supplier. The extent of order is the difference between the considered level and effective inventory level in review time. The effective level refers to the amount of inventory plus on order extent minus backorder cargos or the amount allocated to product. Safety time, here is the interval between ordering and receiving. Periodic review refers to the number of weeks between two reviews. Safety time indicates safety stock described by the number of demand's average weeks. Forecasting is computed by moving average. Therefore, forecasting future demand is constantly updated when in case of facing with new demand actualization. In the central model, a moving average has been used from the last 10 weeks. Bullwhip will be computed using the following equation:

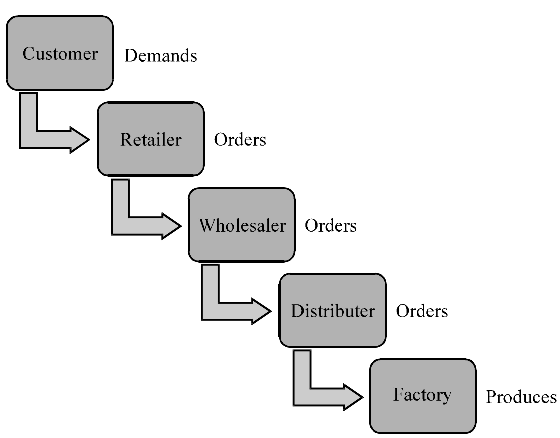

Fig. 1: The studied four-stage supply chain

$$\text{Order} = \text{Considered level} - (\text{Inventory} + \text{On order} - \text{Backorder})$$

$$\text{Considered level} = \text{Forecasting} \times (\text{Lead time} + \text{Periodic review} + \text{Safety time})$$

$$\text{Bullwhip} = \text{Order variance}/\text{Demand variance}$$

If the value of bullwhip equals 1, the variance of order equals the variance of demand in other words there is no increase in variance. If the value of bullwhip is >1 there is bullwhip effect. If bullwhip effect is <1 it is known as smoothing scenario.

Research hypotheses: The research hypotheses can be presented as following:

- It is assumed that customers are highly patient and loyal. In other words they wait for their considered order if it is not available at a time and won't provide their order from another story
- Four-stage supply chain works based on decentralized information sharing policy in which each stage computes its demand forecasting not based on real user demand but based on orders taken from lower stage
- No capacity limitation has been assumed for inventories
- Customer's orders from retailer follow a normal distribution with the mean of 100 and variance of 30
- Fulfilling orders in each stage takes time (lead time); therefore orders cannot be fulfilled immediately
- Backorders are allowed therefore, if one of inventories cannot supply entire the order, its shortage is maintained as backorder to supply the order it as soon as receiving new goods

- Periodic review has been determined 1 week
- Lead time has been definitely considered 2 days
- Safety time has been determined 1 week and half
- In the model, the basic time unit is 1 week
- Simulation is started with the primary valuing of 500 items per inventory
- To compute order, if stock is higher than the considered level order equals zero. That is no order has been fulfilled in this week
- The simulated model is run for 150 weeks and a 35 weeks warm up period is also specified such that the primary valuing is not considered to compute mean statistics

THE MODEL ALGORITHM

Customer-retailer interaction: In the final algorithm, it can be seen how customer and retailer interact. In this algorithm, customer's demand is fulfilled every week. Retailer tries to supply all orders unless a backorder occurs.

Retailer-wholesaler interaction: In the final algorithm, the process of the relation between retailer and wholesaler in supply chain has been described. Such a relation occurs in the form of sending an order to wholesaler based on a weekly review in which retailer's inventory occurs. Wholesaler tries to supply all orders unless a backorder occurs. Retailer receives new goods after predetermined lead time. This lead time can be considered as the time of preparing order and transporting it. When retailer receives the ordered value (or a part of it), he/she primarily begins to supply backorders. If something remains, retailer adds it to his/her inventory.

Wholesaler-distributor-factor interaction: A similar process also occurs between both sequential stages in supply chain (wholesaler-distributor and distributor-factory). At the last stage, i.e., factory, the process is a bit different since here is the end of the chain. Therefore, production should be more emphasized than order from the previous stage.

Simulation algorithm:

```
Setting variables
        W = Week
        RI = Retailer Inventory
        D = Demand
        RB = Retailer Backorder
        O = Order
        WI = Wholesaler Inventory
        RO = Retailer Order
        WB = Wholesaler Backorder
        LT = Lead Time
        RP = Review Period
        ST = Safety Time
        OH = On Hand
        OO = On Order
        BO = Backorder
        T = Target
Customer and retailer ( )
        For n = 1 to W
        D = New Demand ( )
        IF (RI≥D) Then
              RI = RI-D
        Else
              RB = RB+(D-RI)
        RI = 0
W = W+1
Retailer and Wholesaler ()
        IF (WI≥RO) Then
              WI = WI-RO
        Else
              WB = WB+(RO-WI)
              Order. Reset ()
        IF Rb≥RO Then
              RB = RB-RO
        Else
              RI = RO-RB
        Rb.Reset()
        WI.Reset()
Wholesaler and distributer and factory ()
        LT.Set()
        RP.Set()
        ST.Set()
        OH.Set()
        OO.Set()
        BO.Set()
        O.Forcast(Last(10))
        T = O×(LT+RP+ST)
        O = T-(OH+OO-BO)
```

RESULTS

The effect of bullwhip without applying change parameters: The central model has been run with a reiteration and the variances of demand, retailer, wholesaler, distributor and factory have been obtained. These values have been presented in Fig. 2. As shown in the figure, demand variance is increased as a result of

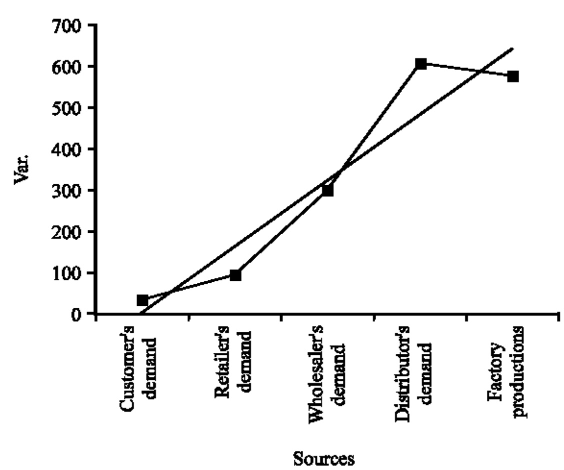

Fig. 2: Variance increase in supply chain

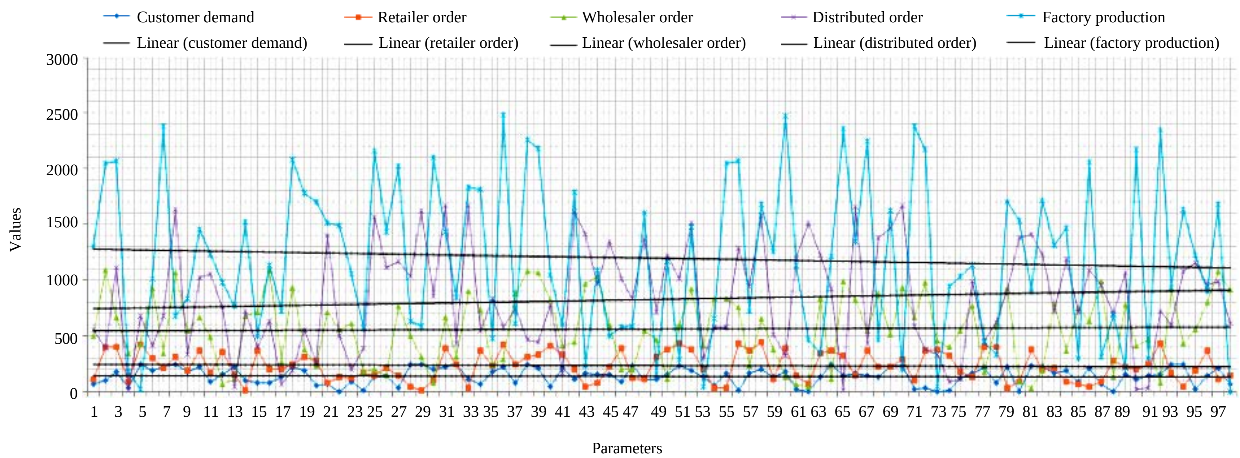

Fig. 3: The amount of order in supply chain: bullwhip effect without applying variant parameters

increasing supply chain stages (other than factory production). Such a phenomenon is called bullwhip effect. The amount of this increase is variable in each stage. It has been proved that such an increase depends on many factors such as lead time, safety time, periodic review and forecast window.

The orders are increased in higher stages of supply chain. It is the same thing shown in Fig. 3. In this Fig. 3, Customer's demand-retailer's demand-wholesaler's demand-distributor's demand-factory productions are compared with each other. Note that the value of orders may be zero; in other words, no order has been fulfilled in this week. Zero orders have been omitted for visual cause and only orders with positive values have been depicted.

Variant parameters effects: Supply chains are controlled by many parameters and some of these factors directly influence bullwhip effect. In this study, we clarify these parameters and monitor system behavior and reaction of bullwhip during their change. The purpose is to decrease or minimize bullwhip effect as well as finding parameters to achieve such an objective. Entering data, we can exactly review the model behavior. Such a fact helps to confirm the model outputs which had fulfilled by detecting numbers and values produced by the system and manually confirming them through mathematical formula employed in the model construction.

Lead time and bullwhip effect: This is the first change in the central model. Increasing lead time has a direct effect on bullwhip effect, leading to increase it. Doubling lead time from 2-4 days and considering orders' variance at various stages, we can clearly see than the variance is more than what it was in the central model. It indicates that bullwhip effect is increased. Figure 4 shows orders

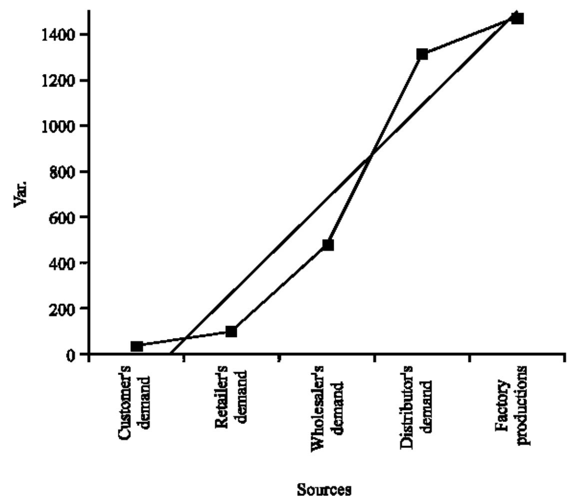

Fig. 4: Changes of variations due to lead time increase

during lead time increase. Currently, the amount of order approximately reaches to 6000 items while it previously was at most 2700 items. To describe, we can state that lead time is a component of equation computing the considered level. Therefore, increasing lead time causes the increase of the considered level and orders can given in fewer times but higher values. The fewer times of ordering may indicate the closure of a factory. In a factory for example, production in fewer times and high amount indicates that the factory sometimes has to produce a high volume of goods. However, factory sometime is inactive has no production and relies on warehouse stock only. Such a fact also may lead to the increase of costs due to high volume of warehouse goods (Fig. 5).

Periodic review, safety time and bullwhip effect: It is expected that the same thing occurred due to lead time

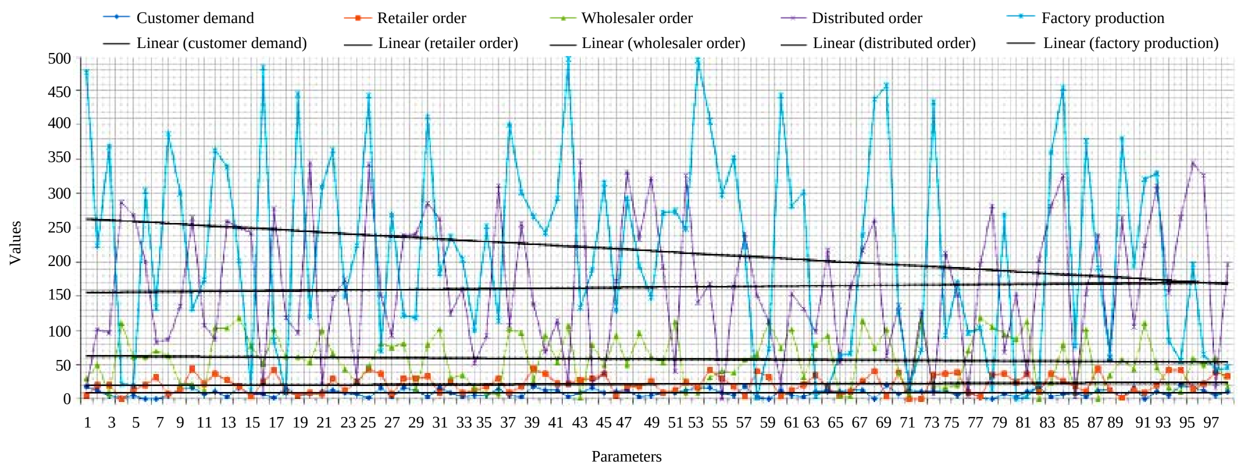

Fig. 5: The increase of order amount due to lead time increase

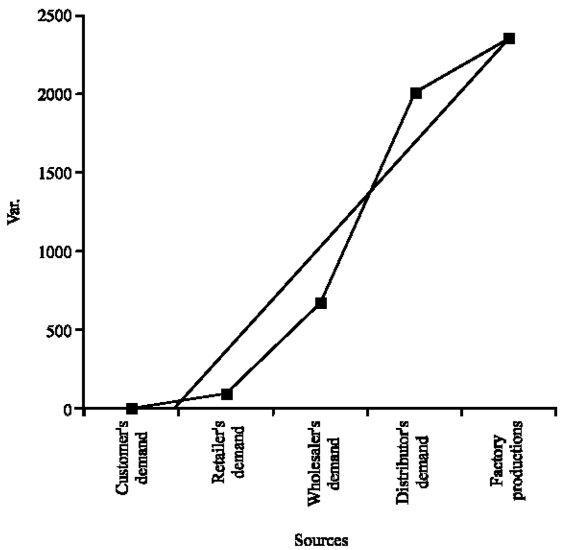

Fig. 6: Changes of variations due to periodic review increase

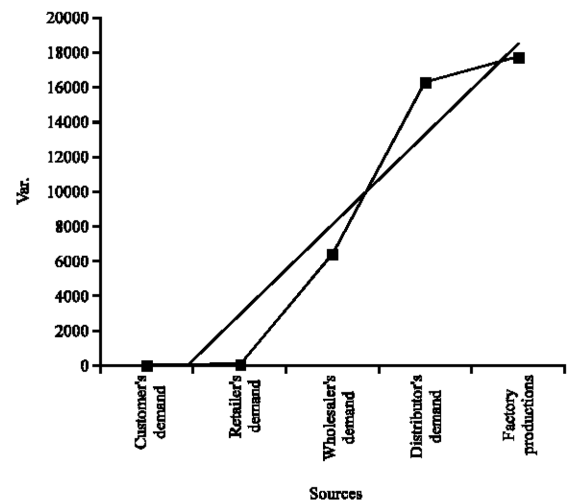

Fig. 7: Changes of variations due to safety time increase

increase occurs regarding periodic review and safety time. These three parameters have identical properties and all the three are the components of an equation computing the considered level. An increase in each of the three parameters causes to an increase in the considered level. Accordingly, it leads to orders with fewer times but high volume. Notably, the amount of order increase is measured to allow comparing the effect of such change in each parameter. In the following this observation will be proved through simulation. In type 2, periodic review has been increased from 1 to 2 weeks. In type 3, safety time has been also changed from 1 and half to 3 weeks. Now, let know about the change in order variance and amount. Clearly, variance is significantly increased, particularly regarding type 3 when safety time is increased. Consider that demand distribution in the central model and all changes of the variations has remained identical: a normal distribution with the mean of 100 and variance of 30 (Fig. 6-9).

Forecast window and bullwhip effect: We employed moving window average as a forecasting technique in the model. Moving window average allows forecasting another parameter called forecast window. In the central model, the window of the last 10 orders has been used. In the model, type 4 is used to increase forecast window to reach the last 20 orders. As shown in Fig. 10, type 4, particularly at the last 3 stages was improved. According to Fig. 8 and comparing it with Fig. 4, a lower order variance can be visually identified. Such a behavior leads to the increase of bullwhip effect. Therefore, the increase

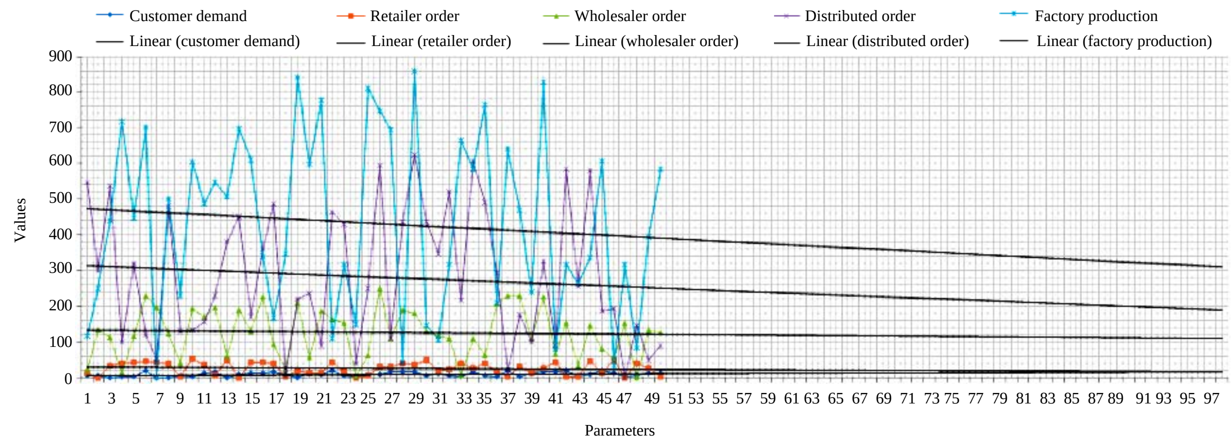

Fig. 8: The amount of order due to periodic review increase

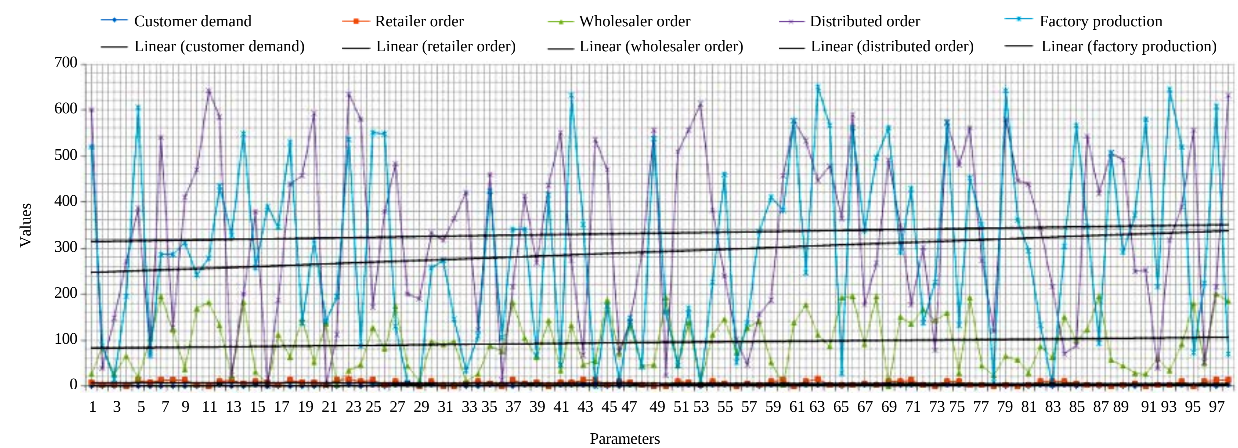

Fig. 9: The amount of order due to safety time increase

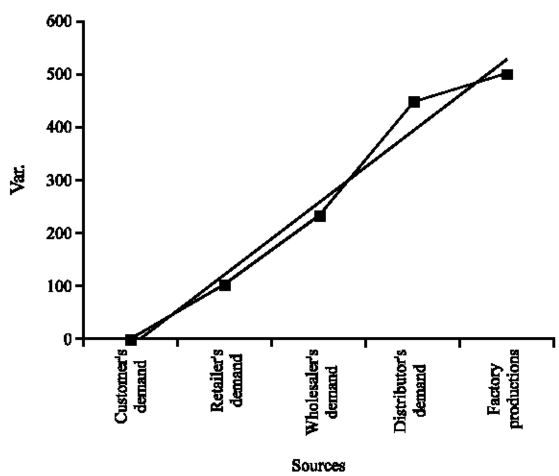

Fig. 10: Changes of type due to forecast window increase

of moving window average causes to foster bullwhip effect. Such a fact is due to the creation of more reliable forecasts (Fig. 11).

Case study: In the study, we worked on a simulated model of a four-stage supply chain which used stock-demand policy in its all stages. The results obtained from the model parameters change have been grouped in Fig. 12 and 13 in terms of order changes between sequential stages.

As shown in the previous figure, a summary of performed investigations was presented indicating that the change of some system parameters and monitoring its effect on variation of orders at all four stages of supply chain. Standard deviation of orders was also shown after the change of lead time, periodic review, safety time and forecast window. Figure 12 presents the results with the increase (in percent) of bullwhip effect compared to the amount of change in parameter (percentages have been measured relative to the central model).

All four parameters were doubled; therefore, we have an identical measurement unit for parameter increase. Accordingly, we will focus on increase percentage in variation of orders and measure an average increase for the entire of the supply chain (Fig. 13 and 14).

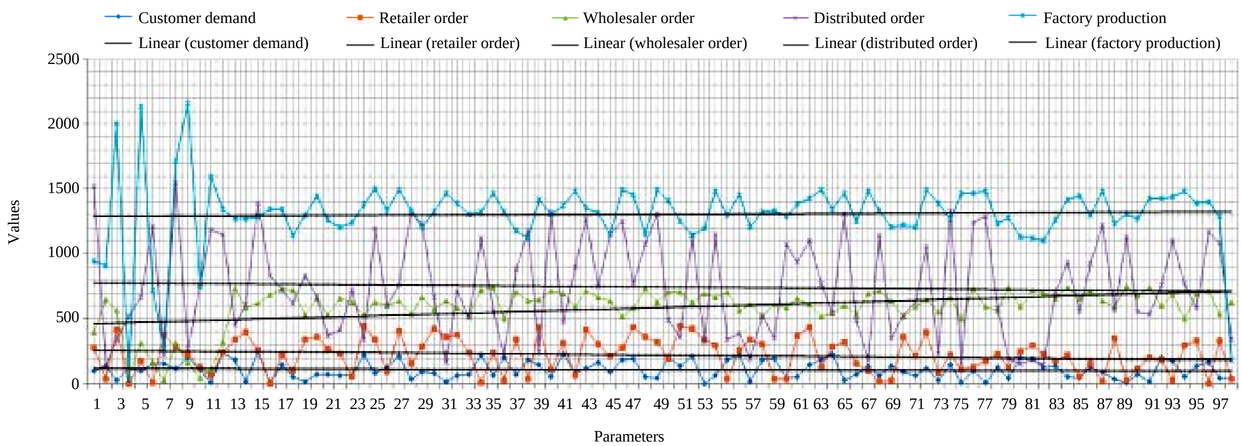

Fig. 11: The amount of order due to forecast window increase

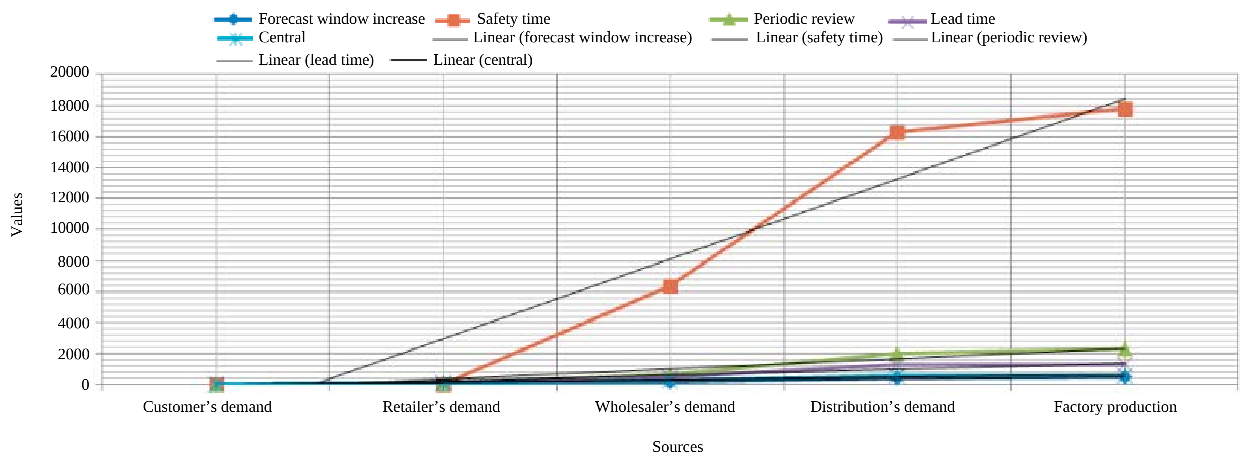

Fig. 12: The real study results

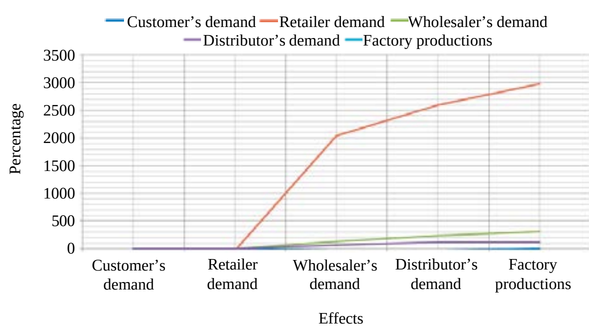

Fig. 13: The percentage of bullwhip effect increase

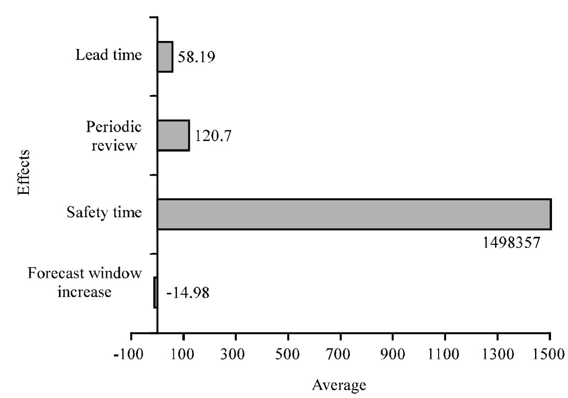

Fig. 14: The average of bullwhip effect change percentage

According to Fig. 14, we can clearly observe that bullwhip effect has been increased due to doubling lead time, periodic review and safety time. However, doubling forecast window has led to the decrease of bullwhip effect. Another important point is that sometimes, bullwhip effect is decreased at the beginning of supply chain but it is increased at the nest stages. According to these observations, we can state that global analysis regarding supply chain is very important. If each stage makes decision based on local analysis, a highly bad management can be created in the entire the supply chain. This bad management, accordingly will influence all stages in supply chain.

CONCLUSION

The factors influencing bullwhip effect are complex which cause more challenges to investigate them. In the present study, we discussed the reaction of bullwhip effect in response to variable parameters of the system. Most of our focused parameters directly rely on the type of stock-to-demand policy at each stage of supply chain. Therefore, we can consider this study as a description of bullwhip effect using stock-to-demand policy as well as the way of regulating this policy's parameters to minimize bullwhip effect. Simulating the central model and its variations indicates that changing the model parameters directly influences bullwhip effect in the entire supply chain. As we observed, doubling lead time led to the increase of bullwhip effect (58.19%), doubling periodic review (120.7%) and doubling safety time (1498.57%). Forecast window was the only variation which had a good effect. In fact, forecast window caused to a decrease of 14.98%, on bullwhip effect. Regulating these parameters can lead to promising results regarding bullwhip effect and identify the best combination of parameters which lead to the least change in order.

REFERENCES

Abadi, E.N.K., J. Heidari, M.K. Shahrestanaki and M. Safaryan, 2007. Investigating the effect of X+Y ordering pattern on the decrease of bullwhip effect in supply chain. Ind. Manage. Seasonal, 1: 19-27.

Barlas, Y. and B. Gunduz, 2011. Demand forecasting and sharing strategies to reduce fluctuations and the bullwhip effect in supply chains. J. Oper. Res. Soc., 62: 458-473.

Bayraktar, E., S.C. Lenny Koh, A. Gunasekaran, K. Sari and E. Tatoglu, 2008. The role of forecasting on bullwhip effect for E-SCM applications. Int. J. Prod. Econ., 113: 193-204.

Bhattacharya, R. and S. Bandyopadhyay, 2011. A review of the causes of bullwhip effect in a supply chain. Int. J. Adv. Manuf. Technol., 54: 1245-1261.

Bray, R.L. and H. Mendelson, 2012. Information transmission and the bullwhip effect: An empirical investigation. Manage. Sci., 58: 860-875.

Carbonneau, R., K. Laframboise and R. Vahidov, 2008. Application of machine learning techniques for supply chain demand forecasting. Eur. J. Oper. Res., 184: 1140-1154.

Chatfield, D.C., J.G. Kim, T.P. Harrison and J.C. Hayya, 2004. The bullwhip effect-impact of stochastic lead time, information quality and information sharing: A simulation study. Prod. Oper. Manage., 13: 340-353.

Chen, F., J.K. Ryan and D. Simchi-Levi, 2000a. The impact of exponential smoothing forecasts on the bullwhip effect. Naval Res. Logist., 47: 269-286.

Chen, F., Z. Drezner, J.K. Ryan and D. Simchi-Levi, 2000b. Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times and information. Manage. Sci., 46: 436-443.

Chopra, S. and P. Meindl, 2007. Supply Chain Management: Strategy, Planning and Operation. 3rd Edn., Prentice-Hall, New Jersey.

Forrester, J.W., 1961. Industrial Dynamics. 1st Edn., Pegasus Communications, Waltham, MA., USA., ISBN: 1883823366.

Jaksic, M. and B. Rusjan, 2008. The effect of replenishment policies on the bullwhip effect: A transfer function approach. Eur. J. Oper. Res., 184: 946-961.

Kelepouris, T., P. Miliotis and K. Pramatari, 2008. The impact of replenishment parameters and information sharing on the bullwhip effect: A computational study. Comput. Oper. Res., 35: 3657-3670.

Lee, H., V. Padmanabhan and S. Whang, 1997. The bullwhip effect in supply chains. Sloan Manage. Rev., 38: 93-102.

Machuca, J.A. and R.P. Barajas, 2004. The impact of electronic data interchange on reducing bullwhip effect and supply chain inventory costs. Transp. Res. Part E Logist. Transp. Rev., 40: 209-228.

Mentzer, J.T., 2004. Fundamentals of Supply Chain Management: Twelve Drivers of Competitive Advantage. Sage Publications Inc., Thousand Oaks, CA., USA., ISBN-13: 9780761929086, Pages: 293.

Nazari, L. and A. Aghayi, 2012. Evaluating bullwhip effect in 3-stage supply chain with more than one product. Ind. Eng. Mag., 1: 105-113.

Paik, S.K. and P.K. Bagchi, 2007. Understanding the causes of the bullwhip effect in a supply chain. Int. J. Retail Distrib. Manage., 35: 308-324.

Rui, X., X. Ri, X. Song and G. Liu, 2007. The analysis of bullwhip effect in supply chain based on strategic alliance. IFIP Int. Fed. Inf. Process., 251: 452-458.

Sengupta, R.N. and K. Shanker, 2009. Impact of information sharing and lead time on bullwhip effect and on-hand inventory. Eur. J. Oper. Res., 192: 576-593.

Sterman, J.D., 1989. Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment. Manage. Sci., 35: 321-339.

Zanvar, R.Y. and M.B. Mahnaj, 2011a. The effect of turbulent demand forecasting system on bullwhip effect in supply chain: A comparative approach. Perspect. Ind. Manage. Mag., 3: 27-29.

Zanvar, R.Y. and M.B. Mahnaj, 2011b. The design of a combinational framework of turbulent demand forecast and predictive pattern control to minimize bullwhip effect. Perspect. Ind. Manage. Mag., 6: 171-178.

Zhang, X., 2004. The impact of forecasting methods on the bullwhip effect. Int. J. Prod. Econ., 88: 15-27.