Reducing bullwhip effect in supply chain of manufacturing industry dependent on many suppliers through forecasting

Rahul K. Parmar[1], Alpesh M. Patel[2]

[1]*Post graduate student, Department of Mechanical engineering, Shri S'ad Vidya Mandal Institute of Technology, Bharuch, Gujarat, India*
[2]*Assistant professor, Department of Mechanical engineering, Shri S'ad Vidya Mandal Institute of Technology, Bharuch, Gujarat, India*

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Abstract - *The Bullwhip Effect is a major problem in supplier and forecast driven industries. The aim of this paper is to understand the nature of bullwhip effect and reduce the bullwhip effect in supply chain of manufacturing industries which dependent highly on many numbers of Suppliers. The fast moving or highly demanded Product which has highest annual consumption is selected for bullwhip effect analysis from all the products produced in one of the* ***glass manufacturing industry (OEM)*** *by using ABC analysis. For ABC analysis last 12 months demands of all products are used. Different forecasting methods accuracy is checked and accurate forecasting method is selected for the Product. Bullwhip effect is simulated for OEM demand of finished Products with respect to Customer demand. Due to bullwhip effect upper of stage of OEM means raw material demand of OEM is highly fluctuated. Selected accurate forecasting method is implemented in actual production of Product. After applying accurate forecasting method OEM demand of finished Products and demand of each raw of materials for the Product both Simulated. Results shows that after choosing accurate forecasting method for the Product the fluctuations in demand of finished Products and demand of raw of materials both are highly reduced means demands become stabilized which is most profitable for OEM suppliers as well as for OEM.*

Key Words**: bullwhip effect, demand fluctuations, accurate forecasting, supply chain, glass manufacturing, OEM demand, raw materials demand**

1. INTRODUCTION

The bullwhip effect is the uncertainty caused from distorted information flowing up and down the supply chain.It is a major problem in supplier and forecast driven industries. Information distorted in one end of supply chain creates larger variations and inefficiencies at upper stage of supply chain. If Customer demand is slightly fluctuated then Supplier Demand is highly fluctuated compared to Customer Demand means variability of orders increases as move up in the supply chain from Customer to Manufacturer to Supplier.It refers to a trend of larger and larger swings in inventory in response to changes in customer demand, as one looks at firm's further back in the supply chain for a product.Optimal ordering policies, Information sharing strategy, choosing proper forecasting method can reduce bullwhip effect.

2. LITERATURE REVIEW

S.M. Disney and D.R. Towill (2001) presented a discrete control theory model of a generic model of a replenishment rule. They analysed that the way to minimise the bullwhip problem with given policy is to increase the average age of forecasts and reduce the rate at which inventory correction are accounted for in the production/distribution-ordering algorithm [1].

J. Dejonckheere et al. (2004) examined the beneficial impact of information sharing in multi-echelon supply chains. They compared a traditional supply chain and an information enriched supply chain. In the traditional supply chain, a smoothing policy can lose its dampening abilities at higher levels of the chain, whereas in the information enriched chain, smoothed order rates may be realised by all levels in the chain [2].

HX Sun and YT Ren (2005) made a comparison between different forecasting methods, and some practical guidelines are developed to help managers to select a forecasting method that yields the greatest desired benefit. Results shown that increase in variability will be greater for longer lead times. However, the size of the impact does depend on the forecasting methods [3].

Andrew Potter and Stephen M. Disney et al. (2006) considered scenarios where orders are placed only in multiples of a fixed batch size, for both deterministic and stochastic demand rates. Using simulation the impact of changing batch size on bullwhip in a production control system is shown. It has been shown that bullwhip levels from batching can be reduced if the batch size is a multiple of average demand [4].

Sunil Agrawal et al. (2007) analyses a two echelon (warehouse–retailer) serial supply chain. It is shown that some part of bullwhip effect will always remain even after sharing both inter as well as intra echelon information. Further, with the help of a numerical example it is shown that the lead time reduction is more beneficial in comparison to the sharing of information in terms of reduction in the bullwhip effect phenomenon [5].

Yanfeng Ouyang (2007) derived robust analytical conditions, based only on inventory management policies, to predict the presence of the bullwhip effect and bound its magnitude. Even with shared information the bullwhip effect will arise as long as the inventory gain is positive. To completely eliminate the bullwhip effect, suppliers have to seek policies that have negative inventory gains [6].

Truong Ton Hien Duc et al. (2008) quantified the impact of the bullwhip effect for a simple two-stage supply chain with one supplier and one retailer. The bullwhip effect does not always exist, but its existence depends on the values of autoregressive and moving average coefficients of the ARMA model. In fact, the bullwhip effect occurs only when the autoregressive coefficient of the demand process is larger than the moving average parameter. The bullwhip effect does not always increase when the lead time L increases [7].

David Wright and XinYuan (2008) provided a simulation of the effect of improved forecasting methods, and finds that Holt's and Brown's methods substantially mitigate the bullwhip effect across a range of performance metrics. It is shown that a relatively slow adjustment of stock levels, combined with a slightly more rapid adjustment of supply line levels provides the most stability when combined with either Holt's or Brown's forecasting method [8].

Marlene Silva Marchena (2010) showed that for certain types of demand processes, the use of the optimal forecasting procedure that minimizes the mean squared forecasting error leads to significant reduction in the safety stock level. This highlights the potential economic benefits resulting from the use of this time series analysis [9].

Ling-Tzu Tseng et al. (2011) proposed a prediction system based on an evolutionary least-mean-square algorithm to estimate the downstream demand, which consequently enables the batch ordering of manufacturer to close the estimated inventory level to cope with the bullwhip effect by taking into account the holding and backorder costs [10].

Sunong Wua et al. (2011) applied ABMS (Agent-based model and simulation), as one of the scientific and dynamic research methods for complex system, to establish a supply chain model and determine its abundant bullwhip effect phenomenon under swarm platform. It proves the ABMS is the effective way to study the bullwhip effect in complex supply chain [11].

Ahmed Shaban et al. (2012) investigated the impact of various classical ordering policies on ordering and inventories in a multi-echelon supply chain through a simulation study. In addition a proposed ordering policy that relies on information sharing in a decentralized way is proposed to mitigate the bullwhip effect [12].

Dean C. Chatfield and Alan M. Pritchard Prabhu (2013) build a hybrid agent/discrete-event simulation model of a supply chain and execute it under various conditions of demand variance, lead-time variance, information sharing, and return allowance. They find that permitting returns significantly increases the bullwhip effect [13].

Borut Buchmeistera et al. (2014) simulated a simple three-stage supply chain using seasonal (SM) and de-seasonal (DSM) time series of the market demand data in order to identify, illustrate and discuss the impacts of different level constraints on the BE. The results are shown that at higher OEE level manufacturers have less variability in production processes; the BE is stronger in DSM than in SM [14].

Marly Mizue Kaibara de Almeida et al. (2014) provided results of trust and collaboration that lead to the mitigation of the bullwhip effect in supply chain management through a systematic literature review. The analysis found that few studies focused on addressing behavioural aspects to reduce the bullwhip effect. Most of them focused on operational and quantitative aspects [15].

Xiangyu Li (2015) put forward some weakening measures aimed at reasons of Bullwhip Effect including strengthening information sharing, adjusting structure of supply chain, preventing shortage game and strengthening inventory control [16].

Ahmad Sadeghi (2015) done a comparison of the bullwhip effect measure when two main forecasting methods i.e. exponential smoothing and moving average are used and empirical results are provided. At last, a cost analysis is conducted based on shortage and holding cost under different bullwhip effect measures [17].

Matloub Hussain et al. (2015) investigated the impact of capacity constraints and safety stock on the backlog bullwhip effect in a model of a two-tier supply chain. This research gives supply chain operations managers and designers a practical way to develop a trade-off between capacity and safety stock at different echelons and to take better decisions about their capacity and safety stocks [18].

B. Sravani and Dr. G. Padmanabhan (2015) investigated the selection of appropriate forecasting parameters in reducing bullwhip effect. The results revealed that increase of smoothing parameter levels had significant impact on bullwhip effect [19].

Junhai Ma and Xiaogang Ma (2016) established the supply chain model with two retailers which followed the different first-order autoregressive models and employed the order-up-to inventory policy in order to consider the market competition. It is interesting to note that market competition and the consistency of demand volatility between two retailers are also two important factors leading to the bullwhip effect apart from autoregressive coefficient, lead time and the span of forecast [20].

3. SELECTION OF PRODUCT FOR ANALYSIS

3.1 ABC analysis

In materials management, the ABC analysis (or Selective Inventory Control) is an inventory categorization technique. The ABC analysis provides a mechanism for identifying different categories of stock that will require different management and controls. The inventory is grouped into three categories (**A, B, and C**) in order of their estimated importance. ABC Analysis is similar to the Pareto principle in that the 'A' items will typically account for a large proportion of the overall value but a small percentage of number of items. The example is given below:

- 'A' items – 20% of the items accounts for 70% of the annual consumption value of the items.
- 'B' items - 35% of the items accounts for 20% of the annual consumption value of the items.
- 'C' items - 45% of the items accounts for 10% of the annual consumption value of the items [21].

3.2 ABC analysis in OEM

In OEM, ABC analysis is performed for all the products of the company which is produced in last 12 months. For ABC analysis last 12 months demands of all the products are used. Following measures used for ABC analysis:

- 'A' items – 70% of demand
- 'B' items – 20% of demand
- 'C' items – 10% of demand

'A' category items are the less numbers of items which has highest demand values and require critical monitoring. From this the fast moving or highly demanded product of company which comes first in 'A' category products is obtained and it is selected for bullwhip effect analysis. This Product has highest annual consumption compared to others products so it is selected for bullwhip effect analysis.

4. ACCURACY OF FORECASTING METHODS

Basic demand forecasting methods used here are moving average and exponential smoothing for the Product. The line incretion graph of actual demands and forecasted demands are shown and approximate accuracy of various forecasting method is discussed. However for selecting exactly accurate forecasting it require to consider MEAN ERROR (ME), MEAN ABOSLUTE ERROR (MAE) and MEANS SQUARE ERROR (MSE) for particular forecasting methods. Values of ME, MAE and MSE are obtained and they are compared to select the best forecasting method which gives accurate demand forecasting for the Product.

4.1 Moving average method

Different moving average forecasting methods are used here to forecast the demand of the Product in last 12 months .The different moving average methods used are 3 month moving average method, 4 month moving average method and 3 month weighted moving average method. For the 3 month weight age moving average method the values of m-1=0.5, m-2=0.3 and m-3=0.2 are taken. The line graph which gives the interaction of all four methods such as actual demand, 3 month moving average demand, 4 month moving average demand and 3 month weighted moving average demand are also simulated. The tables and charts for the various moving average methods applied to forecast the last 12 months demand of the Product are given below:

Table -1: Forecasting with moving average

Month	Actual demand (Units)	3 month M.A (Units)	4 month M.A(Units)	3 month W.M.A(Units)
Feb-15	6799937			
Mar-15	4035082			
Apr-15	2576024			
May-15	3944931	4470348		3858524
Jun-15	2518895	3518679	4338993	3552289
Jul-15	3554059	3013283	3268733	2958131
Aug-15	1376300	3339295	3148477	3321684
Sep-15	3353840	2483085	2848546	2258147
Oct-15	1625820	2761400	2700773	2800622
Nov-15	4816820	2118653	2477505	2094322
Dec-15	2262960	3265493	2793195	3566924
Jan-16	3919700	2901867	3014860	2901690
Feb-16	3071080	3666493	3156325	3602102

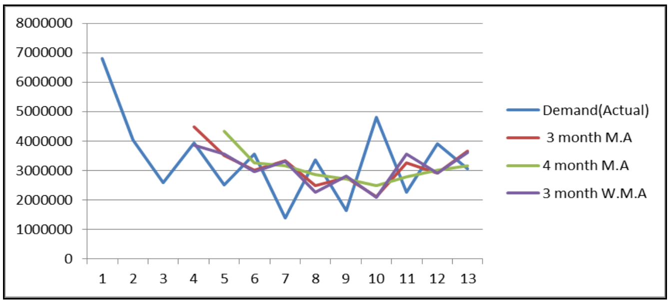

Chart -1: Forecasting with moving average

As shown in above chart, for the Product 4 month moving average method looks most accurate because its data points are close to actual demand data points and it also gives stable demand forecasts compared to other 2 methods.3 month moving average and 3 month weighted methods approximately gives slightly fluctuated demand forecast.

4.2 Exponential smoothing method

In this method value of forecast can be obtained by equation:

$$F2=F1+\alpha\ (A1-F1)$$

Different values of α taken in different Trials for forecasting the demand with exponential smoothing for the last 12 months demand of the Product. The table and line charts which gives the interaction of all four factors such as actual demand, Trial 1 means exponential smoothing with α=0.3, Trial 2 means exponential smoothing with α=0.5, Trial 3 means exponential smoothing with α=0.7 and Trial 4 means exponential smoothing with α=0.9 for the Product are given below:

Table -2: Forecasting with exponential smoothing

Month	Demand (Actual)	Trial 1	Trial 2	Trial 3	Trial 4
		α =0.3	α =0.5	α =0.7	α =0.9
Feb-15	6799937				
Mar-15	4035082	6799937	6799937	6799937	6799937
Apr-15	2576024	5970481	5417509	4864538	4311567
May-15	3944931	4952144	3996767	3262578	2749578
Jun-15	2518895	4649980	3970849	3740225	3825396
Jul-15	3554059	4010654	3244872	2885294	2649545
Aug-15	1376300	3873676	3399465	3353429	3463608
Sep-15	3353840	3124463	2387883	1969439	1585031
Oct-15	1625820	3193276	2870861	2938520	3176959
Nov-15	4816820	2723039	2248341	2019630	1780934
Dec-15	2262960	3351173	3532580	3977663	4513231
Jan-16	3919700	3024709	2897770	2777371	2487987
Feb-16	3071080	3293207	3408735	3577001	3776529

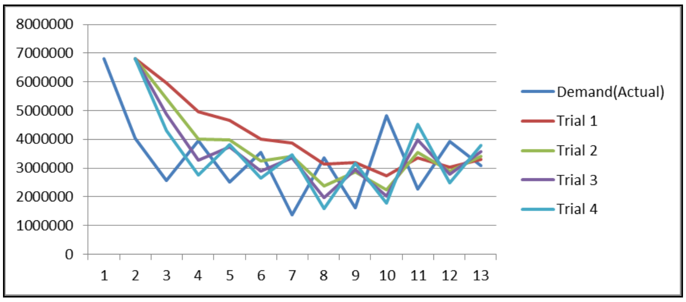

Chart -2: Forecasting with exponential smoothing

As shown in above chart for the Product according to data points Trial 2 means exponential smoothing with α=0.5 looks accurate forecast with respect to actual demand compared to all three Trials.

4.3 Selection of accurate forecasting method

Charts only give the interaction of all forecasting with actual demand and also give accuracy and stability measure approximately. However for choosing best forecasting method for the Product related to accuracy of forecasting as discussed it is required to consider MEAN ERROR (ME), MEAN ABOSLUTE ERROR (MAE), MEAN SQUARE ERROR (MSE) for all the forecasting methods. For all 3 errors ME, MAE and MSE which has minimum positive or negative value is said to be least error. So the forecasting method which has maximum number of least errors is selected as best forecasting method. These main errors obtained from all forecasting methods are given below and the values of least errors are shown in bold letters in below tables:

Table -3: ME, MAE and MSE comparison

ERRORS	3 month M.A	4 month M.A	3 month W.M.A	EXS. Trial 1	EXS. Trial 2	EXS. Trial 3	EXS. Trial 4
				α=0.3	α=0.5	α=0.7	α=0.9
ME	-109419	-138659	**47003**	-992602	-593338	-425843	-305395
MAE	1134925	**1035276**	1150710	1528960	1404264	1538349	1821081
MSE	1714485328368	**1613908543699**	1822636920016	3341344508942	2822391169265	3173127995469	3712017855153

As shown in above table 3 month weightage moving average method has one least ME value 47003 and 4 month moving average method has two least values such as ME value 1035276 and MSE value 1613908543699.So **4 month moving average method** is selected as accurate forecasting method for the Product.

5. BULLWHIP EFFECT ANALYSIS

5.1 OEM actual production Scenario-1

The Product which selected for bullwhip effect analysis is A category Product. For the A category products OEM only concentrate on fulfilling customer need so always keeps one month inventory. End stock inventory of finished goods is not much important for OEM.OEM only gives important on satisfying customer demand and make good relationship with suppliers. So at each month OEM try to satisfy the demand of customer from the starting stock and also make production based on making the end stock up to current month's demand after the end of period. But if the demand of customer is reduced and stock is far more available than OEM may satisfy the demand from its starting stock. Because at that time there is no requirement to make end stock as current month demand because starting stock is greater than current month demand. Given below tables gives the data of customer's demand and finished Products produced by OEM in last 9 months. In table the customer demand is taken as the number of sold Products by OEM in last 9 months.

Table -4: OEM actual production Scenario 1 of the Product

ACTUL PRODUCTION (UNITS)	REJECTION RATE (%)	OEM PRODUCTION (UNITS)	START STOCK (UNITS)	END STOCK (UNITS)	DEMAND (UNITS)	MONTH
1406320	28.683	1092858	3944931	2518895	2518895	Jun-15
5802056	26.428	4589224	2518895	3554059	3554059	Jul-15
0	0.000	0	3554059	2177759	1376300	Aug-15
5548421	22.484	4529921	2177759	3353840	3353840	Sep-15
0	0.000	0	3353840	1728020	1625820	Oct-15
9845646	24.540	7905620	1728020	**4816820**	4816820	Nov-15
0	0.000	0	4816820	2553860	2262960	Dec-15
6724414	27.223	5285540	2553860	3919700	3919700	Jan-16
2762581	24.303	2222460	3919700	3071080	3071080	Feb-16

As shown in Scenario 1 for the Product in last 9 months actual production of OEM is highly fluctuated compared to customer demand which shows the **presence of bullwhip effect** in Customer to OEM stage. End stock goes maximum up to 4816820 units however Own end stock is not much problem for OEM as inventory related problem because there are 4 number of larger and secure warehouses available for finished Products inventory.

5.2 Bullwhip effect in OEM to Customer stage

As shown in Scenario-1 the actual production quantity will be OEM demand because it gives the actual finished quantity produced with adding rejected quantities. So now OEM Demand and Customer Demand in particular period for the Product in last 8 months are shown in below table and charts:

Table -5: Last 8 months OEM and Customer Demand of the Product

MONTH	OEM DEMAND (UNITS)	CUSTOMER DEMAND (UNITS)
Jul-15	5802056	3554059
Aug-15	**0**	**1376300**
Sep-15	5548421	3353840
Oct-15	0	1625820
Nov-15	**9845646**	**4816820**
Dec-15	0	2262960
Jan-16	6724414	3919700
Feb-16	2762581	3071080

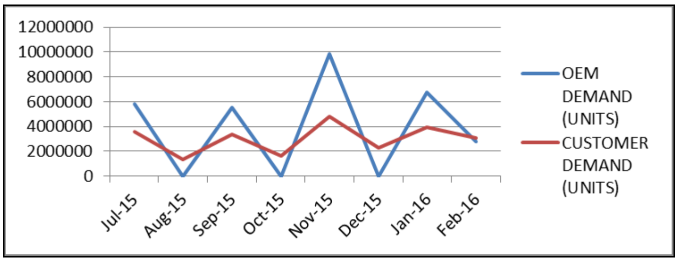

Chart -3: Bullwhip effect in OEM to Customer stage

From the above graphs and tables it is possible to simulate the bullwhip effect in OEM to Customer stage for the Product. Due to bullwhip effect the demand of OEM fluctuated greatly compared to customer's demand. As shown in above graphs and tables if Customer demand fluctuated slightly, OEM demand is highly fluctuated. The fluctuation range of OEM and Customer demand is shown in below table:

Table -6: Demand fluctuation range in last 8 months of the Product

OEM DEMAND FLCTUATION RANGE (UNITS)	CUSTOMER DEMAND FLCTUATION RANGE (UNITS)
0	1376300
9845646	4816820

5.3 OEM production after implementing selected forecasting method Scenario-2

For reduction of bullwhip effect in last 9 months which is observed in Scenario1, selected forecasting method for Product means 4 month moving average method is applied. For that in last 9 months, for the first month as per OEM policy production is followed. So from second month selected forecasting method will be applied and production will be done. As production will be done as per the selected forecasting method, For particular month OEM end stock will may not be remain same as current month demand as per the OEM policy. In this scenario 2 rejection rate is assumed as average rejection caused in Scenario-1 means 25.610.Now if the production is done based on selected forecasting method means 4 month moving average method than Scenario2 in last 9 months for Product will be given in below table:

Table -7: Production by 4 moving average method for Product Scenario 2

ACTUL PRODUCTION (UNITS)	REJECTION RATE (%)	OEM PRODUCTION (UNITS)	START STOCK (UNITS)	END STOCK (UNITS)	DEMAND (UNITS)	MONTH
1372742	25.610	1092858	3944931	2518895	2518895	Jun-15
4105866	25.610	3268733	2518895	2233568	3554059	Jul-15
3954813	25.610	3148477	2233568	4005745	1376300	Aug-15
3578068	25.610	2848546	4005745	3500452	3353840	Sep-15
3392450	25.610	2700773	3500452	**4575405**	1625820	Oct-15
3112002	25.610	2477505	4575405	2236090	4816820	Nov-15
3508542	25.610	2793195	2236090	2766325	2262960	Dec-15
3786976	25.610	3014860	2766325	1861485	3919700	Jan-16
3964670	25.610	3156325	1861485	1946730	3071080	Feb-16

After applying selected accurate forecasting method OEM actual production fluctuation means OEM demand fluctuation highly reduced for the Product. End stock of finished Products goes highest up to 4575405 units which is less compared to Scenario-1 which was 4816820 units and also as discussed OEM has 4 larger and secure warehouses available for finished goods inventory and these are highly demanded Products so these Products are not remains as unsold inventory for larger period.

5.4 Bullwhip effect in OEM to Customer stage after implementing selected forecasting method

As shown in Scenario-2 actual production quantity will be OEM demand because it gives the actual quantity produced with adding rejected quantities. So now after applying accurate forecasting method OEM Demand and Customer Demand in particular month for the Product in last 8 months will be shown in below table and charts:

Table -8: Last 8 months OEM and Customer Demand of the Product

MONTH	OEM DEMAND (UNITS)	CUSTOMER DEMAND (UNITS)
Jul-15	**4105866**	3554059
Aug-15	3954813	**1376300**
Sep-15	3578068	3353840
Oct-15	3392450	1625820
Nov-15	**3112002**	**4816820**
Dec-15	3508542	2262960
Jan-16	3786976	3919700
Feb-16	3964670	3071080

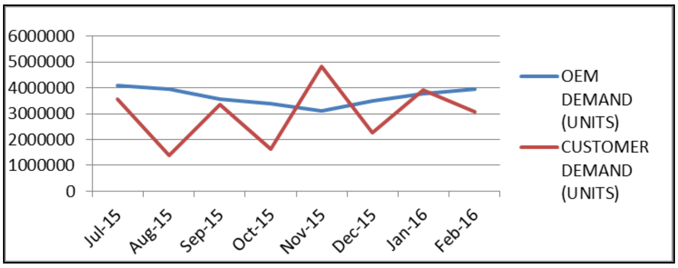

Chart -4: Reduction of bullwhip effect in OEM to Customer stage

From the above charts and tables it is possible to simulate the bullwhip effect reduction in OEM to customer stage for the Product in last 8 months. As shown in Scenario1 if Customer demand fluctuated slightly, OEM demand is highly fluctuated. But after implementing selected forecasting methods fluctuation is highly reduced compared to Scenario 1. Here even customer demand is fluctuated, OEM demand is not fluctuated with respect to customer demand and also remains approximately stable. The fluctuation range of OEM and customer demand is given in below table:

Table -9: Demand fluctuation range in last 8 months of the Product

OEM DEMAND FLCTUATION RANGE (UNITS)	CUSTOMER DEMAND FLCTUATION RANGE (UNITS)
4105866	1376300
3112002	4816820

6. REDUCTION OF BULLWHIP EFFECT

6.1 Reduction of bullwhip effect in OEM demand (unit wise)

Below table gives OEM actual demand and demand after selected forecasting method in unit wise for the Product in last 8 months:

Table -10: OEM actual demand and demand after selected forecasting of Product

Month	OEM actual Demand (Units)	OEM Demand after 4 month moving average forecasting (Units)
Jul-15	5802056	**4105866**
Aug-15	**0**	3954813
Sep-15	5548421	3578068
Oct-15	0	3392450
Nov-15	**9845646**	**3112002**
Dec-15	0	3508542
Jan-16	6724414	3786976
Feb-16	2762581	3964670

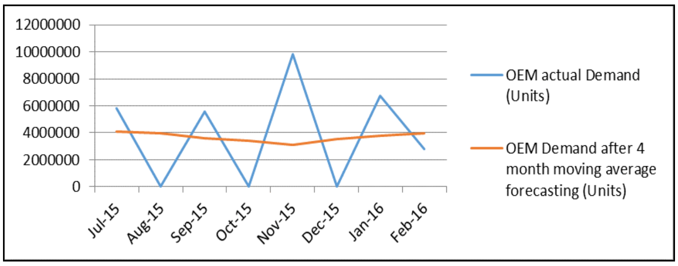

Chart -5: Reduction in OEM demand fluctuations of Product

As show in above tables and charts OEM demand fluctuations can be greatly reduced by selecting accurate forecasting method for the Product. OEM fluctuation range of actual demand and demand after selected forecasting method for the Product is given in below table:

Table -11: Reduction in OEM demand fluctuation range of Product in last 8 months

OEM actual demand fluctuation range (Units)	OEM demand fluctuation range after applied selected Forecasting method (Units)
0	3112002
9845646	4105866

6.2 Reduction of bullwhip effect in OEM demand of pure glass (ton wise)

Total tons of pure glass consumed in satisfying demands of Product gives the measure of actual demand of pure glass. Pure glass ton wise demand will be obtained by multiplying Product's unit wise demand to the weight of the Product. The weights of selected Product is 18.5gm.So OEM demand of pure glass can be calculated. So OEM actual demand of pure glass and demand after selected forecasting method for Product in last 8 months are given in below table:

Table -12: OEM actual demand of pure glass and demand after selected forecasting for the Product

Month	OEM actual Demand (Tons)	OEM Demand after 4 month moving average forecasting (Tons)
Jul-15	107.338	**75.959**
Aug-15	**0.000**	73.164
Sep-15	102.646	66.194
Oct-15	0.000	62.760
Nov-15	**182.144**	**57.572**
Dec-15	0.000	64.908
Jan-16	124.402	70.059
Feb-16	51.108	73.346

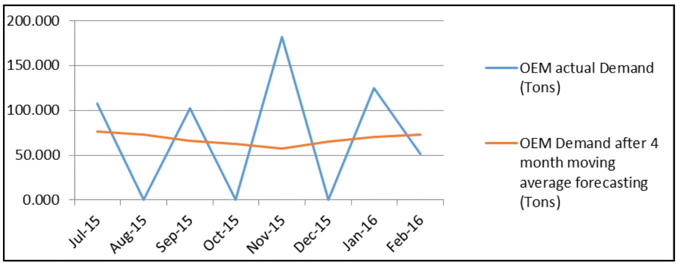

Chart -6: Reduction in OEM demand fluctuations of pure glass for the Product

As shown in above tables and charts OEM demand fluctuations of pure glass can be greatly reduced by accurate forecasting for the Product. The fluctuation range of actual demand of pure glass and demand after selected forecasting method for the Product in last 8 months is given below:

Table -13: Reduction in OEM demand fluctuation range of pure glass for the Product in last 8 months

OEM actual demand fluctuation range (Tons)	OEM demand fluctuation range after selected forecasting method (Tons)
0.000	75.959
182.144	57.572

6.3 Reduction of bullwhip effect in OEM overall raw material demand

OEM has different suppliers for each raw material used in producing glass. The measure of raw materials consumed in 1 ton of pure glass for the selected Product is given in below table:

Table -14: Raw materials used in 1 ton of pure glass for the Product

Types of raw material	Required quantity (Tons)
Raw material 1	0.530
Raw material 2	0.030
Raw material 3	0.200
Raw material 4	0.110
Raw material 5	0.034
Raw material 6	0.010
Raw material 7	0.025
Raw material 8	0.005
Raw material 9	0.046
Raw material 10	0.010

By using above table each raw materials demand for particular month can be calculated. So the reduction in bullwhip effect means reduction of demand fluctuation of each raw material can be shown. Actual demand of each raw materials of OEM and each raw materials demand of OEM after selected forecasting method for the selected Product in last 8 months is calculated which is given in below tables and charts:

Table -15: Reduction in demand fluctuations of Raw material 1

Month	Actual demand of Raw material 1 (Tons)	Demand of Raw material 1 after selected forecasting method (Tons)
Jul-15	56.889	**40.258**
Aug-15	**0.000**	38.777
Sep-15	54.402	35.083
Oct-15	0.000	33.263
Nov-15	**96.537**	**30.513**
Dec-15	0.000	34.401
Jan-16	65.933	37.131
Feb-16	27.087	38.874

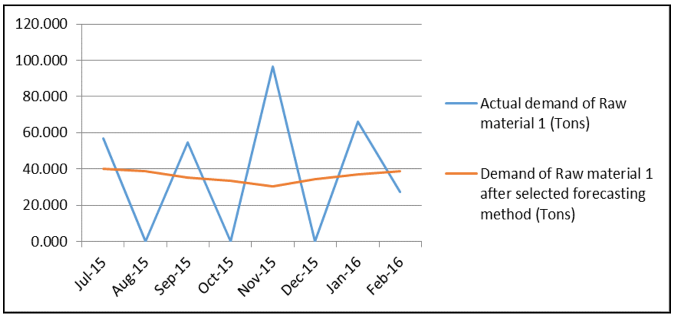

Chart -7: Reduction in demand fluctuations of Raw material 1

Table -16: Reduction in demand fluctuations of Raw material 2

Month	Actual demand of Raw material 2 (Tons)	Demand of Raw material 2 after selected forecasting method (Tons)
Jul-15	3.220	**2.279**
Aug-15	**0.000**	2.195
Sep-15	3.079	1.986
Oct-15	0.000	1.883
Nov-15	**5.464**	**1.727**
Dec-15	0.000	1.947
Jan-16	3.732	2.102
Feb-16	1.533	2.200

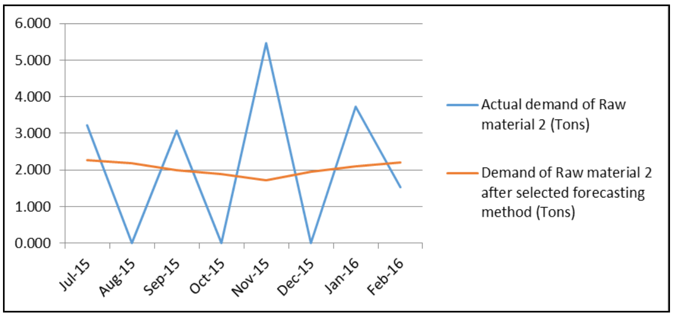

Chart -8: Reduction in demand fluctuations of Raw material 2

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Table -17: Reduction in demand fluctuations of Raw material 3

Month	Actual demand of Raw material 3 (Tons)	Demand of Raw material 3 after selected forecasting method (Tons)
Jul-15	21.468	**15.192**
Aug-15	**0.000**	14.633
Sep-15	20.529	13.239
Oct-15	0.000	12.552
Nov-15	**36.429**	**11.514**
Dec-15	0.000	12.982
Jan-16	24.880	14.012
Feb-16	10.222	14.669

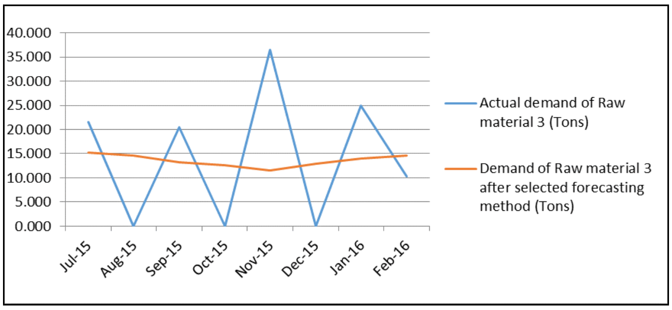

Chart -9: Reduction in demand fluctuations of Raw material 3

Table -18: Reduction in demand fluctuations of Raw material 4

Month	Actual demand of Raw material 4 (Tons)	Demand of Raw material 4 after selected forecasting method (Tons)
Jul-15	11.807	**8.355**
Aug-15	**0.000**	8.048
Sep-15	11.291	7.281
Oct-15	0.000	6.904
Nov-15	**20.036**	**6.333**
Dec-15	0.000	7.140
Jan-16	13.684	7.706
Feb-16	5.622	8.068

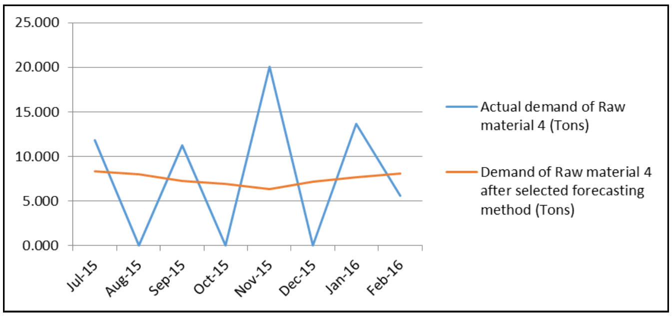

Chart -10: Reduction in demand fluctuations of Raw material 4

Table -19: Reduction in demand fluctuations of Raw material 5

Month	Actual demand of Raw material 5 (Tons)	Demand of Raw material 5 after selected forecasting method (Tons)
Jul-15	3.649	**2.583**
Aug-15	**0.000**	2.488
Sep-15	3.490	2.251
Oct-15	0.000	2.134
Nov-15	**6.193**	**1.957**
Dec-15	0.000	2.207
Jan-16	4.230	2.382
Feb-16	1.738	2.494

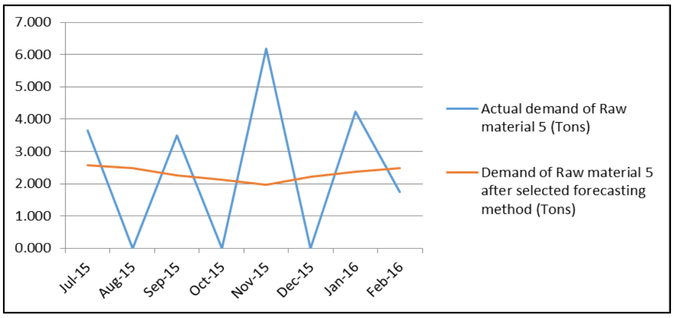

Chart -11: Reduction in demand fluctuations of Raw material 5

Table -20: Reduction in demand fluctuations of Raw material 6

Month	Actual demand of Raw material 6 (Tons)	Demand of Raw material 6 after selected forecasting method (Tons)
Jul-15	1.073	**0.760**
Aug-15	**0.000**	0.732
Sep-15	1.026	0.662
Oct-15	0.000	0.628
Nov-15	**1.821**	**0.576**
Dec-15	0.000	0.649
Jan-16	1.244	0.701
Feb-16	0.511	0.733

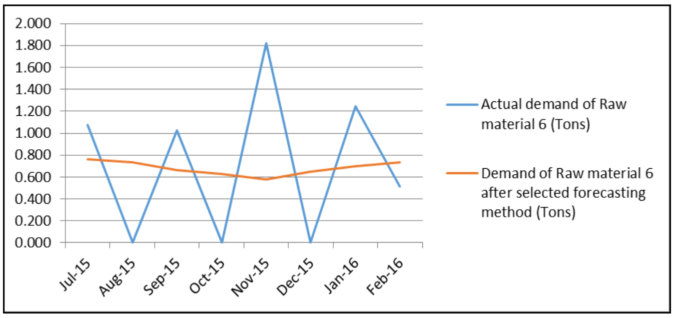

Chart -12: Reduction in demand fluctuations of Raw material 6

Table -21: Reduction in demand fluctuations of Raw material 7

Month	Actual demand of Raw material 7 (Tons)	Demand of Raw material 7 after selected forecasting method (Tons)
Jul-15	2.683	**1.899**
Aug-15	**0.000**	1.829
Sep-15	2.566	1.655
Oct-15	0.000	1.569
Nov-15	**4.554**	**1.439**
Dec-15	0.000	1.623
Jan-16	3.110	1.751
Feb-16	1.278	1.834

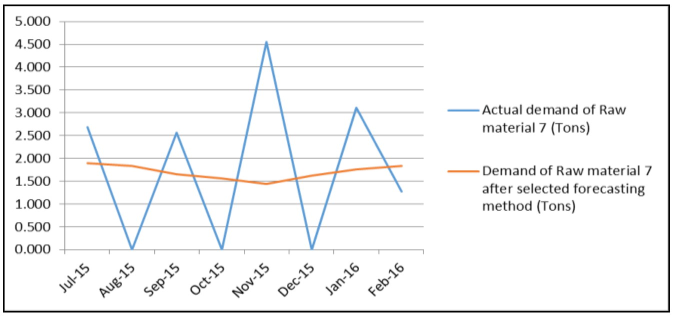

Chart -13: Reduction in demand fluctuations of Raw material 7

Table -22: Reduction in demand fluctuations of Raw material 8

Month	Actual demand of Raw material 8 (Tons)	Demand of Raw material 8 after selected forecasting method (Tons)
Jul-15	0.537	**0.380**
Aug-15	**0.000**	0.366
Sep-15	0.513	0.331
Oct-15	0.000	0.314
Nov-15	**0.911**	**0.288**
Dec-15	0.000	0.325
Jan-16	0.622	0.350
Feb-16	0.256	0.367

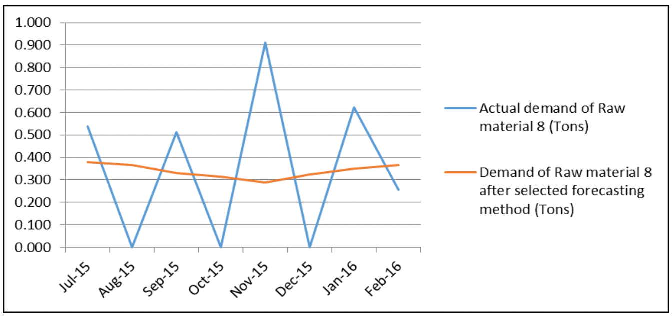

Chart -14: Reduction in demand fluctuations of Raw material 8

Table -23: Reduction in demand fluctuations of Raw material 9

Month	Actual demand of Raw material 9 (Tons)	Demand of Raw material 9 after selected forecasting method (Tons)
Jul-15	4.938	**3.494**
Aug-15	**0.000**	3.366
Sep-15	4.722	3.045
Oct-15	0.000	2.887
Nov-15	**8.379**	**2.648**
Dec-15	0.000	2.986
Jan-16	5.722	3.223
Feb-16	2.351	3.374

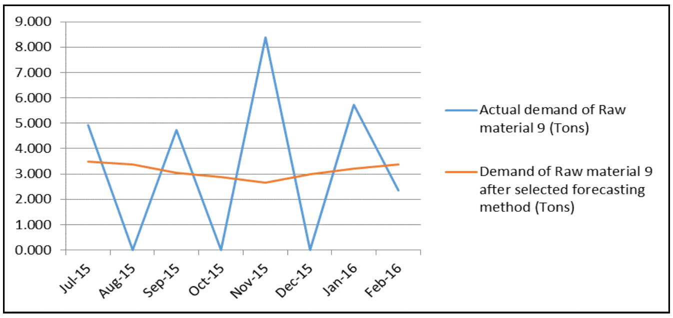

Chart -15: Reduction in demand fluctuations of Raw material 9

Table -24: Reduction in demand fluctuations of Raw material 10

Month	Actual demand of Raw material 10 (Tons)	Demand of Raw material 10 after selected forecasting method (Tons)
Jul-15	1.073	**0.760**
Aug-15	**0.000**	0.732
Sep-15	1.026	0.662
Oct-15	0.000	0.628
Nov-15	**1.821**	**0.576**
Dec-15	0.000	0.649
Jan-16	1.244	0.701
Feb-16	0.511	0.733

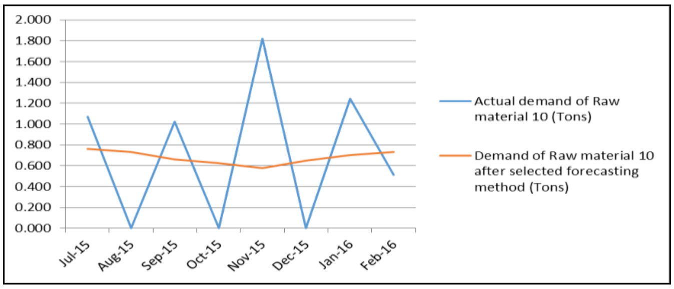

Chart -16: Reduction in demand fluctuation of Raw material 10

From above charts and tables seen that due to bullwhip effect OEM each raw material demands for the Product is highly fluctuated. But after using accurate forecasting for the Product, each raw material demand fluctuation is highly reduced. The actual fluctuation range and reduced fluctuation range of each raw material demand after selected forecasting for the Product in last 8 months is given below:

Table -25: Reduction in each raw material demand fluctuations range for the Product in last 8 months

Raw materials	Actual demand fluctuation range (Tons)	Demand fluctuation range after selected forecasting method (Tons)
Raw material 1	0.000	40.258
	96.537	30.513
Raw material 2	0.000	2.279
	5.464	1.727
Raw material 3	0.000	15.192
	36.429	11.514
Raw material 4	0.000	8.355
	20.036	6.333
Raw material 5	0.000	2.583
	6.193	1.957
Raw material 6	0.000	0.760
	1.821	0.576
Raw material 7	0.000	1.899
	4.554	1.439
Raw material 8	0.000	0.380
	0.911	0.288
Raw material 9	0.000	3.494
	8.379	2.648
Raw material 10	0.000	0.760
	1.821	0.576

7. CONCLUSION

Bullwhip effect is present in Supply chain of manufacturing industries which highly dependent on many numbers of suppliers. Due to bullwhip effect OEM demand of finished Products and demand of raw of materials means demand of upper stages of chain are highly fluctuated. OEM has different suppliers for each raw material used in production of the Product. So for good relationship with suppliers it is required to give stable orders to suppliers so that they can fulfill the OEM demand successfully. After choosing accurate forecasting method for Product and implementing it into actual production, OEM demand fluctuation of finished products and mostly the demand fluctuation of required raw materials for the Product is highly reduced and demands are stabilized. According to OEM raw material demand, Suppliers are given the orders of the raw materials. So this stabilization of OEM raw material demand will be more beneficial to the suppliers of OEM as well as for OEM.

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BIOGRAPHIES

Mr. Rahul K. Parmar
Master of Engineering,
(Advance Manufacturing System)
Semester: IV, SVMIT, Bharuch