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OPTIMIZATION AND VALIDATION OF FORECASTING PARAMETERS TO QUANTIFY BULL-WHIP EFFECT IN A SUPPLY CHAIN

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ABSTRACT

Supply chain is a bridge between demand and supply. It conveys the demand to the supply point and delivers the quantity to the demand point. It is a network, that facilities the functions of procurement of materials, transformation of these materials into intermediate and finished products and the distribution of these finished products to customers. The Bullwhip Effect represents the information distortion in a Supply chain. It represents the phenomenon where orders to supplier tend to have larger variance than sales to the buyer. The customer demand is distorted. This demand distortion also propagates to upstream stages in an amplified form in the supply chain. The demand forecasting is one of the key-factors to influence the bull-whip effect. Winter's Triple Exponential smoothening model is applied to forecast the future demand. The purpose of this study is to analyze the impact of exponential smoothing parameters on the bullwhip effect for Supply Chain Management (SCM). A simulation model is developed to determine the Forecasted demand and bullwhip ratio value. Further, accuracy of Forecasting calculated by the Winter's model is examined by applying Tracking Signal Technique. A sensitivity analysis is done to experiment with the different values of parameters in the forecasting technique. It is found that longer lead times and poor selection of forecasting model parameters lead to strong bullwhip effect in SCM. The optimized values of parameters help to reduce the bullwhip ratio. The most significant managerial implication of this study lies in applying best forecasting technique with accuracy testing of forecasting model, to mitigate the bullwhip effect. The managers are suggested to utilize the best exponential smoothing by selecting lower values for alpha and beta and a mid-value for gamma to keep the bullwhip ratio low, besides the forecasting accuracy.

Keywords: Bullwhip ratio; Forecasting; Exponential smoothing constants; MAD; SCM; Tracking Signal

INTRODUCTION

The sources of uncertainty in a supply chain, lie in the process of matching demand that includes delivery lead times, manufacturing yields, transportation times, machining times and operator performances [10], all lead to uncertainty in the supply chain performance. SCM includes a set of approaches and practices to reduce the uncertainty along the chain through enabling a better integration among `suppliers, manufacturers, distributors and customers [6]. It is ''the efficient management of the end-to-end process, which starts with the design of the product or service and ends with the time when it has been sold, consumed, and finally, discarded by the consumer'' [12]. Demand

forecasting is an essential tool for production and inventory planning, capacity management and the design of the customer service levels. The need to forecast the demand at each level of the supply chain amplifies the forecast errors, known as bullwhip effect in the supply chain. It represents the phenomenon where orders to supplier tend to have larger variance than sales to the buyer, and the customer demand is distorted [7]. This demand distortion also propagates to upstream stages in an amplified form. In return, high inventory levels and poor customer service rates along the supply chain constitute. They are the typical symptoms of bullwhip effect. In addition, production and inventory holding costs as well as lead times increase, while profit margins and product availability decrease [3][8]. In the earlier research, the similar problem is analytically examined by [1][2] for autoregressive demand structures and with linear trend in the demand, ignoring the demand seasonality.].This paper hence presents the sensitivity analysis part & validates forecasting accuracy using Tracking Signal concept. Setting of experimental design is identified, followed by simulation results. Conclusions are in the final section. A simulation model is developed to reduce the bullwhip effect with forecasting parameter optimization [9]. Tracking signal is computed by dividing the total residuals by their mean absolute deviation (MAD). If the tracking signal is within 3 standard deviations, then applied forecasting model is considered to be good enough.

Literature survey

Uncertainty can be defined as unpredictable events in a supply chain that affects pre-planned performance [5]. The bullwhip effect was first noticed and studied by [4] in a series of simulation analysis. He named this problem as ‘‘demand amplification’’. It is suggested [11] that operations managers be provided necessary training on the bullwhip effect. However, [7] indicates that bullwhip effect is present, even though all members of the supply chain behave in an optimal manner unless the supply chain is redesigned with different strategic interactions. Of all causes, the major emphasis has been placed on demand forecasting. Researchers had developed different methodologies to explore the impact of demand forecast on bullwhip effect. Few AR models are developed to quantify the bullwhip effect [1] with the moving the average forecasting model in a two-level supply chain. Their findings support the significance of reducing lead times to mitigate the bullwhip effect. Under similar assumptions, [2] also investigated the double exponential smoothing forecasting technique for demand process with a linear trend. [13] The impact of forecasting parameters, demand patterns and capacity tightness of the supplier on the performance of the supply chain in terms of total cost and service level is investigated by [13]. In fact, demand forecasting has been recognized as one of the four main causes of the bullwhip effect [7]. As described by [9], **Winter’s triple exponential smoothening model** is used to determine forecasted demand and the optimized values of forecasting parameters are calculated. The changes occurring by altering the values of parameters in the given range is computed. The time horizon (Year) is divided into **three seasons** based on either actual demand for the product (or) seasonality index An attempt is made to analyze, the effect of changes in given range of optimal values of smoothening constants in the given season. Finally **Tracking Signal** values are computed to validate **forecasting accuracy**.

Model Development

The supply chain consists of four members as, a manufacturer, a distributor, a retailer and a consumer as shown in Fig 1.

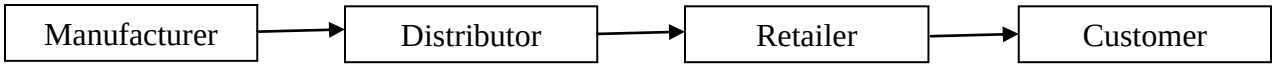

Fig 1 : A simple Supply Chain

An attempt is made to apply **Winters' Triple Exponential Model** to calculate the forecasted demand values for the given Factory, Distributors and Retailers data. Corresponding values of ordering quantity for Factory, Distributors and Retailers are calculated.

The **Winter's Triple Exponential Smoothing Model** is used to calculate the forecast demand for Manufacturer, Distributors and Retailers. The formula as follows

$F_{t+n} = (L_t + T_t \times n) \times S_{t+n-s}$ Where n = 1,2,3…….s

Ft_{+n} : forecast at period t+n,

L_t : level component of demand at period t,

T_t : trend component of demand at period t

S_{t+n-s} : seasonality index for the same period the previous year.

$$L_{t+1} = \alpha \times \frac{D_{t+1}}{S_{t+1-s}} + (1-\alpha) \times (L_t + T_t)$$

$$T_{t+1} = \beta \times (L_{t+1} - L_t) + (1-\beta) \times T_t$$

$$S_{t+1} = \gamma \times \frac{D_{t+1}}{L_{t+1}} + (1-\gamma) \times S_{t+1-s}$$

Subject to $0 < \alpha < 1$, $0 < \beta < 1$, $0 < \gamma < 1$. and $\alpha, \beta, \gamma \geq 0$.

At the beginning of each period, the retailer receives the delivery of the distributor. Mean while the actual customer demand emerges at the marketplace. The retailer fulfils the customer demand (plus back-orders if any) by on-hand inventory, and any unfulfilled customers demand are backordered. After the actual customer demand is satisfied, the retailer analyzes the historical demand data and makes a demand forecast. The retailer decides the quantity of items to order for the distributor using its inventory control policy. In this case, **the manufacturer, Distributor and Retailer follows a simple "order up to policy" to manage the inventory.** The ordering quantity is determined by the following relation

$$Qt = Ft + z\,\sigma_t$$

Where Ft is forecasted demand, σ_t is the standard deviation of forecasting error and z is constant chosen to meet a desired service level. It should be noted that z is also known as the safety factor. Let the retailer selects a 95 % fill rate and selects a threshold z value of 1.65.Since the model explicitly analyzes the impact and focuses on the role of forecasting models on the bull-whip effect and this has a significant diversion from the model. A similar assumption has also been made in several studies [2].

According to [7], the bullwhip ratio is given by the relation

$$\text{Bullwhip Ratio} = \frac{Variance\ of\ Ordering\ Quantity}{Variance\ of\ Actual\ Demand} = \frac{Variance\ of\ (Ft + z\,\sigma t)}{Variance\ of\ DAct} = \frac{Var\ Qt}{Var\ (DAct)}$$

$$= \frac{Var\left(\left(\left[\{\alpha*(Dt/St-n)+(1-\alpha)(Lt-1+Tt-1)\}+\{\beta*(Lt-Lt-1)+(1-\beta)Tt-1\}+\{\gamma(Dt-Lt)+(1-\gamma)*St-n\}\right]+z\,\sigma t\right)}{Var\ (DAct)}$$

Subject to $0 < \alpha < 1$, $0 < \beta < 1$, $0 < \gamma < 1$. and $\alpha, \beta, \gamma > 0$.

Calculation of Tracking Signal

Forecasting Error = Actual Demand- Forecasted demand

Absolute Deviation = $|\text{Forecasting Error}|$

Mean Absolute Deviation = $\frac{\text{Cumulative Absolute Deviation}}{\text{Month}}$

Tracking Signal= $\frac{\text{Sum of Forecasting error}}{|\text{Mean absolute deviation}|}$

Comparative Analysis

A comparative analysis is carried out for before and after application of Winters' triple exponential smoothening model to determine the forecasted demand, ordering quantity and bullwhip ratio. They are presented in Table 1 to Table 4. They are further illustrated graphically in Fig. 3 to Fig. 7.

Sensitivity Analysis:

The Part – I of sensitivity analysis deals with changes occurring in the values of bullwhip ratio, when for one parameter takes value in the specified range for 3 seasons and other two parameters are kept constant. They are presented in Table. 5. They are illustrated graphically in Fig. 8 to Fig. 13.

The Part – II of sensitivity analysis deals with calculation and analysis of Tracking Signal for Factory, Distributor and Retailer's statistics on month-wise for 3 years. They are presented in Table. 6 and Table. 7. They are illustrated graphically in Fig. 14 and Fig. 15.

Development of Soft-ware Programme

A Computer programme is developed in "C – Language". It takes input values as Three years' actual demand statistics and values of α, β and γ.

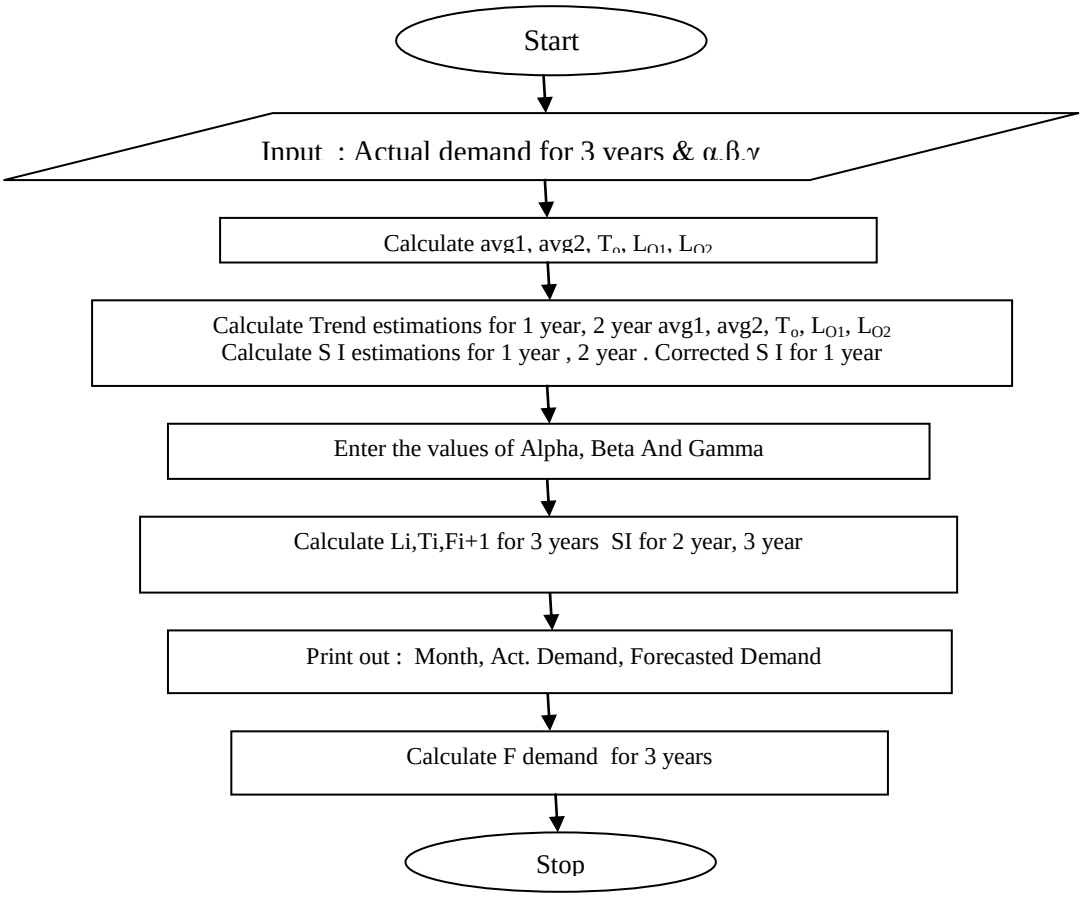

Fig 2. : Flow diagram for Calculation of Forecasted Demand with given actual demand and α, β and γ

Data Collection and Analysis
Calculation of Bull-whip ratio
Before the Application of Winters' model

Table. 1 : Retailer's statistics for 3 years

Month	2007-08		2008-09		2009-10	
	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity
April	4608140	----	5090301	5316363	5035224	4634420
May	4668783	5264784	5211502	5112166	5007126	5584537
June	4655509	4975824	5138866	5184401	5077607	5219118
July	4709680	4963044	5436783	5374174	5133432	5581736
August	4851126	4953842	5442617	6646746	5750024	5484081
September	4801511	4630226	4765322	5129794	5436401	5288090
October	4755305	4856385	4767970	4866084	5540531	5917812
November	4776948	4889109	4940490	4923678	5318657	5766122
December	4860493	4715168	4799055	4946957	5406163	5913988
January	4864709	4833130	4481643	4716293	5154063	5277106
February	4455077	4813680	4403733	4227448	5226119	5446186
March	4883501	5364160	5028594	4939668	5085430	5814570
Bullwhip ratio	2.872593		3.182219		2.524654413	

Table. 2 : Distributor's statistics for 3 years

Month	2007-08		2008-09		2009-10	
	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity
April	4610554	-----	5093070	4631792	5040301	4607131
May	4670604	4865308	5212546	5113716	5010000	5087902
June	4664000	4881068	5140552	5189486	5081846	5025911
July	4712513	4879484	5441404	5374961	5134995	5285036
August	4857564	4758490	5445555	6551538	5755958	5287041
September	4803735	4965763	4771889	5132830	5439241	5292872
October	4759751	4960631	4774773	4873094	5545677	5422522
November	4784000	4792097	4941774	4929204	5325311	6169536
December	4862088	4899292	4806160	4949254	5412846	5419918
January	4866237	4933242	4483586	4719638	5155369	5280683
February	4456466	4909220	4406515	4230008	5235130	4948397
March	4885850	5511160	5030453	4942506	5091294	5814570
Bullwhip Ratio	2.421206654		2.919529		3.036187691	

After the Application of Winters' model (indicated by Red color)

Table. 3 : Retailer's statistics for 3 years

Month	2007-08		2008-09		2009-10	
	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity
April	4608140	---------	5090301	4629078	5035224	5248684
May	4668783	4713925	5211502	5112166	5007126	5084537
June	4655509	4675824	5138866	5184401	5077607	5019118
July	4709680	4863044	5436783	5374174	5133432	5281736
August	4851126	4853842	5442617	5546746	5750024	5284081
September	4801511	4550226	4765322	5129794	5436401	5288090
October	4755305	4756385	4767970	4866084	5540531	5417812
November	4776948	4889109	4940490	4923678	5318657	5666122
December	4860493	4815168	4799055	4946957	5406163	5413988
January	4864709	4733130	4481643	4716293	5154063	5277106
February	4455077	4613680	4403733	4327448	5226119	4946186
March	4883501	5064160	5028594	4939668	5085430	5814570
Bullwhip ratio	1.248698892		0.982596542		1.275902	

With the Optimized values of $\alpha = 0.76$, $\beta = 0.01$, $\gamma = 0.01$

Table. 4 : Distributors' statistics for 3 years

Month	2007-08		2008-09		2009-10	
	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity	Actual Demand	Ordering Quantity
April	4610554	--------	5093070	4631792	5035224	5248684
May	4670604	4715308	5212546	5113716	5007126	5084537
June	4664000	4681068	5140552	5189486	5077607	5019118
July	4712513	4869484	5441404	5374961	5406163	5281736
August	4857564	4858490	5445555	5551538	5750024	5284081
September	4803735	4555763	4771889	5132830	5436401	5288090
October	4759751	4760631	4774773	4873094	5540531	5417812
November	4784000	4892097	4941774	4929204	5318657	5666122
December	4862088	4821292	4806160	4949254	5406163	5413988
January	4866237	4733242	4483586	4719638	5154063	5277106
February	4456466	4615220	4406515	4330008	5226119	4946186
March	4885850	5064160	5030453	4942506	5085430	5814570
Bullwhip Ratio	1.237408955		0.982596542		1.275902	

SENSITIVITY ANALYSIS

Part – I

Analyzing the effect Range of Values of α, β, γ on Bullwhip Effect

The values of Alpha varies in the range (0.7 to 0.9) while values of Beta and Gamma are kept at a constant values as 0.01 each.

The values of Beta varies in the range (0.005 to 0.05) while values of Alpha and Gamma are kept at a constant values as 0.76 and 0.01 respectively.

The values of Gamma varies in the range (0.005 to 0.05) while values of Alpha and Beta are kept at a constant values as 0.76 and 0.01 respectively. The values are presented in the Table 4.1.

Table 5 : Retailers' Statistics (Varied α, β, γ values Vs Bullwhip Ratio)

Variable	Level	Variance of Ordering Quantity Subset	Bullwhip Ratio	Original Ordering Quantity variance	Bullwhip Ratio
Alpha	0.7 0.76 0.8 0.9	1.09685E+11 1.12601E+11 1.14488E+11 1.19167E+11	1.055767597 1.083834495 1.101999812 1.147035436	1.12601E+11	1.083834495
Beta	0.005 0.01 0.05	1.12054E+11 1.12601E+11 1.17174E+11	1.078567107 1.083834495 1.12785511		
Gamma	0.005 0.01 0.05	1.12606E+11 1.12601E+11 1.12563E+11	1.083882955 1.083834495 1.083468986		

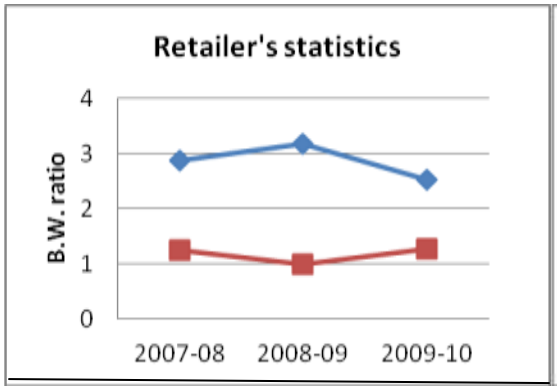

Fig. 3 : Graph showing Retailer's Statistics

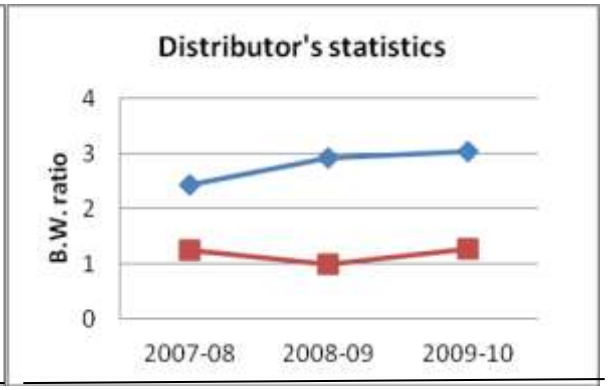

Fig. 4 : Graph showing Distributor's Statistics

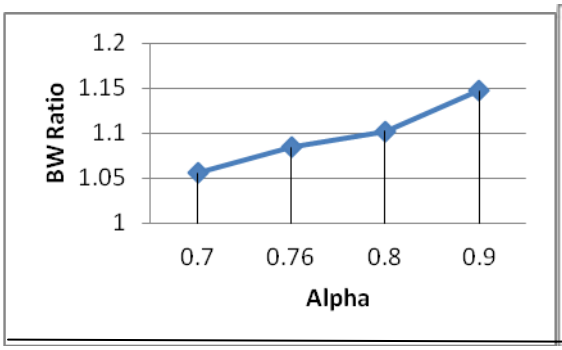

Fig. 5 : Alpha values with Bullwhip Ratio

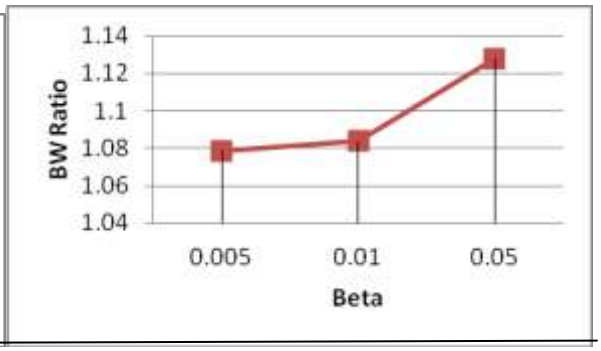

Fig. 6 : Beta values with Bullwhip Ratio

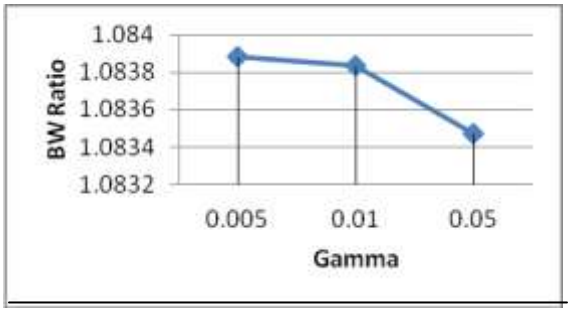

Fig. 7 : Gamma values with Bullwhip Ratio

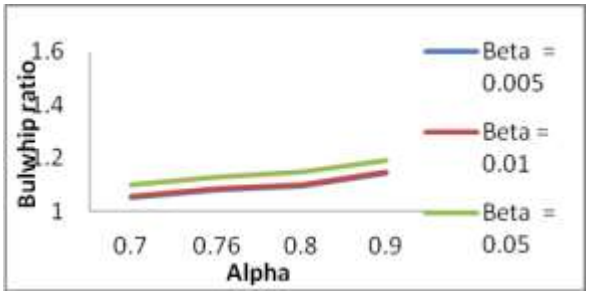

Fig. 8 : Gamma is 0.005 & different values of Alpha and Beta

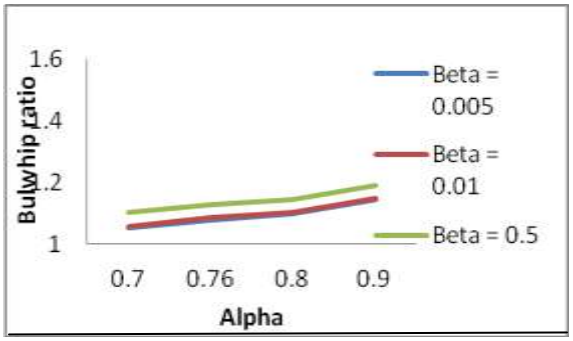

Fig. 9 : Gamma is 0.01 and different values of Alpha, Beta

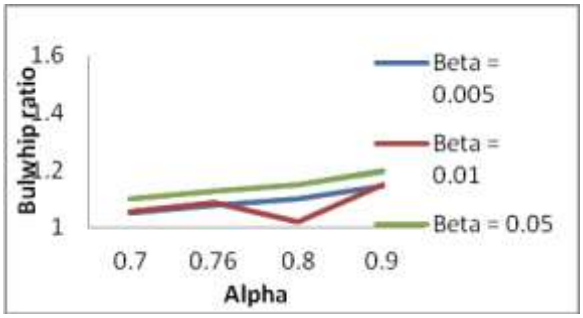

Fig 10 : Gamma is 0.05 and different values of Alpha, Beta

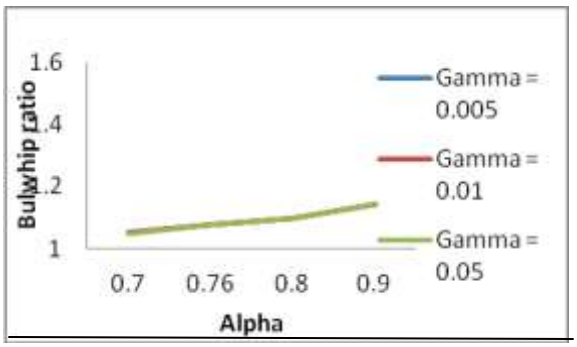

Fig. 11 : Beta is 0.005 and different values of Alpha and Beta

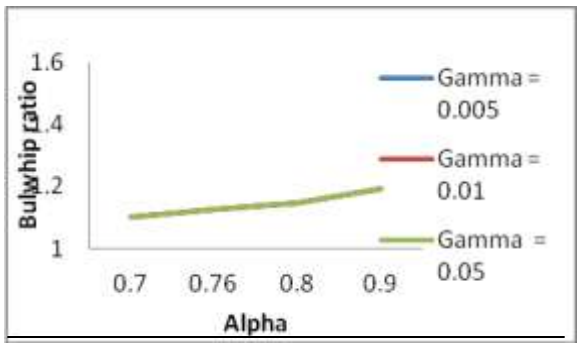

Fig. 12 : Beta is 0.01 and for different values for of Alpha and Beta

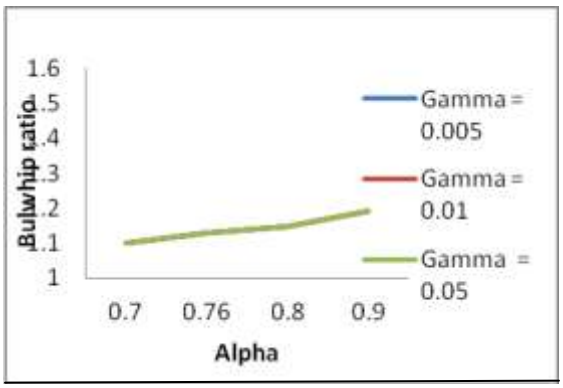

Fig. 13 : Beta is 0.05 and for different values of Alpha and Gamma

Part – II :

Analyzing Tracking signal for both Retailer's and Distributor's statistics

The values of Tracking signal for both retailers' and distributors' data is calculated and tabulated. The tabulated values are as shown below and analyzed to test the accuracy of forecasted model applied to the given data.

Table. 6 : Analyzing the Tracking Signal for Retailers' Statistics

Sl. No.	Month &Year	Actual Demand	Forecasted Demand	Forecasting Error	Sum of Forecasting Error	Absolute Deviation	Cumulative Absolute Deviation	Mean Absolute Deviation	Tracking Signal
1	April.07	4608140	4608140	0	0	0	0	0	0
2	May.07	4668783	4713925	45142	45142	45142	45142	22571	2.00
3	June.07	4655509	4675824	20315	65457	20315	65457	21819	3.00
4	July,07	4709680	4863044	153364	218821	153364	218821	54705	4.00
5	Aug. 07	4851126	4853842	2716	221537	2716	221537	44307	5.00
6	Sept,07	4801511	4550226	-251285	-29748	251285	472822	78804	-0.38
7	Octo,07	4755305	4756385	1080	-28668	1080	473902	67700	-0.42
8	Nov,07	4776948	4889109	112161	83493	112161	586063	73258	1.14
9	Dece,07	4860493	4815168	-45325	38168	45325	631388	70154	0.54
10	Janau,08	4864709	4733130	-131579	-93411	131579	762967	76297	-1.22
11	Feb,08	4455077	4613680	158603	65192	158603	921570	83779	0.78
12	Marc,08	4883501	5064160	180659	245851	180659	1102229	91852	2.68
13	April.08	5090301	4629078	-461223	-215372	461223	1563452	120266	-1.79
14	May.08	5211502	5112166	-99336	-314708	99336	1662788	118771	-2.65
15	June.08	5138866	5184401	45535	-269173	45535	1708323	113888	-2.36
16	July,08	5436783	5374174	-62609	-331782	62609	1770932	110683	-3.00
17	Aug. 08	5442617	5546746	104129	-227653	104129	1875061	110298	-2.06
18	Sept,08	4765322	5129794	364472	136819	364472	2239533	124419	1.10
19	Octo,08	4767970	4866084	98114	234933	98114	2337647	123034	1.91
20	Nov,08	4940490	4923678	-16812	218121	16812	2354459	117723	1.85
21	Dece,08	4799055	4946957	147902	366023	147902	2502361	119160	3.07
22	Janau,09	4481643	4716293	234650	600673	234650	2737011	124410	4.83
23	Feb,09	4403733	4327448	-76285	524388	76285	2813296	122317	4.29
24	Marc, 09	5028594	4939668	-88926	435462	88926	2902222	120926	3.60
25	April.09	5035224	4704420	-330804	104658	330804	3233026	129321	0.81
26	May.09	5007126	5084537	77411	182069	77411	3310437	127325	1.43
27	June.09	5077607	5019118	-58489	123580	58489	3368926	124775	0.99
28	July,09	5133432	5281736	148304	271884	148304	3517230	125615	2.16
29	Aug. 09	5750024	5284081	-465943	-194059	465943	3983173	137351	-1.41
30	Sept,09	5436401	5288090	-148311	-342370	148311	4131484	137716	-2.49
31	Octo,09	5540531	5417812	-122719	-465089	122719	4254203	137232	-3.39
32	Nov,09	5318657	5666122	347465	-117624	347465	4601668	143802	-0.82
33	Dece,09	5406163	5413988	7825	-109799	7825	4609493	139682	-0.79
34	Janau,10	5154063	5277106	123043	13244	123043	4732536	139192	0.10
35	Feb,10	5226119	4946186	-279933	-266689	279933	5012469	143213	-1.86
36	Marc, 10	5085430	5814570	729140	462451	729140	5741609	159489	2.90

Table. 7 : Analyzing the Tracking Signal for Distributors' Statistics

Sl No.	Month &Year	Actual Demand	Forecasted Demand	Forecasting Error	Sum of Forecasting Error	Absolute Deviation.	Cumulative Absolute Deviation	Mean Absolute Deviation	Tracking Signal
1	April.07	4610554	4610554	0	0	0	0	0	0
2	May.07	4670604	4715308	44704	44704	44704	44704	22352	2
3	June.07	4664000	4681068	17068	61772	17068	61772	20590.67	0.829
4	July,07	4712513	4869484	156971	218743	156971	218743	54685.75	2.87
5	Aug. 07	4857564	4858490	926	219669	926	219669	43933.8	0.021
6	Sept,07	4803735	4555763	-247972	-28303	247972	467641	77940.17	-3.18
7	Octo,07	4759751	4760631	880	-27423	880	468521	66931.57	0.013
8	Nov,07	4784000	4892097	108097	80674	108097	576618	72077.25	1.5
9	Dece,07	4862088	4821292	-40796	39878	40796	617414	68601.56	-0.59
10	Janau,08	4866237	4733242	-132995	-93117	132995	750409	75040.9	-1.77
11	Feb,08	4456466	4615220	158754	65637	158754	909163	82651.18	1.921
12	Marc,08	4885850	5065509	179659	245296	179659	1088822	90735.17	1.98
13	April.08	5093070	4631792	-461278	-215982	461278	1550100	119238.5	-3.87
14	May.08	5212546	5113716	-98830	-314812	98830	1648930	117780.7	-0.84
15	June.08	5140552	5189486	48934	-265878	48934	1697864	113190.9	0.432
16	July,08	5441404	5374961	-66443	-332321	66443	1764307	110269.2	-0.6
17	Aug. 08	5445555	5551538	105983	-226338	105983	1870290	110017.1	0.963
18	Sept,08	4771889	5132830	360941	134603	360941	2231231	123957.3	2.912
19	Octo,08	4774773	4873094	98321	232924	98321	2329552	122608	0.802
20	Nov,08	4941774	4929204	-12570	220354	12570	2342122	117106.1	-0.11
21	Dece,08	4806160	4949254	143094	363448	143094	2485216	118343.6	1.209
22	Janau,09	4483586	4719638	236052	599500	236052	2721268	123694	1.908
23	Feb,09	4406515	4330008	-76507	522993	76507	2797775	121642.4	-0.63
24	Marc, 09	5030453	4942506	-87947	435046	87947	2885722	120238.4	-0.73
25	April.09	5040301	4707131	-333170	101876	333170	3218892	128755.7	-2.59
26	May.09	5010000	5087902	77902	179778	77902	3296794	126799.8	0.614
27	June.09	5081846	5025911	-55935	123843	55935	3352729	124175.1	-0.45
28	July,09	5134995	5285036	150041	273884	150041	3502770	125098.9	1.199
29	Aug. 09	5755958	5287041	-468917	-195033	468917	3971687	136954.7	-3.42
30	Sept,09	5439241	5292872	-146369	-341402	146369	4118056	137268.5	-1.07
31	Octo,09	5545677	5422522	-123155	-464557	123155	4241211	136813.3	-0.9
32	Nov,09	5325311	5669536	344225	-120332	344225	4585436	143294.9	2.402
33	Dece,09	5412846	5419918	7072	-113260	7072	4592508	139166.9	0.051
34	Janau,10	5155369	5280683	125314	12054	125314	4717822	138759.5	0.903
35	Feb,10	5235130	4948397	-286733	-274679	286733	5004555	142987.3	-2.01
36	Marc, 10	5091294	5822640	731346	456667	731346	5735901	159330.6	4.59

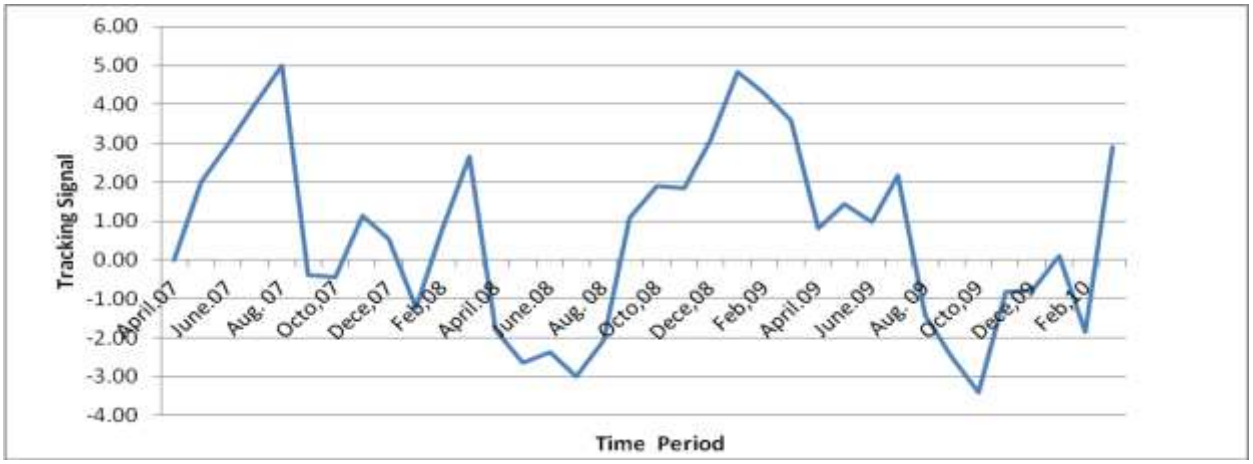

Fig. 14 : Tracking signal for Retailer's Statistics

Fig. 15 : Tracking signal for Distributor's Statistics

CONCLUSIONS

- The Distributor and Retailer are advised to follow a specific Forecasting method to estimate the future forecasting demand and ordering quantity for next periods. Winters' Triple Exponential Smoothening model is suggested.
- From the study of comparative analysis, the Bullwhip Ratio is minimum for Lower value of Alpha, lower values of Beta and small higher values of Gamma.
- The Year is divided into Three Seasons namely Higher, Medium and Lower. An analysis of the relation between Bullwhip Effect with a range of values of Alpha, Beta and Gamma with variations of Seasonality is determined and the following inferences are drawn.

1) During High Seasonality, to minimize the Bullwhip Effect, the values of Alpha should be at the lowest.

2) During High Seasonality, to minimize the Bullwhip Effect, the values of Beta should be at the lowest.

3) During High Seasonality, to minimize the Bullwhip Effect, the values of Gamma should be at the lowest.

4) During Medium Seasonality, to minimize the Bullwhip Effect, the values of Alpha should be at the lower value near to optimal value.

5) During Medium Seasonality, to minimize the Bullwhip Effect, the values of Beta should be at the higher value.

6) During Medium Seasonality, to minimize the Bullwhip Effect, the values of Gamma should be at the lowest value.

7) During Low Seasonality, to minimize the Bullwhip Effect, the values of Alpha should be at the optimal value

8) During Low Seasonality, to minimize the Bullwhip Effect, the values of Beta should be at the optimal value.

9) During Low Seasonality, to minimize the Bullwhip Effect, the values of Gamma should be at the higher value.

- After analyzing the phenomena (pattern) of Tracking signal for Retailer's Statistics, and Distributors' statistics, the following inferences are drawn.

*Tracking signal curve for Retailers' Statistical data is having a range of **+3.0 to - 3.0** for many months during the 3 years of time horizon considered, except with 2 peaks of over estimation at July 2007 and January 2009 months, as shown in Table 6 and followed by graph Fig 14.

*Tracking signal curve for Distributors' Statistical data is having a range of **+4.0 to - 4.0** for many months during the 3 years of time horizon considered, except with 1 peak of over estimation at March 2010 month, as shown in Table 7 and followed by the graph Fig 15.

*Hence the applied winters' model is found to be more accurate.

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