

# Collaborative Forecasting under CPFR®

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**Abstract:** Collaborative Planning, Forecasting and Replenishment (CPFR®) is an inter-industry initiative driven by the Voluntary Interindustry Commerce Standards Association (VICS) to improve partnership between manufacturers and distributors/retailers through the exchange of information. This paper examines the assessment, communication, and reconciliation of forecast errors under CPFR®. A basic spreadsheet program is used to demonstrate how to facilitate analyses. Instructors can use this exercise to demonstrate examples in the classroom.

## I. Introduction

Collaborative Planning, Forecasting and Replenishment (CPFR®) is an inter-industry initiative driven by the Voluntary Interindustry Commerce Standards Association (VICS) to improve partnership between manufacturers and distributors/retailers through the exchange of information. Its mission is to increase visibility along the supply-chain, thereby reducing the variance between supply and demand.

CPFR® evolved from CRP (continuous replenishment process), or better known as the vendor-managed inventory program (VMI). Successful VMI initiatives have been trumpeted by many companies, including Campbell Soup, Johnson & Johnson, European pasta manufacturer Barilla SpA, Shell Chemical, General Electric, Intel, and many others. However, inaccurate forecasts and undependable shipments have been major obstacles to higher performance.

Using decision support tools and standardized data formatting and communications, trading partners take equal roles in developing and managing a plan for "what is going to be sold, how it will be merchandised and promoted, in what marketplace, and during what time frame," based on the category management practices created as part of Efficient Consumer Response.

By eliminating procedures such as order processing and exception processing and taking into account factors such as the manufacturer's supply constraints and the retailer's promotion plan, both parties can use all the information available to make the best possible joint decisions.

CPFR® changes the relationship paradigm between trading partners. CPFR® requires redefinition of a company's goals and direction. It requires trust between partners. The sharing of product information, point of sale (POS) data and market intelligence among trading partners, usually through EDI or exchanges, is the building block to

CPFR®. Periodically, the retailers and their vendors would hold manual collaboration meetings to make their forecasts more accurate. With forecast collaboration, the vendors not only see the demand patterns of their immediate customers (the retailers), but also the demand patterns of the end-users. Thus, their forecasts reflect the actual consumer demand. Periodic collaboration meetings provide proactive decision making and adjustments, thereby improving replenishment orders execution.

This paper examines the assessment, communication, and reconciliation of forecast errors under CPFR®. A basic spreadsheet program is used to demonstrate how to facilitate analyses. Instructors can use this exercise to demonstrate examples in the classroom.

## II. Forecast Errors and Accuracy

The calculation and communication of forecast error (or accuracy) measures among trading partners is crucial to the evaluation of demand planning activities. It is therefore important for trading partners to understand the parameters and alternative formulas for calculating and reporting these metrics.

### II.1 Forecast Errors

Forecast errors are most often reported as absolute values. Regardless of whether forecasts are high by 8% or low by 8%, forecast error is still as 8% error. However, a source of confusion is in the calculation of the percentage forecast error. Some organizations measure the deviation of their forecast from observed (actual) values, while others measure how actual events deviated from their forecast. Both calculation approaches are widely used, and the only difference is the denominator:

- Deviation of Forecast from Actual: % Forecast Error =  $(|Actual - Forecast| / Actual) * 100$
- Deviation of Actual from Forecast: % Forecast Error =  $(|Forecast - Actual| / Forecast) * 100$ .

If the deviation of forecast from actual is being measured, then the actual value is used as the weighting factor. Otherwise, the forecast value is used as the weighting factor. If a trading partner prefers results in terms of forecast accuracy, computing the forecast accuracy is straightforward. Subtracting the % forecast error from 100% yields the forecast accuracy, e.g., instead of reporting a forecast error of 8%, the corresponding forecast accuracy =  $100\% - 8\% = 92\%$ .

There are caveats in using the formula above to calculate the forecast error (or forecast accuracy). An obvious shortcoming is that by using an absolute error in calculating forecast accuracy, it is not possible to see whether there was an under-forecast or over-forecast an event without referring to the detailed data.

Another problem is that it is possible for the forecast accuracy to become negative if forecast error is over 100%! Since negative forecast accuracy is difficult to conceptualize, by convention any forecast accuracy value below zero is reported as zero (i.e., dead wrong!).

## II. 2 Aggregating Forecast Errors

Frequently, forecast errors are reported not for a single item, but for a number of stock keeping units (SKU) across a number of locations. In this case, the relative weight of each individual item must be considered in calculating the error of the next level of aggregation. In practice, aggregation may occur across product, location, and time as follows:

- Product Dimension: SKU, Item, Brand, Category, Cross-Category
- Location Dimension: Store, Customer distribution center/ Store Group / Store Format, Customer, Channel
- Time Dimension: Day, Week, Month, Quarter, Year

In the following examples, it is assumed that the deviation of the actual value from the forecast is being measured. Hence, the forecast value is used as the weighting factor.

## II. 3 Illustrative Example

The calculation and communication of forecast accuracy is fundamental in appraising demand planning activities. Unfortunately, the same reported result could indicate excellent or poor performance, depending upon how it was calculated.

Consider the following example. A product category consists of two SKUs, the forecasts and actual sales are shown below:

	Forecast	Actual	Absolute Error
	<u>Forecast</u>	<u>Actual</u>	<u>Absolute Error</u>
SKU 1	100	80	$ 100-80 =20$
SKU 2	80	100	$ 80-100 =20$
Category	180	180	$ 180-180 =0$

The % accuracy of SKU 1 =  $100\% - 20/100 = 80\%$  and the % accuracy of SKU 2 =  $100\% - 20/80 = 75\%$  (Note: the denominator used is the forecast). At the category level, the forecast is  $(100 + 80) = 180$  units, and the actual is  $(80 + 100) = 180$  units. This may lead one to think that the forecast accuracy at the category level is 100%!

The forecasts for SKU 1 and SKU 2 are 100 and 80 units respectively. The total forecast for the category is 180 units. Thus SKU 1 accounted for  $100/180 = 56\%$  of the category total forecast, and SKU 2 accounted for  $80/180 = 44\%$  of the category total forecast. Hence, the weighted forecast accuracy for the category is  $(56\% * 80\%) + (44\% * 75\%) =$

78%.

Is the forecast accuracy for the category 100% or is it 78%?

When a forecast is calculated at the distribution center (DC) level, the calculated category forecast accuracy can be much different.

Suppose there are two DCs. The forecasts and actual sales of SKU 1 across all DCs are shown below:

	Forecast	Actual	Absolute Error	Forecast Accuracy
SKU 1 at DC 1	50	30	$ 50-30  = 20$	$100\% - 20/50 = 60\%$
SKU 1 at DC 2	50	50	$ 50-50  = 0$	$100\% - 0/50 = 100\%$
SKU 1 Total	100	80		

The forecasts for SKU 1 at DC 1 and SKU 1 at DC 2 are 50 and 50 units respectively. The forecast for SKU 1 across all DCs is 100 units. Thus SKU 1 at DC 1 accounted for  $50/100 = 50\%$  of the total forecast for SKU 1. Likewise, SKU 1 at DC 2 accounted for  $50/100 = 50\%$  of the category total forecast. Hence, the weighted forecast accuracy for SKU 1 across all DCs =  $(60\% * 50\%) + (100\% * 50\%) = 80\%$ .

The forecasts and actual sales of SKU 2 across all DCs are shown below:

	Forecast	Actual	Absolute Error	Forecast Accuracy
SKU 2 at DC 1	40	70	30	$100\% - 30/40 = 25\%$
SKU 2 at DC 2	40	30	10	$100\% - 10/40 = 75\%$
SKU 2 Total	80	100		

SKU 2 at DC 1 accounted for  $40/80 = 50\%$  of the total forecast for SKU 2. Likewise, SKU 2 at DC 2 also accounted for 50%. Hence, the weighted forecast accuracy for SKU 2 across all DCs =  $(25\% * 50\%) + (75\% * 50\%) = 50\%$ .

Since SKU 1 accounted for 56% of the category total forecast, and SKU 2 accounted for 44% of the category total forecast, the weighted forecast accuracy for the category is  $(56\% * 80\%) + (44\% * 50\%) = 67\%$ .

The above example highlights the need for trading partners to have a consensus on the method of calculating and reporting forecast accuracy. That way, trading partners can better understand the performance being measured, and can duplicate the calculations from source themselves, if they desire. They can also request that a trading partner calculate a metric based upon data in their systems.

## III. Negotiating and Reconciling

Companies conduct customer studies and competitive analyses to get a pulse on the marketplace. They also scan the environment for demographic trends, regulatory climate, technological developments, economic conditions, and so forth. Like internally generated data, this external

information most likely is continuously collected and monitored.

For example, manufacturing sees demand by SKU/plant, distribution sees demand by sales category/region, and retailer sees demand by cash versus credit sales. Different views of forecasts inevitably lead to different forecasts. The figure below acknowledges the different forecast views in a typical enterprise. The bottom level is the most detailed, typically with forecast for each stock keeping unit (SKU), region, channel, and brand. The higher levels represent aggregate forecast data at increased levels of summarization. These diverse working views are reconciled with one another to ensure that forecasts are consistent across the whole organization

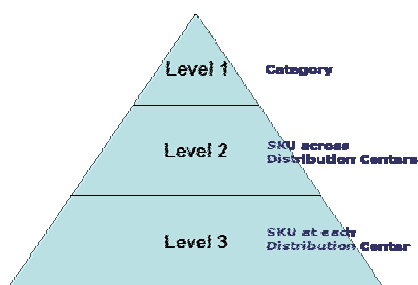


Figure 1. Hierarchical Forecasting

To produce a single unified statement of expected demand, the forecast has to incorporate and reconcile information from diverse sources inside and outside the corporation. To illustrate, consider the following example:

**Level 3 (SKU at each DC) Forecasts.** SKU 1 is sold to customers through distribution centers (DC) 1 and 2, while SKU 2 is sold through DC 3, DC 4, and DC 5. For the coming year, sales forecasts from DC 1 and DC 2 are:

SKU 1	Units	Price	Value
DC 1	8,200	\$20.61	\$169,002
DC 2	4,845	\$10.00	\$48,450
Total SKU 1	13,045		\$217,452

The sales forecasts from DC 4, DC 5, and DC 6 are:

SKU 2	Units	Price	Value
DC 3	7,000	\$20.50	\$143,500
DC 4	12,600	\$18.50	\$233,100
DC 5	8,400	\$21.80	\$183,120
Total SKU 2	28,000		\$559,720

These forecasts correspond to Level 3 Forecasts in Figure 1. The forecast for SKU 1 and SKU 2 across all DCs are \$217,452 and \$559,720, respectively.

**Level 2 (SKU across all DCs) Forecasts.** Suppose the forecasts of the product managers of SKU 1 and SKU 2 are \$250,000 and \$475,000, respectively. These correspond to Level 2 Forecasts in Figure 1. From Level 3, the forecast for SKU 1 across all DCs is \$217,452. How should one adjust the forecasts for SKU 1 at DC 1 and DC 2?

What about the forecasts for SKU 2 at DC 4, DC 5, and DC 6? The forecast for SKU 1 across all DCs at Level 3 is

\$559,720. Should they be proportionately reduced?

**Level 1 (Category) Forecast.** Suppose management has set a goal of \$750,000 for the category. This goal is \$25,000 over the sum of the sales targets (\$250,000 and \$475,000 = \$725,000) at Level 2. The category forecast of \$750,000 corresponds to Level 1 Forecasts in Figure 1. How should the product managers increase their forecasts, to be consistent with the goals of the category manager?

**Adjusting Proportionately** As a first pass, consider adjusting the forecasts proportionately.

First, the Level 2 forecasts (SKU across all DCs) should be revised to make them consistent with the Level 1 forecast (Category). To do this, the Level 2 forecasts must be adjusted by  $(750,000-725,000)/725,000 = 3.45\%$  (an increase). The revised Level 2 Forecasts are \$258,621 for SKU 1, and \$491,379 for SKU 2

Next, the revised Level 2 forecasts are used to adjust the Level 3 forecasts. The forecasts for SKU 1 at each DC must be adjusted by  $(258,621-217,452)/217,452 = 18.93\%$  (an increase). The forecasts for SKU 2 at each DC must be adjusted by  $(491,379-559,720)/559,720 = -12.21\%$  (a decrease).

The revised Level 3 Forecasts, SKU 1 at DC 1 and SKU 1 at DC 2, are 9,752 and 5,762, respectively. The revised Level 3 Forecasts, SKU 2 at DC 3, SKU 2 at DC 4, & SKU 2 at DC 5 are 6,145, 11,062, and 7,374 respectively.

Figure 2 summarizes all the calculations above. The data was entered into an Excel worksheet which shows the sum of forecasts at Level 2 (cell D18) = \$725,000. This is less than the Level 1 forecast of \$750,000 (cell D22). To reconcile the forecasts, the forecasts at Level 2 for SKU 1 and SKU 2 are increased by 3.35% (cells I16 and I17), respectively. The Excel formula for cells I16 is  $I16=(D22-D18)/D18$ . The formula is copied and pasted onto cell I17. The revised forecasts are shown in cells H16= $D16*(1+I16)$  and  $H17 = D17*(1+I17)$ .

To revise the Level 3 forecasts, the pertinent Excel formulae are:

- I3= $(H16-D5)/D5$
- Copy and paste onto cell I4
- H3= $D3*(1+I3)$
- Copy and paste onto cell H4
- I8= $(H17-D11)/D11$
- Copy and paste onto cells I9:I10
- H8= $D8*(1+I8)$
- Copy and paste onto cells H9:I10

	A	B	C	D	E	F	G	H	I	J
1	Level 3 (SKU at each DC)					Level 3 (SKU at each DC) Revised				
2		Units	Price	Value			Units	Value	% Change	
3	DC 1	8,200	\$20.61	\$169,002	DC 1	9,752	200,998		18.93%	
4	DC 2	4,845	\$10.00	\$48,450	DC 2	5,762	\$57,620		18.93%	
5	Total SKU 1	13,045		\$217,452	Total SKU 1	15,515	\$258,621			
6										
7							Units	Value		
8	DC 3	7,000	\$20.50	\$143,500	DC 3	6,145	\$125,979		-12.21%	
9	DC 4	12,600	\$18.50	\$233,100	DC 4	11,062	\$204,439		-12.21%	
10	DC 5	8,400	\$21.80	\$183,120	DC 5	7,374	\$160,701		-12.21%	
11	Total SKU 2	28,000		\$559,720	Total SKU 2	24,581	\$491,379			
12								Sum of Sq % Change	-0.31641	
13										
14										
15	Level 2 (SKU across all DCs)					Level 2 (SKU across all DCs) Revised				
16	SKU 1		\$250,000		SKU 1		\$258,621		3.45%	
17	SKU 2		\$475,000		SKU 2		\$491,379		3.45%	
18	Total Category		\$725,000		Total Category		\$750,000			
19										
20										
21	Level 1					Level 1 (Category) Revised				
22	Total Category		\$750,000		Total		\$750,000		0.00%	

Figure 2. Adjusting Forecasts Proportionately

$J12 = \text{SUMSQ}(I3:I4, I8:I10)$ . SUMSQ is an Excel function. SUMSQ (I3:I4, I8:I10) computes the sum of squared % changes (I3:I4, I8:I10) in Level 3 forecasts. It is a summative measure of the amount of changes in the forecasts for each SKU at each DC.

**Optimization Model** Collaborative forecasting is iterative. To adjust the forecasts proportionately across the board, the original forecasts for SKU 1 at DC 1 and DC 2 must be increased by almost 19%! The managers in these DCs may not have the necessary resources to attain the revised sales goals. Even if they have the resources, the market may not be strong enough to sustain a 19% increase in sales.

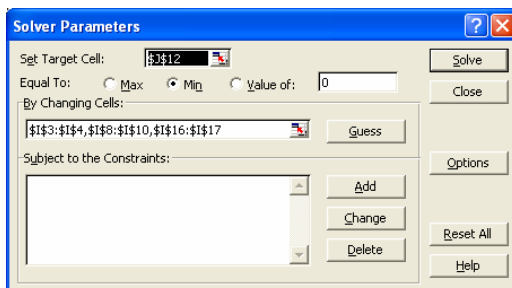
While DC 1 and DC 2 are expected to increase their sales target, DCs 3, 4, and 5 are actually asked to revise their forecasts downwards by -12.21%. If like most business organizations where performance is tied to the ability of attaining sales targets, this may become a sticking point among the managers in the organization.

The following exercise shows how an Excel worksheet can be used to demonstrate how the various organizations in the business can collaborate to arrive at an executable single forecast.

Level 3 (SKU at each DC)			Level 3 (SKU at each DC) Revised				
	Units	Price	Value	Units	Value	% Change	
DC 1	8,200	\$20.61	\$169,002	8,578	182,907	8.20%	
DC 2	4,845	\$10.00	\$48,450	4,959	49,591	2.96%	
<b>Total SKU 1</b>	<b>13,045</b>		<b>\$217,452</b>	<b>13,534</b>	<b>\$232,500</b>		
Level 2 (SKU across all DCs)			Level 2 (SKU across all DCs) Revised				
	Units	Price	Value	Units	Value	% Change	
DC 3	7,000	\$20.50	\$143,500	6,477	132,789	-7.47%	
DC 4	12,600	\$18.50	\$233,100	11,340	209,796	-10.00%	
DC 5	8,400	\$21.80	\$183,120	7,600	165,674	-9.53%	
<b>Total SKU 2</b>	<b>28,000</b>		<b>\$559,720</b>	<b>25,417</b>	<b>\$508,259</b>		
						<b>Sum of Sq % Change</b>	<b>-0.03197%</b>
Level 1 (Category across all DCs)			Level 1 (Category) Revised				
	Units	Price	Value	Units	Value	% Change	
SKU 1		\$250,000		232,500		-7.00%	
SKU 2		\$475,000		508,259		7.00%	
<b>Total Category</b>		<b>\$725,000</b>		<b>\$740,759</b>			
						<b>Sum of Sq % Change</b>	<b>-0.03197%</b>
						<b>Limits on % Change</b>	
						Level 1	± 2.5%
						Level 2	± 7.0%
						Level 3	± 10.0%

Figure 3. Adjusting Forecasts Using Solver

First, notice that the % changes in Figure 3 are different from those found in Figure 2. The cells, highlighted in yellow, are called the decision variables. A tool in Microsoft Excel called Solver can be used to change the values of these decision variables. To use Solver, click Tools on the menu bar, and choose Solver. On the pull down menu, enter the following Solver parameters:



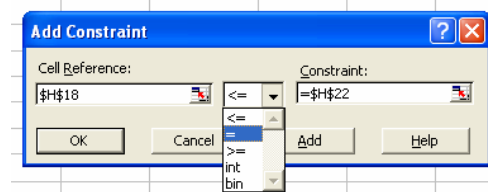
The Set Target Cell is J12, the objective function. Recall that cell J12 a summative measure of the amount of changes in the forecasts for each SKU at each DC. Solver is directed

to help minimize this value. On Equal to, choose Min, to minimize.

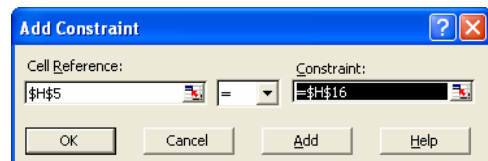
In the By Changing Cells box, enter \$I\$3:\$I\$4, \$I\$8:\$I\$10, \$I\$16:\$I\$17, \$I\$22. Solver is instructed to change the original values of the % changes (cells highlighted in yellow). These are the decision variables. Next, Solver has to be taught how to solve for the decision variables. We do this by introducing constraints in the Solver menu.

To reconcile the forecasts, the forecasts at all levels should be consistent. Therefore, the sum of forecasts at Level 2 (cell H18) must equal the category manager's forecast (cell H22). Likewise, the total forecasts for SKU 1 at Level 3 (cell H5) must equal the forecast for SKU 1 at Level 2 (cell H16), and the total forecasts for SKU 2 at Level 3 (cell H11) must equal the forecast for SKU 2 at Level 2 (cell H17). These constraints must be entered one at a time as follows:

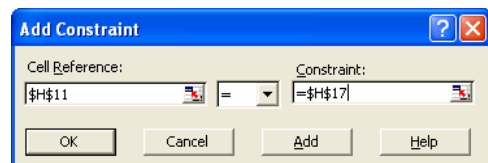
On the Solver Parameter menu, click Add to add the first constraint (Level 2):



After entering the first constraint, click Add to add the next constraint (SKU 1 at Level 3):



Again, click Add to add the next constraint (SKU 2 at Level 3):



In order to complete this task, additional information more information is required. In intra-organization collaborative forecasting, sales targets are to be adjusted based market outlook, and the resources available to the managers in each DC.

Collaborative forecasting requires hard work, high commitment, and willingness to give and to take. Suppose it is agreed that % change at Level 3 should not exceed 10% in either direction, and the % change at Level 2 should not exceed 7% in either direction. Furthermore, the category manager's forecast is constrained not to exceed 2.5%. This information must be translated into Excel formulae, and entered in the "Subject to the Constraints" box in the Solver

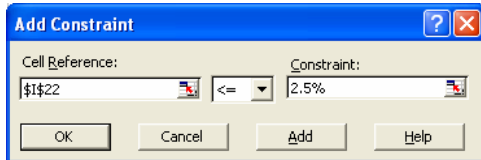
menu.

At Level 1, the constraints are  $I22 \leq 2.5\%$  and  $I22 \geq -2.5\%$ .

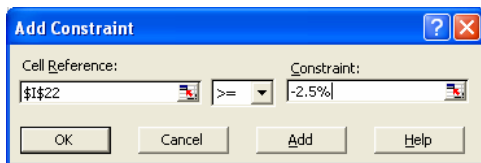
At Level 2, the constraints are  $I16:I17 \leq 7\%$  and  $I16:I17 \geq -7\%$

For SKU 1 at Level 3, the constraints are  $I3:I4 \leq 10\%$  and  $I3:I4 \geq -10\%$ . For SKU 2 at Level 3, the constraints are  $I8:I10 \leq 10\%$  and  $I8:I10 \geq -10\%$ .

Now, click Add to add more constraints:



Click Add to add another constraint:



Repeat, until all constraints have been added. Click OK when done.

Finally, on the Solver Parameter menu click Solve. This is how the optimal % changes in forecasts are all levels (Figure 2) were determined.

The above example, albeit an abstraction, stresses the process of integrating the planning activities across all functions in the organization into coordinated processes.

As shown in Figure 3, the category manager's forecast (Level 1) is to be adjusted downwards by 1.23%, from \$750,000 to \$740,750. This is within the 2% limit. At Level 2, SKU 1 will be decreased by 7% while SKU 2 will be increased by 7%. These adjustments are within the 7% limit. Finally, we see adjustments ranging from a 10% reduction to an increase of 8.23% at Level 3. Again, these changes are within the 10% limit.

The process appears to be straightforward.

Unfortunately, disconnects often occur within the corporate wall, coordinating activities of distinct legal entities along the supply chain often poses a much more formidable challenge.

## IV. Conclusion

This paper illustrates the complex procedure involved in implementing CPFR. It shows the various levels of forecasting and highlights pitfalls in attempting to coordinate the activities of different levels of the firm and its Supply Chain partners. Instructors may find this exercise useful as a classroom example demonstrating how the use of a basic spreadsheet program (e.g. Excel), allows the possibility of reconciling many diverse perspectives from different levels of management into one coherent forecast.

Future studies can examine the imperative for

interorganization collaborative demand planning, and what industry is doing today to accomplish it.

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