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ABSTRACT

Recognizing the value of information sharing among supply chain partners, a growing number of firms have expressed keen interest in jointly creating customer demand, managing business functions and leveraging the strength of their supply chain partners. In particular, such interest sparked the rapid development and implementation of collaborative planning, forecasting and replenishment (CPFR) that was proven to be successful in minimizing safety stocks, improving order fill rates, increasing sales, and reducing customer response time. Despite increasing popularity, key drivers for the successful development and implementation of CPFR have not been fully understood by practitioners and academicians alike. This paper unveils the invisible challenges and opportunities for adopting and implementing CPFR. Also, it provides an overview of CPFR in comparison to other alternative forecasting techniques such as agent-based forecasting and focus forecasting, while synthesizing the past evolutions and future trends of CPFR in a supply chain setting.

***Key words**:* Collaborative Planning, Forecasting and Replenishment, supply chain management, demand planning

1. INTRODUCTION

In contrast to the traditional business paradigm that focuses on the effectiveness and efficiency of separate business functions, a growing number of firms have begun to realize the strategic benefits of jointly planning, controlling, and designing a supply chain as a whole through inter-functional and inter-organizational integration. These benefits include: reduced inventory (or working capital), less frequent rush delivery, faster product flow, quicker customer response time, higher asset utilization, larger marker share, and increased revenue and profit. Despite a host of benefits gained from supply chain integration, only a few firms have adopted and successfully implemented a concept of jointly planning, controlling, and designing a supply chain. In fact, Gustin (2001) reported that less than one third (26%) of the 300 U.S. companies surveyed recognized and successfully implemented supply chain integration. Also, the respondents of the American Shipper/Mercer Management Consulting Survey conducted by Artman and Sabath (1995) indicated that supply chain integration was one of the most pressing logistics related problems. A lack of success in implementing supply chain integration is often due to poorly coordinated data exchange or information sharing among supply chain partners. Thus, the ultimate success of supply chain integration will depend on supply chain partners' willingness to share real-time information throughout the supply chain and develop joint planning processes for adding value to end-customers' needs (see, e.g., Raghunathan, 1999; Cachon and Fisher, 2000; Lee et al., 2000; Thonemann, 2002; Zhao et al., 2002 a, b for various benefits of sharing information in supply chains). An information sharing process that has gained increased popularity over the years is collaborative planning, forecasting, and replenishment (CPFR).

In general, CPFR is referred to as a nine-step joint demand planning process that aims to enhance supply chain visibility by improving order forecasts and fulfillment through continuous communications among multiple supply chain partners. The nine-step process is comprised of: (1) develop front-end agreement; (2) create joint business plan; (3) create sales forecasts; (4) identify exceptions for sales forecasts; (5) resolve/collaborate on exception items; (6) create order forecasts; (7) identify exceptions for order forecasts; (8) resolve/collaborate on exception items; (9) order generation (see, e.g., Ackerman, 2000; Logility, 2000). The detailed steps of CPFR are graphically displayed in Figure 1. Although CPFR evolved from traditional collaborative tools, such as: electronic data interchange (EDI), vendor managed inventory (VMI), and efficient consumer response (ECR), it differs from others in that it brings mutual benefits to all the supply chain partners involved by utilizing more interactive, broader communication processes throughout the supply chain rather than relying on limited transaction-level automation. Other benefits of CPFR include: higher inventory turnover, lower stock-out rate, improved order fill rate, improved cash flow; more accurate production scheduling, more amicable business relationships among supply chain partners, reduced cycle time, reduced order picking/receiving costs, reduced labor costs, and quicker response to customer needs (Sherman, 1998; Williams 1999; Barratt and Oliveira, 2001; Langabeer and Stoughton, 2001; McKaige, 2001; McCarthy and Golicic, 2002; Andraski and Haedicke, 2003). For example, the pilot implementation of CPFR by Wal-Mart and its supplier, Warner-Lambert, increased average in-stock rates from 87 to 98%, reduced lead time from 21 to 11 days, and increased sales volume by $8.5 million in 1995 (Fahrenwald et al, 2001). A German office supplies manufacturer named Herlitz AG, which shared information with its retailer named Metro through CPFR, reduced its inventory by 15%, curtailed its stock-outs by 50%, and increased its annual sales by 3% (Andraski, 2000). Similarly, Johnson & Johnson reported to increase its in-stock rate from 91.5% to 93.8% after adopting CPFR (Inventory Management Report, 2002). After CPFR was implemented for Sears and Michelin in 2001, they reported that in-stock levels at the Sears stores were improved by 4.3% and Sears distribution centers-to-store fill rate was increased by 10.7%, while the combined Sears and Michelin inventory levels were reduced by 25% (Steermann, 2003). The detailed illustration of CRPF implementation success for other companies can be found in Seifert (2003).

Despite the aforementioned promises, CPFR is not without its obstacles. These obstacles may include: cultural and technical incompatibility among supply chain partners, lack of trust among supply chain partners, lack of scalability, lack of internal alignment, inadequate software and technology support, substantial start-up investment for building a communication infrastructure, antitrust laws, legacy systems, and difficulty in real-time coordination of information exchange (e.g., Mentzer et al., 2000; Barratt and Oliveira, 2001; McCarthy and Golicic, 2002; Seifert, 2003). One way of overcoming such obstacles is the integration of CPFR with other alternative forecasting tools, such as: agent-based forecasting and focus forecasting, that can complement CPFR. With this in mind, the primary purposes of this article are to:

1. Compare and contrast CPFR with other related demand forecasting and planning techniques such as agent-based forecasting and focus forecasting;
2. Synthesize the existing CPFR literature with respect to their practical implications and technical merits;
3. Develop a hierarchical taxonomy for the existing CPFR literature and categorize it according to its application area, problem scope, and methodology;
4. Summarize research trends and identify untapped research topics associated with CPFR;
5. Discuss the future outlook for extensions of existing CPFR literature.

2. CPFR VS. AGENT-BASED FORECASTING

Since a supply chain involves the synchronization of a series of inter-related but different stages of business processes influencing multiple trading partners, its demand planning and forecasting cannot rely on a single, stand-alone forecasting tool. One of the emerging concepts that fits into the supply chain framework is agent-based forecasting which was designed to automate the coordinated planning and communication processes throughout the entire supply chain. In general, agent-based forecasting is a computer-based forecasting system that aims to facilitate enterprise-wide integration through non-proprietary message transfers and automated reasoning capabilities available from intelligent software agents. According to Reis (1999), an agent refers to an autonomous entity that can take certain actions to accomplish a set of goals and can compete and cooperate with other agents while pursuing its individual goals. An agent is often characterized by its ability to exploit significant amounts of domain knowledge, overcome erroneous input, use symbols and abstractions, learn from the environment, operate in real time, and communicate with others in natural language (Newell, 1989).

Exploiting such characteristics, an agent concept was recently introduced to handle various logistics and supply chain issues including a shop floor control within a material requirement planning (MRP), traffic control, joint production planning, and business-to-business communication and negotiation (Van Dyke Parunak, 1988; Satapathy et al., 1998; Swaminathan, 1998; Garcia-Flores et al., 2000; Fox et al., 2000; Ito and Saleh, 2000). More recently, Yu et al. (2002) developed an agent-based forecasting system to predict end-customer demand through information exchange among supply chain partners. In forecasting applications, they utilized four multiple agents with different roles: task agents; coordination agents; data collection agents; interface agents (see Figure 2 for a graphical display of these agents). Their experiments with actual data showed that agent-based forecasting performed better to predict end-customer demand than a collection of traditional time series forecasting techniques in a supply chain setting. Thus, they conclude that agent-based forecasting was suitable for demand planning in a supply chain setting as a substitute for CPFR. Though CPFR and agent-based forecasting have similarities in that both are intended to coordinate multiple sources of data for joint demand planning and forecasting, they differ in many respects. The differences between CPFR and agent-based forecasting are summarized in Table 1.

3. CPFR VS. FOCUSED FORECASTING

Focus forecasting is an expert system that identifies a simple forecasting rule-of-thumb, which worked best in the past, and uses it to make a short-term prediction for future events such as sales or customer demands. Focus forecasting is often comprised of three steps: (1) simulate the past forecasts using a variety of simple forecasting rules; (2) evaluate the performances of these simple rules with respect to forecasting errors such as mean absolute deviation (MAD) and mean absolute percentage error (MAPE); (3) select the forecasting rule that performed best as the forecasting method that will used to forecast the next period’s demand. Also, focus forecasting is characterized by its simplicity, lack of file maintenance, and user friendliness (Smith, 1991; Smith, 1997). Focus forecasting is different from CPFR in that the former does not involve trading partners for making forecasts and focuses on internal forecasts within the company, whereas the latter shares information with the multiple supply chain partners and develop both intra- and inter-organizational demand plans (see Table 1 for detailed distinctions between CPFR and focus forecasting).

4. TAXONMY OF THE CPFR LITERARURE

The CPFR taxonomy to be developed here uses three broad classification schemes: (1) *problem scope* as a criterion for measuring the breadth and depth of the CPFR study, (2) the *methodology* as a criterion for evaluating the theoretical advance of the CPFR study, and (3) the *implementation status* for assessing the practicality of the CPFR study.

4.1 Problem scope

The problem scope is categorized with respect to the level of CPFR integration: (1) *intra-organizational integration* across different business functions; (2) *inter-organizational integration* across vertical supply chain links. The inter-organizational integration can be further sub-classified into: (1) *two-tier* integration; (2) *n-tier* integration. A two-tier integration focuses on the collaborative relationship between two primary supply chain partners (typically the manufacturer and retailer); whereas, a n-tier integration involves more than two (multiple) supply chain partners across the industry and vertically extends information sharing mechanism to minimize "bullwhip" effects as illustrated in Figure 3. The bullwhip effect is generally referred to as an inverse ripple effect of forecast errors throughout the supply chain that often leads to amplified supply and demand misalignment where orders to the upstream supply chain partner tend to exaggerate the true patterns of end-customer demand since each supply chain partner's view of true demand can be blocked by its immediate downstream supply chain partners (see, e.g., Lee et al. 1997; Min, 2000). Either two-tier or n-tier integration can also be subdivided into one-to-one, one-to-many, and many-to-many integration (e.g., CPFR partnerships among multiple manufacturers and multiple retailers) depending on the number of horizontal supply chain partners involved in CPFR.

4.2 Methodology

The broad subcategories of methodological classification are descriptive (conceptual) and normative (analytical) studies. The descriptive studies often illustrate the numerous managerial benefits of using CPFR or evaluate the outcomes of CPFR in comparison to traditional stand-alone demand planning through case examples. On the other hand, normative studies designed quantitative models to assess the positive impact of CPFR (or information sharing across the vertical supply chain) on various supply chain performances in comparison to old legacy systems or less structured forecasting procedures. These quantitative models can be broken down into mathematical models and simulation experiments. The core mathematical models also include various forecasting techniques which may be categorized as: time series and causal methods. Time series (univariate forecasting) methods assume that the past is an adequate representation of the future and that a product's past demand pattern can be extrapolated to predict future demand (Tyagi, 2002). Causal (multivariate forecasting) methods make predictions of the future by modeling the relationship between a series and other series (DeLurgio, 1998). Time series methods include moving average, exponential smoothing, decomposition, linear trends, and Box-Jenkins, while causal methods include regression and econometric models (Chambers et al., 1971; DeLurgio, 1998).

4.3 Implementation status

Since supply chain managers may be interested in determining the applicability of the proposed model and procedure, we included the third dimension of the taxonomy indicating whether or not the proposed model and procedure was implemented, and whether or not the model was developed based on actual data.

5. SYNTHESIS AND FUTURE RESEARCH DIRECTIONS

Despite the relatively short history of CPFR, we have noticed a clear research stream established by many pioneering scholars who initiated CPFR studies during the last few years. A few of these studies worth noting include: (1) Aviv (2001) who developed a mathematical model as a means of measuring the magnitude of the benefit of joint demand forecasting and inventory planning on supply chain performance (e.g., supply chain cost); (2) Barratt and Oliveira (2001) who identified key inhibitors for CPFR implementation through an empirical survey; (3) McCarthy and Golicic (2002) who proposed managerial guidelines for successful implementation of CPFR based on their case studies; (4) Chen et al. (2000) who introduced a mathematical framework that helped measure the impact of demand forecasting on order variability (or bullwhip effect) in supply chains. Regardless of methodological differences among these studies, all of these studies share a common theme -- a verification of the positive impact of CPFR on supply chain performance (see Table 2 for detailed summaries of past CPFR studies). Following this theme, Zhao et al. (2001), Zhao and Xie (2002), Zhao et al. (2002a, 2002b), and Dejonckheere et al. (2002) attempted to evaluate the impact of demand forecasting on supply chain performance including the bullwhip phenomena using simulation models. Most of these models, however, are confined to two-tier supply chain integration and focused their attention on supply chain costs in measuring the supply chain performance. With many open research questions unanswered and buoyed by increasing interest in CPFR, additional research is needed to consider the following areas:

- As visibility increases proportionately to the number of tiers participating in inter-organizational collaboration, future research efforts should be directed toward the development of n-tier CPFR that can support multiple supply chain partners and multiple industries. In other words, the scope of CPFR should be extended to include distributors (e.g., carriers and 3PLs) and multi-tier suppliers, while encompassing the elements of collaborative product design, transportation, event and categorical management. In particular, the integration of collaborative transportation management (CTM) into CPFR or vice versa may enhance logistics efficiency by increasing freight consolidation opportunities, updating shipment status on a real-time basis, and utilizing trucking capacity. Thus, the integration of CTM with CPFR can be an intriguing subject of future research.
- Although the potential benefits of CPFR were listed in the past literature, its success in a real-world setting has not been well documented. Additional case studies reporting the CPRF success and failure stories are needed to convince CPFR critics to consider CPFR as a major demand forecasting and planning tool. In particular, these studies should identify key enablers and impediments for the successful implementation of CPFR.
- In evaluating the magnitude of CPFR benefits, most of the existing literature relied on traditional supply chain performance measures such as inventory carrying costs and backorder costs. The development of more specific supply chain performance metrics for measuring CPFR benefits should be in order for future research. These metrics may include: cash-to-cash cycle time, inventory turns, order fill rates, and stock-out rates (see, e.g., Min and Zhou 2002 for a detailed discussion of supply chain performance metrics).
- Since CPFR is intended to bring joint benefits for all the supply chain partners involved in the demand forecasting and planning process, future research endeavors may focus on the verification of joint benefits gained from CPFR during the multiple time periods. That is to say, more longitudinal studies should be conducted to examine the long-term effects of CPFR on supply chain connectivity and visibility.
- Given the evolution of agent-based forecasting and focus forecasting that can replace or complement CPFR, the comparative analyses of CPFR versus agent-based forecasting or focus forecasting may be a fruitful area for future research. Similarly, the complementary nature of CPFR and ECR or CPFR and VMI needs to be investigated to gain further insights into the role of ECR or VMI in CPFR.

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REFERENCES

1. Ackerman, K.B. (2000), "CPFR-How it could change the warehouse," *Warehousing Forum* 15(10), 1-2.
2. Andraski, J.C. (2000), "Logistics Strategies for the New Millennium, CPFR, the Here and Now," presented at the *Warehousing Education and Research Council Conference*, San Antonio, Texas, May 3.
3. Andraski, J.C. and Haedicke, J. (2003), "CPFR: Time for the Breakthrough?" *Supply Chain Management Review* 7(3), 54-60.
4. Aviv, Y. (2001), "The effect of collaborative forecasting on supply chain performance," *Management Science* 47(10), 1326-1343.
5. Artman, L.B. and Sabath, R.E. (1995), "Are you ready for change?" *American Shipper* 37(2), 42-48.
6. Barratt, M., and Oliveira, A. (2001), "Exploring the experiences of collaborative planning initiatives," *International Journal of Physical Distribution & Logistics Management* 31(4), 266-289.
7. Cachon, G.P. and Fisher, M. (2000), "Supply chain inventory management and the value of shared information," *Management Science* 46, 1032-1048.
8. Cachon, G.P. and Lariviere, M.A. (2001), "Contracting to assure supply: How to share demand forecasts in a supply chain," *Management Sciences* 47(5), 629-646.
9. Chambers, J.C., Mullick, S.K., and Smith, D.D. (1971), "How to choose the right forecasting techniques," *Harvard Business Review*, 49(4), 45-74.
10. Chen, F., Drezner, Z., Ryan, J. K. and Simchi-Levi, D. (2000), "Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times, and information," *Management Science* 46(3), 436-43.
11. Dejonckheere, J., Disney, S. M., Lambrecht, M. R., and Towill, D.R. (2002), "Transfer function analysis of forecasting induced bullwhip in supply chains," *International Journal of Production Economics* 78(2), 133-144.
12. DeLurgio, S.A. (1998), *Forecasting Principles and Applications*, New York, NY: Irwin-McGraw-Hill..
13. Fahrenwald, B., Wise, D., and Glynn, D. (2001), "Supply chain collaboration: Close encounters of the best kind," *Business Week (special advertising section)*, March 21, 1-14.
14. Foote, P.S. and Krishnamurthi, M. (2001), "Forecasting using data warehousing model: Wal-Mart's experience," *The Journal of Business Forecasting* 19, 13-17.
15. Fox, M.S., Barbiceanu, M., and Teigen, R. (2000), "Agent-oriented supply chain management," *International Journal of Flexible Manufacturing Systems* 12, 165-188.
16. Garcia-Flores, R., Wang, X.Z., and Goltz, G.E. (2000), "Agent-based information flow for process industries' supply chain modeling," *Computers and Chemical Engineering* 24, 1135-1141.
17. Gustin, C.M. (2001), "Supply chain integration: Reality or myth?" *Distribution Business Management Journal* 1(1), 71-74.

18. Inventory Management Report (2002), "CPFR-No longer a question of if but when," *IOMA Inventory Management Report: Improving Logistics and Supply Chain Management*, December, 1-14.
19. Ireland, R. and Bruce, R. (2000), "CPFR: Only the beginning of collaboration," *Supply Chain Management Review* 4(4), 80-88.
20. Ito, T. and Saleh, M.R. (2000), "A blackboard-based negotiation for collaborative supply chain systems," *Journal of Material Processing Technology* 107, 398-403.
21. Langabeer, J. and Stoughton, T. (2001), "Demand planning and forecasting in the high technology industry," *The Journal of Business Forecasting* 19, 7-10.
22. Lee, H.L., So, K.C., and Tang, C.S. (2000), "The value of information sharing in a two-level supply chain," *Management Science* 46, 626-643.
23. Lee, H.L., Padmanabhan, V., and Whang, S. (1997), "Information distortion in a supply chain: the bullwhip effect," *Management Science* 43, 546-558.
24. Logility (2000), *Collaborative Transportation Management: An Executive White Paper*, Atlanta, GA: Logility, Inc.
25. McCarthy, T.M. and Golicic, S.L. (2002), "Implementing collaborative forecasting to improve supply chain performance," *International Journal of Physical Distribution & Logistics Management* 32(6), 431-454.
26. McKaige, W. (2001), "Collaborating on the supply chain," *IIE Solutions*, 33(3), 34-37.
27. Mentzer, J.T., Foggin, J.H., and Golicic, S.L. (2000), "Collaboration: The enablers, impediments, and benefits," *Supply Chain Management Review* 4, 52-58.
28. Min, H. (2000), "The bullwhip effect in supply chain management," in *Encyclopedia of Production and Manufacturing Management* edited by P. Swamidass, Norwell, MA: Kluwer Academic Publishers, 66-70.
29. Min, H. and Zhou, G. (2002), "Supply chain modeling: past, present and future," *Computers & Industrial Engineering* 43(1), 231-249.
30. Newell, A. (1989), "Putting it all together," in *Complex Information Processing: The Impact of Herbert A. Simon*, edited by D. Klahr and K. Kotovsky, Hillsdale, NJ: Lawrence Erlbaum Associates.
31. Raghunathan, S. (1999), "Interorganizational collaborative forecasting and replenishment systems and supply chain implications," *Decision Sciences* 30(4), 1053-1071.
32. Reis, B.Y. (1999), "A multi-agent system for on-line modeling, parsing and prediction of discrete time series data," in *Computational Intelligence for Modeling, Control & Automation* edited by M. Mohammadian, IOS Press, 164-169.
33. Satapathy, G., Kumara, S.R.T., and Moore, L.M. (1998), "Distributed intelligent architecture for logistics (DIAL)," *Expert Systems with Applications* 14, 409-424.
34. Sherman, R. J. (1998), "Collaborative planning, forecasting & replenishment (CPFR): Realizing the promise of efficient consumer response through collaborative technology," *Journal of Marketing Theory and Practice* 6(4), 6-9.
35. Seifert, D. (2003), *Collaborative Planning, Forecasting, and Replenishment: How to Create a Supply Chain Advantage*, New York, NY: AMACOM.
36. Smith, B.T. (1991), *Focus Forecasting and DRP: Logistics Tools of the Twenty-First Century*, New York, NY: Vantage Press.
37. Smith, B.T. (1997), *Focus Forecasting: Computer Techniques for Inventory Control Revised for the Twenty-First Century*, Fredericksburg, VA: Book Crafters.
38. Steermann, H. (2003), "A Practical Look at CPFR: The Sears-Michelin Experience," *Supply Chain Management Review* 7(4), 46-53.
39. Swaminathan, J.M. (1998), "Modeling supply chain dynamics: A multiagent approach," *Decision Sciences* 29(3), 607-632.
40. Thonemann, U.W. (2002), "Improving supply-chain performance by sharing advance demand information," *European Journal of Operational Research* 142(1), 81-107.
41. Tyagi, R. (2002), "How to evaluate a demand planning and forecasting package," *Supply Chain Management Review* 6(5), 48-56.
42. Van Dyke Parunak, H. (1998), *Practical and Industrial Applications of Agent-based Systems*, White Paper, Ann Arbor, MI: Industrial Technology Institute.
43. Williams, S.H. (1999), "Collaborative planning, forecasting, and replenishment," *Hospital Material Management Quarterly* 21(2), 44-51.
44. Yu, W., Graham, J.H., and Min, H. (2002), "Dynamic pattern matching for demand forecasting using temporal data mining," *Proceedings of the 2nd International Conference on Electronic Business*, December, 400-402.
45. Zhao, X. and Xie, J. (2002), "Forecasting errors and the value of information sharing in a supply chain" *International Journal of Production Research* 40(2), 311-335.
46. Zhao, X., Xie, J., and Lau, R.S.M. (2001), "Improving the supply chain performance: use of forecasting models versus early order commitments," *International Journal of Production Research* 39(17), 3923-3939.
47. Zhao, X., Xie, J., and Leung, J. (2002a), "The impact of forecasting model selection on the value of information sharing in a supply chain," *European Journal of Operational R*esearch 142(2), 321-344.
48. Zhao, X., Xie, J., and Wei, J.C. (2002b), "The impact of forecast errors on early order commitment in a supply chain," *Decision Sciences* 33(2), 251-280.

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