Advanced Solutions for a Supply Chain with Stochastic Information

Rodrigue Cauchois and Atour Taghipour
International Business Faculty, University of Le Havre, Le Havre, France
Email: {rodrigue.cauchois, atour.taghipour }@univ-lehavre.fr

Daeseok Kang
College of Business Administration, Inha University, Incheon, South Korea
Email: kang0180@inha.ac.kr

Nesrine Zoghlami
Laboratoire d'Automatique Génie Informatique et Signal, Ecole Centrale de Lille, Lille, France
Email: nesrine.zoghlami@gmail.com

Mourad Abed
UVHC, LAMIH, University of Valenciennes, Valenciennes, France
Email: mourad.abed@univ-valenciennes.fr

***Abstract*—With the increasing variability of the demand and the growing intensity of the competition, it became indispensable for companies to make sure to meet their customers' needs. In this context, the coordination of operations plays an important role to satisfy not only the customers but also all partners of a supply chain. The coordination can be considered as one of the main elements of supply chain management. In order to achieve the objective of coordination, it is possible for a company to collaborate with their partners, or even competitors. This paper first reviews the existing methods to achieve coordination in decentralized systems, with the stochastic information, to satisfy variable demand, and then classifies these solutions into a framework.**

***Index Terms*—stochastic demand, supply chain management, collaboration, coordination, operations planning**

I. Introduction

Due to the increasing competition and the progressive application of new management methods, such as the Lean manufacturing, for example, the activity of companies often became client-centered, since it seems to be an effective way to gain market share. The main objective of the activity, thus became the satisfaction of the client, not only the final client, but also other parts of the supply chain. For instance, some producers' direct clients can be retailers, and their activity can be oriented in the satisfaction of this retailer. However, the demand of a retailer is directly linked with the demand of the final client, even if the producer doesn't have this information. In addition, the retailer's demand and the final client's demand might not be the very same in all cases. As a result, it is difficult for a company to anticipate their partners' demand, even if most of the companies are nowadays using forecasting, which is better than guessing of course, but it might mislead the production if the company lacks some part of the necessary information. In order to achieve customer satisfaction, a possible solution is to collaborate with partners, not only to acquire information, but also to create a win-win situation that motivates all parts of the supply chain in the satisfaction of the final client.

There are many existing methods of collaboration that have been studied in the literature that are aimed to the satisfaction of the client in the case of variable (or stochastic) demand, in the case of decentralized systems. However, each method doesn't necessarily have the same uses as others, that's why we can ask: what are the existing methods to achieve collaboration in a decentralized supply chain aimed to satisfy a variable demand, and how can we classify them?

In order to classify the literature based on the proposed solutions we need to create different categories of solutions, which will give the main characteristics of each solution. Such a similar classification had already been proposed in the literature by [1]. In this paper, the authors propose a classification of supply chain coordination solutions according to two main criteria: mutuality of coordination, and focus of coordination. These criteria allowed the authors to create four categories of solutions.

However, this study wasn't aimed to classify a given number of determined solutions as it is the case in this work. Moreover, this classification concerns the general coordination of the supply chain and not specifically the coordination in the case of decentralized supply chain

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facing stochastic demand.

In order to answer the above question, we will first present the existing methods studied in the literature. Then to create a more appropriate classification, we propose an analysis framework based on two main criteria. Then a classification will be given afterwards. We terminate this paper with a brief conclusion.

II. Literature Review

Supply chain coordination is a solution to planning conflicts, which negatively influence on the global performance of a supply chain. Different coordination mechanisms are proposed to improve the plans and to achieve an optimal or near to the optimal solution for all members of a supply chain. But the coordination is difficult when there exists an asymmetric information, which affects the quality of decision making. The difficulty increases, more specifically, when the demand is stochastic and the partners do not have access to the exact information of a demand.

During the next paragraphs, this section tries to study the distinguished methods proposed in the literature to coordinate a decentralized supply chain in a stochastic environment. Approximately, thirty methods are distinguished, which will be explained here, in the next paragraphs:

Quality Discount: First of all, the method that has been encountered most often during the research is the quantity discount. This method simply consists in agreeing on a discount on the price of the goods between the provider and the client, in order to make buying operations easier for the client (a retailer for example). This can also help in the relationship between the actors of the supply chain. Among other sources, this method is described by [2]. This method is divided into two sub-methods by [3]. In their paper, the authors distinguish two types of quantity discounts: continuous (discount is correlated with order quantity) and discrete (discount on the wholesale price). However, this method had described as ineffective alone by some authors, such as [4].

Safety Stock: In addition to the above frequent method of coordination, many others exist. This includes safety stock ([5]). This solution consists in agreeing on the safety stock to set up in a company and communicating it with partners. It only involves the transmission of information about this safety stock, and the company which realizes it is the one directly concerned.

Improved Forecasting: This method consists in improving forecasting through the communication of accurate and precise data by the partners ([5]). However, it directly concerns only the company which is going to use the forecast for its production or order.

CPFR (Collaborative Planning, Forecasting and Replenishment): This method involves the communication of real-time, accurate and sometimes strategic information in order to realize global decisions for planning, forecasting and replenishment in the whole supply chain ([6]).

VMI (Vendor Managed Inventory): This solution consists in sharing precise information about stock level through Electronic Data Interchange (EDI). The information is automatically updated and aimed to joined order decision ([7]).

Level of EDI Used: It consists in deciding which information will be shared between companies through the use of EDI (which nature, level of importance and etc.) ([8]).

Penalty Policy: This strategy consists in deciding under which condition a single company will have to face penalties, and communicating information concerning this decision ([9]).

Choosing Quality Suppliers: This method aims to deal with demand uncertainty by reducing the bullwhip effect caused by the variable supply of unreliable suppliers. The chooser and the provider chosen are concerned, but only information about the choice is concerned in this solution ([9]).

Inspection/Audit: This solution can used in both cases: to solve a detected problem or identify problems. In both cases, the examined company is directly concerned, and it communicates all requested information while receiving all necessary information for its improvement ([9]).

Lot-sizing: This solution consists in ordering lot sizes adapted to the producer's capacity, the retailer's stock options (if the products are going to be stocked), and the demand of the final client. Only information about possible order quantity and actual order quantity are communicated ([9]).

Multiple Sourcing: This solution has objectives very close from the "choosing quality suppliers" solution, except that it involves more companies at a time, and can be more complex as a result ([9]).

Revenue Sharing Contract: The aim of this solution is to share the revenues of a company according to the participation of each member of the supply chain, and it involves sharing information only about the revenue as a result. As mentioned above in the literature review, these contracts can be one-way or two-way ([10], [11]).

Share Risks: This solution consists in dividing the risks of the supply chain (production stopping, order late…) between different actors, in order to prevent from one single actor to collapse under a problem too important for itself alone. It implies sharing information about actual or expected risks, as well as experience learned from risks encountered in the past ([2]).

CRP (Continuous Replenishment Planning): Through the communication of accurate data about providers and clients' expectations and possibilities, a company will be able to make more effective choices concerning its ordering policy ([12]).

Inventory Subsidy: This method consists in reducing out-of-stocks products frequency by financing, totally or partially, the stock of the company in charge of serving the client. Both financial and physical information needs to be provided ([13]).

Buy-back Contracts: This solution aims to help a retailer that couldn't sell all of its products. Once again, financial information (buy-back price agreed) and physical information (quantity) have to be shared ([14]).

Partial Return: Is has similar characteristics than the

latter solution, except that the seller will take in charge only part of the unsold goods ([4]).

Cooperative Advertising: This possibility aims to reduce uncertainty at the beginning of the commercialization of a product by agreeing on the advertising policy (targeted clients, amount invested…). Agreeing on this policy can prevent an actor from being surprised by an unexpected demand, in quantity or nature, caused by an advertising policy adopted by a partner which is very different from the one realized internally ([4]).

Choice of Strategy: This solution consists, for a single company, to choose a specific strategy (Make to Order, Make to Stock…), and informing partners about it (Make To Order, Make To Stock and etc.) ([15]).

Managing Information Systems: This alternative consists in making sure than the information system of two different companies can communicate with each other, in order to communicate all sorts of information easily, and updating it as soon as possible ([1]).

Forecast Sharing: This solution aims to create a common forecast with information from all the supply chain, in order to reduce the bullwhip effect caused by different order quantities ordered by different actors. The forecast must be as accurate as possible, since it will be the only one used ([16]).

Bill Back: This solution only concerns the financial aspects that will affect one company ([17]).

Physical Flow Coordination: This alternative consists in tracking the flow of products within the supply chain in order to provide information about the location of the products to the concerned actors, and information about eventual problems as well ([18]).

Shared Capacity Information: This solution aims to provide a buyer with accurate and updated information about its provider's possible deliveries ([19]).

Price Protection: This alternative provides an actor some information about its promised financial income ([20]).

Credit Option: In this solution, financial and quantitative information (the object of the subsidy) is shared in order to give financial support to a given part of the supply chain ([21]).

Optimal Stock Control: This possible collaboration method aims to inform all the supply chain about the stock level of all partners, in order to take adapted decisions ([22]).

Consignment Stock: This solution, that involves two partners of the supply chain, requires the communication of various information (order quantity, stock availability…) in order to realize common decisions about which company will be in charge of the warehousing operations, and how will they be done ([23]).

Payment Transfer: This last alternative concerns the payment modalities that will be applied in all the supply chain ([24]).

III. Classification

In order to classify the above literature, we propose two criteria which help us to categorize the analyzed literature into four principles groups.

The first criterion is the number of partners who will benefit from the collaboration, one way adjustment against two ways adjustment. The second criterion is the level of information sharing necessary for the implementation of the solution, which could divided into low level of information sharing against high level of information sharing. As the result, we can create four categories used to classify the solutions mentioned in part II, as shown in the following table.

TABLE I. Mechanisms of Coordination in a Decentralized Supply Chain with Stochastic Demand

		Who will benefit?	
		One way	Two way
Level of information sharing	Low	Separated performance improvement	Win-win organization
	High	Focused collaboration	Complete collaboration

We will now describe with more precision each category, before analyzing each solution in terms of actors who benefit from the solution, and in terms of information sharing, among other noticeable criteria.

First of all, the "Separated performance improvement" category. This category includes solutions that aim to improve the supply chain's ability to meet the final client's needs, but only by focusing on one single actor. In addition, the measures taken will not involve the distribution of confidential information in the supply chain. A quantity discount is an example of this kind of solution.

The "win-win organization" solutions aim to take into account the performance of each part of the supply chain, but each of these parts still take their decisions independently, with their own information and the basic information provided by partners. For instance, these solutions include two-way revenue-sharing contracts.

The "focused collaboration" consists in all the actors of the supply chain put all their resources on the improvement of one particular part of it. This type of solution can be useful if a bottleneck work center is clearly identified. A possible example of these solutions is the realization of an audit.

Finally, the "complete collaboration" is based on a relation of trust between partners, who will willingly share as much information as they can to others, in order to make global decisions for the supply chain possible and optimal. For instance, CPFR (Collaborative Planning, Forecasting and Replenishment) will fit in this category.

Now we will classify the studied literature in these four categories, according by the solution(s) proposed by each paper. Since some papers propose more than one solution, they might be situated in several categories.

TABLE II. MECHANISMS OF COORDINATION IN A DECENTRALIZED SUPPLY CHAIN WITH STOCHASTIC DEMAND

Class	Mechanisms
"Separated performance improvement"	Safety stock, Penalty policy, Quantity discount, Choice of strategy, Bill back, Price protection
"Win-win organization"	Level of EDI used, Choosing quality suppliers, Lot-sizing, Multiple sourcing, Revenue sharing contract, Optimal stock control, Payment transfer
"Focused collaboration"	Improved forecasting, Inspection/audit, CRP (Continuous Replenishment Planning), Inventory subsidy, Buy-back contracts, Partial return, Shared capacity information, Credit option
"Complete collaboration"	CPFR (Collaborative Planning, Forecasting and Replenishment), VMI (Vendor Managed Inventory), Revenue sharing contract, Share risks, Cooperative advertising, Managing information systems, Forecast sharing, Physical flow coordination, Consignment stock

IV. CONCLUSION

To highlight the main streams of research, this paper studied the case of coordination of operations in a decentralized supply chain with stochastic demand. Based on a two criteria of analysis, the studied approaches could be categorized into four main classes, from non-collaborative to complete collaborative approaches. Each approach has different characteristics, and each method might be more appropriate than others for solving problems, or for certain sectors. Some solutions might not be as effective as others. For example, the quantity discount possibility has been proposed as an effective solution by some authors, and rejected by others.

In order to develop the proposed framework we propose to consider more literature on stochastic demand to complete the actual framework. A quantitative analysis of studied approaches also could be used to better contextualize the literature.

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Rodrigue Cauchois is logistics specialist. He received a master degree in Logistics and Transport, and a bachelor degree in Marketing from the University of Le Havre in France. His interest of research is supply chain management.

Dae-seok Kang is Associate Professor in the College of Business Administration at the Inha University, Incheon, South Korea. He received his PhD from the University of Minnesota in 2004. He has published extensively in the field of human resources and organizational management. His research has appeared in several journals, including Personnel Review, Service Industries Journal, Career Development International, and Human Resource Development Quarterly. He enjoys playing football every weekend and spending time with his two children.

Nesrine Zoghlami is a teacher-researcher in logistics and Computer Science in LAGIS laboratory at the high School Ecole Centrale de Lille (EC-Lille) where she obtained her PhD degree in industrial computer science and automatic, in Novembre 2008. Her main research areas are the Optimization, the Artificial Intelligence and Supply chain management. She obtained her master degree in electronic and telecommunication in July 2004 from the University of Valenciennes and her National Engineer diploma in 2003. She takes an active part in the national working group ORT of GDR MACS and she was responsible of the Organizing and Program Committees of international conferences and workshops MHOSI' 2005, LT'2006 and LT'2007, LT' 2009,MSLT 2011,Sysco 2012,ICALT 2013, GOL 2014, ICALT 2014, ICIT 2015. Dr Zoghlami is author or co-author of about 30 Publications, communications and book chapters. She is author of a book in supply chain management "opimisation à base d'agents communicants des flux logistiques pour la gestion de crise".

Atour Taghipour is a professor and the head of an international management master program at the University of Le Havre in France. He holds a PhD in Industrial Engineering from the Polytechnic School of Montreal in Canada. He received two masters' degrees, one in Management, Logistics & Strategy and other in Industrial Engineering. He has more than ten years of experiences as a manager in automobile industries. He has published two books and many research papers in international journals. His areas of research are supply chain and operations management.

Mourad Abed has obtained his Ph.D in 1990 and HDR in 2001. He is professor (Class1) in Computer Engineering at the University of Valenciennes and member of the "Human- Computer Interaction and Automated Reasoning" research group in the LAMIH. He is chair or cochair of international conferences or special sessions, Lectures for International journals, author or co-author (more 180): numerous book chapters, journal articles and communications. He is coordinator of several European projects. He is involved in several research networks, projects and associations. He is Main Coordinator of "Technological Innovations", Vice-director at Institute of Sciences and Technology (from 2000 to 2010), Director of Master study program of Sciences and Technology, Coordinator European of projects (From 2011-2014), Co-President National Research Group Petri Nets, He is Vice-President of the Scientific Association CEMUR Network (Europe-Maghreb Cooperation Universities Network), today 42 European Universities members and Maghreb.