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ABSTRACT

Good collaboration plays an important role in effective supply chain management. The main obstacle to collaboration within a supply chain is a conflict between each enterprise's local optimization and the chain's global optimization. We show that in addition to relationships, trust, contract and other social factors, sharing and reallocation of payoff are critical to align the objective of each member enterprise from local optimization to global optimization. We propose collaboration systems, which take advantage of information technology in the digital economy, to set up payoff reallocation and information sharing mechanism. These systems can be used to foster solid collaboration relationships within one supply chain. We identify the system requirements and outline the Web-based systems schema. The collaboration systems have four indivisible components: measuring performance; monitoring performance and payoff re-allocation; global optimization algorithm, and reconfiguration: planning, forecasting and recommendation. The challenges, impediments and enablers to implement the proposed collaboration systems are also discussed in the paper.

Keywords

Supply Chain Management, Collaboration, Web-based Systems, Digital Economy

INTRODUCTION

In the process of forming and maintaining a good supply chain, collaboration among various parts of the chain is crucial to ensure actions that increase total supply chain value and at the same time benefit each participant. Supply chain collaboration has different dimensional meanings: mutual trust, sharing of information, sharing of knowledge, relatively long planning horizon, multiple-level relationship and process for sharing benefits and burdens (LaLonde 2004). Return on relationship will become a core metric in this collaborative business activity. Lots of research has been done on the benefits that the relationships in supply chain can achieve such as increased sales, lower costs from reduced inventory, fewer personnel, improved customer service, better delivery through reduced cycle times, and increased speed of marketing new products (Hibbard, Hogan and Smith 2003; Walter and Ritter 2003; Gummesson 2004). Collaboration is also seen as positively impacting the public image (Mentzer, Foggin and Golicic 2000).

On the other hand, lack of good collaboration results in increased transaction cost and magnifies bullwhip effect. Chopra and Meindl (2004) point out that the lack of supply chain coordination has the following performance effects: increasing costs such as manufacturing cost, inventory cost, transportation cost, labor cost for shipping and receiving; enlarging replenishment lead time; hurting the level of product availability and negatively impacting the relationship across the supply chain. They also show that the coordination problem in supply chain mainly results from either local optimization by different nodes of the supply chain, or an increase in information delay, distortion and variability within the supply chain. In general, incentive obstacles arise when participants in different stages try to achieve local optimization, which leads to global non-optimization; information obstacles refer to the situation where information flow within the supply chain is inaccurate, incomplete, unavailable or distorted. Watson (2001) discusses the likely obstacles for the failure of integrated supply chain management approaches in the real world. To get improved coordination within the supply chain, we should reduce or eliminate these obstacles, i.e. align the incentive of different participants to achieve the global optimization and improve information assurance to accomplish the global optimization.

Previous researches have investigated the barriers to collaboration and provided some solutions to help build collaboration from various perspectives such as relationships (McQuiston 2001), commitment (Tellefsen 2002; Friman et al. 2002), trust (Sabath and Fontanella 2002; Bennett and Gabriel 2001), contract (Fawcett, Magnan and Williams 2004; Handfield and

Bechtel 2002; Roxenhall and Ghauri 2004), information technology (Deeter-Schmelz and Kennedy 2004; Ryssel, Ritter and Gemunden 2004) and other social bonds (Perry, Cavaya and Coote 2002). This paper investigates the collaboration problem in supply chain management from a different prospective: the institute mechanism and information technology. Among the obstacles to supply chain collaboration, the information assurance, sharing and communication problems can largely be solved by current IT-enablers. Nonetheless, mechanisms to apply current information technology to align each entity's optimization from local level to global level have not been fully explored. Such an IT-enabled approach will involve not only information technology, but also complex mechanism design. In this paper, we first introduce the economics of cooperation, which can guide us to design the collaboration mechanism. We study, from the economic prospective, the difficulties in maintaining the inter-organizational collaboration. While the ultimate goals for each entity on supply chain are revenue- or profit-oriented, we emphasize the role of the payoff sharing and transfer to foster the relationship, trust and commitment. This will result in solid collaboration within the supply chain. As Mentzer, Foggin and Golicic (2004) point out, with increased trust from sharing revenue, information, ideas and technology, the supply chain partners act more like one virtual enterprise. We do not mean that our proposed Web-based collaboration systems can replace the roles of relationship, trust and commitment in the collaboration establishment. The goal of this study is that, in addition to (or along with) the relationship, trust, commitment and other social factors, can the payoff sharing and transferring arrangement supported by information technology be used to help foster the solid collaboration within supply chain, and how?

Our study is related to Garcia-Dastugue and Lambert (2002), which address the challenges encountered by a business firm when choosing the Internet-enabled coordination mechanism to fit a variety of business situations in the supply chain. They outline a framework to assist the manager with his business decisions and mainly focus on the current existing markets available in the electronic marketplaces. However, we propose a new mechanism to align the incentive of each enterprise from local optimization to global optimization in a supply chain. Particularly, we emphasize the revenue and cost sharing and collaboration mechanism design.

We introduce economics of cooperation in Section II. In Section III, we analyze the collaboration systems requirements and outline the systems schema. Implementation challenges and enablers are discussed in Section IV. Section V concludes our study.

THEORETICAL FOUNDATION: ECONOMICS OF COOPERATION

In a supply chain, different participants are more likely to chase their local optimization. Each entity has its own interest and the supply chain has "public good" properties and there is a free rider problem.

Without a centralized authority in the supply chain, each entity might behave as an opportunist. This process can be described in a "prisoner's dilemma" game. With cooperation, there will be pareto improvement for both parties. We look at two cases. Suppose we have two entities, A and B in a supply chain (The analysis of 2-players game can be extended to *n*-players game. For simplicity, we only demonstrate the 2-players game in this study). In the first illustration, the payoffs for A and B under different strategies are listed in Table 1.

Table 1. Payoffs in the 1st Illustration

		B: Cooperate	B: Not Cooperate
A	Cooperate	2, 2	1/2, 3
A	Not Cooperate	3, 1/2	1, 1

In this simple example, we can see that both entities will choose "Not Cooperate" as in Nash equilibrium. However, the other three strategy profiles give higher total payoffs. If one entity plays "Cooperate", the total payoffs are 3.5 if the second entity plays "Not Cooperate", and total payoffs are 4 if the second entity plays "cooperate" as well. Both payoffs are greater than the payoffs of 2 under the strategy profile where neither of them chooses "Cooperate". The optimal option to both parties is to cooperate and each one has payoffs of 2 without any payoff transfer. Suppose A and B initially establish a cooperation relationship. However, since (Cooperate, Cooperate) is not a Nash equilibrium, both entities have an incentive to deviate to "Not Cooperate". For example, given B chooses "Cooperate", A has an incentive to choose "Not Cooperate" because he can get a higher payoff of 3 instead of 2. Thus, we can see that even if each entity realizes that cooperation is a better choice to them, we still need a mechanism to have cooperation as a stable equilibrium.

Let us look at the second illustration. In this example, the Nash equilibrium is still ("Not Cooperate", "Not Cooperate"). However, we can see that entity A has a stronger incentive to persuade B to cooperate, as A will increase his payoff from 1 to 4. But B has no incentive to cooperate with A unless A is willing to transfer some payoff to B. So, it is more difficult for the two entities to set up a cooperation relationship in this scenario. They need to measure each entity's payoff under "cooperation" and also set up a mechanism to transfer payoff between the two entities. In this case, suppose the cooperation is already established between the two entities. It's obvious that B has an incentive to deviate unless his payoff is increased to 3 in the one-shot game. We can see that it is A's willingness to transfer some payoff to B that will make the cooperation possible. In this illustration, even if the cooperation is initially established, maintaining a stable equilibrium is still a challenge.

Table 2. Payoffs in the 2nd Illustration

		B: Cooperate	B: Not Cooperate
A	Cooperate	4, 1	1/2, 3
	Not Cooperate	3, 1/2	1, 1

From economic theory, we know that under an infinite repeated game, we can achieve the ('Cooperate', 'Cooperate') as a Nash equilibrium by incorporating an appropriate punishment. To simplify our analysis, we use the second illustration for the infinite repeated game. We assume that A and B agree to establish cooperation relationships by transferring payoff of 1 from A to B. So, under the cooperation, A's payoff is 3, and B's payoff is 2. Although this one-shot game cannot lead to a stable outcome of (Cooperate, Cooperate), the two players can establish a stable cooperative relation by playing an infinitely repeated game. There are infinite strategies for each entity to play in this infinitely repeated game. In this example, suppose both A and B use the same "Grim" strategy: plays "Cooperate" ("C") at the first round; plays "C" if all previous rounds consisted of (C, C); otherwise, plays "Non-Cooperate" ("N") forever. We argue that if both players adopt such a strategy, they can establish a stable cooperative relation that will benefit all the players, and hence the entire supply chain.

Proposition 1: If each entity applies the "Grim" strategy: plays "Cooperate" ("C") in the first round; plays "C" if all previous rounds consisted of (C, C), otherwise, plays "Non-Cooperate" ("N") forever; they will reach a stable "cooperative" relation by playing an infinitely repeated game.
Proof: The action sequence can be described as (CC, CC, CC…) under the (Grim, Grim) strategy profile. The strategy profile is a Nash equilibrium.

The average payoff of A and B is $\pi_A = \frac{1}{n}(3+3+...) = 3$ and $\pi_B = \frac{1}{n}(2+2+...) = 2$ as $n \to \infty$. Given that B plays the "Grim" strategy, let us see whether A has an incentive to deviate from the "Grim" strategy. If he chooses to play "N" in any pair of actions sequence, B will choose "N" forever, so will A. If this happens, the maximum average payoff that A can get is 12 because $\pi_A = \frac{1}{n}(3+...+3+1+1+...) \to 1$ as $n \to \infty$. Therefore, A has no incentive to deviate from "Grim" strategy. The same applies to B. So, (Grim, Grim) is a Nash equilibrium in this game.

There are 2 types of sub-games in this infinitely repeated game. Type 1: Proceed by all "C's". The two players play the same strategy in the whole game, which has already been shown to be a Nash equilibrium. Type 2: Proceed by at least one "N" somewhere, then the two players play "N" forever. This is a Nash equilibrium since each player wins 1 and 1 at each round respectively, and can not do better against "N" forever. Therefore, the strategy profile (Grim, Grim) is also sub-game perfect.

QED

Through this example, we can see that if we can implement a fair payoff measurement and re-allocation mechanism, each participant has an incentive to stick to the collaboration systems in an infinite repeated game. The difficulty in reality is measuring each entity's contribution to the cooperation and accomplishing the payoff transfer among the entities. With the progress of information technology, it is now possible to establish such systems so that each entity's contribution is computed and payoff transfer is fairly implemented among the parties within a supply chain. The above economic analysis gives us a guidance to design such systems so that the supply chain values increase and benefit every participant in the chain.

WEB-BASED COLLABORATION SYSTEMS SCHEMA

Systems Requirements

Since supply chain collaboration systems involve different business entities, the inter-firms system requirements are different from the internal firm systems. Generally, in managerial level, the systems should satisfy the following requirements:

Web-based: To successfully integrate their supply chains, companies must use the Internet, Intranet and Extranet. Reary (2002) shows that web-based systems have the following benefits: low cost of ownership, collaborative portal efficiency, increased return on relationship, supplier relationship management, and standardized connections internet standards like HTTP, HTML, and XML. Sharma (2001) discusses how B2B marketers use the Internet to increase their operational efficiency and effectiveness. Berthon et al. (2002) analyze how the Internet can reduce transaction costs to facilitate more efficient exchanges and markets. In addition, the general supply chain system requirements are also applied to the collaboration systems. We list some of system requirements from Smith (2002) as below:

Visibility and Accessibility: Ubiquitous access to real-time supply chain information for use within one organization and to share the information with business partners and customers.

Improved Data Accuracy and Integrity: As the data accuracy and integrity directly affect the performance measurement and associated payoff transfer, the systems need accurate and complete data inputs in order to establish a stable cooperation.

Scalability: Try to maximize the systems' flexibility to conform to various workloads and numbers of participants. Systems with high scalability allow the enterprise grows without frequent upgrading the systems. Scalability has never been more important in the current dynamic environment.

Innovation: Current systems should accommodate future information technology progresses. Future expansions and upgrades should be considered when developing current systems.

Integrating with Enterprise Applications: Each entity's enterprise systems should be tightly linked to the collaboration systems to establish complete integrated systems within and among the chain participants.

Collaboration Systems Schema

The collaboration systems in supply chain management can be described in Figure 1. The bottom part of Figure 1 illustrates a basic supply chain framework except that the cash flow is bilateral-directed instead of unilateral-directed. This implies a payoff transfer in the new schema. The collaboration systems are explained in details below:

Stage 1: ***Measuring Performance***

In this stage, each entity in the chain sends relevant data to the collaboration systems. This can be done by integrating each entity's ERP with the collaboration systems. With different information sent by different partners in the chain, data filtering is needed to ensure data accuracy, completeness and integrity. The purpose of this process is to prepare sufficient data and information for algorithm computation that measures each entity's performance. In this stage, the systems will calculate each entity's contribution to the global optimization, that is, the supply chain values, and each entity's payoff from the supply chain. For each entity's payoff, the systems need to identify which part is based on activities that do not affect the effectiveness of the supply chain and which part is based on supply chain partners' coordination. In certain circumstances, one entity might sacrifice its own interests to achieve a global optimization for the supply chain. Its loss due to cooperation is also needed to be estimated. In most cases, there is an asymmetry between one entity's contribution to and its benefit from supply chain collaboration. This implies that payoff transformation is required within the supply chain.

We develop a supply chain value assessment (SCVA) framework to address the above question. SCVA is a framework that links performance metrics of specific supply chain to the desired financial outcomes (global optimization). Supply chain value assessment is more than diagnostic; it is a framework for building fact-based value propositions to align each entity's objective from local optimization to global optimization.

Stage 2: ***Monitoring and Payoff Reallocation***

In this stage, the systems mainly compare "what each entity should do" and "what each entity has done". "What each entity should do" is from the reconfiguration: planning, forecasting and recommendation (see Stage 3 next) from the previous cycle. "What each entity has done" is from the measuring performance stage. The comparison result is important to diagnose whether any entity deviates from "cooperation", particularly, for its own interest. For example, if one entity's rapid revenue increase (local objective) results from deviating from the global objective, further examination is needed to see whether it is due to market change or the entity's self-interests drive. If one entity's increasing revenue results in decreasing global revenue, more investigation should be conducted and constructive advices should be given to the entity. As we mentioned above, the supply chain is a long-term relation. In order to stabilize collaboration in the chain, any entity that purposely violates cooperation for its own interest should be punished like in the "grim" strategy.

After the monitoring processes, the sources of supply chain values become clear, and the contribution of each entity is quantified. Payoffs should be transferred among different entities according to pre-determined reallocation rules or agreements. In general, the reallocation payoff should be based on each entity's contribution to and benefit from the supply chain.

Stage 3: ***Global Optimization Algorithm***

In this stage, the systems estimate and simulate the optimal global revenue that the supply chain can achieve under various business environments such as different demand and prices in the next period. The purpose of this stage is to give operational guidance for each entity so that every entity can perform better for the whole chain in the next round. By tightly integrating pricing actions and supply chain actions, global optimization algorithm (GOA) provides the companies with the tools they require to quickly and effectively achieve optimization goals (Phillips 2001). We can use current information technology and operation management to plan and make decisions at the tactical and operational level. In this stage, simulation or calibration should be used to test different market conditions.

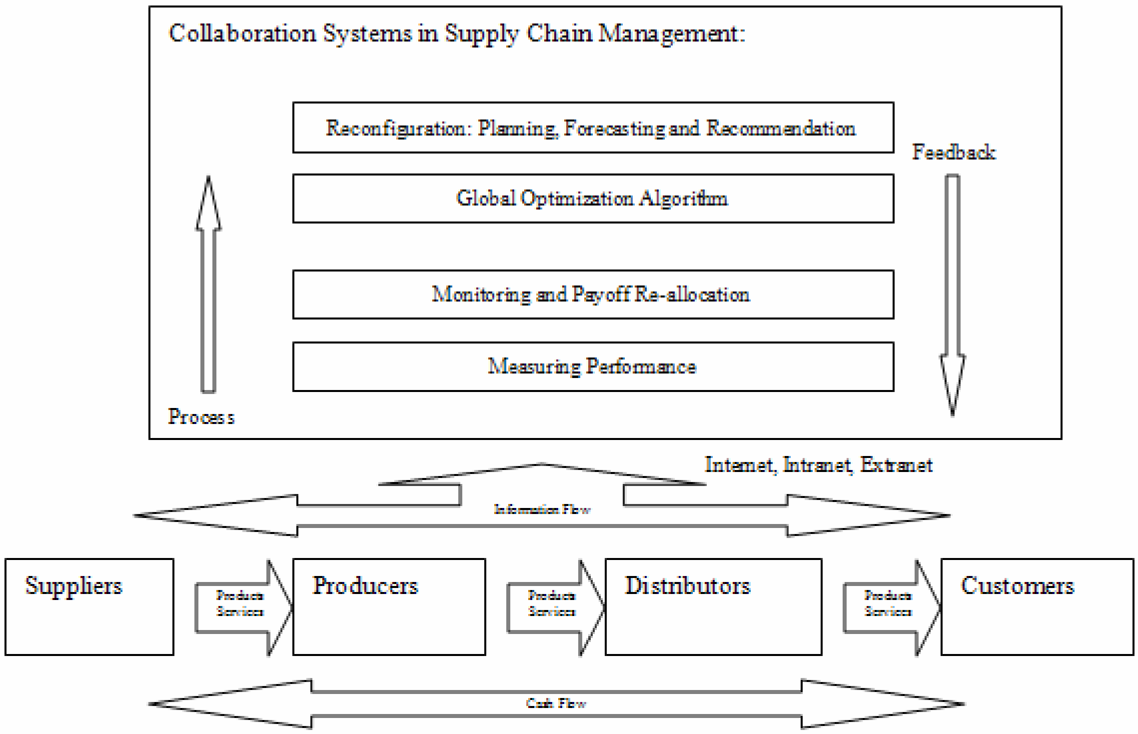

Figure 1. The Schema of SCM Coordination Systems

Stage 4: *Reconfiguration: Planning, Forecasting and Recommendation*

In this stage, the systems conduct joint business planning for all the entities in the chain. To have optimal productions and operations, the planning is mainly based on global optimization computing results contingent on different situations. As there are uncertainties in the future, forecasting is needed to redefine the planning. The planning also needs to be flexible so that it is still valid when market conditions change. Also some entities may withdraw from the chain, and some new entities may join. Based on the planning, forecasting and new partnerships, the systems propose an appropriate set of recommendations to each entity in the supply chain. After getting the recommendations, each entity has to adjust its activities to reflect the core spirit and requirements of global optimization in collaboration relationships.

SYSTEMS IMPLEMENTATION CHALLENGES AND ENABLERS

Collaboration requires redefinition of company goals and direction. It requires trust among partners. To have successful collaboration systems, partners must be willing to share their promotion schedules, POS data and inventory data. While redefining a company's direction is no easy task, the benefits can be great for the companies that do manage the leap across traditional barriers (Anderson 2000). Achieving these gains, however, requires a comprehensive strategy for implementing GOA capabilities. Creating a collaborative supply network typically requires a sponsor — a leader in the chain who can offer the required resources for the initial creation of the large-scale supply network. A supply chain consortium might be one of the solutions for the ownership of the systems. In addition, we need to bear in mind the following challenges:

Multiple industries with own peculiarities: As the entities in the supply chain involve different multiple industries with their own peculiarities, business practices and contractual requirement, etc., how to align their interests and integrate their activities towards the supply chain needs to be further addressed.
Multi-Chains involvement problem: One firm might join several supply chains. For this entity, it will be quite difficult to optimize only one of the supply chains. As the entity joins more supply chains, it will not care only about one coordination system. Such an entity can either join only one supply chain, or integrate other supply chains into one collaborative system to solve this problem. However, as the number of entities increases, we require more efficient algorithm and knowledge management for the expanded systems.
Integration with ERP: It is desirable to integrate the collaboration systems within supply chain management with each firm's Enterprise Recourse Planning systems. For example, Advanced Planning and Scheduling (APS) is a key part of an SCM application. Most APS products have been embedded with sophisticated optimization logic, making APS almost synonymous with supply chain optimization.
Information accuracy: One challenge to the proposed systems is achieving a credible guarantee that the data and information submitted are correct. Although each entity realizes that collaboration and cooperation will achieve higher global payoff, the complicated systems, data missing, incompleteness and inaccuracy will affect the performance measurement and payoff reallocation. Highly reliable database management and communication within the systems is necessary.

Other some of the impediments to collaboration from Quinn (2001) are summarized below:
Time investment: Collaboration takes time and requires hard work. To get people involved, we need to show them the expected benefits so that each entity has a high incentive to invest.
***Conventional accounting practices**:* The conventional accounting practices impede to collaboration as they focus on the traditional accounting role for a single firm, rather than measure the cross-company values.
Inadequate communications: Inadequate communication among supply chain partners will increase the potential problems exponentially.
Inconsistency: If some entities behavior strategically, these behavioral attitudes and operational execution are inconsistent at all interfaces in the supply chain relationship, and result in other entities' strategic behavior.
Although it is not easy to build such collaboration systems within any supply chain, some key collaboration enablers should be identified to use (Quinn 2001).
Common interest and clear expectations: As all entities share the collaboration's outcome, this helps ensure long-term commitment. In addition to relationship, trust and commitment, contracting helps to set up clear payoff and cost sharing for the collaboration systems among the entities involved.
Openness and trust: Openness and trust help to share information, discuss their practices and processes, and solve some potential problems related to systems and benefit/cost sharing.
Leadership: One leading entity can help to move collaboration forward.
Cooperation first, punishment last: When some problems about relationship happen, right approach might be to jointly solve the problem. Punishment might be the last alternative.

The benefits from good collaborations are obvious. Therefore, we need to build such collaboration systems to materialize these values. Business entities, especially the executive managers, should understand the implementation challenges and try to use all kinds of enablers to make the collaboration systems successful.

CONCLUSIONS

Good collaboration plays an important role in effective supply chain management. The main obstacle to collaboration within a supply chain is the conflict between various enterprises' local optimization and the chain's global optimization. We show that in addition to relationships, trust, contract and other social factors, the payoff sharing and reallocation is critical to establishing collaboration among different business entities. By taking advantage of information technology progresses in the digital economy, we propose collaboration systems, which can be used to foster and establish solid and long-term collaboration relationships within a supply chain. We identify the systems requirements in the digital economy environment. We outline one conceptual framework of Web-based collaboration systems, where information technology and Internet are considered as significant enablers to initiate and implement such systems. The collaboration systems have four indivisible components: measuring performance; monitoring performance and payoff re-allocation; global optimization algorithm, and reconfiguration: planning, forecasting and recommendation. We also discuss the challenges, impediments and enablers to the collaboration systems. It is obvious that great efforts are required to materialize the proposed collaboration systems. We hope that our conceptual analysis offers some insights into building an effective collaboration in supply chain management and more business firms can create and capture the values derived from the digital economy.

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