Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 2837 - 2851, 2005

THE SYSTEM FRAMEWORK FOR EVALUATING THE EFFECT OF COLLABORATIVE TRANSPORTATION MANAGEMENT ON SUPPLY CHAIN

Cheng-Min FENG
Professor
Institute of Traffic and Transportation
National Chiao Tung University
4F, No. 114, Sec. 1, Chung-Hsiao W. Rd.,
Taipei 10012, Taiwan
Tel: 886-2-23494956
Fax: 886-2-23494965
E-mail: cmfeng@mail.nctu.edu.tw

Chien-Yun YUAN
Ph.D. Student
Institute of Traffic and Transportation
National Chiao Tung University, Taipei, Taiwan
Associate Professor
Department of Marketing and Logistics Management
Chihlee Institute of Technology, Taipei, Taiwan
E-mail: yuan@mail.ccmtc.edu.tw

Yi-Chen LIN
Associate Professor
Department of Business Administration
Chihlee Institute of Technology
313, Sec.1, Wunhua Rd., Banciao City,
Taipei County 220, Taiwan
E-mail: ychlin@mail.chihlee.edu.tw

Abstract: More and more factories operate on a just-in-time basis. In order to shorten planning cycles and minimize inventory levels in the value chain, transportation plays a critical role in the supply chain process. Collaborative Transportation Management (CTM) is based on the interaction and collaboration between trading partners and carriers on the supply chain, in order to avoid the inefficiency of physical distribution and accomplish the objective of improving the efficiency of supply chain management. This paper proposes a concept of CTM and a system framework for evaluating the benefits of CTM. Based on the beer game, we develop a beer game model of supply chain with CTM, and present the different simulation scenarios: (1) Constrained transportation capacity in beer game with CTM; (2) Constrained transportation capacity in beer game without CTM; and (3) Unconstrained transportation capacity in beer game without CTM. The manufacturers, distributors and carriers in the supply chain are considered as the partners of CTM. Results of the simulation reveal that CTM can significantly reduce the total supply chain costs, including inventory costs and backlog costs, and improve transportation capacity utilization.

Key Words: Collaborative transportation management, The beer game, Supply chain, System dynamics.

1. INTRODUCTION

Business trends such as mass customization and e-commerce are forcing manufacturers and retailers to shorten planning cycles, re-plan and re-allocate on the fly, and expedite execution. With shorter planning windows and the universal objective to minimize inventory in the value chain, transportation has become a critical opportunity in the process (Browing et al., 2000). Many researches point out that collaboration can create significant value in the relationships along the value chain (Sutherland, 2003; Bishop, 2004; Douglas et al., 1996). In recent years, the collaboration among disparate partners within the supply chain and e-supply chain has been widely discussed. Interestingly, the transportation and its impact to the entire supply chain have seldom been explored. For instance, two trading partners in a supply chain generally execute Collaborative Planning, Forecasting, and Replenishment (CPFR), in order to improve the inventory cost, revenue and service. However, the connection with transportation and distribution management is often neglected. Consequently, the missing link of transportation blurs the lines between planning and execution of the supply chain. The financial and operational performances for the sellers' and the buyers', therefore, would be highly affected (Sutherland, 2003; Browing et al., 2002; Bishop, 2004).

In a short period of time, transportation has the characteristics of not being able to increase supply capacity and not easily finding an alternative. Can the replenishment appear at the right time and in the right place? Often, the order is in the process, but its status is unknown or delayed due to unavailable carrier capacity. Buyers and sellers must maintain higher levels of inventory to accommodate these uncertainties. Another consequence is to increase transportation costs to use secondary carriers, whose contract rates are not as advantageous as primary carriers. In order to avoid the inefficiency of transportation caused by insufficient interaction and collaboration, trading partners of the supply chain should consider transportation management as part of the collaboration, when dealing with an order, production, and shipment schedule. Through the integration and cooperation of the buyer, seller and carrier, the flexibility and overall value of business chain would be enhanced.

Since supply chain management is a kind of dynamic system, this paper uses a system dynamics approach with the beer game in order to incorporate the dynamic character of supply chain management. Besides, it considers the transportation component which is rarely explored in previous researches. We develop a beer game model of supply chain with Collaborative Transportation Management (CTM), and evaluate the effect on the partners of the supply chain (manufacturers, distributors, and carriers), when they implement CTM. We assume three simulated situations: (1) Constrained transportation capacity in beer game with CTM; (2) Constrained transportation capacity in beer game without CTM; and (3) Unconstrained transportation capacity in beer game without CTM. One compares the different performances of the above situations, including total supply chain costs and utilization rate of transportation capacity. The paper consists of six sections. The first section is an introduction. The second section is the review of related literatures. The third section is the evaluation framework of CTM. The fourth section is the development of a beer game model of supply chain with CTM. The fifth section is the analysis of simulation results and finally the sixth section makes the conclusion and proposes prospective research.

2. LITERATURE REVIEW

2.1 CTM definition

According to the CTM Sub-Committee of the VICS Logistics Committee(2003, 2004), Collaborative Transportation Management (CTM) is defined as a holistic process that brings together supply chain trading partners and service providers to drive inefficiencies out of the transport planning and execution process. The objective of CTM is to improve the operating performance of all parties involved in the relationship by eliminating inefficiencies in the transportation component of the supply chain through collaboration.

CTM focuses on enhancing the interaction and collaboration between three principle parties (a seller, a carrier, and a buyer) in their logistics roles of shipper, carrier, and receiver, as well as secondary participants including 3PL's. Participants collaborate by sharing key information about demand and supply, e.g. forecasts, expected capacity, and assets, where feasible. In order to achieve the positive results of CTM, the processes between participating companies should be real-time, extendible, automated, and cost-effective.

2.2 Supply Chain Dynamics

System Dynamics was first proposed in 1956 by Professor Jay W. Forrester of MIT. Supply Chain Dynamics is the behavior of a very complex system involving many "players", whose decision-making procedures may be ill chosen or who may act on misinterpretation of true market demand (Sterman, 1989). The Industrial Dynamics Simulation Models proposed by Towill (1996) is an example. Lee (1997) also proposed an article on exploring supply chain behavior with system dynamics. In this research, he brought up a brief structure of a supply chain model constructed with system dynamics. Current research on System Dynamics Modeling in supply chain management focuses on inventory decision and policy development, time compression, demand amplification, supply chain design and integration, and international supply chain management (Angerhofer et al., 2000).

In supply chain management, "bullwhip effect" means the end demand variance of a supply system, through the delivery of information downstream, midstream and upstream, would usually be amplified. That is to say, the order variance upstream is much larger than the actual end demand variance. The upstream inventory costs thus increase rapidly which boosts the total costs of the supply chain. This is a typical inefficient situation of the supply chain. The previous researches mostly focus on exploring how demand forecasting, ordering strategy, lead times, inventory policy, and information sharing affect the efficiency of SCM (Zhang, 2004; Kelle, 1999; Chen et al., 2000; Disney, 2003; Lee et al., 1997; Joshi, 2000; Meters, 1996). However, few people worked on the effect of transportation toward business value chain. The previous researches treated transportation as an external variable and assumed that there is no constraint of capacity. This way of simplification does not match the real system.

2.3 MIT beer game

2.3.1 The beer game

The Beer Game is a logistics game that was originally developed by Massachusetts Institute Technology, MIT, in the ‘60s. The earliest description of the game dates back to the work of Forrester (1961). The beer game is a realistic simplification of the supply chain for beer manufacturer, which is popularly used as an introduction to systems thinking, dynamics, computer simulation, and supply chain management (Joshi, 2000). It serves as an excellent experiment for studying the effect of system microstructure (individual behavior and decision-making under given circumstances) on supply chain dynamics (Lee, 1997).

The Beer Distribution Game is a simulation of a supply chain with four co-makers (retailer, wholesaler, distributor, and factory). Participants take the role of a co-maker and decide, based on their current stock situation and customer orders, how much to order from their suppliers. All co-makers have a common goal: Minimizing costs for capital employed in stocks while avoiding out-of-stock situations. The surprising results of the simulation explain inefficiencies of supply chains known as the bullwhip effect. The beer distribution network is shown in Figure 1.

Traditional beer game of supply chain simulation is much simplified than the real system. For example, capacity constraints are not imposed, supply lead time and order delay time are constants, random events of transportation issues are excluded, and each unit in the supply chain acts individually without collaboration (Joshi, 2000).

Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 2837 - 2851, 2005

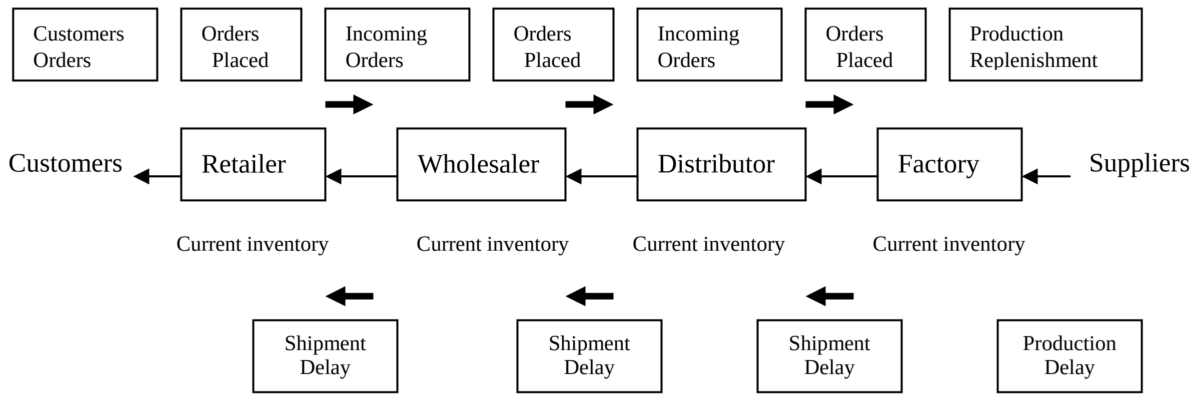

Figure 1 The Beer Distribution Network

2.3.2 The beer game with information visibility

Kirkwood built a Vensim model for the beer distribution network based on Sterman's (1989) description of the beer games as designed at MIT. Since there isn't any collaboration between individual units in a traditional beer game, each unit observes the demand patterns of its customer and place orders accordingly with its supplier. End customer demands are only visible to the retailer. Furthermore, inventory levels and backlogs at individual units are cut-off from each other. Each unit forecasts its own demand. These constitute a lack of information visibility and collaboration.

Joshi (2000) built new models of the beer game with information visibility and collaboration. In his simulation, the customer demand is made visible to all the four units in the supply chain directly in real time, not restricted only to the retailer. Although not used in the policy for making forecasting and shipping decisions, also available to all units is information about inventory and backlog levels at each of the units. The result of his simulation reveals that the information visibility of customer demand at each unit and collaboration have eliminated the bullwhip effect and reduced the supply chain total costs.

3. THE EVALUATION FRAMEWORK OF CTM

3.1 Evaluation framework

The CTM evaluation framework proposed by this paper is illustrated in Figure 2. The operational steps are described in the following. First, the transportation problem of the supply chain is analyzed and described. The main transportation problem for the supply chain is that the short-term transportation capacity is constant, there is no substitute within this short period of time, and if the transportation capacity is insufficient it would result in delayed delivery and extra cost to the supply chain. Then the paper conducts the face-to-face interviews with eight managers of manufacturers and carriers in Taiwan, attempts to find out the key points of CTM, selects the key performance indicators, and develops the beer game model with CTM, Finally, this paper evaluates the effect of CTM through the simulation.

The outline of the interview includes (1) How does the shipper generate shipment forecast? (2) When should the carrier be informed of the shipment forecast? (3) How does the carrier manage to meet the requirement for transportation equipments? (4) What are the contents of distribution strategies? (5) How to manage the exceptions of shipment? (6) What are the goals of collaboration? Interviewees of carriers include ocean carrier, freight forwarder and logistics service provider. Interviewees of manufacturers are mostly from the import and export industry in Taiwan, whose trade fields include electronics, textile, interior furniture, plastic products, etc.

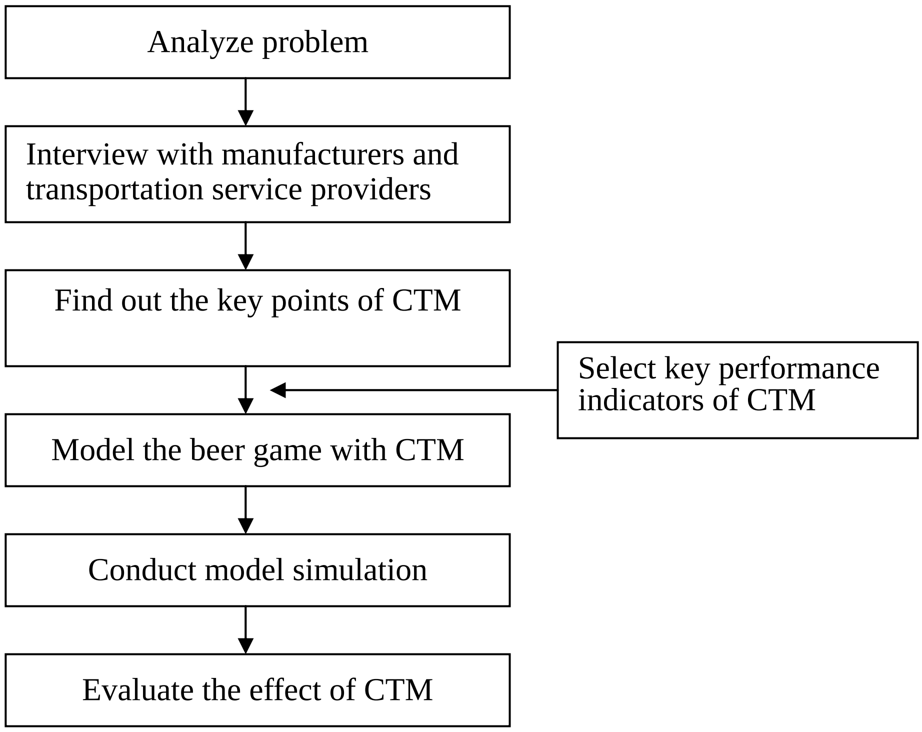

Figure 2 The Evaluation Framework of CTM

3.2 How to find out the key performance indicators of CTM

One division of a large multinational company evaluates the logistical performance of its supply chain management systems through five key performance metrics: fill rate, confirmed fill rate, response delay, stock, and delay. Supply Chain Council’s integrated supply chain metrics include customer satisfaction/quality, order fulfillment lead time, total supply chain costs, and asset performance (Kleijnen et al., 2003). Since the approach of this paper is the beer game, the simulated component of the beer game is the total costs of the supply chain which consists of total inventory costs and total backlog costs. Further, with the CTM model constructed by this paper, we would obtain the utilization rate of transportation capacity. Since total costs of the supply chain and utilization rate of transportation capacity are the final quantified results which include diverse metrics, this paper adopts them as key performance indicators for measuring CTM.

4. THE BEER GAME MODEL WITH CTM

4.1 Description of the problems

Transportation has the characteristics of not being able to increase short-term capacity and not easily finding an alternative. In order to improve the high inventory costs and high transportation costs caused by the lack of collaboration, one has to re-engineer the process of an enterprise. The focus should be on the collaborative of logistics strategies and planning and sharing information of the supply chain, which starts with order/shipment forecasts including capacity planning, scheduling, and delivery execution. When the manufacturer's planned shipment quantity (transportation demand) exceeds the available capacity of the carriers, Carriers can adjust the transportation planning strategy through CTM such that the available transportation capacity matches the shipper's demand. They can even adjust the available capacity to the maximum available transportation capacity, in order to reduce the gap between planned shipment quantity of manufacturer and transportation available capacity.

The paper skips the description of various negotiation details of the partners of CTM and directly refers to the result of transportation collaboration, because this paper focuses on constructing the beer game model with CTM.

4.2 The model formulation

The CTM model developed in this paper can be discussed as follows:

1. If at time t, the planned shipment quantity (transportation demand) of manufacturer is less than available transportation capacity, then the transportation demand would be equal to actual shipment quantity of manufacturer. In this case, the adjustment of transportation planning is not necessary.

   $Q_t = D_t$, if $D_t \leqq V_t$

   Q_t: actual transportation quantity at time t = actual shipment quantity of manufacturer at time t

   D_t: transportation demand at time t = planned shipment quantity of manufacturer at time t

V_t: available transportation capacity at time t

Transportation capacity means the space and equipment that the carrier is able to offer for shipment. In regard of ocean transport, it refers to the quantity of containers or the cubic meters (CBM) number of consolidation. As for air transport, it represents aircraft Unit Load Device (ULD), such as the quantity of aircraft containers or aircraft pallets. When it comes to land carriage, it is the total number or the CBM number of trucks.

2. If at time t, the planned shipment quantity of manufacturer is more than available transportation capacity and less than the maximum available transportation capacity, then an upward adjustment could allow the available transportation capacity to match the actual demand of shipment.

   $Q_t = Max\ \{Min\ \{C, D_t\}\ , V_t\}$

   $D_t \leqq C, V_t \leqq C$

   C: maximum available transportation capacity, assumed constant

   D_t and V_t cannot be higher than the maximum available transportation capacity

3. If at time t, the planned shipment quantity of manufacturer is more than available transportation capacity and exceeds the maximum available transportation capacity, then an upward adjustment could increase the available transportation capacity to its maximum.

   $Q_t = Min\ \{C, D_t\}$

4. With CTM, theoretically, the improved transportation efficiency of the supply chain is:

$$\text{Improvement of transportation} = \frac{Min\{C, D_t\}}{C} - \frac{Min\{V_t, D_t\}}{C}$$

5. Transportation capacity utilization at time t is:

$$U_t = \frac{Q_t}{C}$$

4.3 Modeling CTM in Beer Game

The paper is based on Kirkwood's Vensim model for the traditional beer game and further incorporates the concept of CTM, but only considers manufacturer, distributor, and carrier or third party logistics as the participators of CTM. The demand forecast function would typically be either the SMOOTH (Exponential Smoothing Forecast) or FORCAST (moving Average Forecast) function of Vensim. The FORECAST function provides a trend extrapolation forecast of the future value of a variable based on its past behavior. The SMOOTH function provides an exponential smoothing of input depending on delay time input to the function. The time delays for the crates to move between units are accounted by the FIXED DELAY function.

Since traditional beer game does not consider the constraint of transportation capacity, this simplification does not meet the real situation. In the real world, the planned shipment quantity of manufacturer (D_t) and the actual shipment quantity (Q_t) will both be constrained by the available transportation capacity (V_t) or the maximum available transportation capacity (C), With the consideration of the constraint of transportation capacity, we describe the beer game with CTM as shown in Figure 3.

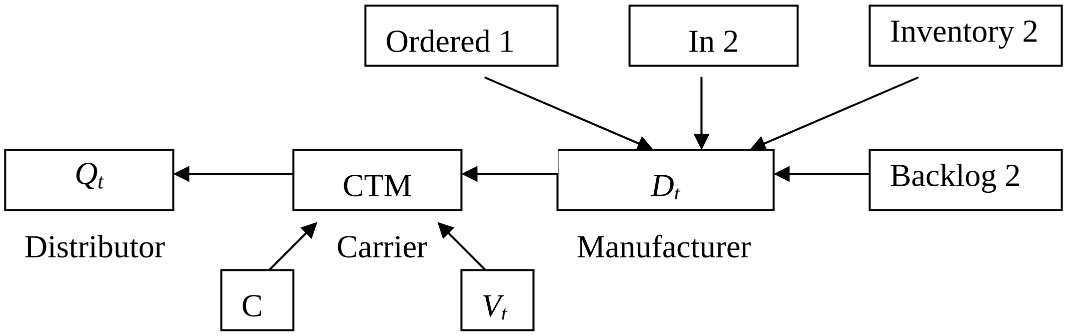

Figure 3 Modeling CTM in Beer Game

The variables in figure 3 are defined as follows:

Inventory 2: Physical inventory at manufacturer

In 2: Incoming orders at manufacturer

Ordered 1: In transit orders by distributor

Backlog 2: Backlog at manufacturer

D_t: Planned shipment quantity by manufacturer at time t (sold quantity by manufacturer)

Q_t: Actual shipment quantity by manufacturer at time t (incoming orders at distributor)

C: Maximum available transportation capacity, assumed constant

V_t: Available transportation capacity at time t

5. MODEL SIMULATIONS AND RESULS ANALYSIS

5.1 Model Simulations

In the following, we present three different simulated scenarios for the beer game, intended to produce varying system dynamics. With the assumption of constrained transportation capacity or unconstrained transportation capacity, we simulate the beer game with CTM and without CTM, and further compare their effects.

Case 1: Unconstrained transportation capacity in beer game without CTM (the traditional beer game)

D_t in beer game is defined as the minimum of the current inventory at manufacturer plus incoming orders at manufacturer and in transit orders by distributor plus backlog at manufacturer. Without the constraint of transportation capacity, the planned shipment quantity of manufacturer (D_t) is equal to the actual shipment quantity of manufacturer (Q_t).

$D_t = Q_t$ (1) = MIN (Inventory 2 + In 2, Ordered 1 + Backlog 2)

Q_t (1) is Q_t for case 1

Case 2: Constrained transportation capacity in beer game without CTM.

The planned shipment quantity of manufacturer is counted as the above and cannot be excess available transportation capacity (V_t). the actual shipment quantity of manufacturer (Q_t) for case 2 is defined as the minimum of the available transportation capacity and planned shipment quantity of manufacturer.

Q_t (2) = MIN (Vt, MIN (Inventory 2 + In 2, Ordered1 + Backlog2))

Q_t (2) is Q_t for case 2

Case 3: Constrained transportation capacity in beer game with CTM.

If the planned shipment quantity of manufacturer exceeds available transportation capacity (V_t), carrier can increase available transportation capacity through CTM to the maximum available transportation capacity (C).

$$Q_t(3) = \begin{cases} D_t, & \text{if } D_t \leqq V_t \\ Max\ \{Min\ \{C, D_t\},\ V_t\}, & \text{if } D_t \geqq V_t \\ Min\ \{C, D_t\}, & \text{if } D_t \geqq C \end{cases}$$

D_t = MIN (Inventory 2 + In 2, Ordered 1 + Backlog 2)

Q_t (3) is Q_t for case 3

Inventory 2*(t)* = Inventory 2*(t-1)* + In 2*(t)* – Sold 2*(t)*

Backlog 2*(t)* = Backlog *(t-1)* + Ordered 1*(t)* – Sold 2*(t)*

Ordered 1*(t)* = *max (0, IO(t))*

The variables are defined as follows:

Inventory 2*(t)*: Physical inventory at manufacturer, at time *t*

In 2*(t)*: Incoming orders at manufacturer, at time *t*

Sold 2*(t)*: Crates sold by manufacturer, at time *t*

Ordered 1*(t)*: Orders placed by distributor, at time *t*

Backlog 2*(t)*: Cumulative backlog at manufacturer, at time *t*

IO(t): Indicated order rate, at time *t*

D_t: Planned shipment quantity of manufacturer (sold quantity by manufacturer), at time *t*

Q_t: Actual shipment quantity of manufacturer (incoming orders at distributor), at time *t*

V_t : Available transportation capacity, at time *t*

C: Maximum available transportation capacity

We ran the simulation for a span of 36 weeks, which is the typical time period for which the beer game is played. Inventory costs are assumed to be 0.50 $/unit/week and backlog costs are assumed to be 1.00 $/unit/week. The customer demand was applied at the 5th week and the demand level maintained constant at 8 crates throughout the rest of the simulation (Sterman, 1989). The demand order forecast is based on the SMOOTH (Exponential Smoothing Forecast) function. The variation in available transportation capacities is 4 to 12 crates. It is generated randomly by Uniform Distribution. The maximum available transportation capacity is assumed to be 12 crates.

5.2 Results Analysis

The result of simulation is as shown in Table 1. The total supply chain costs in Case 1 is much lesser than Case 2 and Case 3. The main reason is that Case 1 does not have the constraint of transportation capacity, thus the goods delivery of manufacturer is totally not affected by transportation capacity. The inventory and backlog levels are certainly lower. However, in Case 2 and Case 3, with the constraint of transportation capacity, when compared with traditional beer game, their swing of “bullwhip effect” is larger and inventory and backlog levels are higher. Besides, they need more time to stabilize the supply chain which increases the total supply chain costs. However, the situation with the constraint of transportation capacity is closer to real world.

Case 2 and Case 3 are under the constraint of transportation capacity. However, since we implement CTM in Case 3, when the planned shipment quantity of manufacturer is more than available transportation capacity, with negotiation and planning in advance, the carrier can adjust and increase available transportation capacity to reduce part of the inventory and backlog levels of manufacturer. The paper performed the simulation ten times and in comparing Case 3 against Case 2 we can find the apparent improvement of average total supply chain costs (including inventory costs and backlog costs). The supply chain total costs are reduced from 10,413 to 5,450 and the reduction rate is as high as 48 %. On the other hand, the effect of CTM can increase the transportation capacity utilization which is improved from 54% to 73%.

Table 1 Comparison of the Three Cases

Case	Constrained Transportation Capacity	Collaborative Transportation Management	Total Supply Chain Costs $	Transportation Capacity Utilization
1	No	No	2,250	---
2	Yes	No	10,413	54%
3	Yes	Yes	5,450	73%

6. CONCLUSIONS

CTM is based on the collaboration between trading partners and carriers of a supply chain in order to avoid the inefficiency of physical distribution and accomplish the objective of improving managerial efficiency of the supply chain. Currently, more and more factories operate on a just-in-time basis. With the expectation of shortening planning cycles and pursuing minimum inventory cost of the value chain, transportation efficiency becomes one of the crucial factors for efficient supply chain management. It is important that business partners cooperate to reduce inefficiency, lower costs, and ensure the delivery of goods. That is why collaboration among partners in a supply chain has become a topic of great interest for many and an essential element of company strategy.

The paper proposes a concept of CTM and a system framework of evaluating CTM effect, as well as elaborates on how CTM affects the supply chain total costs and transportation capacity utilization. Following the evaluation framework, we first analyze the problems in detail. After the face-to-face interviews and discussion with eight managers of manufacturers and carriers, we find out the key points of collaboration and select key performance indicators. Based on the traditional beer game model, with the consideration of constraint transportation capacity, the paper develops a beer game model with CTM. Within the supply chain, the manufacturers, distributors and carriers are considered as the partners to implement CTM. The result of computer simulation points out that the total supply chain costs of the beer game model with CTM is higher than that of the traditional beer game model. The reason is that the former is under the constraint of transportation capacity and thus the bullwhip effect is larger and the cost is higher. However, if they are under the same constraint of transportation capacity, the implementation of CTM can actually reduce the total supply chain costs by nearly 50%, including inventory costs and backlog costs. Besides, it can also improve the utilization rate of transportation capacity by a margin of nearly 20%.

Although the paper is based on the beer game model, beer crates, its calculation unit of order, inventory, shipment, and backlog, is similar to that of general cargo shipment unit, such as cartons, CBMs (cubic meters), pallets, containers, etc. Therefore, we developed the beer game model with CTM, is applicable to the research upon any other industry, not aiming at the beer industry only. The model provides a tool for examining the effects after CTM is implemented to the supply chain.

The paper skips the description of actual negotiation details of the partners in CTM and directly refers to the result of transportation collaboration as the basis for developing a simulation model of the beer game with CTM. The focus of this paper is to solve the problem resulting from the constraint of transportation capacity. Since supply chain is a complicated dynamic system, every decision of each actor in the supply chain will affect the overall structure differently. It is suggested that the further research can work on detailed and complete procedure of actual CTM execution. Moreover, one can implement CTM toward all actors of the supply chain, including upstream supplier of manufacturer and downstream retailer or customer of distributor, in order to obtain more real effects on the supply chain. On the other hand, in the future, it is also a worthwhile issue to explore how to apply CTM in solving the problem of idle transportation capacity.

REFERENCES

Angerhofer, B. J. and Angelides, M. C. (2000) System dynamics modeling in supply chain management : research review, **Proceeding of Winter Simulation Conference**, Brunel University, UK, 342-350.

Bishop, S. B. (2004) Collaborative transportation management benefits, Supply Chain Systems, Inc., http://www.vics.org

Browning, B. and White, A. (2000) Collaborative transportation management – A proposal, Logility Inc., http://www.vics.org

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, Vol. 46, No. 3**, 436-443.

Collaborative Transportation Management white paper, Version 1.0 (2004) **CTM Sub-Committee of the Voluntary Inter-Industry Commerce Standards (VICS) Logistic Committee**, http://www.vics.org

Collaborative Transportation Management: Core elements of CTM, Version 2.0 (2003) **CTM Sub-Committee of CPFR Committee**, http://www.vics.org

Dejonckheere J., Disney, S. M., Lanbrecht, M. R. and Towill, D. R. (2003) Measuring and avoiding the bullwhip effect: A control theoretic approach, **European Journal of Operation Research, Vol. 147**, 567-590.

Disney, S. M. and Towill, D. R. (2003) On the bullwhip and inventory variance produced by an ordering policy, **Omega, Vol. 31**, 157-167.

Dogulas, J. T. and Paul, M. G.. (1996) Coordinated supply chain management, **European**

Journal of Operational Research 94, 1-15.

Forrester, J. W. (1961) Industrial Dynamics, **MIT Press**, Cambridge, MA.

Hughes, M. (2003) Process modeling using system dynamics: A combined case study and tutorial , Department of Information Science and Technology, Drexel University.

Instructions for playing the beer game. http://suplychain.mit.edu/innovation/beergame.html.

Joshi, Y. V. (2000) Information visibility and its effect on supply chain dynamics, Department of Mechanical Engineering, Massachusetts Institute of Technology.

Kelle, P. and Milne, A. (1999) The effect of (s, S) ordering policy on the supply chain, **International Journal of Production Economic**s, Vol. 59, 113-122.

Kirkwood, C. W. (1998) System dynamics methods: A quick introduction, **College of Business Arizona State University**.

Kirkwood, C. W. Business process analysis workshops: System dynamics models', Department of Management, Arizona State University, U.S.A. Http://www.public.asu.edu/~kirkwood/sysdyn/SDwork/SDWork.htm

Kleijnen, J. P. and Smits, M. T. (2003) Performance metrics in supply chain management, **Journal of the operational Research Society**, 1-8.

Lee, H. L., Padamanabhan, V. and Whang, S. (1997) Information distortion in a supply chain : The bullwhip effect, **Management Science**, **Vol. 43, No. 4**, 546-565.

Lee, H. L., Padamanabhan, V. and Whang, S. (1997) The bullwhip effect in supply chains, **Sloan Management Review, Vol.38, Iss. 3**, 93-102.

Lee, P. (1997) Exploring supply chain behavior with system dynamics, **Supply Management, Vol. 2, Iss. 18**, 38.

Metters, R. (1996) Quantifying the bullwhip effect in supply chains, **Journal of Operations Management, Vol. 15**, 89-100.

Towill, D. R. (1996) Industrial dynamics modeling of supply chains, **Logistics Information Management, Vol. 9, Iss. 4**, 43-56.

Sterman J. D. (1989) Modeling managerial behavior misperceptions of feedback in a dynamic decision-making experiment, **Management Science, Vol. 35, No. 3**, 32-39.

Sutherland, J. (2003) Collaborative transportation: The "Missing Link" of CPFR, Transplace Inc., http://www.vics.org

Sutherland, J. (2003) Collaborative transportation management – Creating value through increased transportation efficiencies, http://www.transplace.com

Zhang, X. (2004) The impact of forecasting methods on the bullwhip effect, **International Journal of Production Economics**, Vol. 88, 15-27.