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3PL-HUB Supply Chain Logistics Cost Simulation Study Based on System Dynamics

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Abstract. System dynamics provides a more intuitive and effective tool for system analysis in area supply chain logistics. By using method of system dynamics, this paper builds up a 3PL-HUB three echelon supply chain system from the perspective of costs, compares supply chain logistics costs variation in two cases with and without 3PL-HUB involved in, simulates logistics costs of each node enterprise, and fully analyzes the influence of 3PL-HUB on bullwhip effect and fluctuation of inventory of supply chain members. It shows that 3PL-HUB can reduce costs and benefit all the enterprises of whole supply chain, which represents a method to enhance supply chain synergy.

Introduction

Supply chain is a dynamic system made up of multiple node enterprises, the interaction between these nodes and the resulting information flow, logistics, cash flow make supply chain system very complicated. In recent years, with the unceasing change of market demand and continuous shortening of product life cycle, the supply chain operation model shows higher dynamic and complexity, which put forward higher requirements in logistics system operation.

3PL-HUB (Third Party Logistics-HUB) generally refers to the Third Party Logistics distribution and supply center located nearby manufacturer，which is used to store all or part of the supply materials. 3PL enterprise sends materials straight to production location according to manufacturer's MRP, and pays the corresponding cost to suppliers only when materials are consumed [1]. 3PL- HUB can effectively integrate suppliers' resources, promote collaboration of supply chain, timely and precisely respond to manufacturers' requirements, simplify suppliers' operation, therefore, reduce cost significantly, increase flexibility and responsiveness of the whole supply chain system greatly.

In 3PL-HUB synergy of supply chain, 3PL service providers are the actual logistics operation administrators, their logistics operation ability and logistics service level largely determine performance of the entire supply logistics system[2]. Due to the importance of 3PL enterprises to the whole system, the core manufacturers and 3PL enterprises tend to establish strategic partnership and keep long time cooperation.

System Dynamics (SD) was put forward by Jay W. Forrester[3] in 1956, a professor of Massachusetts institute of technology. SD is a kind of science which closely integrates multiple fields of study. In new supply chain system, there are many complicated nonlinear and dynamic relations in internal and external environments of each node enterprise, traditional methods are difficult to reach satisfactory results. However, combining with feedback cybernetics, system theory, decision theory, and computer simulation, SD can achieve qualitative and quantitative analysis in

complex system, and can finally give higher leverage solutions to dynamic complex problems and improve system performance through time-dependent simulation modeling[4]. As a result, SD is a kind of effective and feasible method for dynamic study of supply chain logistics system.

Fundamental Assumption

1. Build a 3PL-HUB three echelon supply chain model with one 3PL enterprise and two suppliers (S1 and S2) participated in. Manufacturer (M) is the core enterprise, which plays a leading role in supply chain, in addition, 3PL is responsible for the entire JIT logistics processes from suppliers to manufacturer, and manufacturer to distributor. 3PL enterprise achieves information sharing with manufacturer, periodically completes Milk-Run process on the basis of manufacturer's production plan, and fulfills the corresponding product delivery process according to the demand of downstream distributors. Therefore, 3PL's inventory is actually made up of suppliers' parts inventory and manufacturer's finished goods inventory. (refer with: Fig. 1)

2. Regardless of capacity constraints of transportation and storage, 3PL enterprise delivers all parts from suppliers S1 and S2 to manufacturer M, conversion ratio for spare parts from S1 and S2 to finished products is 1:1:1.

3. Downstream customer needs obey normal random distribution. Distributor D places orders to manufacturer M according to downstream customer demands, and 3PL enterprise delivers finished products to D in accordance with orders.

4. The whole supply chain process doesn't permit out of stock, while existing production delay and transport delay;

5. Manufacturer M's inventory is work-in-process inventory, and finished products produced by M are stored in 3PL finished-products warehouse.

6. Distributor's replenishment strategy: when distributor's inventory < target inventory, distributor makes replenishment instructions to 3PL enterprise; when distributor's inventory ≥ target inventory, distributor stops replenishment.

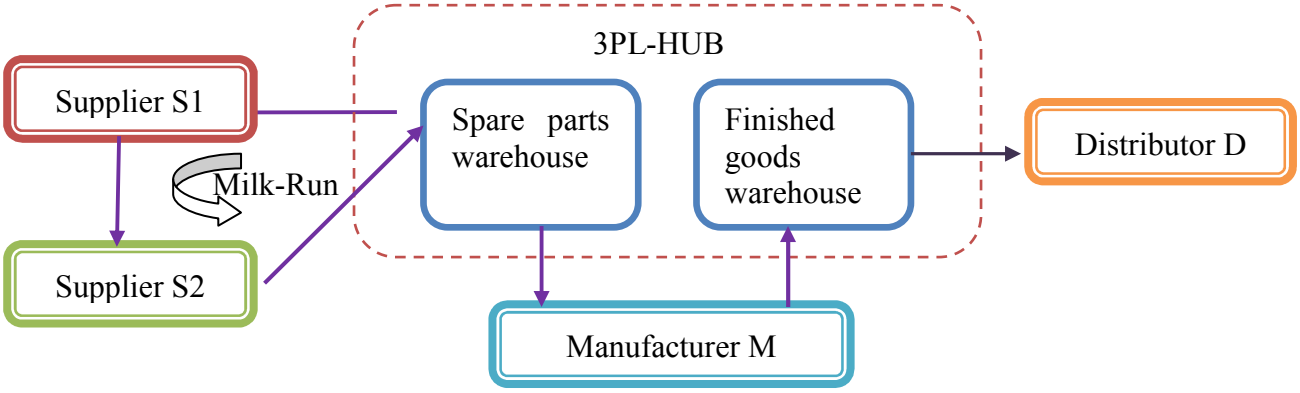

Fig. 1 3PL-HUB three echelon supply chain model

Buildup of System Dynamics Model

In Sterman's *book Business Dynamics*[5], basic flows of enterprises in supply chain are described, and stack - flow diagrams are given, which give good references and inspirations to the following research. Based on Sterman's supply chain model, a SD three echelon supply chain model (refer with : Fig. 2) based on above fundamental Assumptions is set up.

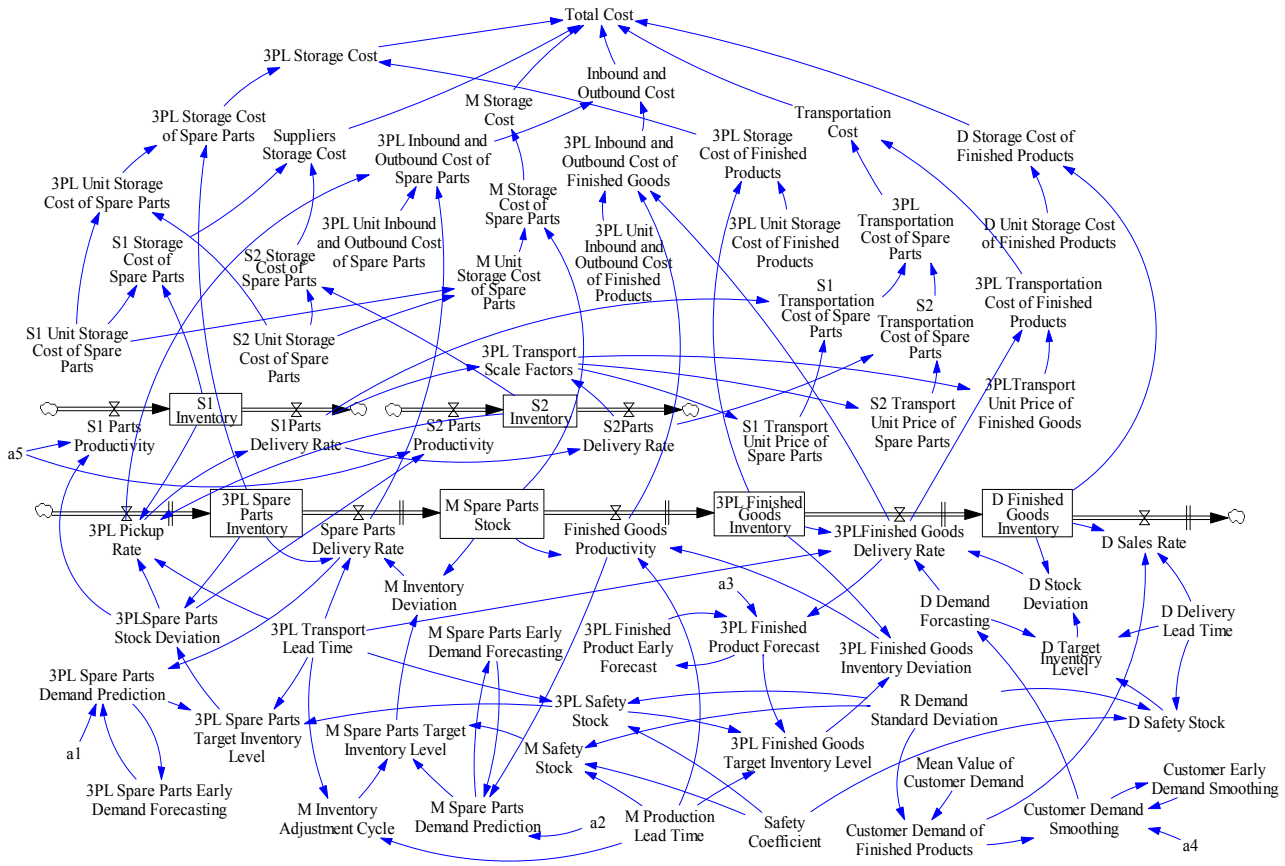

Fig. 2 System dynamics model of 3PL-HUB three echelon supply chain

System Dynamics Model simulation

Establishing formulas and initial values for variables (refer with: Table 1).

Table 1 Variables Setting

Echelon of supply chain	Variable name	Formula	Initial Value and Units
3PL	3PL Spare Parts Inventory	INTEGER("3PL Pickup Rate"-Spare Parts Delivery Rate)	1500
	3PL Finished Goods Inventory	INTEGER(Finished Goods Productivity-"3PLFinished Goods Delivery Rate")	1500
	3PL Pickup Rate	MAX(0,MIN(MIN(S1 Inventory, S2 Inventory), "3PLSpare Parts Stock Deviation"))/"3PL Transport Lead Time"	Units/Day
	3PL Finished Goods Delivery Rate[6]	DELAY FIXED(IF THEN ELSE(D Stock Deviation>=0, MIN(MIN(D Stock Deviation/"3PL Transport Lead Time" ,D Demand Forecasting),"3PL Finished Goods Inventory"/"3PL Transport Lead Time"),0),"3PL Transport Lead Time",0)	Units/Day
	Spare Parts Delivery Rate	MIN("3PL Spare Parts Inventory", M Inventory Deviation)/"3PL Transport Lead Time"	Units/Day
Supplier S1 and S2	S1(S2) Parts Productivity	SMOOTHI("3PLSpare Parts Stock Deviation", 1/a5 , 0)	Units/Day
	S1(S2)Parts Delivery Rate	3PL Pickup Rate	Units/Day

	S1 Inventory	INTEGER(S1 Parts Productivity-S1Parts Delivery Rate)	1000
	S2 Inventory	INTEGER(S2 Parts Productivity-S2Parts Delivery Rate)	800
Manufacturer M	M Spare Parts Stock	INTEGER(Spare Parts Delivery Rate-Finished Goods Productivity)	1200
	Finished Goods Productivity	MIN(M Spare Parts Stock,"3PL Finished Goods Inventory Deviation")/M Production Lead Time	Units/Day
Distributor D	D Finished Goods Inventory	INTEGER("3PLFinished Goods Delivery Rate"-D Sales Rate)	1200
	D Sales Rate	DELAY FIXED(IF THEN ELSE(Customer Demand of Finished Products>=0, MIN(D Finished Goods Inventory/D Delivery Lead Time, Customer Demand of Finished Products) , 0),D Delivery Lead Time , 0)	Units/Day
	Customer Demand of Finished Products	RANDOM NORMAL(100, 400 , Mean Value of Customer Demand , R Demand Standard Deviation , 30)	Units
Total Cost		Inbound and Outbound Cost+"3PL Storage Cost"+Transportation Cost+M Storage Cost+Suppliers Storage Cost+D Storage Cost of Finished Products	$

Output of simulation results

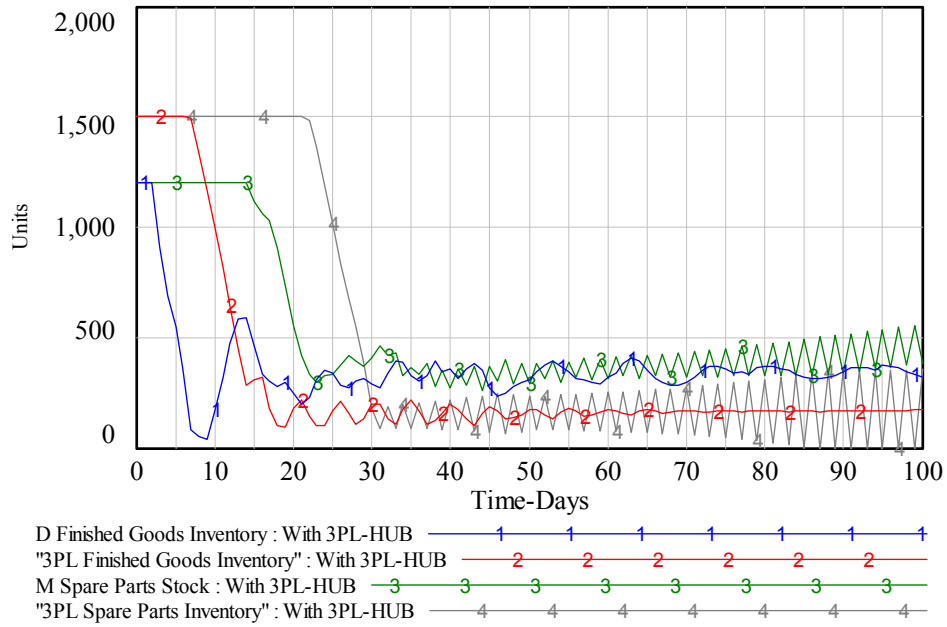

Fig. 3 Nodes Inventory comparison under condition of 3PL-HUB involved in

Fig. 3 represents variations in inventory of different node enterprises, from the simulation, two conclusions can be made:

1. From Line1 to Line 4, it can be judged that inventory variations of each node enterprise increase gradually, bullwhip effect exists in this supply chain. But with introduction of 3PL-HUB, the bullwhip effect is decreased a lot comparing with the traditional supply chain without 3PL-HUB involved in.

2. Judged from peaks and troughs of Fig. 3, delayed effect is shown in this supply chain. For example, peaks and troughs of line2 lag a few days behind those of line1, the same as line 3 and line 4.

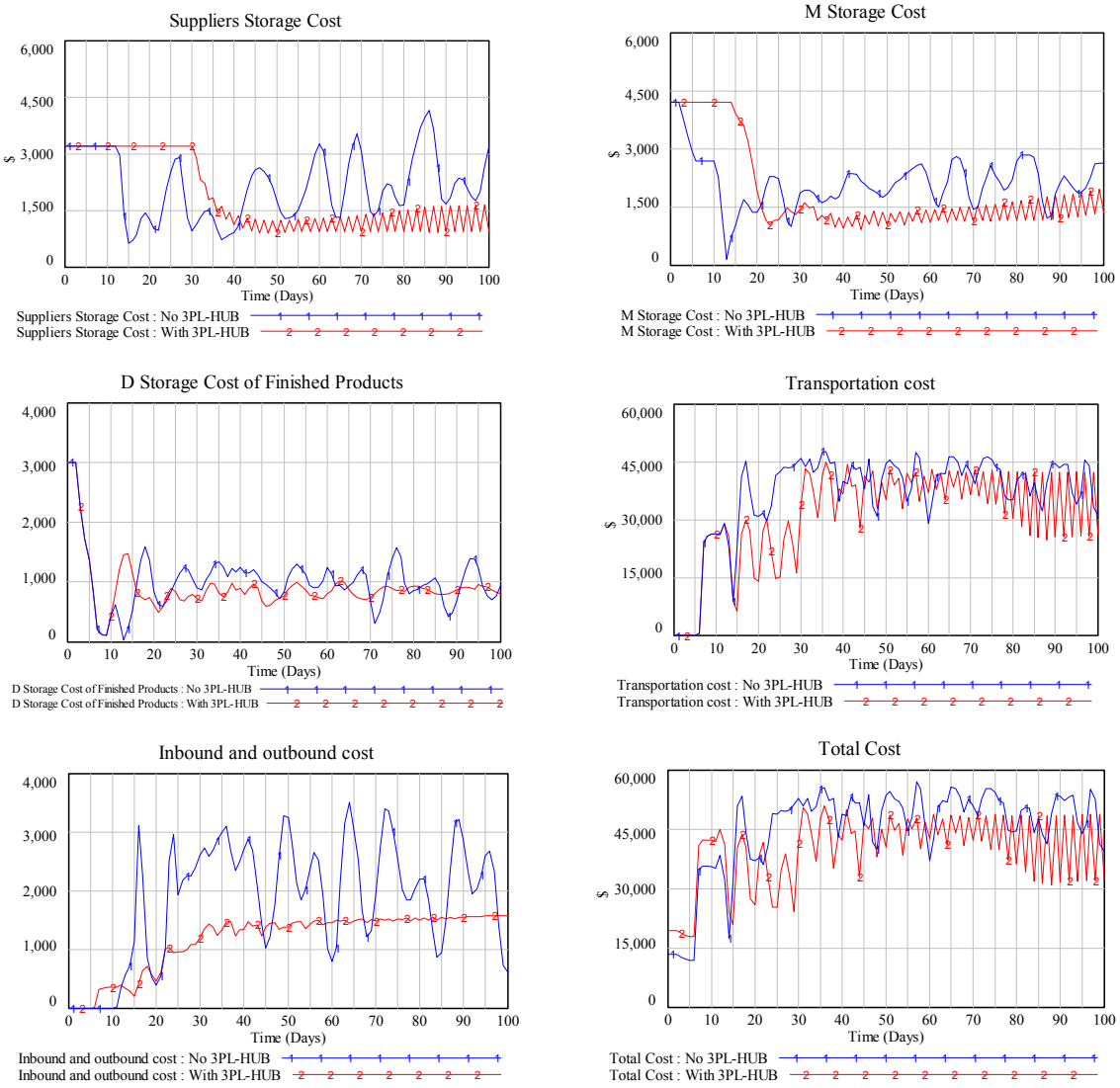

Fig. 4 Costs comparison Between conditions with and without 3PL-HUB involved

From Fig. 4, contrasts are made in both cases, with the introduction of 3PL-HUB, the inbound and outbound cost, inventory cost and transportation cost of new supply chain reduce significantly in comparison with those of traditional supply chain without 3PL-HUB involved in. As a result, the total cost drops significantly as well. At the same time, the fluctuations of cost curves in both cases are compared, which indicates that amplitude of fluctuations of each cost curve in the 3PL-HUB supply chain tapers off gradually. It shows that the introduction of 3PL-HUB makes the inventory of supply chain less volatile and more stable, reduces total costs consequently, and benefits each node enterprise in this supply chain.

Summary

System dynamics provides a tool for studying area supply chain logistics, which is more understandable than other systems. System dynamics simulation also provides an intuitive way of system analysis[7]. By using method of system dynamics, this paper simulates a 3PL-HUB three echelon supply chain system from the perspective of costs, compares logistics costs of each node

enterprise in 3PL-HUB supply chain to situation without 3PL-HUB involved in, and fully analyzes the influence of 3PL-HUB on bullwhip effect and fluctuation of inventory of supply chain members. The simulation shows that supply chain with 3PL-HUB involved in can solve bullwhip effect to some extent, and can make logistics costs drop significantly. Therefore, 3PL-HUB is an effective way to improve efficiency of whole supply chain, and can benefit all the enterprises of supply chain, which represents a method to enhance supply chain synergy.

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