Study on 4PL as Coordinating and Constructing Agent for Supply Chain System – A Transaction Cost Theory Approach

Guojun Ji (School of management, Xiamen University, Xiamen Fujian 361005, China)

Abstract—**This paper introduces a new mathematical model for analyzing the economic benefits of incorporating 4PL, which is a contractor (i.e. agent) for the supply chain coordination and construction based on the division of community and the outsourcing development. The mathematical model enriches the connotation of 4PL and it broadens the thought for 4PL development. Secondly, the proposed mathematical model predicated on transaction costs, is supported by Transaction Cost Theory (TCT) and acts as the theoretical analysis tool of 4PL for coordinating 3-party generic supply chain. Through the model, some trendy conclusions can be drawn to provide theoretical support for 4PL's practices.**

Key Words—Fourth-Party Logistics, Supply Chain, Coordination, Transaction Cost

I. INTRODUCTION

Globalization of business markets has given rise to drastic competition for market share that motivates the formulation of collaborative networked enterprises, for example the use of supply chains (SCs), virtual enterprises, and the like. Simultaneously, such drastic competition transforms the coordinative pattern between SC members from the conventional less dynamic to dynamically adaptive patterns. Hence, the integration and coordination of SCs are focused by its member enterprises' resources, core competency as well as risk sharing capacity and capability, amongst other intellectuals. Generally, a core enterprise, called the "Chain Lord", will be elected as the leader of the SC and it acts as the organizer and coordinator who are accountable for the entire SC performance. This leader usually has one or more strong controlling capabilities, such as supplying of raw materials, manufacturing process technology, or dedicated marketing channel or shares. However, for the group of Small to Medium Enterprises, which comprise majority firms in a country's economic market, e.g. in the China often do not possess the required leadership and resources (tangible and intangible) quality and capacity. The SC formed without the highly competent "Chain Lord" leader will gain less competitive advantage in the global market place. It is therefore logical and necessary for SMEs to seek an external agent as "inter-mediator" to assume "Chain Lord" role to organize and coordinate the SC's strategic, tactical, and operational activities. Thus Fourth-Party Logistics (4PL) is employed as the inter-mediator in the course of integrating SC. In practice, 4PL has itself predominantly plays vital role in the SC, such as offering information service or counseling etc. The definition of 4PL was introduced and registered as a brand by Accenture in 1996. A 4PL provider is a SC integrator that assembles and manages the resource, capacities, and technology of its own organization with those of complementary service providers to solve a comprehensive SC solution. The 4PL system was developed by Accenture in 2002 predicated on the four factors for the successful 4PL (Bumstead, J., Cannons, K., 2002), i.e., Architect and Integrator, Intelligence Control Room, Supply-chain Infomediary, Resource Providers. Therefore, 4PL works collaboratively with its customers, and it analyzes, models, integrates, controls, and supervises the selected transaction and information process flows in the intra- and inter- SCs. Those tasks and responsibilities show that the 4PL lies in the command and control (i.e. higher managerial) position in the logistics operational network of the entire SC. In fact, 4PL supplies the integrated outsourcing services (Thomas Craig, 2003). The main characteristics are synthesized by Gattorna, J. & Selen, W (2004) as follows: SC perspective layout, SC planner and optimization, transaction figurer and maker, SC reengineer, project management, service and system or information integrator, continuing innovator (Heok, Chong. 2001). However, most of 4PLs are developed with other professional logistics service suppliers' development. These are contained in third party logistics, SC management consulting company and SC information technological company etc. Adam Smith, an early economist, suggested that productivity would rise significantly when the division of labor principle was used. Output per worker would be raised while costs per unit produced would be reduced. Division of social spins off more enterprises, for example, due to greater specialization of enterprise function, enterprise information is more divided, hence more massive of asymmetrical information among those enterprises. Such asymmetrical information results in greater issues of complication in information processing among the enterprises which ultimately incur the higher relative cost to communicate and coordinate with customers from upstream and downstream. 4PL acts as the integrated service supplier of SCs, it participates in the

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coordinative strategic and tactical tasks but not the routine SC operation (Gattorna, J. & Selen, W, 2004). By way of the SC' coordinator, 4PL may not hold facilities (such as warehouses, vehicles) and apply itself characteristics to deal with the coordinative work. For the concentrated SC organized by a core enterprise, 4PL can bear most of the coordinative tasks. Furthermore, 4PL has the core professional coordination skills capable of delivering higher quality of coordination services than the core member enterprise can deliver. For the decentralized SC organized by the non-powerful enterprise, 4PL will become a leader or an agent of the SC, who is charged with the mandate to organize and coordinate whole SC operation.

For the purpose of this study, 4PL is treated as a contractor of the SC integrator, inclusive of organizing and coordination SC operations. The prominent effect and function for 4PL is to integrate the SCs, which constitute multi-stage modes: supplier, manufacturer, retailer and third party logistics provider. These member enterprises (or parties) of a typical SC have their own independent decision-making ability (Chopra, S., Meindl, P., 2001). Extant SC management literature posits that for maximizing the benefits of the whole SC, "SC Coordination" is one of the core research issues. Accordingly, different levels of the SC coordination systems or the coordination systems among enterprises were introduced and developed. For example, Virtual Enterprises and Strategic Alliance have arisen in the macro-level coordinative organization among enterprises, as they provide a great deal of the theoretical reference in SC coordination. The SC costs generally consist in two main components: the production cost and transaction cost (TC) based on new institutional economics. Where the production costs are happened in the relationship between human and nature, production costs are typically easier to define and measure than TCs. Nevertheless, TCs are often acknowledged to be important and they are critical components of the total economic costs for a particular enterprise in a given industry. Williamson (1991) suggested that TCs have two components: ex ante and ex post economic costs. Ex ante economic costs include: (1) search and information costs, (2) drafting, bargaining and decision costs, and (3) costs of safeguarding an agreement. Ex post economic costs include: (1) costs of measuring input, (2) costs of measuring output, (3) monitoring and enforcement costs, and (4) adaptation and haggling costs. From the TC theory, there exists mismatch of coordination aim in SC due to "each does things in their own way" among members. To achieve SC operation objectives based on lower cost, there must be a better organization and stimulating mechanism. From costs perspective, reducing production costs is determined within enterprise, controlled by member enterprises themselves. But, reducing TCs is the shared responsibility among enterprises in the SC, individual enterprise can not effectively achieve the goal, so it often has to be settled by a dedicated agent who can then effectively integrate and coordinate all members in the SC. In fact, in the information economy of today, the TCs of a 3-party SC dominated the whole costs, thus the main objective of SC coordination will focus on theTCs, which is well supported by literature. For example, the theoretical framework of SC TCs (Hobbs & Jill, 1996), outsourcing and manufacturing/purchasing decision-making, investment distribution, coordination, integration, distribution in a SC are analyzed based on TC theory (Grover and Malhotra,2003) etc. Therefore, the TC theory can be adapted to analyze 4PL as agent for coordinating and constructing SC.

In this paper, a mathematical model, based on TCs, is established by using Transaction Cost Theory as the theoretical analysis tool of 4PL coordinating SC. Through the model development process, some conclusions are drawn to provide theoretical support for 4PL's practices.

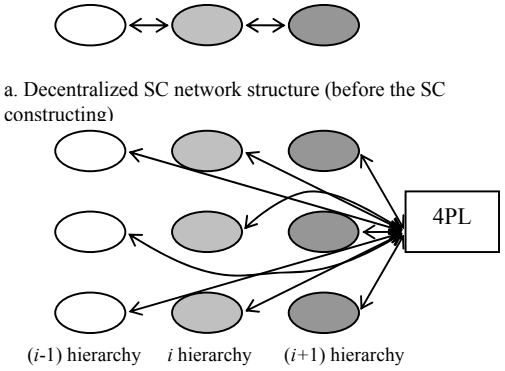
II. THE TC ANALYSIS MODELS FOR 4PL COORDINATING SC

From the macro viewpoint, a SC coordination can be divided to decentralized and centralized. Decentralized refers to the SC coordination is voluntary organized by the enterprises in the SC, such mode is appeared in the industry group constructed by Small & Medium Enterprise. Centralized mode means that the SC coordination is organized by a core enterprise, which is the leader in its SC. Centralized mode is widely applied at present, e.g., Dell computers. In fact, the coordinative mode based on 4PL belongs to the centralized mode. Based on Williamson viewpoints, we think that the TCs of SC coordination are divided to ex ante costs and ex post costs. In order to set up our model, we give the following basic assumptions: (1) enterprises at the same hierarchy in the SC have same production costs; (2) the constructed SC is a cluster, i.e. all member enterprises in the SC implement single shared strategy; (3) there is only one 4PL that participates SC operation. Variables considered in the proposed mathematical model are as follows: m denotes that general hierarchy in the SC network; n_i denotes the selected enterprises of i hierarchy in SC network; s represents the selected 4PL in SC network.

2.1 The TC model based on the decentralized SC coordination

In a decentralized SC, all member enterprises search information using top-down approach, i.e. from super-hierarchy or down-hierarchy enterprises respectively. The outcome of search information process leads to the selection of performance standard and then sign up a series of contracts, for subsequent construction of a SC, see Figure 1 (a). After constructed the SC, enterprises coordinate with super-hierarchy or down-hierarchy enterprises respectively and implement the SC operation, see Figure 2 (a). Figures 1 (b) and 2 (b) represent the SC structure before and after the establishment of decentralized supply-chain coordination respectively. The selected 4PL will take on the coordinative tasks in the constructed SC. To the decentralized SC, the TCs incurred in signed contract (ex ante) can be expressed as:

$$C_a = \sum_{i=1}^{m} \sum_{j=1}^{n_i} \left[\sum_{k=1}^{n_{(i-1)}} a_{ijk} + \sum_{l=1}^{n_{(i+1)}} a_{ijl} \right] \tag{2.1}$$



a. Decentralized SC network structure (before the SC constructing)

b. Decentralized SC network structure based on 4PL (before the SC constructing)

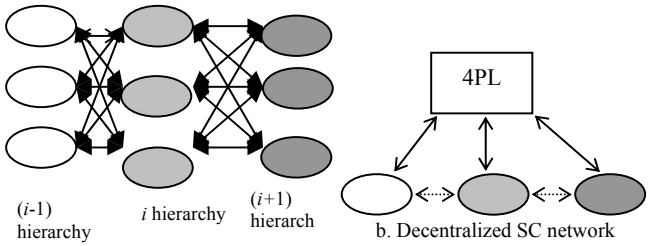
Fig. 1 Decentralized SC network structure fore-and-aft 4PL entered (before the SC constructing)

where, a_{ijk} denotes i hierarchy j enterprise's committed ex ante TCs between i hierarchy j enterprise and $(i-1)$ hierarchy k enterprise in the SC; a_{ijl} denotes i hierarchy j enterprise's committed ex ante TCs between i hierarchy j enterprise and $(i+1)$ hierarchy l enterprise in the SC. Thus ($\sum_{k=1}^{n_{(i-1)}} a_{ijk} + \sum_{l=1}^{n_{(i+1)}} a_{ijl}$) represents i hierarchy j enterprise's committed ex ante TCs. To the decentralized SC, th TCs incurred in the signed contract (ex post) can be expressed as

$$C_p = \sum_{i=1}^{m} p_i \tag{2.2}$$

where, p_i denotes the ex post transaction economic costs happened in i hierarchy enterprise with upper and lower hierarchy enterprises. Then, the TCs of decentralized SC are given by:

$$C = C_a + C_p \tag{2.3}$$



a. Decentralized SC network structure (after the SC constructed)

b. Decentralized SC network structure based on 4PL (after the SC constructed)

Fig. 2 Decentralized SC network structure for-and-aft 4PL entered (after the SC constructed)

Once there is 4PL entering the decentralized SC, such SC will become a centralized supply chain, the ex ante TCs incurred before the SC construction are given by:

$$C_a^F = \sum_{i=1}^{S} a_i + \sum_{i=1}^{m}\sum_{j=1}^{n_i} a_{ijF} + \sum_{i=1}^{m}\sum_{j=1}^{n_i} a_{Fij} \tag{2.4}$$

where, a_i denotes i 4PL ex ante TCs when 4PL is selected; a_{ijF} denotes i hierarchy j enterprise's committed ex ante TCs between 4PL and i hierarchy j enterprise; a_{Fij} denotes 4PL's committed ex post TCs between i hierarchy j enterprise and 4PL. At the same time, when 4PL entering the decentralized SC, the ex post TCs incurred after the SC is constructed can be expressed:

$$C_p^F = \sum_{i=1}^{m} q_i + \sum_{i=1}^{m} p_{iF} + \sum_{i=1}^{m} p_{Fi} \tag{2.5}$$

where, q_i denotes the ex post TCs happened in i hierarchy enterprise with upper and down hierarchy enterprises (under 4PL took on the coordinative tasks), such costs happened in 4PL can not bear ex post coordinative works; p_{iF} denotes the ex post TCs happened in i hierarchy enterprise committed costs between 4PL and i enterprise; p_{Fi} denotes the ex post TCs happened in 4PL committed costs between 4PL and i enterprise. Therefore, the ex ante and ex post economic TCs can be described respectively as, regardless whether 4PL has entered SC or not.

$$\Delta C_a = C_a - C_a^F = \sum_{i=1}^{m}\sum_{j=1}^{n_i}\left[\sum_{k=1}^{n_{(i-1)}} a_{ijk} + \sum_{l=1}^{n_{(i+1)}} a_{ijl} - a_{ijF} - a_{Fij}\right] - \sum_{i=1}^{S} a_i \tag{2.6}$$

$$\Delta C_p = C_p - C_p^F = \sum_{i=1}^{m}\left(p_i - q_i - p_{iF} - p_{Fi}\right) \tag{2.7}$$

and, the transaction economic costs when 4PL has entered are represented as follows:

$$\Delta C = \Delta C_a + \Delta C_p \tag{2.8}$$

Without loss of generality, suppose that $n_i = n$, $a_{ijk} = a_{ijl} = a$, $a_{ijF} = a_{Fij} = a_F$, $a_i = b$, $p_i = p$, $q_i = q$, $p_{iF} = p_{Fi} = p_F$, then, (2.6), (2.7) and (2.8) can be formulated respectively as:

$$\Delta C_a = 2mn(na - a_F) - sb \tag{2.9}$$

$$\Delta C_p = m\left(p - q - 2p_F\right) \tag{2.10}$$

$$\Delta C = \Delta C_a + \Delta C_p = m\left(2an^2 + p - 2na_F - q - 2p_F\right) - 2sb \tag{2.11}$$

Considering 4PL characteristics, it has information search ability and the professional negotiation ability for constructing SC, hence, the sense level for 4PL constructed SC is usually higher than other members; 4PL constructs effective SC based on integrated view, often hold complete information and alleviated asymmetrical information influence, and thus reduces the opportunism appearance; 4PL is effective at the SC coordinating work that results in the special assets being used repeatedly, thereby, lower the special assets investment risk; holding the comprehensive information and profuse constructing SC experience, then 4PL has powerful ability to respond to uncertainty. Consequently, 4PL uses lesser transaction economic costs for the operation of the constructed SC. For example, if $a \geq a_F$, then $na \geq a_F$ such that $2mn(na - a_F) \geq 0$. And that, $a < a_F$, as long as $na \geq a_F$, still guarantee that $2mn(na - a_F) \geq 0$ holds, this is due to SC structure changed. As well as, $sb \geq 0$, means that $na > a_F$, and only if $2mn(na - a_F) > sb$, we have $\Delta C_a > 0$, i.e., if and only if the committed transaction economic costs are lower

when 4PL entering constructed SC, 4PL just can take on the SC construction tasks. In addition, 4PL has vast experience in ways of SC integrating operation and excellent manpower utilization, so 4PL has higher sense level than other members; 4PL acts as information platform in SC operation, so it can alleviate the asymmetrical information effectively, improve the SC operation efficiency, herein it ensures furthest information sharing and is the preferable means to deter opportunism appearance. In short, 4PL commits much less transaction economic costs to construct a SC. For example, if $p \geq q + 2p_F$, then we have $\Delta C_p > 0$, i.e., when 4PL enters the SC, it can lower the transaction economic costs effectively in SC operation, besides undertake the SC coordinating works.

Suppose $\Delta C_a < 0$ or $\Delta C_p < 0$, but if only $\Delta C > 0$, i.e., lowering the entire TCs in SC after 4PL entered, then 4PL can still be competent for the SC coordinating tasks. From (2.9), (2.10) and (2.11), when $(na - a_F) > 0$ (4PL can economize the ex ante TCs in all levels of the SCs), it is easy to see that ΔC_a is in direct ratio to m, then ΔC_a will increase along with the SC network hierarchy add on, and there is a critical point K_1 such that if $m \geq K_1$, then $\Delta C_a \geq 0$, and K_1 satisfies:

$$K_1 = \frac{sb}{2n(na - a_F)} \tag{2.12}$$

If $(p - q - 2p_F) > 0$ (4PL can economize the ex post TCs in all levels SCs), ΔC_p is in direct ratio to m, then ΔC_p will increase along with the SC network hierarchy add in; when $(2an^2 + p - 2na_F - q - 2p_F) > 0$ (4PL can economize the TCs in all levels of the SCs), ΔC is in direct ratio to m, then ΔC will increase with the SC network hierarchy add in, and there is a critical point K_2, such that if $m \geq K_2$, then $\Delta C \geq 0$, and K_2 satisfies:

$$K_2 = \frac{sb}{(2an^2 + p - 2na_F - q - 2p_F)} \tag{2.13}$$

We can find that increasing ΔC_a and ΔC_p support 4PL enlarging the profit space fore-and-aft in the constructed SC. In fact, with the social division becomes more significant, the whole SC hierarchy will be expanded, thus 4PL entering SC networks probability will increase.

The expression (2.9) can be translated into as follows:

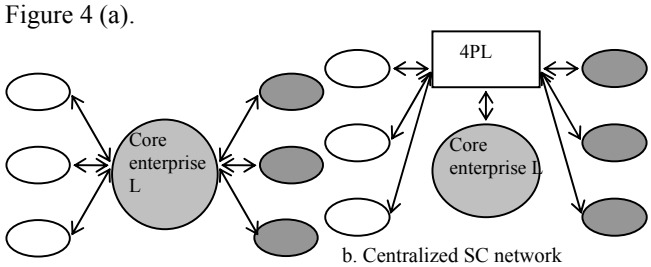
$$\Delta C_a = 2ma(n - \frac{a_F}{2a})^2 - \frac{ma_F^2}{2a} - sb \tag{2.14}$$

It is easy to see that ΔC_a is a quadratic function about n implying that the same hierarchy enterprises in the SC also increases, resulting to ΔC_a increases rapidly, this is due to two different SC networks. When 4PL entering SC, it can change the network structure, enterprises' contact time decreases obviously, so will reduce negotiation times, lower the search costs among enterprises, and economizing the ex ante TCs largely. There exists a critical value K_3, if $n \geq K_3$, then $\Delta C_a \geq 0$, here K_3 satisfies:

$$K_3 = \frac{a_F}{2a} + \sqrt{\frac{ma_F^2 + 2asb}{2ma^2}} \tag{2.15}$$

2.2 The TC model based on the centralized SC coordination

In the centralized SC, there is a core enterprise that takes charge all search members of the SC based on the determined standard, and constructs a SC by using the series of the signed contracts, see Figure 3 (a). After constructed the SC, 4PL assumes the coordination role for the entire SC operation, see Figure 4 (a).



a. Centralized SC network structure (before SC

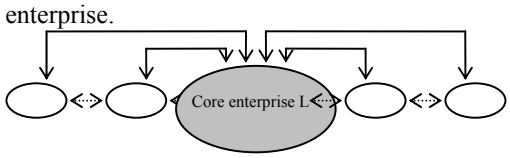
b. Centralized SC network structure contained 4PL (before SC constructing)

Fig. 3 Centralized SC network structure fore-and-aft 4PL entered (before the SC constructing)

To the centralized SC, the TCs incurred in the signed contract (ex ante) satisfy as follows:

$$C_a = \sum_{\substack{i=1 \\ i \neq L}}^{m} \sum_{j=1}^{n_i} (a_{ijL} + a_{Lij}) \tag{2.16}$$

where a_{ijL} denotes i hierarchy j enterprise's committed ex ante TCs between i hierarchy j enterprise and the core enterprise in SC; a_{Lij} denotes the core enterprise's committed ex ante TCs between i hierarchy j enterprise and the core enterprise.



a. Centralized SC network structure (after SC constructed)

b. Centralized SC network structure contained 4PL (after SC constructed)

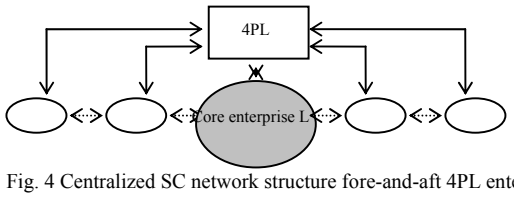


Fig. 4 Centralized SC network structure fore-and-aft 4PL entered (after the SC constructed)

To the centralized SC, the TCs committed in signed contract (ex post) satisfy as follows:

$$C_p = \sum_{\substack{i=1 \\ i \neq L}}^{m} (p_{iL} + p_{Li}) + \sum_{i=1}^{m} p_i \tag{2.17}$$

where, p_{iL} denotes i hierarchy committing the ex post TCs when the core enterprise coordinating i hierarchy enterprises; p_{Li} denotes the core enterprise's committed ex post TCs when

the core enterprise coordinating i hierarchy enterprises; p_i denotes i hierarchy enterprise's committed ex post TCs produced in upper and down enterprises.

In this way, the TC in the centralized SC is as follows:

$$C = C_a + C_p \tag{2.18}$$

When 4PL entered SC network, the selected 4PL will substitute the core enterprise to constructing SC and bear the coordinating work in the constructed SC.

When 4PL entered, the TCs before SC constructing (ex ante) satisfy:

$$C_a^F = \sum_{i=1}^{m}\sum_{j=1}^{n_i}(a_{ijF} + a_{Fij}) + \sum_{i=1}^{s}(a_{iL} + a_{Li}) \tag{2.19}$$

where, a_{ijF} denotes i hierarchy j enterprise's committed ex ante TCs incurred between 4PL and i hierarchy j enterprise in SC network; a_{Fij} denotes 4PL committed ex ante TCs incurred between 4PL and i hierarchy j enterprise in SC network; a_{iL} denotes the selected i 4PL's committed ex ante TCs incurred between i 4PL and the core enterprise; a_{Li} denotes the core enterprise's committed ex ante TCs produced between i 4PL and the core enterprise.

When 4PL entered SC network, the TCs committed in the constructed SC (ex post) are represented:

$$C_p^F = \sum_{i=1}^{m}(p_{iF} + p_{Fi}) + \sum_{i=1}^{m} q_i \tag{2.20}$$

where, p_{iF} is i hierarchy enterprises' committed ex post TCs when 4PL is coordinating i hierarchy enterprises; p_{Fi} is 4PL's committed ex post TCs when 4PL is coordinating i hierarchy enterprises; q_i is i hierarchy enterprises committing the ex post TCs produced between 4PL and upper and down hierarchy enterprises.

Moreover, when 4PL entered SC or not, the ex ante transaction economic costs and the ex post transaction economic costs are as follows, respectively:

$$\Delta C_a = C_a - C_a^F = \sum_{\substack{i=1\\ i\neq L}}^{m}\sum_{j=1}^{n_i}\left[a_{ijL} + a_{Lij} - a_{ijF} - a_{FLij}\right] - \sum_{i=1}^{S}(a_{iL} + a_{Li}) \tag{2.21}$$

$$\Delta C_p = C_p - C_p^F = \sum_{\substack{i=1\\ i\neq L}}^{m}(p_{iL} + p_{Li} - p_{iF} - P_{Fi}) - \sum_{i=1}^{m}(p_i - a_i) - (p_{FL} + p_{LF}) \tag{2.22}$$

Therefore, the transaction economic costs when 4PL entered SC satisfy:

$$\Delta C = \Delta C_a + \Delta C_p \tag{2.23}$$

Without loss of generality, suppose $n_i = n$, $a_{ijL} = a_{Lij} = a_L$, $a_{ijF} = a_{Fij}$, $a_{iL} = a_{Li} = c$, $p_{iL} = p_{Li} = p_L$, $p_{iF} = p_{Fi} = p_F$, $p_i = p$, $q_i = q$, $p_{FL} = p_{LF} = t$, then expressions (2.21), (2.22) and (2.23) can be simplified as follows, respectively:

$$\Delta C_a = 2(m-1)n(a_L - a_F) - 2sc \tag{2.24}$$

$$\Delta C_p = 2(m-1)(p_L - p_F) + m(p-q) - 2t \tag{2.25}$$

$$\begin{aligned}\Delta C = \Delta C_a + \Delta C_p = m(2na_L + 2p_L + p - 2a_F - 2p_F - q)\\ -2(na_L + p_L - a_F - p_F) - 2sc - 2t\end{aligned} \tag{2.26}$$

Similar to the discussion in section 2.1, it is easy to see that $a_L \geq a_F$ satisfies averagely. Since $sc \geq 0$, if $a_L > a_F$ and such that $2(m-1)n(a_L - a_F) > 2sc$ eventually, we just have $\Delta C_a > 0$, i.e., when 4PL entered SC and can lower the TCs incurred in the constructed hierarchy, thus justifying 4PL's undertaking the task of constructing SC.

In addition, it is easy to see that $p_L \geq p_F$ averagely. p and q are the coordinating costs committed in the core enterprise and 4PL can not substitute other members in the SC, if the difference between p and q is not too large, we can approximate $p = q$. Since $2t \geq 0$, if $p_L > p_F$ and such that $2(m-1)(p_L - p_F) + m(p-q) > 2t$, we just have $\Delta C_p > 0$, i.e., when 4PL entered SC and can lower the TCs incurred in the operation hierarchy, it is justifiable for 4PL to undertake the task of SC operation.

Suppose $\Delta C_a < 0$ and $\Delta C_p < 0$, but if only $\Delta C > 0$, i.e., when 4PL entered SC and can lower the TCs incurred in the entire SC, it is still justifiable for 4PL to undertake the task of SC coordination.

Similar to the decentralized SC, from (2.24), (2.25) and (2.26), when $(a_L - a_F) > 0$ (4PL can economize the ex ante TCs in all levels of SCs), we can find ΔC_a is in direct ratio to m, i.e., along with the SC network hierarchy add in, ΔC_a can increase gradually, and there is a critical point K_4 such that when $m \geq K_4$, $\Delta C_a \geq 0$, and K_4 satisfies:

$$K_4 = \frac{sc}{n(a_L - a_F)} + 1 \tag{2.27}$$

When $\left[2(p_L - p_F) + (p-q)\right] > 0$ (4PL can economize the ex ante TCs in all levels of SCs), ΔC_p is in direct ratio to m, i.e., along with the SC network hierarchy add in, ΔC_p can increase gradually, and there is a critical point K_5 such that when $m \geq K_5$, $\Delta C_p \geq 0$, and K_5 satisfies:

$$K_5 = \frac{2(p_L - p_F) + 2t}{2(p_L - p_F) + (p-q)} \tag{2.28}$$

When $(2na_L + 2p_L + p - 2a_F - 2p_F - q) > 0$ (4PL can economize the ex ante TCs in all levels of SCs), ΔC is in direct ratio to m, i.e., along with the SC network hierarchy add in, we can find ΔC increase gradually, and there is a critical point K_6 such that when $m \geq K_6$, $\Delta C \geq 0$, and K_6 satisfies:

$$K_6 = \frac{2(na_L + p_L - a_F - p_F) + 2sc + 2t}{2na_L + 2p_L + p - 2a_F - 2p_F - q} \tag{2.29}$$

We can find that increases of ΔC_a and ΔC_p support 4PL's enlarging of the profit space fore-and-aft of the constructed SC. From (2.24), we can know $m \geq 1$ generally, hence, if $(a_L - a_F) > 0$ (4PL can economize the ex ante TCs in all

hierarchy SCs), ΔC_a is in direct ratio to n, i.e., along with the SC hierarchy add in, we can find ΔC_a increases gradually, and there exists a critical point K_7 such that if $n \geq K_7$, then $\Delta C_a \geq 0$, and K_7 satisfies:

$$K_7 = \frac{sc}{(m-1)(a_L - a_F)} \tag{2.30}$$

We can know that increases ΔC_a will support 4PL's enlarging the profit space before constructing the SC. However, since the SC network does not change too, not as good as the decentralized SC, ΔC_a will increase along with n rapidly.

By the TCs analysis for 4PL in coordinating SC, we can find, no matter what 4PL coordinating the decentralized or centralized SCs, the types of 4PL coordinating SC can be divided based on the operation types of SC contract signed. 4PL may do nothing but constructing SC, such as counseling service, agency platform service, cooperative members selecting service in SC etc.; 4PL can undertake the operation task in the construction of SC too, such as management service in SC. Certainly, 4PL can undertake all fore-and-aft tasks simultaneously, but it needs to consider 4PL current ability. In addition, the TCs incurred in 4PL entered the decentralized SC are usually higher than those incurred in 4PL entered the centralized SC, hence, 4PL in the decentralized SC is economically more justifiable. Therefore, to earlier 4PL, it is easy to enter the decentralized SC, thus focusing on the development of the coordinating work to the decentralized SC. From the scale of SC (here, the scale determined m hierarchy in SC and the selecting enterprises n_i), scale of SC has deterministic effect on 4PL economizing the TCs of entire SC, i.e., larger scale of SC is favorable of 4PL's entering. With the social division becomes more and more detailed, the scale of SC will become enlarge, so 4PL has the cost advantage to entering SC in the future. Based on abovementioned, 4PL can combine its specialization and actuality, adopt the flexible strategy to develop, begin from SC coordination parts, and extend to coordinating the entire SC gradually. In fact, many 4PLs' development is based on such strategy.

For example, Alcatel-Lucent Technologies, Inc. is a global leader provider in telecom equipment field, manufactures products used to build communications network infrastructure. Its copper line transmission and switching, wireless, and optical gear is used in core telephony and data networks worldwide. From 1999, Alcatel-Lucent Technologies, Inc. first built leading logistics provider (LLP) relationship, through Ryder ran Alcatel-Lucent's SC across regions involving North America, Caribbean and Latin America. LLP is as the primary phase of 4PL, its objective is to improve the efficiency of SC and the distributing facilities, decrease touch point and turnover time. Ryder helps Alcatel-Lucent implement 4PL service process as follows: Set up team; Put forward plan and actualization; Continual improvement. During 4PL managing Alcatel-Lucent's SC process, Alcatel-Lucent took action as follows: Evaluate 4PL's core ability when handing over the logistics activities; Use the region logistics and the distributing team to manage 4PL; Emend each objective to improve 4PL performance. Alcatel-Lucent uses 4PL's core ability and capacity to construct its SC and gain higher profit, results in Lucent concentrate in research and development and does not fall into the daily affairs of its SC.

IV. CONCLUSIONS

With 4PLs are integrated into SCs, the selection of SCs is an important issue as core competency of each enterprise must be matched prior to jointly implementing a unify business strategy/model. This paper introduces a new mathematical model to justify the concept of using 4PL, which is a contractor of the SC coordination based on the division of community and the outsourcing development. The proposed mathematical model enriches the connotation of 4PL concept and broadens the thought for 4PL development. Secondly, the proposed mathematical model, based on TCs, is established by using Transaction Cost Theory can be used as the theoretical analysis tool of 4PL coordinating SC.

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REFERENCES

[1]Bumstead, J., Cannons, K.. (2002) From 4PL to Managed Supply-Chain Operations [J], Focus Magazine, No. 5, pp. 35-49.

[2]Thomas Craig. (2003) 4PL versus 3PL-A business Process Outsourcing Option for international Supply Chain Management [J], World Wide Shipping, No. 4, pp. 47-60.

[3]Gattorna, J. & Selen, W (2004) Characteristics, Strategies and Trends for 3PL/4PL in Australia, *Alpha Research Consortium Research Report 2004.*

[4]Heok, Chong. (2001) Epilogue: UPS Logistics - practical approaches to the e-supply chain [J], International Journal of Physical Distribution & Logistics Management, No. 6, pp. 463-468.

[5]Chopra, S., Meindl, P. Supply chain management-Strategy [M]. Planning and Operation, USA: Prentice Hall, Inc. Press, 2001.

[6]Hobbs, Jill E.. (1996) Transaction cost approach to supply chain management [J], Supply Chain Management, No.1, pp. 15-38.

[7]Grover, V., Malhotra, M. K..(2003) Transaction cost framework in operations and supply chain management research: theory and measurement [J]. Journal of Operations Management, Vol.21, pp. 457-473.

[8]Williamson, O. E. (1991) Comparative Economic Organization: The Analysis of Discrete Structural Alternatives [J]. Administrative Science Quarterly, Vol.36, pp.269-296.

[9] http://www.alcatel-lucent.com/wps/portal.