Asia Pacific Journal of Advanced Business and Social Studies
ISBN (eBook): 978 0 9943656 7 5
Year: 2015 , Volume: 1, Issue: 1

A SYSTEM DYNAMICS MODEL FOR HORIZONTAL COLLABORATION IN AIR CARGO TRANSPORT SERVICES

Tommy King-Yin Cheung and Collin Wai Hung Wong
Hang Seng Management College, Hong Kong
Corresponding Author: tommycheung@hsmc.edu.hk

Abstract

Horizontal collaboration among air cargo transport service providers is gaining wide spread acceptance because of the opportunity to cut costs for customers and companies, optimizing routes through sharing, improving overall logistics efficiency and gaining more customers. This paper applies the system dynamics simulation methodology to model and analyze the interactions between collaborative partners. Specifically, it shows that while there are strong incentives to collaborate horizontally, the strategic alliances may fail when the risks of information sharing increase. A more comprehensive horizontal alliance is needed to achieve an optimal collaboration level.

Keywords: Horizontal collaboration, Logistics, System dynamics.

Introduction

Two-partner horizontal collaboration models provide a new perspective to study the partnership gain in a logistic industry. In horizontal collaboration, two global logistic companies are connected to each other through sharing their distribution networks, capacities, planning, and handling services. The sharing constitutes a set of the contractual agreements necessary to establish the cooperation between two partners. A key characteristic, here, is the presence of network scaling by transporting more volume in each network while reducing the number of redundant routes. In recent years, many freight forwarders formed global horizontal alliances, in which their warehousing facilities are shared and their delivery orders are distributed in the same air networks as those of their partners [7]. This is due to the increased competitiveness within the air cargo transport industry and with other modes of transport services, coupled with high operating costs such as fuel, crew, and overhaul of aircraft etc. The increasing opportunities for competition have also created excess capacity in many markets based on size, volume and services [11]. Couriers, postal services, forwarders and integrators all increasingly compete on similar market segments [8]. The more markets are competitive, the more is important to be efficient. Cost reduction strategies are becoming very important. Horizontal collaboration is effective in lowering the distribution cost and increasing logistic efficiency. This trend will continue, as pressure grows in cost saving while improving responsiveness to customer demands. Horizontal collaboration, if effectively implemented, can deliver the significant operational changes that are needed to stay competitive, particularly in air transport industry where customer preferences and transport requirements have become more challenging.

The main contribution of this paper is to show the System Dynamics (SD) simulation model of air cargo transport collaboration on a horizontal level, with a focus on the integrative logistics service providers, such as DHL and FedEx. The SD model captures the flows and volume of freights handled by the logistic service provider as well as between its collaborative partners. The analysis of our model suggests that while horizontal collaboration forms a strategic partnership, risks of enterprise information sharing in a tactical operating environment increases with the level of collaboration. However, service and efficiency are the same goal of both service providers, which is the basis of their collaboration.

Related Work

Simulation modeling has been an indispensable tool for studying the behaviors of supply chain networks and their transport systems [16]. Supply chain network is a dynamic complex system involving several independent units with individual preferences and behaviors. The multiple units are interconnected dynamically by material, financial, information flows and decision flows. Many models have been developed to analyze the interactions among the independent units [10, 15, 2]. Simulation provides an effective mean to observe the whole supply chain performance given the behavior of each unit. The results are often used to develop policies in planning, production, inventory, responsiveness and distribution [3].

System dynamics (SD) is a simulation modeling methodology that is best suited for dealing with strategic or policy issues by considering aggregates (of freights or people, etc) and not individual entities in the system [5]. It captures the dynamics of a system as a continuous flow of resources that change over time and the changes come from within the system boundary due to the generation of its own actions, and interactions with other units. The flow rate, resource level, and the dynamics of the system are governed by a set of differential and integral equations. Overall, SD model captures that each unit in a network can be influenced by the actions of all other units to which it is linked, and thus, influences the timing of its actions in the environment. Feedback loops are often used to model these mutual causal relationships between the units within the network [6].

Although previous studies have discussed collaborations in supply chains and transport systems [12. 13, 10], they focused mostly on coordination of various activities between suppliers and buyers in supply chains, or between freight forwarders and airlines in air cargo transport. Only a few focused on horizontal collaboration between companies that operate at the same level of the value chain. S. Ankersmit et al [1] studied the horizontal transport collaboration in air cargo industry, with an emphasis on the benefit of combined transport in dynamic short-distance transport systems. There has been little to no attention to the actual interactions and mutual causal relationships between two companies that collaborate on a horizontal level. In particular, this paper applies system dynamics simulation to analyze the detail interactions between two integrative logistics service providers. It examines the combined effects of (i) collaborative cost reduction, (ii) potential added value of freight transport due to increased efficiency, and (iii) the enterprise information sharing risks as collaboration level increases, on the service providers' organizational processes.

System Dynamics Model For Air Cargo Transport Service Provider

Single SD Model

To explore how the relationship between two integrative logistic service providers (A and B) evolves over time, a basic SD model is first constructed to capture the warehousing process of a single logistic service provider. Warehousing is the most critical part in the operation of any logistic company. For the purpose of understanding the warehouse activities and collecting operational data, several site visits to the warehouse of a large international logistic service provider located at the Hong Kong International Airport were conducted. The secondary sources included, for example, company website and industry reports. The raw data collected on site includes warehouse capacity, consignment inspection rate and time, document processing time, sorting time, and moving time. Figure 1 illustrates the SD model of the two service providers (A and B). The green and blue lines define the system boundary of A and B respectively.

The warehouse operation consists of six processes, which are:

1. Receiving consignments from forwarder
2. Receiving consignments from Less-Than-Container-Load
3. Sorting the consignments
4. Regular consignment inspection
5. Releasing consignments to forwarder
6. Releasing consignments to direct delivery

In this SD model, the structure is represented by a stock and flow diagram which is used to explain both variables, i.e. the stocks and flows. Stocks refer to the values of variables at a point in time, while flows exist during a period of time. Stocks are accumulated over time through inflows and outflows. In Figure 1, the square represents stock and the pipe represents flow. A flow rate is defined for each pipe. As an example, the variable "ForwarderIn" represents the number of consignments from forwarder, and its outflow rate is defined by the parameter "InspectionRateOfForwarder".

Combined SD Model

The two basic models are combined in a way to allow the two service providers transfer freights to each other (see Figure 1), thereby leveraging the network scaling and cost reduction in a two-partners collaboration. In essence, service providers A and B share their capacities to improve profitability. It is also assumed that A and B are only identical in their operations, and not their processing rates, times and capacities. All activities associated with the combined model involve a coordinated effort in collecting and delivering the air cargo shipments from multiple sources to several destinations, making it possible to consolidate deliveries and reduce the total number of shipments.

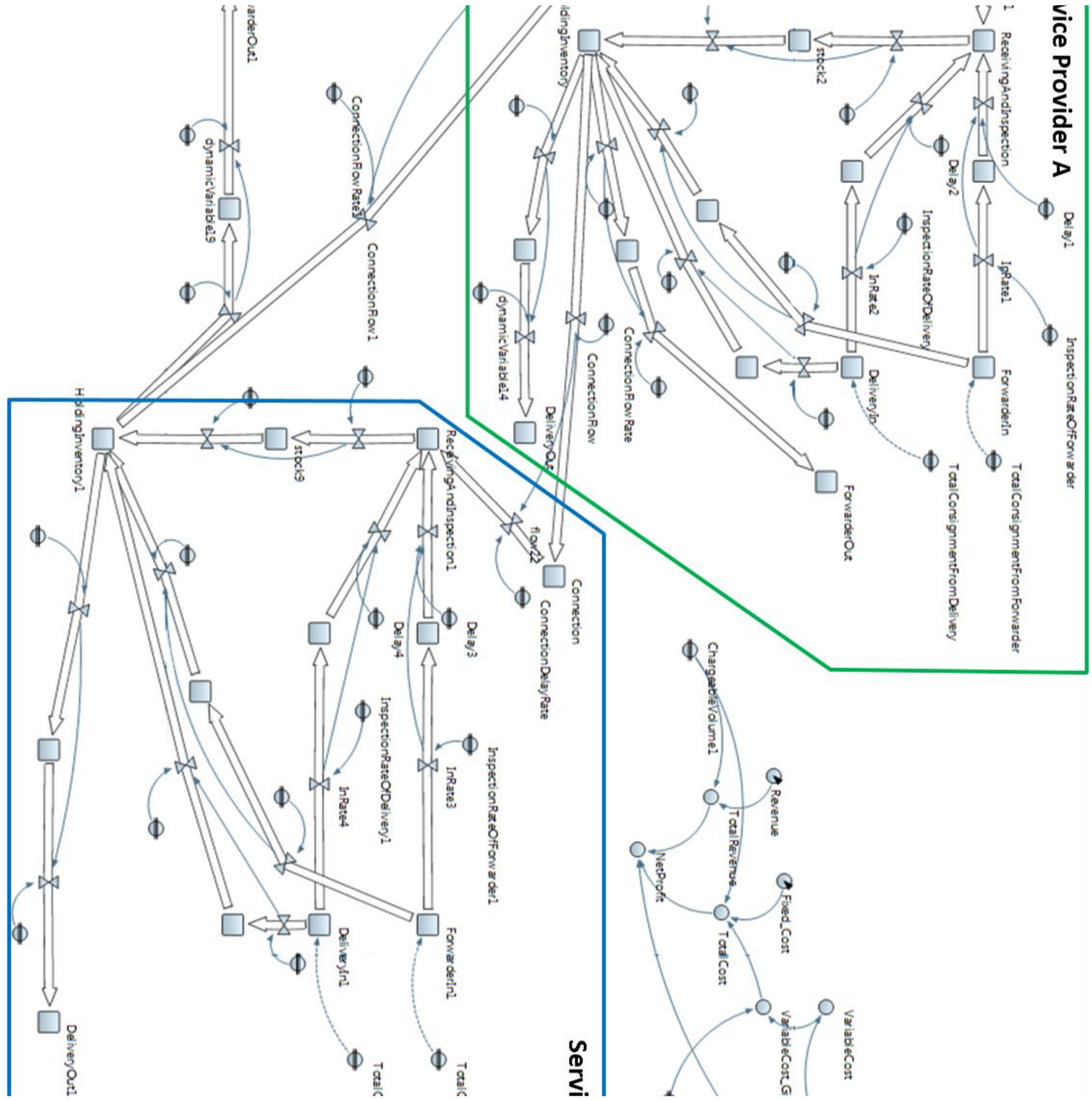

Figure 1: System Dynamics Model of Two Integrative Logistics Service Providers

Horizontal collaboration in air cargo transport is related to three main issues: capacity sharing, information sharing, and route sharing. Concerning capacity sharing, the two logistics service providers can provide complementary and/or substitutable services to each other. Prices and/or volumes can be agreed in a service contract, which provides collaboration incentives to both parties. For the information sharing, this is not modeled explicitly. However, it is assumed that there is a platform to exchange information between the two service providers. Wang [14] suggested strategies for information collaboration. Madlberger [9] explained that companies share information if the firms will benefit financially. Although there are benefits for information sharing, the level of risks increases with the degree of horizontal collaboration, as the two service providers are also competing against each other in a tactical operating environment. In this SD model, information sharing risk is an auxiliary dynamic variable defined as a function of collaboration strength. For the route sharing, this is similar to that of logistics pooling. An air cargo transport pooling involves deliveries having a common path of destinations. The decisions to share routes are taken by both logistics service providers, and involve logistics planning and optimization.

Horizontal Collaboration Payoffs

To quantify the outcome of horizontal collaboration, a parameter "Theta" ($\theta \in [0,1]$) as depicted in Figure 1 is introduced to measure the effects of cost reduction through collaboration. At the same time, θ also represents the level of information sharing. In practice, the collaboration level increases with the level of information sharing, but is unrelated to the freight volume passed between the service providers. At $\theta = 0$, the two service providers are completely separated, whereas at $\theta = 1$ corresponds to the maximum level of collaboration. As discussed in the previous section, the value θ is a result of a coordinated efforts made by the two service providers, each of which put in different time, resources, and capitals in the horizontal collaboration process.

Unit Cost Function

To calculate the cost reduction through collaboration, we define a unit cost function that is uniformly decreasing as θ increases from 0 to 1 (Figure 2). In the figure, each logistic service provider (A or B) has a potential variable unit cost in addition to a fixed cost. Though the cost function is uniformly decreasing, the rates of reduction for A and B are asymmetric. In a horizontal collaboration process, both A and B can take on any value within their potential variable cost ranges for a given θ. However, neither A nor B knows the other's unit cost. In essence, the amount of cost saving between the two service providers can be different as the collaboration level varies.

Let $k_{A,\theta}$ be the variable cost of A at θ.
Let $\beta_{A,0}$, $\beta_{A,1}$ be the variable costs of A when $\theta = 0$ and 1 respectively.
Let $\lambda_A = \frac{\beta_{A,1}}{\beta_{A,0}}$
Let $C_{A,Fixed}$ be the fixed cost of A.

By geometry, the unit cost function of A is given by:

$$C_A(\theta, \chi_A) = C_{A,Fixed} + \beta_{A,0}[1 - (1 - \lambda_A)\theta]\chi_A$$

where $\chi_A \in [0,1]$ represents the potential variable cost level that is realized by A. Similarly, the unit cost function of B is given by:

$$C_B(\theta, \chi_B) = C_{B,Fixed} + \beta_{B,0}[1 - (1 - \lambda_B)\theta]\chi_B$$

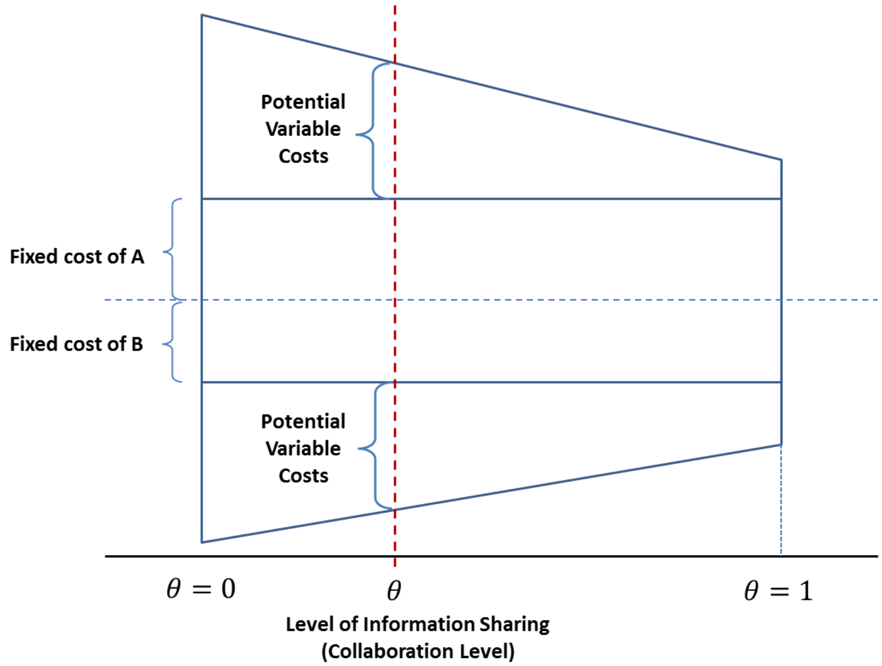

Figure 2: Unit Cost Function for Two Logistics Service Providers in a Horizontal Collaboration

Revenue Function

The total revenue of a shipment, R with a chargeable volume weight w and a chargeable rate in dollar per kg, r equals to

$$R = rw$$

In practice, the chargeable rate, r can usually be looked up in a volume-rate table published in the logistics service provider's website.

Risk Function

In a horizontal collaboration, the information sharing risk increases with θ. At a given $\theta < 1$, the information of one service provider may not completely relay to the other service provider, as it will use the information to its advantage. When $\theta = 1$, this information becomes completely transparent. Information sharing is not risk-free, especially when both service providers operate and compete at the same level of value chain [4].

In this model, risk is regarded as a cost function dependent on the collaboration level. The risk function is approximated by the following equation:

$$risk(\theta) = 1074e^{2.7211\theta}$$

as shown in Figure 3. In reality, costs to a service provider increase nonlinearly with the collaboration level, θ. The costs accelerate when θ moves beyond a certain level.

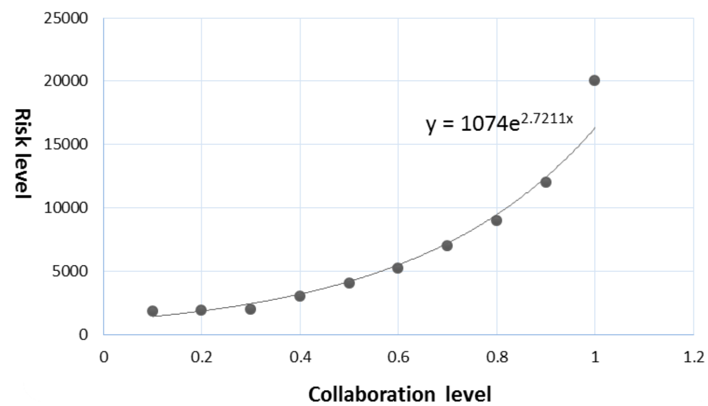

Figure 3: Risk Function

Net Profit Calculation

Given the information sharing risk, revenue, and cost reduction, the profit can be computed by the following equation:

$$P_A(\theta, \chi_A) = \frac{V}{6}[R - C_A(\theta, \chi_A)] - risk(\theta)$$

$$P_B(\theta, \chi_B) = \frac{V}{6}[R - C_B(\theta, \chi_B)] - risk(\theta)$$

where V is the chargeable volume of the air cargo shipment passed between two service providers. The quantity, V is obtained directly from the SD simulation. Figure 4 shows a plot of this net profit function. It indicates that the net profits initially increase with the collaboration level θ, but as the information sharing risk factor becomes dominant, the net profits decrease with θ. It can be easily shown that the turning point for the service provider A occurs when the following condition is satisfied.

$$\theta_A = \frac{1}{2.7211} ln \left[\frac{\beta_{A,0}(1 - \lambda_A)\chi_A}{17534.77}\right]$$

Similarly, the turning point for B occurs when:

$$\theta_B = \frac{1}{2.7211} ln \left[\frac{\beta_{B,0}(1 - \lambda_B)\chi_B}{17534.77}\right]$$

That is, for a given variable cost level χ, the best θ that gives the maximum profit can be determined. As θ_A could take on a different value than θ_B, this suggests that there will be a strategic game play in which A and B will eventually arrive at a collaboration level that satisfies them both.

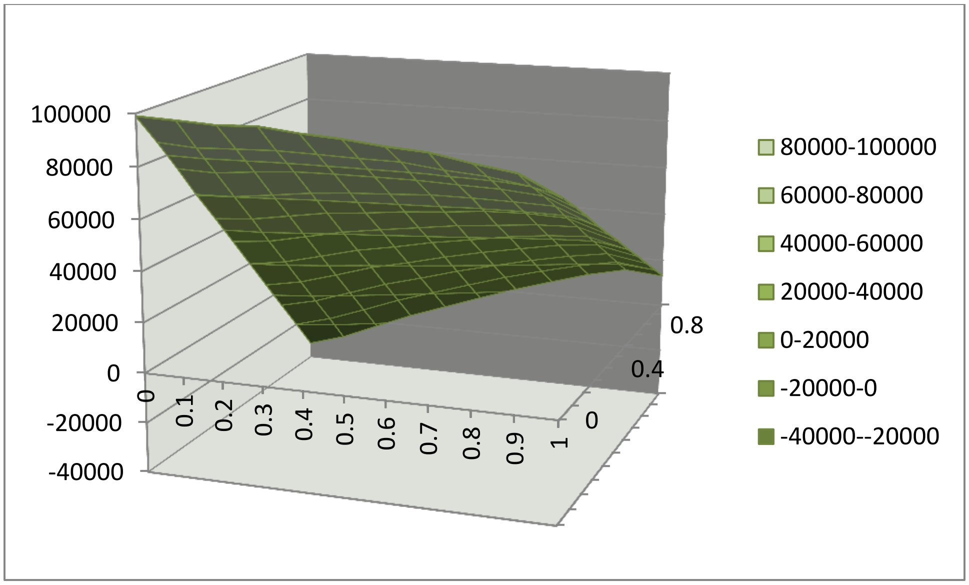

Figure 4: Net Profits with Varying θ and χ

Conclusion

This paper presented a two-partner horizontal collaboration model for air cargo transport companies. The effects of horizontal collaboration on net profits, information sharing and cost reduction have been analyzed using system dynamics simulation. The quantitative results demonstrated the potential benefits for collaboration, and identified the maximum profit condition in a dynamic setting to attain some target collaboration levels. Lastly, by employing system dynamics modeling, the interactions between the two logistics service providers in the horizontal collaboration can be observed and analyzed. The SD model analysis presents the logistics services provider with some strategic play to maximize its overall benefits (profit payoffs) in the collaboration process.

References

[1] S. Ankersmit, J. Rezaei, L. Tavasszy. (2014*), The potential of horizontal collaboration in airport ground freight services*, J. of Air Transport Management, 40, pp169-181.

[2] B. Asgari, M. A. Hoque. (2013*), A system dynamics approach to supply chain performance analysis of the ready-made-garment industry in Bangladesh*, Ritsumeikan Journal of Asia Pacific Studies, Vol. 32.

[3] Y. Chang, H. Makatsoris. (2001), *Supply Chain Modeling Using Simulation*, Int. J. of Simulation, Systems, Science and Technology, Vol 2, No. 1, pp24.

[4] F. Cruijssen. (2006), *Horizontal Cooperation in Transport and Logistics*, Center for Economic Research, Tilburg University.

[5] B. Dangerfield. (2014), *Systems thinking and system dynamics: A primer, Discrete-Event Simulation and System Dynamics for Management Decision Making*, Ed. S. Brailsford, L. Churilov, B. Dangerfield, Wiley, pp26-50.

[6] J. P. Davis. (2014), *The Emergence and Coordination of Synchrony in Organizational Ecosystems*, In Collaboration and Competition in Business Ecosystems, pp197-237.

[7] I. Iankoulova. (2012), *Business Intelligence for Horizontal Cooperation - Measuring the performance of a transportation network sharing cooperation between logistics companies*, MSc Thesis, University of Twente, The Netherlands, Web site: http://essay.utwente.nl/61588/1/Iankoulova_Thesis_BI4HC_UNRESTRICTED.pdf

[8] A. Lennane. (2013), *Forwarders move into express products as integrators take on freight*, Web site: http://theloadstar.co.uk/forwarders-move-into-express-products-as-integrators-take-on-freight/

[9] M. Madlberger. (2008), *Interorganizational Collaboration in Supply Chain Management: What Drives Firms to Share Inforamtion with Their Trading Partners?*, Proceedings of the 41st Annual Hawaii International Conference on System Science, 11-11.

[10] U. Ramanathan. (2014), *Performance of Supply Chain Collaboration – A Simulation Study, Expert Systems with Applications*, 41, pp210-220.

[11] H. Ross. (2012), *An Unsettled Question in Transport Economics: The Importance of Excess Capacity in Transport Infrastructure*, Liber Amicorum in Memoriam Jo van Nunen, Chapter 19, p225-227.

[12] M. Simatupang, A. C. Wright, R. Sridharan. (2004), *Applying theory of constraints to supply chain collaboration*, Supply Chain Management: An International Journal, Vol 9, Iss 1, pp57-70.

[13] C. Vanovermeire, K. Sorensen. (2014), *Measuring and rewarding flexibility in collaborative distribution including two-partner coalitions*, European Journal of Operational Research, 239 pp157-165.

[14] X. Wang (2011), *The Strategies of Supply Chain Collaboration in Informatization Environment, Int. Conference on Information management, Innovation Management and Industrial Engineering*, 74-77.

[15] W. Wisetjindawat, K. Sano, S. Matsumoto. (2005), *Supply Chain Simulation for Modeling the Interactions in Freight Movement, J. of the Eastern Asia Society for Transportation Studies*, Vol 6, pp2991-3004.

[16] X. Zheng, H. Yu, A. Atkins. (2008), *An Overview of Simulation in Supply Chains, Advanced Design and Manufacture to Gain A Competitive Edge*, Springer, pp407-416.