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Research Report: ZLC-2010-16
Design of Closed Loop Supply Chain Under Uncertainties
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Design of Closed Loop Supply Chain Under Uncertainties

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Summary:
This thesis discusses how the uncertainties influence the transportation and fixed cost in closed loop supply chain system. Its purpose is to find whether there are correlations between three sources of uncertainties, and whether these uncertainties have the same influence to the whole system under different situations.

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KEY INSIGHTS

1. Closed Loop Supply Chain is an integration network combined by seamless connection of forward logistics and reverse logistics.
2. Closed Loop Supply Chain has no uniform type due to different return production, which forms different types of reverse logistics.
3. Varied uncertainties exist in closed loop supply chain system, which have different influences on the performance of the system.

Introduction

Modern logistics is an important component of economics. With the wider globalization, rapid economic development has led to a significant increase in the volume of logistics activities. From the supply chain management point, the complications of modern logistics systems are not only the logistics activities moving forward (cargo sent from plants to final customers through distribution centers), but also reversed (items sent back to plants or distribution centers with defects or as waste). With the fast-growing consumer production volumes, more types of return items appear in bigger numbers. So nowadays, mass production has generated mass cargo circulation, and then generated more complicated logistics networks (open or closed loop supply chain system).

The economic value of most of the returned products still can be recovered through appropriate treatment. Two important results could be achieved. First, the environment can be protected. Most natural materials in the earth are limited and if they are used continuously and carelessly, we will face the dilemma of no resources in the future. A good solution to this problem is to collect the recoverable materials and then reuse them to prolong the their life cycles. With this target, a recycle closed loop that puts the forward logistics and reversed logistics network together to deal with the movement of resources, production, return items, and reproduction will have been generated. Second, from the corporation management viewpoint, a very constructive theory is that the company can get a new and sustainable source of profit from closed loop supply chain. With this system, companies can get many benefits such

as lowering cost, reducing the cycle time of production, or reducing the purchase volume of raw materials. With all these benefits, companies not only can generate more profits, which have a positive outcome on the financial statements, but also enhance the customer service level with lower costs, finally enhancing the total annual profit.

The most important component of closed loop supply chain is the reverse logistics network. It has been proved from many industries that reverse logistics movement is information intensive, labor intensive process. Furthermore, the return items' reverse logistics network is not a symmetrical structure like forward logistics system, but a more complex one.

Many papers have done research o building reverse logistics, and they have proposed that due to the kinds of return items, the reverse two types of logistics networks can be established: constructing a reverse system that is totally separate from the forward logistics network or building the two networks together to create an integral one. Just as there is no uniform expression for reverse logistics, the closed loop supply chain also has no standard definition. As mentioned above, some papers have done research on building the network, but they have chosen different types of production and have solved the location problem from different angles.

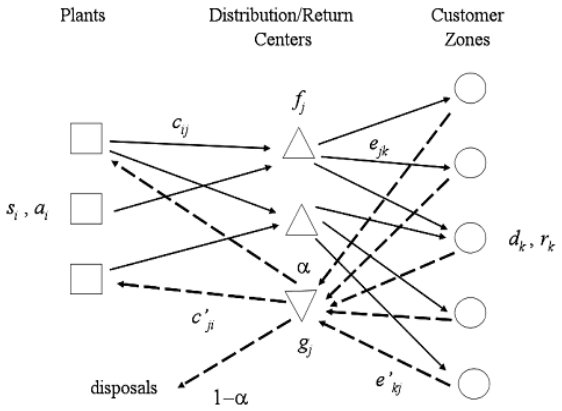
In this paper, besides building a closed loop supply chain system and finding the best location solutions, we focused more on resource uncertainties from customer zones and how these uncertainties affected the total cost of the closed loop supply chain system. The following questions were addressed: Where did the uncertainty come from? How will the uncertainty influence the whole closed loop supply chain and what are the relationships between the uncertainties? We focused on three main uncertainties to analyze their performance of the closed loop supply chain system, which were: Return Ratios, Recovery Ratios, and variations in demands from customer zones.

Deterministic Model and Stochastic Model

Due to different productions, different types of networks can form in closed loop supply chain by different treatment methods; here we chose reusable production in the closed loop system to reflect the real world's circulation system.

With the main objective of analyzing how the uncertainties in the reusable production closed loop supply chain could affect the total cost of the system, we chose the model from the paper "Designing Distribution Systems with Reverse Flows", (Vedat et al. 2009) as our basic model. This model best reflected the real circulation system in the real word for reusable production. After the model was confirmed, we established the main approaches: A simulation program based on the mathematical model and an extension of the model to a setting, taking account into the demand and return volumes uncertainty.

Deterministic Model



Minimize transportation cost and fixed cost in closed loop supply chain system

$$Z_P = \min \sum_j f_j Y_j + \sum_j g_j T_j + \sum_i \sum_j C_{ij} U_{ij} + \sum_j \sum_k e_{jk} X_{jk}$$

$$\sum_i \sum_j C'_{ji} V_{ij} + + \sum_j \sum_k e'_{jk} W_{jk}$$

Stochastic Model with Uncertainties

To reflect the uncertain demands and return volumes, we have assumed that the demand is normal distribution with customer service level of 95%. Then we have designated different standard deviations to the demands from the different customer zones, and considered three levels of standard deviations which are high/median/low (each responding to 1/0.5/0.25 times of the demand mean). With the objective to simulate the program to reflect a real situation, we also designated the return ratio and recover ratio with high/median/low rate.

Then 27 Scenarios has been generated.

	Standard Deviation			Return Ration			Recovery Ration		
	Low	Media	High	Low	Media	High	Low	Media	High
1	x			x			x		
2	x			x				x	
3	x			x					x
4	x				x		x		
5	x				x			x	
6	x				x				x
7	x					x	x		
8	x					x		x	
9	x					x			x
10		x		x			x		
11		x		x				x	
12		x		x					x
13		x			x		x		
14		x			x			x	
15		x			x				x
16		x				x	x		
17		x				x		x	
18		x				x			x
19			x	x			x		
20			x	x				x	
21			x	x					x
22			x		x		x		
23			x		x			x	
24			x		x				x
25			x			x	x		
26			x			x		x	
27			x			x			x

The Influence of Recovery Ratio Change (Low-Media-High) to the Total Cost in Closed Loop Supply Chain		Standard Deviation		
		Low	Media	High
Return Ratio	Low	not significant	not significant	not significant
	Media	significant	significant	significant
	High	very significant	very significant	very significant

The Influence of Return Ratio Change (Low-Media-High) to the Total Cost in Closed Loop Supply Chain		Standard Deviation		
		Low	Media	High
Recovery Ratio	Low	significant	significant	significant
	Media	significant	significant	significant
	High	very significant	very significant	very significant

The Influence of Standard Deviation Change (Low-Media-High) to the Total Cost in Closed Loop Supply Chain		Recovery Ratio		
		Low	Media	High
Return Ratio	Low	significant	significant	significant
	Media	significant	significant	significant
	High	significant	significant	significant

Results Analyzed

With the objective to find the relationships between these three factors and how they could affect the total cost of the closed loop supply chain. After analyzing the results from Arena simulation, we found that the three factors do have some correlations in affecting the system.

- One uncertain factor changing can cause the same influence on the closed loop supply chain in different scenarios, which means it is independent of other factors (When variation in demand changes from low level to median level then to high level, while the other two factors are stable, it has the same influence on the system, no matter how the recovery and return rates change.)
- In some scenarios, one factor is dependent on another. We found that in the simulation, the recovery ratios have higher correlation to return ratios rather than to variations in demand.

Conclusion

Closed loop supply chain is a dynamic system, and its distinguishing features are the greater difficulty of building the network and control of uncertainties. In reality, there are a number of uncertain factors that exist in the closed loop supply chain, since it is the integration system based on the network of forward and reverse logistics. The uncertainties in the loop not only come from the reverse logistics part, but also from forward logistics. We already know that the uncertain demands in forward logistics can affect the cost, but it is only one factor. There are still many other uncertain factors, and the situation is even more complicated in a closed loop supply chain. It is more difficult to forecast and operate the closed loop supply chain system than to handle a simple forward network. Through our analysis, we found that some correlations exist among different uncertain factors, and in some scenarios, the influence on Nevertheless, our simulation only considered three uncertainties, and in reality there are many more that need to be considered in further studies.