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Abstract

Purpose – The aim of this paper is to study reverse logistics network design in order to better facilitate the location of factories, online retailers, and the third party logistics in the context of e-commerce.

Design/methodology/approach – Drawing on types of third party collections of returned products, the paper proposes a 0-1 mixed integrate linear programming (0-1MILP) mathematic model for reverse logistics networks in e-business and a further mathematical model is discussed in relation to determining the market demands and returns. Furthermore, a case study is developed and described with the intention of illustrating the value of this model and network.

Findings – The paper identifies possibilities for the application of the reverse logistics network models to deal with returned products from customers in companies using e-business.

Research limitations/implications – There is scope for future research to build on the present research and consider further factors in relation to the influences on return logistics.

Originality/value – This paper provides novel insights for e-companies setting up and operating a reverse logistics network. The application of these models could decrease costs and allow optimal decisions on price and return price in order to increase efficiency and profit levels.

Keywords Electronic commerce, Return policy, Returns, Reverse logistics, Third-party logistics

Paper type Research paper

1. Introduction

Reverse logistics of e-commerce refers to the return, counter-flow or reverse-flow of products which are ordered on the internet from customers to suppliers. These products are generally returned for reasons of poor quality or other factors of customer dissatisfaction (Xiong, 2005). Considering the potential significance of reverse logistics for e-business, this issue persists as an important one, and requires urgent attention, if businesses want to survive in competitive market environments. The overall problematic can therefore be postulated as the design of a reasonable reverse logistics network to minimize the overall logistic costs in the context of e-business. Compared with traditional consumption patterns, e-business is becoming more acceptable and popular among customers owing to its high efficiency, convenience and low costs. This development is, of course, intrinsically linked to the rapid contemporary development of information technology and, obviously, the internet.

This paper focuses, in particular, on the e-commerce situation in relation to China. According to statistics, the overall trade volume of e-commerce in 2010 in China has risen to 3,220 billion yuan (£321 billion pounds sterling), five times than that of 2005. However, because of imbalanced information exchanges between sellers and buyers on

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issues such as quality, sizing or colour, products are more likely to be returned than in more traditional face-to-face transactions. In 2004, the value of online products returned by customers in America was as much as $23.1 billion dollars (£17 billion pounds sterling), in connection to which the direct economic loss was approximate to $2.5-8.2 billion (Krishnan *et al.*, 1999). As a consequence, reverse logistics of e-commerce is gradually being paid more and more attention by producers.

In the past, the reverse network design for traditional business patterns has been thoroughly studied, including, for example, re-manufacturing, repairing, re-fabricating and recycling. For instance, the model proposed by Fleischmann *et al.* (2000) is one of the most generic for the design of reverse logistics network in which forward and reverse logistics are integrated. This model deals with primarily re-manufacturing. Zhou and Wang (2008) extended Fleischmann's model by taking account of both repairing and re-manufacturing however both models were designed for traditional business contexts. Considering the common concerns shared by e-business and traditional business regarding reverse logistics networks, it is possible to suggest that these models can be applied to a new business environment in which returned products mainly refer to new ones rather than end-of-life products. Moreover, some papers when studying reverse logistics location problems assume that the market demand and returns are known or knowable factors (Liu *et al.*, 2010). However, in reality, this assumption is not so reliable or calculable in advance. Therefore, in our paper, in order to consider the uncertainty of demands and returns, we analyse the return policies whereby, when price and return price are determined in a certain market, demands and returns are able to be predicted precisely.

The subsequent argument in the paper is organized as follows: in Section 2, the mathematical formulation of the reverse logistics network model is outlined; in Section 3, in an attempt to assess market demand and returns, a proposal for an optimal return policy model is put forward; in Section 4, a numerical example is constructed in order to illustrate the model and its parameters are analyzed. Finally, Section 5 presents a discussion on the direction of future research.

2. Generic model for reverse logistics network based on e-commerce

Reverse logistics models based on e-business environment have received a degree of attention (Ni and Liao, 2009). Generally, there are three typical forms and these include manufacturing collecting, online retailer collecting and the third-party logistics providers (3PL) collecting. In the infancy of e-business, the most adopted models were the first two. However, they have struggled to satisfy business and customer and appear to have reached certain limits of their potential due to complex logistics service and high-cost issues. Furthermore, as more and more retail stores are set up on the internet, competition has become extremely intensive and this further pressurized reverse logistics operations in those particular settings. Therefore, owing to concerns to reduce logistics costs and improve efficiency, it is hardly surprising that enterprises tend to prefer outsourcing it to the third-party reverse logistics service providers. This then allows enterprises to be able to focus on their core business and provide customers with better service at lower cost at the same time. In the light of the limitations of the first two models it will be useful to examine 3PL collection as a developing and growing trend (Figure 1).

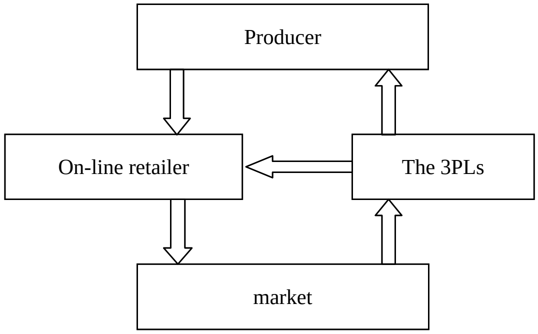

Figure 1.
The 3PLs and the collection mechanism

In this section, we propose a general quantitative model for online product return, which considers the application of 3PLs involving collection of products from customers and the return policy strategy of the market.

2.1 Assumption

At first, there are three assumptions taken into consideration in this model:

Assumption 1. There are four participants: factories, online retailers, the 3PLs and markets.

Assumption 2. Only one kind of product is considered in the model.

Assumption 3. To simplify the model, we only take the costs of transporting between two sites into consideration.

At the market end, there are products demanded and products ready to be returned for one or another reason. All returned products are centralized at the 3PL which would deliver some products from markets back to the online retailers where they would be used to meet the demands of market again and deliver some products to factories where they would be processed further as shown in Figure 2.

2.2 Donation

In this network problem, the reverse effect of the channel consists of three levers – the number and locations of three facilities of three different kinds – factories, online retailers and the 3PLs. Therefore, this is a three-lever location problem with three different types of facilities:

(1) Index sets:
$I = \{1, 2, 3, \ldots, N_f\}$ donates potential factories locations.
$J = \{1, 2, 3, \ldots, N_b\}$ donates potential online retailers locations.
$K = \{1, 2, 3, \ldots, N_l\}$ donates potential 3PLs locations.
$L = \{1, 2, 3, \ldots, N_M\}$ donates fixed consuming markets.

(2) Variables:
X_{ijl} – faction of demand of market l to be served from factory i and online retailer j, $i \in I$, $j \in J$, $l \in L$ $0 \leq X_{ijl} \leq 1$.
X_{kjl} – faction of demand of market l to be served from the 3PL k and online retailer j, $k \in K$, $j \in J$, $l \in L$ $0 \leq X_{kjl} \leq 1$.

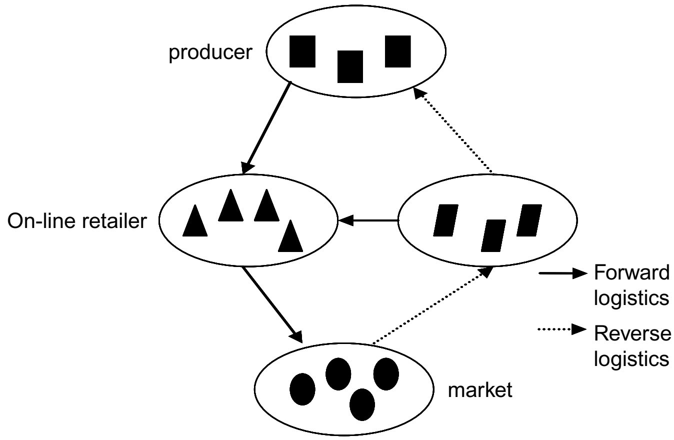

Figure 2.
Reverse logistics network

X_{lki} – faction of returns of market l which are collected by the 3PL k and delivered to factory i, $i \in I, k \in K, l \in L$, $0 \leq X_{lki} \leq 1$.

X_{lkj} – faction of returns of market l which are collected by the 3PL k and delivered to online retailer j, $k \in K, j \in J, l \in L$, $0 \leq X_{lkj} \leq 1$.

Y_i – indicator opening factory i, when factory i is open, $Y_i = 1$, otherwise, $Y_i = 0$.

Y_j – indicator opening online retailer j, when online retailer j is open, $Y_j = 1$, otherwise $Y_j = 0$.

Y_k – indicator the opening 3PL k, when the 3PL is open, $Y_k = 1$, otherwise $Y_k = 0$.

(3) Costs:

C_{ab} – the transport cost of unit product from location a to b.

C_{ijl} – unit transport cost of serving demand of market l from factory i and online retailer j, $i \in I, j \in J, l \in L$.

C_{kjl} – unit transport cost of serving demand of market from the 3PLs k and online retailer j, $k \in K, j \in J, l \in L$.

C_{lki} – unit transport cost of returned products from market l via the 3PL k to factory i, $i \in I, k \in K, l \in L$.

C_{lkj} – unit transport cost of returned products from market l via the 3PL k to the online retailer j, $k \in K, j \in J, l \in L$.

f_i – fixed costs for opening factory i, $i \in I$.

f_j – fixed costs for opening online shop j, $j \in J$.

f_k – fixed costs for opening the 3PL k, $k \in K$.

M_i – the maximum capacity of factory.

N_j – the maximum capacity of online retailer.

Q_k – the maximum capacity of the 3PLs.

η – the minimum portion of returned products delivered to factories.

(4) Parameters:
   d_l – demand from market l, $l \in L$.
   r_l – returns from market l, $l \in L$.

2.3 The design of the model

Then the formulation of the problem as a mixed integer linear problem is given as follows.

Objective function:

$$\min Z = \sum_{i\in I} f_i Y_i + \sum_{k\in K} f_k Y_k + \sum_{j\in J} f_j Y_j + \sum_{i\in I}\sum_{j\in J}\sum_{l\in L} C_{ijl} X_{ijl} d_l +$$

$$\sum_{k\in K}\sum_{j\in J}\sum_{l\in L} C_{kjl} X_{kjl} d_l + \sum_{l\in L}\sum_{k\in K}\sum_{i\in I} C_{lki} X_{lki} r_l + \sum_{l\in L}\sum_{k\in K}\sum_{j\in J} C_{lkj} X_{lkj} r_l$$

Subject to:

$$\sum_{l\in L}\sum_{j\in J} X_{lkj} r_l = \sum_{l\in L}\sum_{j\in J} X_{kjl} d_l, \quad \forall k \in K \tag{1}$$

$$\sum_{l\in L}\sum_{k\in K} X_{lkj} r_l \geq \sum_{l\in L}\sum_{k\in K} X_{kjl} d_l, \quad \forall j \in J \tag{2}$$

$$\sum_{j\in J}\sum_{k\in K} X_{lki} + \sum_{j\in J}\sum_{k\in K} X_{lkj} = 1, \quad \forall l \in L \tag{3}$$

$$\sum_{i\in I}\sum_{j\in J} X_{ijl} + \sum_{k\in K}\sum_{j\in J} X_{kjl} \geq 1, \quad \forall l \in L \tag{4}$$

$$\sum_{l\in L}\sum_{k\in K} X_{lki} r_l \leq \sum_{l\in L}\sum_{j\in J} X_{ijl} d_l, \quad \forall i \in I \tag{5}$$

$$\sum_{j\in J} X_{ijl} \leq Y_i, \forall i \in I, \quad \forall l \in L \tag{6}$$

$$\sum_{i\in I} X_{ijl} + \sum_{k\in K} X_{kjl} \leq Y_j, \quad \forall j \in J, \ \forall l \in L \tag{7}$$

$$\sum_{i\in I} X_{lki} + \sum_{j\in J} X_{lkj} \leq Y_k, \quad \forall k \in K, \forall l \in L \tag{8}$$

$$\sum_{l\in L}\sum_{j\in J} X_{ijl} d_l \leq M_i, \quad \forall i \in I \tag{9}$$

$$\sum_{i\in I}\sum_{l\in L} X_{ijl} d_l + \sum_{k\in K}\sum_{l\in L} X_{kjl} d_l \leq N_j, \quad \forall j \in J \tag{10}$$

$$\sum_{l\in L}\sum_{i\in I} X_{lki} r_l + \sum_{l\in L}\sum_{j\in J} X_{lkj} r_l \leq Q_k, \quad \forall k \in K \tag{11}$$

$$\sum_{i \in I} \sum_{k \in K} X_{lki} \geq \eta, \quad \forall l \in L \tag{12}$$

$$Y_i, Y_j, Y_k \in \{0, 1\}, \quad \forall i \in I, \forall j \in J, \forall k \in K \tag{13}$$

$$0 \leq X_{ijl}, X_{kjl}, X_{lkj}, X_{lki} \leq 1, \quad \forall i \in I, \forall j \in J, \forall k \in K \tag{14}$$

The above objective function aims to minimize the logistical cost of the whole system. The first three terms give the cost of opening factories i, the 3PLs k and online shops j. The fourth term represents the transport cost of products which are used to meet the demand of market from factories, while the fifth term signifies the transport cost of products from the 3PLs. The sixth and the seventh terms, respectively, show the transport cost of returned products from market to factories and to online retailers.

In this formulation:

Constraint 1 ensures that all returned products delivered to the online retailers are used to meet the demand of market.

Constraint 2 guarantees that the returned products sold by each online retailer would not surpass the returned products delivering from the 3PLs.

Constraint 3 shows all returned products from markets are delivered either to factories or to online retailers.

Constraint 4 ensures products provided by factories and the 3PLs are all enough to meet the demand of market.

Constraint 5 requires the total outgoing flows to be at least as big as the total incoming flows for each factories.

While Inequalities 6-8 ensure that there is no product flow through the path when factories, or online retailers or the 3PLs are not open.

Moreover, Inequalities 9-11 constrict that the potential products in each factory, online retailer, and the 3PLs could not overflow their maximum capacity.

And Constraint 12 means that among all returned products from market, the flawed ones which should be delivered to factories would account for at least η.

Finally, Constraint 13 specifies the binary nature of the location variables.

And Constraint (14) preserves the non-negativity restriction on the decision variables.

3. The determination of the demand and return

To consumers, the fact of whether refund is allowed or not has a great impact on choices between traditional business and e-business. Considering the shift cost of online shopping is approximate to zero, the return policy contributes much to market demand. Generally speaking, the more generous the policy is, the more demand is likely to increase with the attendant resultant profits. However, this effect is twofold: the generous return policy also leads to more return and thus increase the overall logistic cost. This then begs the question how to make an optimal return policy whilst maximising profits is the issue that requires urgent and imperative attention.

There are two indicators when customers do shopping on the internet: one is the price of product p_l, and the other is the credibility of online retailers which could be measured by the return price q_l when a return occurs. Obviously, online retailers with a higher credibility are more likely to refund at a higher price. Therefore, we can assume that the demand is the function of both price p_l and return price q_l and it is directly proportional to the return price q_l, but reversely proportional to the selling price p_l. It can be shown as follows, where, α_l denotes the fixed demand which is not influenced by the return policy, and β_l presents the insensitivity of demand to p_l while δ_l shows the insensitivity of demand to q_l:

$$D_l = f(p_l, q_l) = \alpha_l - \beta_l + \delta_l q_l \tag{15}$$

$$\text{While } \frac{\partial D_l}{\partial p_l} \leq 0. \frac{\partial D_l}{\partial q_l} \geq 0$$

Besides, based on the prerequisite that the quality of product is non-discriminatory among retailers, the return is only related to the return policy as well as the demand. Thus, its function can be shown as:

$$R_l = f(q_l) = \lambda_l +_l q_l \tag{16}$$

And λ_l stands for the fixed return uninfluenced by the return policy.

Then the profit function is:

$$\pi_l = D_l p_l - R_l q_l = (\alpha - \beta p_l + \delta q_l)p_l - (\lambda + \varphi q_l)q_l \tag{17}$$

When $4\beta_l \mathrm{n}_l - \delta_l^2 \geq 0$, there is unique optimal solution:

$$p_l^* = \frac{2\varphi_l\alpha_l - \lambda_l\delta_l}{4\varphi_l\beta_l - \delta_l^2}, \quad q_l^* = \frac{\delta_l\alpha_l - 2\beta_l\lambda_l}{4\varphi_l\beta_l - \delta_l^2} \tag{18}$$

Then, put equation (18) into the formula (15) and (16):

$$d_l^* = \frac{2\alpha_l\beta_l\varphi_l - \beta_l\lambda_l\delta_l}{4\varphi_l\beta_l - \delta_l^2} \tag{19}$$

$$r_l^* = \frac{2\beta_l\varphi_l\lambda_l + \varphi_l\delta_l\alpha_l - \lambda_l\delta_l^2}{4\varphi_l\beta_l - \delta_l^2} \tag{20}$$

Therefore, If we obtain the parameters of α_l, β_l, δ_l, λ_l, φ_l on a market, we could deduce the demand and return of product from formula 19 and 20.

4. Illustrative example and insight into the model

In Section 2, we proposed a reverse logistics network model under the context of the 3PL and e-business. In addition, in Section 3, another model with respect to the demand and return was also constructed. Consequently, in this Section, we will use a numerical example to illustrate how this model works.

Although consumers and online retailers are spread broadly all over the world with the help of internet, we restricts markets to ten sites, namely L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8, L_9, L_{10}, and online retailers to eight sites, $J_1, J_2, J_3, J_4, J_5, J_6, J_7, J_8$. In addition, four potential sites are assigned to factories I_1, I_2, I_3, I_4, while three sites are proposed for the 3PLs, namely, K_1, K_2, K_3.

Table I shows the costs for opening factories, online retail stores, and the 3PLs as well as the characteristic value of market. Tables II-VI present the costs of transportation

Table I. The parameter of model and market

Description	Parameter	Values
The fixed cost of factory	f_i	3,000,000
The fixed cost of online retail	f_j	8,000
The fixed cost of the 3PLs	f_k	1,500,000
The capacity of factory	M_i	30,000
The capacity of the online retailer	N_j	8,000
The capacity of the 3PLs	Q_k	40,000
The minimum portion of returned products to factories	η	0.2
The characteristic value of market		
Non-influenced demand	α_l	10,000
The sensitivity of demand to price	β_l	6
The sensitivity to return price	δ_l	3
Non-influenced return	λ_l	200
The sensitivity of return to return price	φ_l	4

Table II. Transport cost per product from factory to online retailer (per product)

$\cos t_{ij}$	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8
I_1	2	3	1	2	3	2	3	2
I_2	1	2	1	2	3	2	5	3
I_3	2	1	3	3	1	3	6	4
I_4	2	2	4	3	3	2	1	1

Table III. Transport cost per product from online retailer to market

$\cos t_{jl}$ (km)	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}
J_1	5	6	7	6	5	8	7	7	7	6
J_2	7	5	10	5	6	5	7	5	5	5
J_3	6	7	8	8	10	6	7	5	7	8
J_4	7	5	6	10	5	7	5	5	6	10
J_5	6	7	10	8	10	6	5	7	7	8
J_6	5	7	7	7	6	5	6	6	5	10
J_7	6	8	6	8	8	6	6	8	5	8
J_8	10	6	5	6	5	6	5	10	5	5

Table IV. Transport cost per product from market to the 3PL

$\cos t_{lk}$	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}
K_1	5	10	8	5	8	10	5	8	5	10
K_2	8	5	4	10	5	8	4	4	5	5
K_3	4	10	8	4	8	5	5	10	8	4

between two sites. Although, in different locations, the value of parameters for four participants are different, we assign the same value to simplify the data.

We solve this problem using Lingo9.0 and the resultant solution of network is present in the Tables VII and VIII and Figure 3. From Table VIII, we know the minimum cost of network is 8.005172E + 006 and the demand and return are, respectively, 5,476 and 1,469 under the optimal return policy. In addition, from the Figure 3, we could see there are two producers I_3, I_4, seven online retailers $J_1, J_2, J_3, J_5, J_6, J_7, J_8$, and one 3PL K_2, the producer I_3 provide products to online retailers J_1, J_2, J_5, while J_1, J_6, J_7, J_8 are served by producer I_4.and the 3PL K_2 also provides returned products to J_1, J_3.

The Table VIII reveals the fraction of customer demand and return severed by producers and the 3PLs. For example, the demand of market L_4 is totally satisfied producer located in I_3, while market L_8's demand is totally supplied by the 3PLs located in K_2 whereas market L_3 has its demand supplied by two e-retailers from one producer: 54 percent by e-retailer located in J_8 and 46 percent by e-retailer in J_7. And market L_5 has its demand satisfied by both producer and the 3PLs: 91.16 percent by the 3PLs located in K_2 and 8.84 percent by producer in I_3. In terms of returns, we can see, products from all markets are collected by 3PLs located in K_2 and all sent back to producer in I_4. For market L_1, 80 percent is sent back to online retailer J_1 while 20 percent is sent back to I_4.

$\cos t_{kj}$	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8
K_1	2	2	1	3	3	2	1	2
K_2	1	3	1	2	2	3	2	3
K_3	1	3	2	2	1	1	3	2

Table V. Transport cost per product from the 3PLs to online retailer

$\cos t_{ki}$	I_1	I_2	I_3	I_4
K_1	2	4	2	1
K_2	1	2	4	1
K_3	3	1	1	2

Table VI. Transport cost per product from the 3PLs to factory

Demand	Return	Total variables	Number of constraints	Runtimes	Objective values
5,476	1,469	955	271	00:00:18	8.005172E + 006

Table VII. The results of model

$I_3-J_1-L_2$	0.0782	$I_4-J_7-L_9$	1	$L_1-K_2-J_1$	0.8	$L_1-K_2-I_4$	0.2
$I_3-J_1-L_5$	0.0884	$I_4-J_8-L_3$	0.5391	$L_2-K_2-J_3$	0.8	$L_2-K_2-I_4$	0.2
$I_3-J_2-L_2$	0.461	$I_4-J_8-L_{10}$	0.9218	$L_3-K_2-J_1$	0.8	$L_3-K_2-I_4$	0.2
$I_3-J_2-L_4$	1	$K_2-J_1-L_5$	0.9116	$L_4-K_2-J_3$	0.8	$L_4-K_2-I_4$	0.2
$I_3-J_5-L_2$	0.439	$K_2-J_3-L_6$	0.2345	$L_5-K_2-J_3$	0.8	$L_5-K_2-I_4$	0.2
$I_3-J_5-L_7$	1	$K_2-J_3-L_8$	1	$L_6-K_2-J_3$	0.8	$L_6-K_2-I_4$	0.2
$I_4-J_1-L_1$	0.3046	$I_4-J_7-L_3$	0.4609	$L_7-K_2-J_1$	0.8	$L_7-K_2-I_4$	0.2
$I_4-J_1-L_{10}$	0.0782			$L_8-K_2-J_1$	0.8	$L_8-K_2-I_4$	0.2
$I_4-J_6-L_1$	0.6954			$L_9-K_2-J_1$	0.8	$L_9-K_2-I_4$	0.2
$I_4-J_6-L_6$	0.7655			$L_{10}-K_2-J_1$	0.8	$L_{10}-K_2-I_4$	0.2

Table VIII. The route of transport and the percentage of delivering

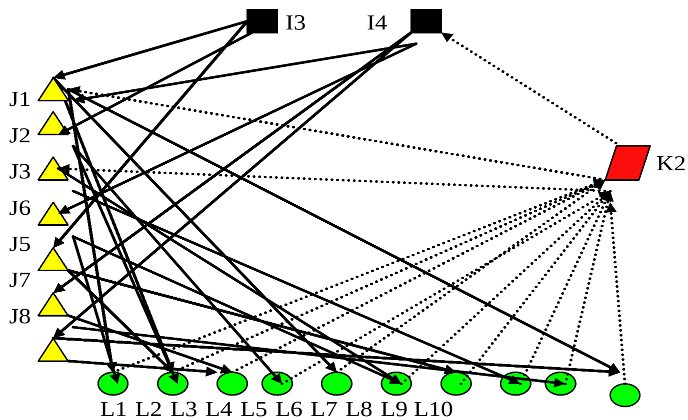

Figure 3.
The network of reverse logistics

Moreover, from the table, we could discover that for all markets, products sent back to e-retailers accounts for 80 percent while the rest 20 percent is sent to producer. That is just the minimum portion required by system. Actually, when products have no problems, the 3PLs are more likely to send them back to online retailers to be sold again on the market, as transport cost as well as other costs like inventory, handling or time can be saved in this situation.

5. Conclusion

The number of scientific publications on logistics has been growing steadily in recent years, reflecting the significance of this aspect. However, most reported works on distribution and network area are limited to traditional business. Therefore, they are no longer applicable to the background of e-business. Furthermore, within the limited number of publications on reverse logistics networks in e-business, the factors of demand and return are frequently assumed to be certain, which is a poor reflection of the realities experienced in live situations. Therefore, there is a critical need for modeling reverse logistics system for e-commerce and uncertain demands and returns. Our model provides an important direction for the design of such system. Thus, the model proposed in this paper is based on e-commerce and takes into the uncertainty of demands and returns into consideration and develops and determines ideas of return policy.

However, we must note that there are some aspects that are not taken into account in above model. One aspect is the penalty cost for not serving market demand and for not collecting returns from market. A further aspect not included concerns second market business wherein many products are collected from customers and sold into the second market at a lower price. Therefore, future work would extend this model to cover these aspects.

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Further reading

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