Reverse Logistics Operation Management Based on Virtual Enterprises and Evaluation

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Abstract—Based on analyzing the difficulties of reverse logistics operation management, considering the new environment as the economic society developing continuously and discussing the feasibility of virtual enterprise, an operation management mode for reverse logistics based on virtual enterprise is presented in this paper. Evaluation of virtual enterprises for reverse logistics operation is based on the firms’ multi-criteria which are qualitative or quantitative. By using Fuzzy AHP technique, the hierarchical and the multi-criteria decision making problems for virtual enterprise are considered and the optimized selection is presented.

Keywords—Reverse logistics; Virtual enterprise; Operation management; Fuzzy AHP

I. INTRODUCTION

Reverse logistics is a new logistics form which from the customers or distributors to the manufacturers is contrary with the traditional logistics. Concretely speaking, because some productions lost the obvious use value such as the packaging, or lost the function such as the spoiled products, or are difficult to sale in the general market such as the overstocks, or must be reclaimed for some reasons such as the cars with disfigurement, they have to flow reversely from the downstream to the upstream in supply chain. Reverse logistics management is the process of planning, implementing, and controlling the reverse logistics. The rapid development of reverse logistics is along with the increased research both in practice and the theory. Some literatures have provided some feasible solving method in distribution location, inventory management and network structure. For example, Dobos (2003) represented an optimal control model based on double warehouses in order to minimize cost of reverse logistics inventory management; considering the location problem of the reverse distribution center, Jayaraman et al. (2003) proposed a mathematical programming model; Srivastava et al. (2004) developed a hierarchical model of reverse logistics network design in profit-motivated. Taking one with another, there are very few literatures focusing on the whole reverse logistics operation management, in place of most researches on application of technologies and methods in reverse logistics. Marisa et al. (2002) gave an understanding framework of reverse logistics: the why-what-how, and a decision framework, i.e. strategic-tactic-operational decisions, which is straightforward in reverse logistics management. Reverse logistics operation management is restricted by the cost, the practice, and the human resource etc. Considering the environmental consciousness and the policy impact, the outsourcing is the better selection for the enterprises driven by economic profit. In order to make full use of the third provider services’ advantage, virtual enterprise will be most appropriate. The concept of virtual enterprise was proposed by Kenneth Preiss, Steven L. Goldman, and Roger N. Nagal in 1991 in their report called “21st Century Manufacturing Enterprises Strategy: An Industry-Led View”. The way of only depending on a single enterprise to respond rapidly to changing market opportunities and intensely global competition have been inapplicable. The key technique determined by utilizing agile manufacturing practices is based on virtual enterprise. With the urgent demand of implementing, it is significant to find an effective operation management mode for reverse logistics. Therefore, we represent an operation management mode based on virtual enterprise. In this paper we analyze primarily the difficulties of reverse logistics and the characters of virtual enterprise, finding the advantages of integrating. Then we discuss the framework of virtual enterprise for reverse logistics, and provide an operation process.

II. VIRTUAL ENTERPRISE AND REVERSE LOGISTICS OPERATION MANAGEMENT

A. Existing Barriers of Reverse Logistics Operation Management

Reverse logistics operation management is a new field for modern enterprise, which their objectives of reducing risk and pursuing profit is conflicted by a great many of uncertainties and the large investment risks at the beginning. Comparing with the tradition logistics, reverse logistics is more complex and uncertain. The uncertainties of reverse logistics involve four facts as follows: the uncertain time, the uncertain place, the uncertain reason, the uncertain disposal. Consequently, the flexibility and agility of reverse logistics operation management must be taken more attention, considering the character of uncertainties in time, place, reason and disposal. For most enterprise, reverse logistics operation management need invest the large input of money and resource, influencing the enterprise in every parts, e.g. the planning is adjusted just for the potential reverse logistics; a new network need to design; the inventory management is impacted by reverse flow; it must be supported by adding the special equipment and training employee, etc. Furthermore, the economic benefits from reverse logistics hiding in total profit can not display obviously in account, which enlarges the capital press and the investment risk for enterprise. In addition, reverse logistics theory and application that is still in a developing
C. The Advantages of Reverse Logistics Operation Management Based on Virtual Enterprise

In the today’s competition market, the enterprises should adjust themselves in strategy, organization structure, and operation management etc., i.e., changing from the traditional competition strategy to the value renovation strategy based on cooperation, from pyramidal organization structure to the flat organization structure adding dynamic network, from the close operation management considering the competition of cost and quality to the open operation management considering the competition of time and speed. The virtual enterprise, a dynamic alliance consisted of several independent enterprises quickly, is triggered by sudden market opportunities in order to overcome the uncertainties of reverse logistics, reduce cost and increase profit by utilizing core resources of partner enterprises. The advantages of reverse logistics operation management based on virtual enterprise are focused on four facets: (1) Rapid response. Reverse logistics is often paroxyasmal. When the affairs beyond the planning take place, reverse logistics management play the role of remedy (e.g. the cars recalled for disfigurement); sometimes the happening is foreseeable but it is hard to know the exact time and clear place (e.g. the electronic products of end-of-life). The outstanding advantage of virtual enterprise is to respond the market changing rapidly, that will endow operation with agility. Based on virtual enterprise obviating mass preparation, the operation management of reverse logistics can integrate the particular resources of partner enterprises together at once to cope with the changing environment, by improving the competition. (2) Flexibility. The flexibility motivation comes from two aspects: the uncertainties of reverse logistics require multiform disposal; for most enterprises, reverse logistics from begin to end is just a short-term process, so the flexibility and efficiency are regarded as the key factors. Reverse logistics will benefit from the flexibility attribute of virtual enterprise. The organization structure formed by some independent enterprises provides more options of disposal. Besides we notice that a virtual enterprise is from configuration to disbandment along with the appearance and disappearance of market opportunity. The feature driven by market will suit for the flexible operation of reverse logistics. (3) Reducing cost. Generally speaking, reverse logistics is often driven by legislation constraint and environmental responsibility. Nevertheless the enterprise with the aim at profit takes more attention to the direct or indirect economic benefits. The operation management mode based on virtual enterprise is an effective approach to reduce the reverse logistics cost, in respect that enterprises make use of the external strength to cut down cost by reason of homologous resource advantage. (4) Sharing risk. Reverse logistics is also a large challenge for enterprise with respect to the long-term operation of traditional logistics. It induces several risks, e.g. the assets proprietary risk. In contrast with the high risk of single enterprise, the subdivision operation can share risk among partner enterprises. The remark is to elude the external manage risk resulting from many enterprises combination.

III. REVERSE LOGISTICS OPERATION MANAGEMENT BASED ON VIRTUAL ENTERPRISE

A. The Framework of Organization

The difficulties of reverse logistics management are enlarged by lots of partners and their flexibility. Hence a “leader enterprise” is necessary to administer the virtual enterprise, namely the core enterprise. The sponsor manufacturer always plays the role of core enterprise; the fourth service provider is also an appropriate option. Comparing with the traditional organization structure, the virtual enterprise organized by two layers (core enterprises and non-core enterprises) is flat, availing interaction of partners. The flat structure is easy to respond the changing market, as well as to eliminate the information distortion effectively. There are three main reverse logistic functions: collection, inspection/sort, and reprocessing. Collection refers to bringing the products from the customer to a point of recovery, including return, transportation, and storage. At this point the products are inspected, i.e. their quality is assessed and a decision is made on the options of disposal, according to that the products are sorted. The disposal of reprocessing includes the following options: direct reuse, repair, recycling, remanufacturing and harmless disposal. The type of recovery can be separated between product recovery, component recovery, material recovery and energy recovery. The abovementioned functions are necessary for reverse logistics. Based on virtual enterprise operation, subdividing the functions to several independent enterprises by integrating their core competencies is just the advantage we seek, e.g., lowering cost, eluding risk, etc.
B. The Process of Operation Management

The process of reverse logistics operation management based on virtual enterprise, which follows four phases:

- Identifying opportunity: In order to utilizing the rapid response attribution of virtual enterprise with respect to the uncertainties of reverse logistics, enterprises have to track the trends of market development timely. The useful information will be evaluated relative to reliability, worthiness, feasibility.

- Constructing organization: Based on abovementioned, virtual enterprise means the integration of the core competencies for participating in enterprises. Therefore identifying the core competency, evaluating the alternative enterprises and estimating the entire performance are crucial, that directly influence the operation efficiency of reverse logistics. The core competencies concerning reverse logistics reflect return channels, logistics capabilities, design or research & development technology, manufacture arts and crafts, assets proprietary etc., determined by the relevant decision support system (DSS). Information system and the logistics network are necessary absolutely to support the virtual enterprise.

- Organization operation: The organization form of virtual enterprise is at the expense of coordination among partners. It implies that the excellent organization management is the precondition of virtual enterprise operation. The operation management is extended to the application of coordination mechanism, dynamic contract by stages, risk identification and control etc. As the dynamic developing, examine the running status continuously, and improve the process according to the feedback.

- Disbandment: The disbandment of virtual enterprise takes place after the disappearance of market opportunity. There is the assets liquidation among partners without disbandment.

C. The Dynamic Durative of Virtual Enterprise

It is easy to see, depending on virtual enterprise, every chance of reverse logistics can be held in developing market. However, considering reverse logistics exist in the enterprise at all times, the operation management based on virtual enterprise do not end after disbandment. Contrarily, it is the beginning of the new virtual enterprise. Facing the uninterrupted opportunities the independent enterprises broke from one virtual enterprise, then take part in another dynamic alliance immediately. In fact, the virtual enterprise is that organization of the older members left and the newer members’ ingress. So the virtual enterprise for reverse logistics is the dynamic durative process organization from the phase of opportunity identifying to the phase of enterprise disbandment.

IV. Evaluation Method and Numerical Example

A. Evaluation method

The evaluation of virtual enterprises for reverse logistics operation is based on the firms’ multi-criteria which are qualitative or quantitative. AHP is often used in such problems (Saaty, 1990). But, the unbalanced estimations, unconsidered the uncertainty and risk, the subjective judgment error etc., those show the technique exists some disadvantages. Based on those reasons, we integrate the concept of fuzzy set theory with the AHP to overcome some above disadvantages in our proposed model [12]. Fuzzy AHP approach is applied in some practical problems widely. In order to facilitate comparison, all elements of the judgment matrix and weight vectors are represented by the triangular fuzzy values. The virtual enterprises for reverse logistics first choose the alternative virtual enterprises from those which can build reverse activities, based on the basic requirements, such as Quality Certified. Then, the hierarchical structure is constructed by the criteria of SCOR model and the chain which is linked by the product flow, the alternative virtual enterprises are considered as similar types on the similar phase.

The disbandment of virtual enterprise takes place after the disappearance of market opportunity. There is the assets liquidation among partners without disbandment. In fact, the virtual enterprise is that organization of the core competencies for participating in enterprises. Therefore identifying the core competency, evaluating the alternative enterprises and estimating the entire performance are crucial, that directly influence the operation efficiency of reverse logistics. The core competencies concerning reverse logistics reflect return channels, logistics capabilities, design or research & development technology, manufacture arts and crafts, assets proprietary etc., determined by the relevant decision support system (DSS). Information system and the logistics network are necessary absolutely to support the virtual enterprise.
the relationship between firm $k$ on level $i-1$ and firm $j$ on level $i$ and let $r_{ij}^k$ denotes that relationship coefficient which Expert $s$ scores the relationship between firm $j$ on level $i$ and firm $l$ on level $i+1$. Therefore, by integrated $S$ experts' evaluations, the values are $r_{ij} = \frac{\sum r_{ij}^k} S$ and $r_{ij}^l = \frac{\sum r_{ij}^k} S$, respectively. (4) Integrate the basic value of the criteria of the firms with relationship coefficients. Relationship coefficients just effect on the exterior correlated criteria and not on the interior correlated criteria. Let $Z$ denotes that the subscript set of the exterior correlated criteria and let $\bar{Z}$ denotes that the subscript set of the interior correlated criteria. Relationship coefficients are measured the relationship between the firm and its nearness firms, thus the upstream firm and the downstream firm both effect on it. To integrating two relationship coefficients, the Integrated Relationship Coefficients are $r_{ij} = \sqrt{r_{ij}^l r_{ij}^l}$. On the boundary of the defined supply chain, let $r_{ij} = 1$ while $i = 1$ and let $r_{ij} = 1$ while $i = N$. The Integrated Sub-criteria based on effect of the upstream and downstream firms satisfy

\[
\tilde{C}_{ijt} = \left( \sum_{ijl} r_{ijl} M_{ijl} U_{ijl} \right) t \in Z
\]

And

\[
\tilde{C}_{ijt} = \left( \sum_{ijl} r_{ijl} M_{ijl} U_{ijl} \right) t \in Z
\]

Then Integrated Criteria are $\tilde{C}_{ijt} = \sum_{ijl} \tilde{C}_{ijl}$, $\tilde{C}_{ijt} = \sum_{ijl} \tilde{C}_{ijl}$, respectively. (5) Evaluate the fuzzy weight vector. The industrial experts evaluate the four criteria of the firms and the weight of any levels, then the weighted vectors are obtained $W_i = (\tilde{w}_{i1}, \tilde{w}_{i2}, \ldots, \tilde{w}_{in})$, respectively. (6) Synthesize the criteria and the weighted values, after that select the optimal virtual enterprises. The total fuzzy score of Chain $x$ among $X$ supply chains is expressed as follows:

\[
\tilde{H}_x = \left( X \tilde{w}_i \right) \otimes \left( X \tilde{G}_{ijl} \right) \otimes \left( X \tilde{w}_i \right)
\]

The supply chain has the greatest finial score is the best one by comparing the finial score which is deduced by the following steps: Let $\tilde{H}_x = (L_x M_x U_x)$, consider that $h^L_x = L_x + \lambda (M_x - L_x)$ and $h^U_x = U_x - \lambda (U_x - M_x)$ (where $0 < \lambda < 1$ is the degree of confidence), and define that $h^d_x = [h^{L}_x, h^{U}_x]$, then the finial score is calculated by $H^d_x = \beta h^d_x + (1 - \beta) h^d_x$ (where $0 < \beta < 1$ is the risk index).

### B. Numerical Example

In this section, a case study will illustrate our results. A three-stage network of the electronic industry is incorporated by two virtual enterprises (denoted by F11 and F12), two manufactories (denoted by F21 and F22) and one retailer. The virtual enterprises implement the reverse activities, and the manufactories perform assembly line work to achieve the finial products. The retailer sells these products. According to their historical data, our aim intends to evaluate every virtual enterprise. Let $\lambda = 0.5$ and $\beta = 0.5$. By using abovementioned processes, and the solution is presented in Table 1.

<table>
<thead>
<tr>
<th>Supply chain</th>
<th>$H^d_x$</th>
<th>No considering the relationship</th>
<th>Considering the relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>F11-F21-F31</td>
<td>52.67244</td>
<td>57.22441</td>
<td></td>
</tr>
<tr>
<td>F11-F22-F31</td>
<td>41.74084</td>
<td>56.32318</td>
<td></td>
</tr>
<tr>
<td>F12-F21-F31</td>
<td>49.90745</td>
<td>59.00566</td>
<td></td>
</tr>
<tr>
<td>F12-F22-F31</td>
<td>50.42136</td>
<td>48.44038</td>
<td></td>
</tr>
</tbody>
</table>

It is easy to see the best virtual enterprises that formed chain is F11-F21-F31. At the same time, we can find that the chain relationship effect on the order of finial scores, i.e., virtual enterprises should pay attention to the chain relationship in course of constructing the reverse logistics. In addition, virtual enterprises can comprehend the important degree of every criterion in the different industries by using the criteria weight evaluation, thus performance can be improved efficiently. In the same time, such technique can be used as a decision support system in virtual enterprises. Virtual enterprises can provide more consulting service and realize the integrative optimization of the reverse logistics.

### REFERENCES