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Reverse Logistics Operation Management Based on Virtual Enterprises and Complaint Service Management

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ABSTRACT

Based on analyzing the difficulties of reverse logistics operation management and discussed 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. By analyzing the relationships between complaint service management and reverse logistics, the complaint service management (CSM) is considered in reverse logistics, we take into consideration the process computing of CSM by combing the computer technology, the communication technology and the information technology. Using by the computer telephone integration technology, an integration multi-channels collection can be designed; the evaluation of complaint and production is supported by intelligent decision support system; considering the different disposal countermeasures, the CSM processing system is determined to implement corresponding disposal which reflects the utility of CSM. The organization framework, the operational process, the dynamic durative of virtual enterprise, those are expounded in detail. 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, Complaint service management, Operation management, Fuzzy AHP*

1. Introduction

Reverse logistics (RL) 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 returned 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 RL activities.

The rapid development of RL is along with the increased research both in practice and the theory. Some literatures have provided some feasible solving methods mainly reflected as follows: (1) Operational management meaning. Literatures represented the impact factors such as determined automated pipeline, inventory and order-based production control system [36]; cost or time [33]; product life cycle [4] etc. (2) Operational model. The main works involved return models, network structures, inventory management, information technologies etc. In return aspect, such as compared with OEM takeback, Pooled takeback and third party takeback [28]; third-party reverse logistics providers selection and evaluation [15]; a contractor of fourth-party logistics [5] etc., As far as network structures, such as network design principles [20]; the product return network structure [19]; the strategic-tactic-operational decisions framework [19]; the hierarchical model of RL network design [27]; the mix integer linear program applied in reverse network [30]; empirical study [21] etc., To inventory management, the key work centralized in optimal methods, such as optimal control model based on double warehouses [8]; newsboy problem [12]; average cost approach [12]; Lagrange function [8] and so on. For information technology, most of work reflected the definite role in RL, such as the superior performance through focused resource commitments to information technology [22]; supply chain information system [17]; material recovery and environmental impact through a Decision Support System [24]. And, other works are represented in forecast [11]; design of reverse distribution networks [32]; disassembly and reassembly [29] etc. In fact, RL has become one of important strategy for enterprises and even countries to seizure the global plateau. With the industrial ecology issues are extensive popularity among the fields of society, government and industry etc., such as 3R (reducing, reusing and recycling) strategies, cost-saving ecological ideas and plan, green production and so on. On the other hand, the leading actors in today's markets have transformed from sellers to buyers, whether or not meet customers' individuation demands become an important factor to show enterprises' talents in the competitive environment. The information asymmetry between enterprises and customers, the com-

plexity in the business environment, the diversity of customers' demands and so on, all indicate that customer complaint is unavoidable [1]. Based on the modern organizational behavior theory, the viewpoint of complaint reflects that an enterprise should admit customer complaint, even more advocates it. Customer complaint helps an enterprise win the customer again and provides with the change to improve product [10] Therefore, enterprises in supply chain must take active manners to treat customer complaint and manage it effectively. The complaint information such as the returned product from consumer is portion of RL activities; at the same time, complaint service management (CSM) in a supply chain needs to be analyzed. From the strategic view, CSM is the crucial composing of RL strategy and an effective approach of reverse information, such as, CSM can help organization build the customer loyalty and find the new value-added; an enterprise via successful managing complaint, it can improve its customer satisfaction degree, retain the old customers and allure the new customers; an enterprise via analyzing the customer complaint, it can find out its customer preference, so make for updating or developing product; the return product attached complaint information is just core activity in RL etc. Nowadays the computer technology, the communication technology and the information technology have been active and progressing aggressively. Those would give CSM important stimulus and prompting to perform more efficiently and effectively. Under the supply chain circumstance, based on online complaint management as well as auctions to sell refurbished or old parts are discussed by Rainer Alt (2000) [25]. If the partial order does not deliver on time, it is important to get the system to notify System Manager such that KiMs can initiate the action instead of customer filing a complaint [23]. The service provider's reaction can either reinforce a strong customer relationship, or change a smilingly minor complaint into a major incident. The visibility concept into the domain of mobile information systems in a supply chain, it can offer when incorporated into business customer solutions and solves company related to certain complaint management problems [31]. Aspects of Social Dialogue, freedom of association and complaint management are clearly separated as distinct issues by another enterprise representative who fundamentally distances himself from the task of forcing union participation through the companies: As an enterprise representative, one did not want to assume a mediating role for unions at suppliers', representation being the task of the unions themselves [2]. In fact, personal relationships play a fundamental role in business relations, in which technical aspects of communication prevail on emotional ones [3]. From those literatures' results, we can see the main RL activities driven by the coercive conditions or enterprise' sustaining objectives. From the customer's behavior, specially, CSM applied in RL rarely and combing the computer technology to managing complaint is unperceived.

RL operation management is restricted by the cost, the practice, the human resource and uncertainties in market etc. Considering the environmental consciousness and the policy impact, the outsourcing is the better selection for enterprises driven by economic profit. In order to make full use of the third provider services' advantage, a virtual enterprise (VE) fashion will be most appropriate. The concept of VE was proposed by Kenneth Preiss *et al*. (1991) [14]. 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 VE. With the urgent demand of implementing, it is significant to find an effective operation management mode for RL. From presented works, we can see the main RL operation was presided over enterprise's oneself or cooperation fashion or third party logistics supplier, CSM applied in RL rarely and combing the computer. How to consider the VE model in RL operation, it is significance. Therefore, we represent an operation management mode based on VEs.

This paper organization is as follows: In section 2, the relationships between complaint service management and RL are analyzed, the complaint service management in RL is probed into; In section 3, we analyze primarily the difficulties of RL and the characters of VE, finding the advantages of integrating; In section 4, we discuss the framework of VE for RL, and provide an operation process, and the evaluation of VEs for RL operation is based on the firms' multi-criteria which are qualitative or quantitative is presented in section 5. Finally, a numerical example is reflected our conclusions.

2. CSM and RL

2.1. CSM is an important reason of engendered RL

As a whole, RL can be classified by return and reclaim in a supply chain. Return is "push" logistics produced by all distributors or end customers; and reclaim driven by manufacturers is called "pull" logistics [17]. "Push" logistics mostly involves reverse flowed products and information; customer complaint is just aim at the product information feedback except the government policy. One of causes for RL engendering is determined by fashion of an enterprise takes cognizance of complaint. If an enterprise is attention to the customer complaint information, throw into CSM, it will clean off obstacles of the return flow of product or information, whereas, if an enterprise disregards the customer complaint, RL service will be wave aside. In fact, any complaint may trigger reverse activities in a supply chain. When analyzing the customer complaint information professionally, some bugs in product designing or production processes could be find out,

enterprises must recall those products initiatively, i.e., results in the "pull" RL. It is obvious that CSM is an important reason for engendering RL, as shown in Figure 1.

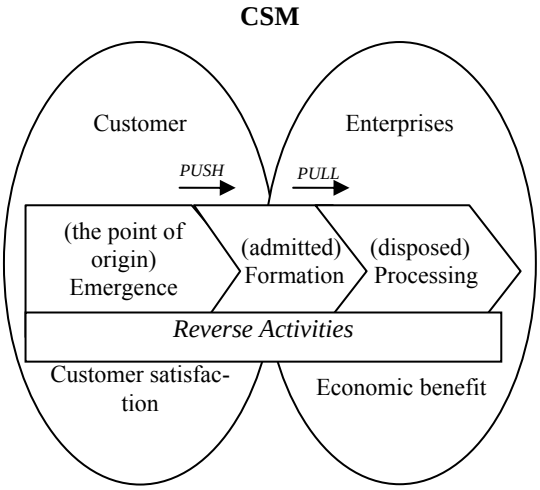

Figure 1. The fashion of "push" and "pull" RL

2.2. CSM is the crucial portion of RL management

Complaint information of customers is the feedback information, as well as products; those information and products flow conversely are just all RL activities. The drive force to implement CSM comes from customer, that because if considering the customers as the point of origin of RL, the enterprises act can be regarded as the "transfer" or terminal. Based on sufficient communication with customers, enterprises collect the external complaint information to track investigation and integrating analysis; different departments share information at the same time, such as client data, product status, processing flow etc.

From logistics management, RL activities are organized according to CSM, those activities include: Reuse-where packaging is reused or a product is returned to polish for resale to another customer; Repair/repackage-where a moderate magnitude of repairs and/or repackaging will allow the product to be reused; Return to supplier-if the product was purchased from a supplier and is returnable, or materials from return disassembled product; Resell-where the product is resold in a secondary market "as is." Some logistics companies have found a niche in matching sellers with buyers in secondary markets and say that there is a market for virtually anything; Recycle-where the product is broken down and "mined" for components that can be reused or resold; Renew-where a used product's utility is restored by replacing worn parts or remanufacturing in some manner, such that the product can reuse; Harmless disposal-where the unworthiness item is sent to a landfill, which can be fired with high temperature or buried. There is a far more expensive choice than most organizations operation, e.g., transportation costs, disposal facilities and IT cost etc. When payment for goods or compensation has happened between enterprises and customers, the content of CSM involve financial management committed in RL. In fact, CSM will help enterprises to implement RL operation exactly [6].

2.3. CSM objective is based on customer satisfaction

CSM is aim to improve customer satisfactory degree, this is not contradiction to the objective of the enterprises' economic benefit in implementing RL. If enterprises want to win customers, customers enjoyable is necessary, there is need to provide the better service after purchased. That is to say, RL strategy is of an important approach to meet customer demand involving repair, replacing etc. To develop CSM, enterprises can implement RL management to reclaim actively the spoiled products in customers or overstock in downstream distributors, these ways will be propitious to improve the relationships with downstream actors as distributors and customers, and then increase satisfaction degree availably. With satisfaction degree improving, a good brand will prevail widely, after then higher market share and production profit will be received. On the other hand, reproducing for spoiled, rebuilding for disused etc., form which enterprises can excavate more potential value.

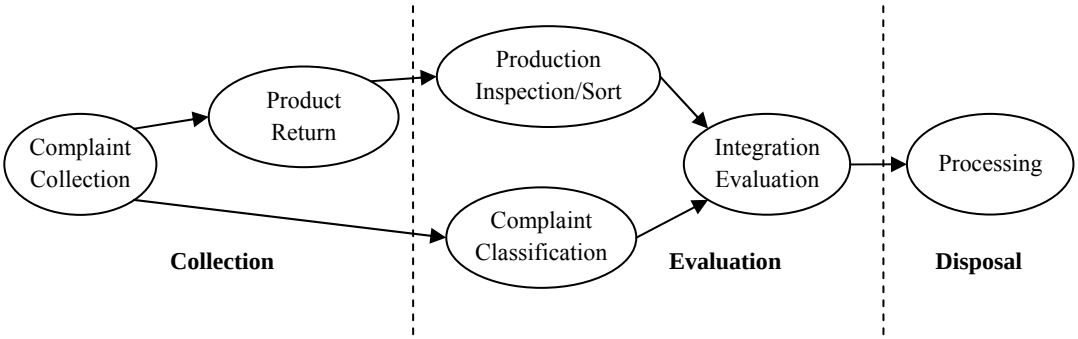

Figure 2. CSM of RL in a supply chain

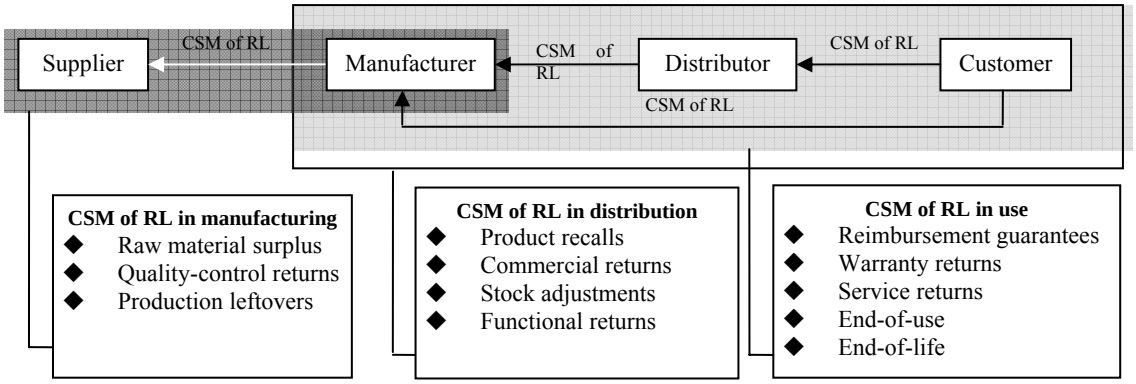

Figure 3. The process of CSM

2.4. Process management of CSM

The different emergence patterns of RL in a supply chain affect the application of CSM in RL, which can be split into three aspects: in manufacturing, in distribution, in use, see Figure 2 shows.

As shown in Figure 2, we consider CSM of RL in manufacturing as an example. CSM of RL in manufacturing activities refers to raw material surplus, quality- control returns and production leftovers etc. Considering a supplier as an "enterprise", a manufacturer then means the a "customer", there maybe some complaints form the manufacturer follows materials that supplier supplied, such as quality, fashion etc., so the supplier must respond to those matters quickly in order to meet customer demand. CSM of RL is one of the important items in RL strategy, via implementing process achieves three functions: collection, evaluation and disposal, see Figure 3 shows.

2.4.1. Collection

Complaint Collected: To capturing complaint information, enterprises need to lower "the threshold" to invite the voice of complaint. Some inspirit methods can be used, such as the initiative consultation, using by gifts to encourage complaint etc; to customers, there are not any proper routes to express complaint, so enterprises should open the relative channels, such as Internet, poster, phone or fax, E-mail etc. To unwillingness expression complaint customers, enterprises must launch some trigger strategies initiatively to search for the customer's dissatisfaction. The familiar forms are questionnaire, consultation, visit, promotion etc.

Product Return: based on the customer complaint information, enterprises can collect the returned product that dispersed in customers' hands. Those activities include collection, transport, and storage etc.

A convenient channel is very important to improve the response service to RL. Traditionally, the complaint channels that enterprises provide to customers are telephone, letter, fax, etc; nowadays, the web language, wireless information technology are new emerging field. These techniques all have their own advantages. To maximize the customer satisfaction, the integrated multi-channel service model should be a good choice. Before completely integration of the channels, let us consider a computer integration technique, the Computer Telephone Integration system called CTI for short. Generally speaking, the phonetic system is separate from a computer network system, but CTI technique can integrate the two functions together [35]. A typical service process of CTI is represented in Figure 4.

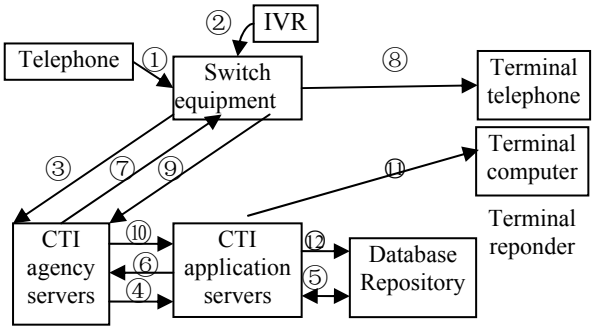

Figure 4. The CTI service process

(1) Customer-call-organization switch equipment. The switch equipment receives the key request service number via Automatic Number Identification (ANI) and Dialed Number Identification Service (DNIS).

(2) If Interactive Voice Response (IVR) equipment is available, the switch equipment will memorize the key-press information of customers automatically.

(3)The switch equipment can transfer the numbers and key-press information from step ① and step ② to the CTI agency servers.

(4)The information format is transformed in the agency servers, then the information is sent to the CTI application servers.

(5)According to the input parameters, the CTI application servers will implement relevant logical operations, for example, search for the best responder in the database.

(6)Return the search result (the best responder) to the CTI

agent servers.
⑺The CTI agent servers send the information of the best responder to the switch equipment.
⑻The communication is turned into the best responder by the switch equipment.
⑼After finished the communication, the switch equipment send the end-of-exchange signal to the CTI agent servers.
⑽The success-of-exchange signal is transmitted from the CTI agent servers to the CTI application servers.
⑾ The CTI application servers transmit the data information to the terminal responder, such as pop-upping the calling prompt automatically, calling the videotext of customers, and so on.
⑿ The all related complaint information is recorded in the CSM database and repository.

We can design an integrated multi-channels collection routeway based on the CTI technique. The CTI service process is extended as shown in Figure 5.

The details of every process in the Figure 5 above are similar as the CTI service process; so there are not repeated expatiations. The complaint information via the integrated multi-channels in CSM could achieve the CSM processing system which will be represented in detail in the next part.

2.4.2. Evaluation

Production Inspection/Sort In this phase, the returned products are being sorted based on their current quality, spoilage degree, etc., after that it is the enterprise's turns to determine the reuse manner of the products and then classify them. Those products can be divided into no spoilage, partial spoilage, or complete spoilage and so on.

(i) No spoilage: If returned products keep in the good state, then can often be reused directly by using cleaning or maintaining easily.

(ii) Partial spoilage: If returned products have been damaged partly, and need to be disassembled, inspected or tested, and repaired or replaced by parts, in this way their quality may be lowered. Usually, the products may be delivered to customers, or be sold at a discount in the secondary market.

(iii) Complete spoilage: If returned products are damaged or deteriorated badly, though they may include valuable components, but that can be reused restrictedly. So enterprises just implement the relative operation activities, such as recycle, remanufacture or harmless process etc.

Complaint Classification Customer complaints can reflect different information according to the diversities of customer preference, the types of products etc. Therefore, enterprises need to apply different processing techniques; it is necessary to classify the complaint information firstly. Based on the customer response, the complaint information is split up into three levels. Level I: Customers feel the complaint is too inappreciable and do not want to unfold, such information is obtained often through questionnaires.

Level II: Customers have some tempered complaint or appeal, which they want to make enterprises known. The integrated multi-channels collection route in CSM could be their right choices.

Level III: The customers are with a strong fashion or conflict. When appeal to enterprises they may take violent attitudes and insist on own viewpoints all along.

Evaluated Conclusion The integration evaluation conclusions are determined by the comparison of customer

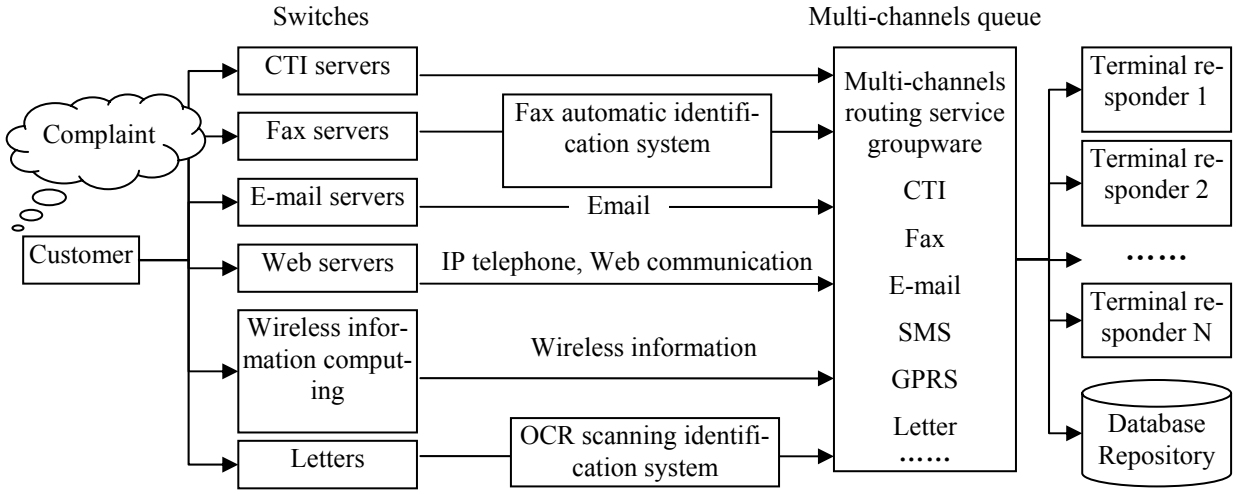

Figure 5. The integrated multi-channels collection route in CSM

complaint and product quality; it is the key gist for CSM of RL. The different customers have the different apperceptions of product and service utility. It is necessary for enterprises to discern the customer reaction based on the product spoilage degree, or the spoilage degrees based on the customer complaint levels in order to reply with the corresponding disposal countermeasure.

In modern times, the intelligent system is extensive applied to help decision-making increasingly. The intelligent "experts" based on the database and data-storage can respond customer complaint quickly. With the advance of complaint level, in order to respond customer complaint exactly, the database and data-storage should integrate more comprehensive information about customers and products. Intelligent decision support system (IDSS) is integration of artificial intelligence (AI) and decision support system (DSS). By using expert system (ES) technique, we can make the traditional DSS more humanized and flexible [13] [34]. The framework of IDSS consists of three subsystems, inlaid languages system (LS), problems processing system (PPS) and knowledge management system (KMS), namely 3S system. Figure 6 presents the framework of IDSS model. In practice, enterprises may setup an expert team together with IDSS to evaluate the relative complaint. At the same time, utilizing "the virtual expert team" based on Web (knowledge database) is good fashion.

There are some main advantages of IDSS: first, it is the synthesis of AI techniques, mathematics techniques and decision-making approaches, i.e., the integration of knowledge consequences and mathematics calculations to provide strong support to decision-making; second, it is based on the thoughts of ES or KMS (Knowledge Management System) to implement uniform preparation, uniform management, uniform control etc.; third, it makes full use of experts' knowledge, experience, judgment and decision-making cases. Consequently, the evaluation processing in CSM of RL will be supported by IDSS effectively.

2.4.3. Disposal

Disposal countermeasures

According to abovementioned, the disposal countermeasures of CSM in RL are presented in Table 1.

Utility of CSM

Customers' responses to the spoiled product show the expectation of the purchased products, so the utility of CSM in RL reflecting the customer expectation can be measured by two factors, i.e., the product spoilage degree and the customer complaint level. The more serious complaint means the higher customer's expectation, here the utility of CSM in RL will be greater. The lower expectation of customer may be easy to satisfy, so the utility of CSM will not be great any more. It is obvious that the utility of CSM in enterprises have inverse ratio with the spoilage degree, and direct ratio with the complaint level.

Suppose that α denotes the return relative index in RL, such as spoilage degree, return ratio etc., and β denotes the customer complaint level. γ is the utility of CSM, namely $\gamma = \beta / \alpha$. Let us see the slanting diagonal in Table 1, if just considering spoilage degree, the value of γ equal or approach 1 in the conditions of No spoilage-Complaint on Level I, Partial spoilage-Complaint on Level II, Complete spoilage-Complaint on Level III. These show the well-balanced utility of CSM in RL. Compartmentalize the table into two parts according to this diagonal, the value is $\gamma > 1$ in the top right. Here customers have high product expectation; CSM in RL is significant and implies a great utility. In the lower left of the diagonal, $\gamma < 1$ means the low customer expectation. To improve the utility of CSM and increase the customer satisfaction, enterprises should take into more consideration the product design and marketing.

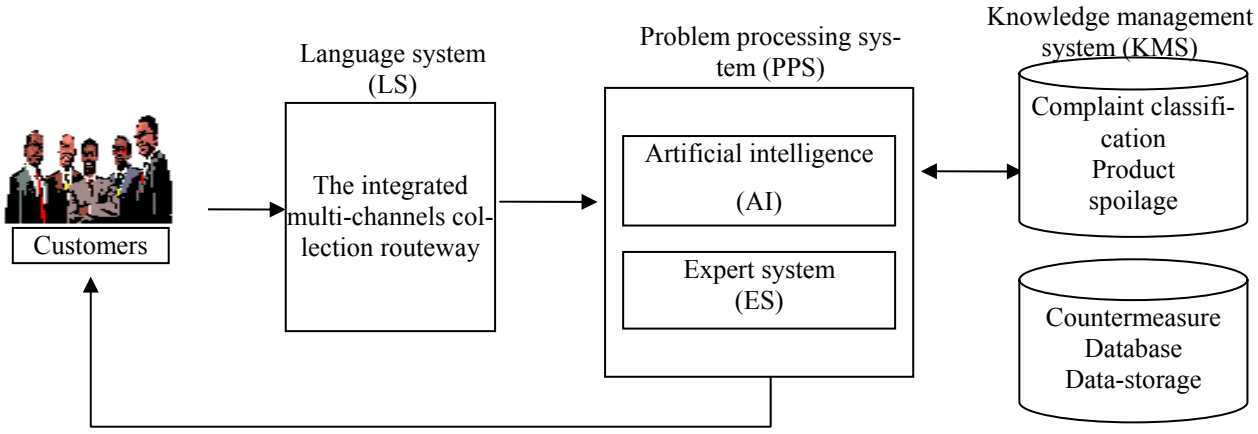

Figure 6. The framework of IDSS model

Table 1. The disposal countermeasures of CSM in RL

	Complaint on Level I	Complaint on Level II	Complaint on Level III
No spoilage	—	Explain carefully; Good service	Replace by new products; Resell the returned ones at a discount or in a secondary market
Partial spoilage	Reclaim the products in lower price; Sales promotion; Resell the return ones at a discount or in a secondary market after being repaired	Give the returned ones back to the customers after being repaired	Replace by new products; Resell the returned ones at a discount or in a secondary market after being repaired
Complete spoilage	Reclaim the products free; Sales promotion Recycle, remanufacture, or dispose the returned ones harmlessly	Replace by inferior products; Recycle, remanufacture, or dispose the returned ones harmlessly	Replace by new products; Resell the returned ones at a discount or in a secondary market after being recycling, remanufacturing, or harmless disposal; A compensation perhaps

The CSM in RL processing system

By receiving the complaint information and inspecting the products, the experts would give a reasonable disposal countermeasure. When the level of customer complaint is lower and the product spoilage is not bad, the feedback can be disposed in the place of distributors, such as wholesalers and retailers. Especially, the retailers must keep in touch with the customers directly, which are the chief and basic nodes for CSM in RL. For the complaint on Level I, the good customer service is necessary, such as the feasible propaganda in the right time. To reply the customer complaint on Level II and Level III, a lot of different means should be chosen based on the product status, for instance recycle the products at a discount, replaced by new products, and so on. Then the returned products can be resold in a secondary market after being repaired.

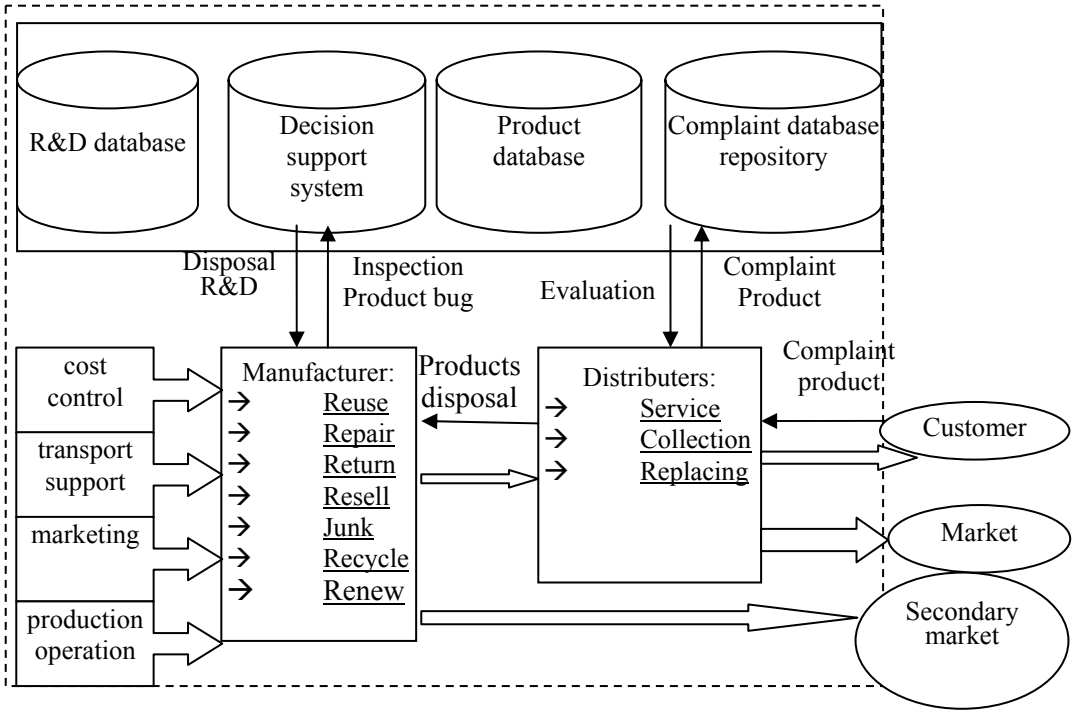

Figure 7. The CSM processing system

If the products are broken or even damaged badly, they should be transported to the manufacturers directly. The professional processing of manufacturers is significant for customer satisfaction. In a word, there is corresponding process for CSM processing system in RL as follows in Figure 7 [30].

The CSM processing system in allusion to different disposal countermeasures is supported by the embedded information system; the real-time information exchange helps to provide the decision-making with support and improve the manufacture technique. Furthermore, the functions of the CSM processing system are controlled and supervised by related function modules, such as cost con trol, transport support, channel management, marketing, production operation etc., to help enterprises construct the resources economized and harmonious system [26].

3. The VE and RL Operation Management

3.1. Existing Barriers of RL Operation Management

RL operation management is a bran-new field for the 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, RL is more complex and uncertain. The uncertainties of RL involve four characteristics mainly as follows:

The uncertain time: different people favoritism often result in products having different lifecycle, such that RL happening time is difficult to speculate.The uncertain place: The customers distribute all over the world, that means RL happening place is possible everywhere.

The uncertain reason: The reasons of RL is involved in multi-factors, such as changing market, product quality, usage method etc., which resulting in uncertainty.

The uncertain disposal: The numerous reasons of RL done bring on different measures to dispose. The corresponding disposal can not be identified until inspecting.

Consequently, the flexibility and agility of RL operation management must be taken more attention, and we need analyze the characteristics of uncertainties in time, place, reason and disposal.

For most enterprises, specially the RL operation based on themselves, so RL operation management needs to invest the large of money and resource, influence the enterprises in every ways, e.g. the planning is adjusted just for the potential reverse logistics; a new network need to design; the inventory management is impacted by the bidirectional flow; it must be supported by increasing the special equipment and training employee, etc. Furthermore, the economic benefits from RL hiding in total profit can not display obviously in account, which enlarges the investment risk for an enterprise. In addition, RL theory and application that is still in a developing process and few successful cases for references are also the barriers.

3.2. The characteristics of a VE

To overcome the abovementioned barriers, we analyze some important characteristics in a VE as follows:

Virtual function: The theory of core competency figures that an enterprise is a set of resources and capabilities; the heterogeneous resources and the special capabilities are the key strengths, called the core competencies differentiating it from other enterprises. A VE is a function aggregation; the subdivided functions are assigned to several independent enterprises according to their particular competencies.

Virtual organization: Nowadays, the rapid development of information technology and the computer technology bring an opportunity for the organizing mode of modern enterprise. The VE is also a dynamic alliance, made up of independent enterprises, which can be self-organization. They may locate in the world everywhere and communicate with each other via Internet and Intranet, i.e. it is a virtual organization without fixed place.

Virtual region: The advancement of science and technology also are impelling the development of transportation industries; the information systems applied in model logistics result in physical distribution among enterprises more effective and efficient, i.e., the distance is not the barrier any longer; the goods can flow among partner enterprises at any moment.

3.3. The advantages of RL operation management based on a VE

In today's competitive market, the enterprises should adjust their strategies, organization structures, and operation management, i.e., change from the traditional competition strategy to the value-renovation strategy based on cooperation – from the pyramidal organization structure to the flat organization structure forming a dynamic network, from the close-operation management that considers competition in cost and quality, to the open-operation management that considers competition in time and speed. VE, a dynamic alliance consisting of several quick (or agile) independent enterprises quickly, is triggered by sudden market opportunities in order to overcome the uncertainties of the RL, reducing cost and increasing profit by utilizing the core resources of partner enterprises. The advantages of RL operation management based on a VE are focused on four aspects:

Rapid response: RL is often paroxysmal. When the affairs beyond the planning take place, RL management play the role of remedy (e.g. the cars recalled for disfig-

urement); 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 VE is to respond the market changing rapidly, that will endow operation with agility. Based on VE obviating mass preparation, the operation management of RL can integrate the particular resources of partner enterprises together at once to cope with the changing environment, by improving the competition.

Flexibility: The flexibility motivation comes from two aspects: the uncertainties of RL require multiform disposal; for most enterprises, RL from begin to end is just a short-term process, so the flexibility and efficiency are regarded as the key factors. RL will benefit from the flexibility attribute of a VE. The organization structure formed by some independent enterprises provides more options of disposal. Besides we notice that a VE is from configuration to disbandment along with the appearance and disappearance of market opportunity. The driven-market feature will suit for the flexible operation of RL.

Reducing cost: Generally speaking, RL is often driven by legislation constraint and environmental responsibility. Nevertheless the enterprise with the aim at profit pays more attention to the direct or indirect economic benefits. The operation management mode based on a VE is an effective approach to reduce the RL cost, in respect that enterprises make use of the external strength to cut down cost by reason of homologous resource advantage.

Sharing risk: RL is also a large challenge for enterprises 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 e nterprise, the subdivided operation can share risk among partner enterprises. It has been noticed to elude the exter nal manage risk resulting from many enterprises combination.

4. RL Operation Management Based on AVE

4.1. The framework of organization

The difficulties of RL management are enlarged by lots of partners and their flexibility. Thus a “leader enterprise or organization” is necessary to administer the VE, namely the leader enterprise. The sponsor manufacturer always plays the role of core enterprise, e.g., the large-scale enterprise or the fourth-party service provider is also an appropriate option [6]. Comparing with the traditional organization structure, the VE organized by two layers (core enterprises and non-core enterprises) is flat, allowing 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 etc. At this point the products are inspected, i.e. their quality is assessed and a decision is made on the options of disposal, then 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 etc. The abovementioned functions are necessary for RL. Based on the VE operation, subdividing the functions to several independent enterprises by integrating their core competencies is just the advantage we hope seek, e.g., lowering cost, evading risk, etc. Therefore, the organization frame of RL operation management based on a VE can presented, as shown in Figure 8.

4.2. The process of operation management

Table 2 depicts the process of RL operation management based on a VE, which follows four phases:

Identifying opportunity: In order to utilizing the rapid response attribution of a VE with respect to the uncertainties of RL, enterprises have to track the trends of market development timely. A mass of collected data using for forecasting should be from enterprises, customers, industries, markets, legislation and so on. The useful information will be evaluated relative to reliability, worthiness, feasibility.

Organization configuration: Based on abovementioned, a VE 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 RL. The core competencies concerning RL reflect return channels, logistics capabilities, R & D technology, manufacture arts and crafts, assets proprietary etc., and are determined by the relevant decision support system (DSS). Information system and the logistics network are necessary absolutely to support the VE.

Organization operation: The organization form of a VE is at the expense of coordination among partners. It implies that the excellent organization management is the precondition of the VE 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.

Organization disbandment: The disbandment of a VE takes place after the disappearance of market opportunity. There is the assets liquidation among partner enterprises.

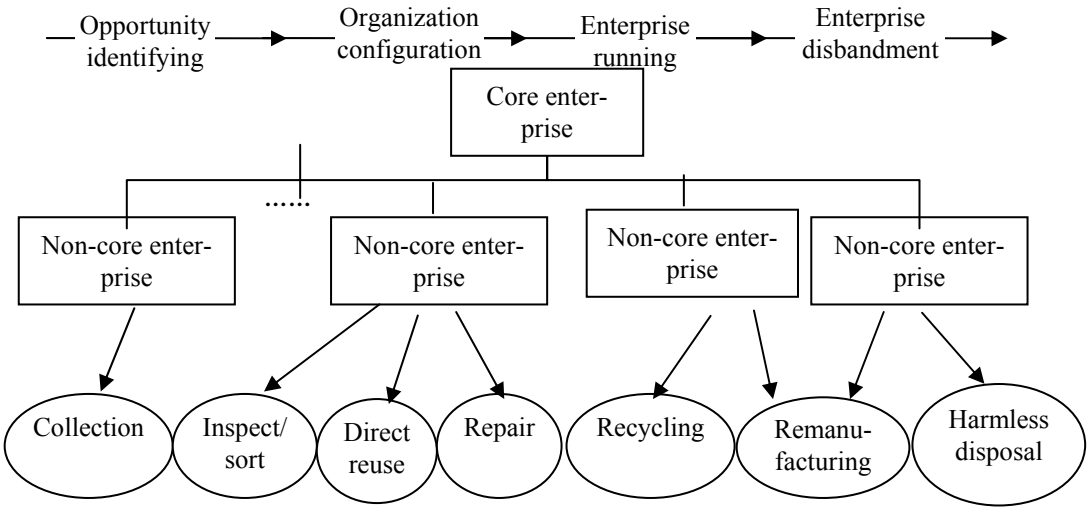

Figure 8. The organization framework of a VE for R

Table 2. The operation management mode of RL based

Opportunity identifying
✓ information collection ✓ data mining ✓ analysis and estimate
Organization configuration
✓ the core competency identifying ✓ evaluating and selecting partners ✓ the information system and RL network ✓ estimating the holistic performance
Organization operation
✓ coordination mechanism ✓ dynamic contract ✓ risk identification and control ✓ monitor system and improvement
Organization disbandment
✓ the assets liquidation ✓ knowledge management

The knowledge management runs through the whole operation management of the VE.

4.3. The dynamic durative of a VE

It is easy to see, depending on a VE, that there is every chance of RL in developing market. However, considering RL exist in enterprises at all times, the operation management based on the VE do not end after disbandment. Contrarily, it is the beginning of the new VE. Facing the uninterrupted opportunities the independent enterprises broke from one VE, can then take part in another dynamic alliance immediately. In fact, the VE is that organization of the older members left and the newer members' enter. So the VE for RL is the dynamic durative process organization from the phase of opportunity identifying to the phase of organization disbandment as shown in Figure 9:

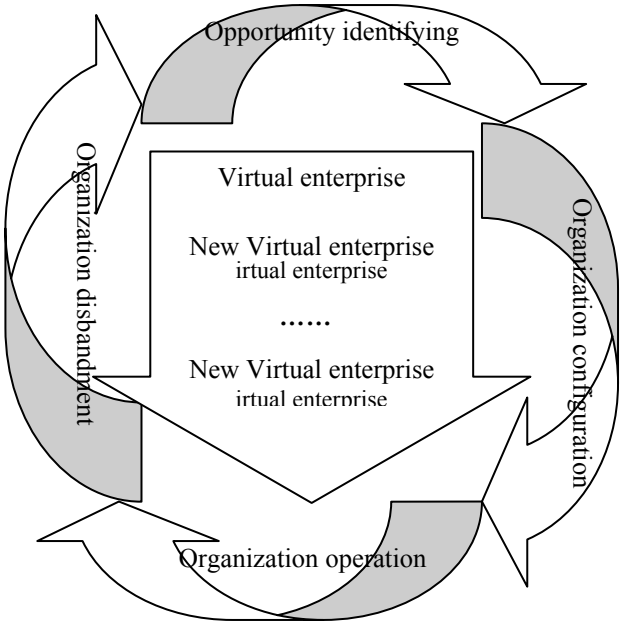

Figure 9. **The dynamic durative of a VE for RL operation m anagement**

4.4. The compare with the traditional mode

In contrast with the traditional logistics management, the operation management of RL based on a VE is improved in agility, flexibility, lowering cost and sharing risk as abovementioned. The details of the compared conclusions are listed in Table 3.

5. Evaluation Method and Process

5.1. Evaluation method and process

The evaluation of a VE for RL operation is based on the firms' multi-criteria which are qualitative or quantitative. AHP is often used in such problems [36]. 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 [7]. 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 VE for RL selection process are as follows:

(1)Determine alternative firms and construct the evaluating hierarchical structure. RL first choose the alternative VEs from those which can bear reverse activities, based on the basic requirements, such as Quality Certificated. Then, the hierarchical structure is constructed by the criteria of SCOR model and the chain which is linked by the product flow, see Figure 10, the alternative VEs are considered as similar types on the similar phase. The SCOR (Supply-Chain Operations Reference-model) is a process reference model that has been developed and endorsed by the Supply-Chain Council as the cross-industry standard diagnostic tool for supply-chain management. SCOR enables users to address, improve, and communicate supply-chain management practices within and between all interested parties. SCOR is a management tool. It is a process reference model for supply-chain management, spanning from the supplier's supplier to the customer's customer. The SCOR-model has been developed to describe the business activities associated with all phases of satisfying a customer's demand. By describing supply chains using process building blocks, the Model can be used to describe supply chains that are very simple or very complex using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any supply chain.

Considering that the full chain or part of supply chain can be selected by VEs, and many firms are involved in the scope and may operate different industries. So, there is more diversity among those, and SCOR model adapt to the cross-functional framework, the metrics of Level Ⅰ of SCOR model as the criteria and sub-criteria of alternative will be referenced ,see Table 4.

These 13 sub-criteria can be categorized into the qualitative criteria and the quantitative criteria. Unmeasured indirectly through firms' historical data are called as the qualitative criteria. And measured directly are called as the quantitative criteria. All values are listed in Table 5. The quantitative criteria can be found from the historical data, and the qualitative criteria can be evaluated by experts and experiential managers, based the firm's correlative data and their experience, which can decrease the subjective errors.

(2)Evaluate the alternative VEs. Based on the defined scope, the experts begin to evaluate those alternative firms, based on the criteria of SCOR model. The quantitative criteria can be gained by the VEs historical data and the alte rnative degree measured by five scales from the worst to t he best, here we use 1-9 triangular fuzzy number (from (1, 1, 3) to (7, 9, 9)) that is similar to Wu Lei and Guojun Ji (2006) [16]. The qualitative criteria are obtained by the experts evaluating values. To reducing the experts' subjec tive effect, the following approach is adopted for the qualitative criteria. Suppose that there are S_i experts to score on level i, $\tilde{C}_{ijts}$ is a basic value which Expert s scores VE j on level i about Sub-criteria t ($i=1,2,\cdots,N$, N is the total number of levels in the RL; $j=1,2,\cdots,M_i$, M_i is the total number of firms on the level i in RL; $t \in Q$, Q is the subscript set of the qualitative criteria, then $\overline{Q}$ is the subscript set of the quantitative criteria). The expert's lingual descriptions from the worst to the best are relevant to the fuzzy number from (1, 1, 3) to (7, 9, 9) using by five scales. Let $\tilde{C}_{ijts} = (l_{ijts}, m_{ijts,} u_{ijts})$, $L_{ijt} = \min(l_{ijts})$, $M_{ijt} = \dfrac{\sum_{s=1}^{S_i} m_{ijts}}{S_i}$, $U_{ijt} = \max(u_{ijts})$, then the integrated fuzzy number is $\tilde{C}_{ijt} = (L_{ijt}, M_{ijt,} U_{ijt})$ based on the S_i experts' evaluating result on level i.

(3)Evaluate the VEs relationship. The RL is constructed by selecting firms from VEs and the relationship among the firms is evaluated. The basic values in step (2) may be considered the average value of the VEs criteria, and that the effect of the upstream and downstream to the firms may be positive or negative. But the relationship among the firms is not determinant factor to some performance criteria. It happens that the double effect of performance. In addition, the negative effects produced by the relationship to the performance criteria can not reach zero. Herein, these two situations need not discussed. The relationship Coefficients are from 0 to 2 ranked by 9, which are relevant to some sub-criteria from descending by 100% to ascending by 100%. Assume that S experts score the relationship among the firms, and let r_{ikjs} denotes that the relationship coefficient which expert s firm j on level i and let r_{ijls} denotes that relationship coefficient which Expert s scores the relationship be tween firm j on level i and firm l on level $i+1$. Therefore, scores the relationship between firm k on level $i-1$ and

Table 3. Differences between two modes in the process of RL

Process	Traditional management	VE
Identifying opportunity	Simple collection, forecasting and decision-making	Special information collection, data mining and evaluation; forecasting with precision; quick response
Organization configuration	Most activities in-house, a little even none by outsourcing; large resources and money invested; adjusting continually	Most activities by utilizing the third party; lower investment for single enterprise; constructing virtual enterprise fast
Organization operation	Widely influence to the current process; high risk; simple disposal	Cooperating with the partner enterprises; the risk sharing between enterprises; more special, flexible and agile
Organization disbandment	Hard to take full advantage of the resources and upgrade the competence	The dynamic durative of virtual enterprise to make use of the resources fully; well-collaboration with other enterprises; accumulating knowledge; mining knowledge

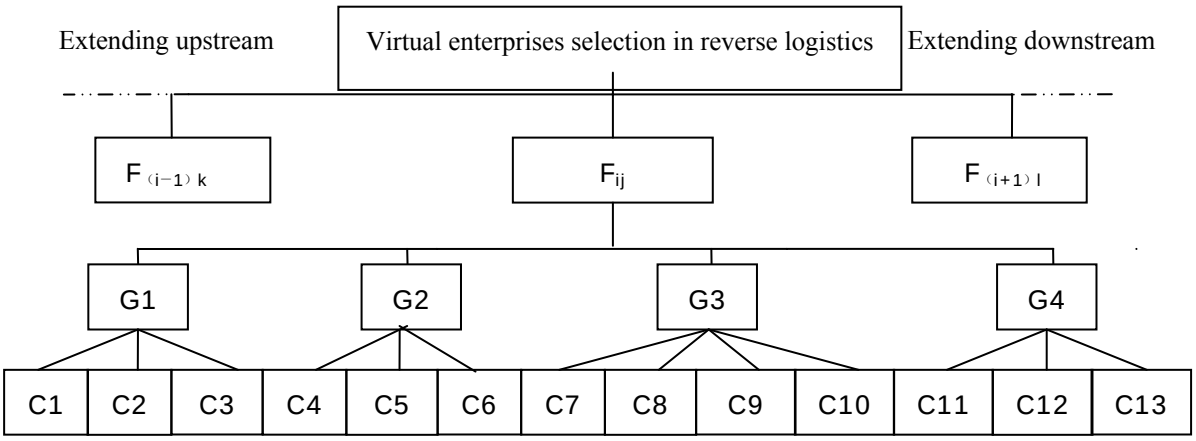

Figure 10. The hiberarchy of VEs selection in RL (Where Fij represents firm j on stage i in the supply network, F（i−1）k represents firm k on stage i-1 in the supply network, F（i+1） represents firm l on stage i+1 in the supply network)

Table 4. The criteria and sub-criteria from the metrics of Level Ⅰ of SCOR model

Criteria and Code	Sub-criteria and Code	Criteria and Code	Sub-criteria and Code
Delivery Reliability(G1)	Delivery Performance(C1); Fill Rates(C2); Perfect Order Fulfillment(C3)	Cost(G3)	Cost of Goods Sold(C7);Total Logistics Management (C8); Value-added Employee Productivity(C9); Warranty/Return Cost(C10)
Responsiveness and Flexibility(G2)	Order Fulfillment Lead Time (C4); Supply Chain Response Time(C5); Production Flexibility(C6)	Asset Management Efficiency(G4)	Cash-to-cash Cycle Time(C11); Inventory Day of Supply(C12); Asset Turns(C13)

Table 5. The category of sub-criteria

Category	Sub-criteria
Quantitative	C2; C4; C5; C7; C8; C10; C11; C12
Qualitative	C1; C3; C6; C9; C13
Exterior Correlated	C1; C2; C3; C4; C5; C7; C8; C10; C11
Interior Correlated	C6; C9; C12; C13

by integrated S experts' evaluations, the values are $r_{ikj} = \frac{\sum_{s=1}^{S} r_{ikjs}}{S}$ and $r_{ijl} = \frac{\sum_{s=1}^{S} r_{ijls}}{S}$, 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 $\overline{Z}$ 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 $r_{ikjl} = \sqrt{r_{ikj} r_{ijl}}$. On the boundary of the defined supply chain, let $r_{ikj} = 1$ while $i = 1$ and let $r_{ijl} = 1$ while $i = N$. The Integrated Sub-criteria based on effect of the upstream and downstream firms satisfy

$$\tilde{C}_{ikjlt} = \begin{cases} (L_{ijt} r_{ikjl}, M_{ijt} r_{ikjl}, U_{ijt} r_{ikjl}) & t \in Z \\ \tilde{C}_{ijt} & t \in \overline{Z} \end{cases}$$

Then Integrated Criteria are defined as follows:

$\tilde{G}_{ikjl1} = \sum_{t=1}^{3} \tilde{C}_{ikjt}$, $\tilde{G}_{ikjl2} = \sum_{t=4}^{6} \tilde{C}_{ikjt}$, $\tilde{G}_{ikjl3} = \sum_{t=7}^{10} \tilde{C}_{ikjt}$,

$\tilde{G}_{ikjl4} = \sum_{t=11}^{13} \tilde{C}_{ikjt}$, 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 $W_i = (\tilde{w}_{i1}, \tilde{w}_{i2}, \tilde{w}_{i3}, \tilde{w}_{i4})$ and $W = (\tilde{w}_1, \tilde{w}_2, \cdots, \tilde{w}_n)$, respectively.

(6)Synthesize the criteria and the weighted values, after that select the optimal VEs. The total fuzzy score of Chain x among X supply chains is expressed as follows: $\tilde{H}_x = \sum_{i=1}^{N} \left[\tilde{w}_i \otimes \sum_{q=1}^{4} (\tilde{G}_{ikjlq} \otimes \tilde{w}_{iq}) \right]$. The supply chain has the greatest finial score is the best one using by compared the finial score which is deduced by the following steps: Let

$$\tilde{H}_x = (L_x, M_x, U_x) ,$$

consider that $h_{xl}^{\lambda} = L_x + \lambda(M_x - L_x)$ and $h_{xr}^{\lambda} = U_x - \lambda(U_x - M_x)$ (where λ （$0 < \lambda < 1$） is the degree of confidence), and define that $H_x^{\lambda} = \left[h_{xl}^{\lambda}, h_{xr}^{\lambda} \right]$, then the finial score is calculated by $H_{x\beta}^{\lambda} = \beta h_{xl}^{\lambda} + (1-\beta) h_{xr}^{\lambda}$ (where β ($0 < \beta < 1$) is the risk index).

5.2. Numerical example

Considering a three-stage network of the electronic industry is incorporated by two VEs (denoted by F11 and F12), two manufactories (denoted by F21 and F22) and one retailer. The VEs 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 VEs. Let $\lambda = 0.5$ and $\beta = 0.5$, By using above-mentioned processes, and the solution is presented in Table 6.

Table 6. The final scores of Ves

Supply chain	$H_{x0.5}^{0.5}$	
	No considering the relationship	**Considering the relationship**
F11-F21-F31	52.67244	57.22441
F11-F22-F31	41.74084	56.32318
F12-F21-F31	49.99745	50.00566
F12-F22-F31	50.42136	48.44038

It is easy to see the best VEs that formed chain are F11-F21-F31. At the same time, we can find that the chain relationship effect on the order of finial scores, i.e., VEs should pay attention to the chain relations in course of constructing the RL. In addition, VEs 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 VEs. VEs can provide more consulting service and realize the integrative optimization of RL.

6. Conclusions

In this paper, CSM was considered in RL. Based on the computer telephone integration technology, an integration multi-channels collection has be designed; the evaluation of complaint and product is supported by intelligent decision support system; in accord with the different disposal countermeasures, the CSM processing system was established to implement corresponding disposal which reflects the utility of CSM. The operation management mode of RL based on a VE was analyzed. The organization structure, RL functions and the framework were discussed too. The process of operation management based on a VE includes opportunity identifying, organization configuration, organization operation and organization

disbandment, in that the superiority of a VE in contrast with traditional management is unveiled. The evaluation of VEs for RL operation was 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 VEs were considered and the optimized selection is presented. Our conclusions help to impel the development of RL in practice.

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