A review of reverse logistics

Wang Bei and Sun Linyan

Abstract

The impact of economics and environmental statutes has caused a new set of generic issues in reverse logistics. The other challenges in this field have been caused by the rapid development of e-commerce, the boom of online retailers, and the like. Again, companies bear enormous losses from huge returned products due to liberal return policies. In order to add customers' value, improve the relationship with customers and strengthen a company' s competitive advantages, there is a need for companies to find ways of how to reduce wastes and recover the value from used products for further utilities. Likewise, returned products also need to be aptly managed. All these challenges make reverse logistics a contemporary area of interest among managers and researchers of this field. First, it is proposed that the emergence of reverse logistics emanates from environmental concerns and economical drives. The connotation of reverse logistics is given in a narrow and a broad senses. The differences between reverse logistics and traditional forward logistics; and green logistics and closed-loop supply chain are analyzed. Moreover, reverse logistics' distinct characteristics such as: high uncertainties of supply on time, quantity and quality; complexities of recovery options and implementing barriers are pointed out in this paper. Next, using the qualitative and the quantitative case study analyses, the basic tenets of managerial and operational practices of reverse logistics are discussed in detail in this paper. Mathematical models have also been introduced to a great extent. Finally, the paper concludes by stating possible directions for further investigations on this subject.

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Key words: reverse logistics, recovery options, reuse, remanufacturing, recycling.

1 Introduction

Reverse logistics deals with the processes associated with the reverse stream from owners to re-users. It encompasses all the logistic activities from used products no longer required by the users to products again usable in a market. The notion ' reverse ' denotes that the direction of physical flow in reverse logistics is opposite to the conventional forward supply chain'. This paper provides a review and content analysis of scientific literature of reverse logistics case studies and mathematics models. A large number of references are quoted. It is believed that prospective readers of this paper will obtain a comparatively panoramic and deep understanding of reverse logistics.

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2 Background of Reverse Logistics

2.1 Environmental Concerns

In the past decades, due to dwindling landfill and incineration capacities and growing environmental concern to the limited natural resources, waste reduction has becomes a primary challenge for industrialized countries. More and more environmental legislations are imposed on the OEM (original equipment manufacturer) to take corresponding responsibility for the whole life cycle of their products [18]. In many European countries, producers are required to take back packaging from their customers. In the U.S., local and state governments are often responsible for the recycling packaging [48]. In the EU, the WEEE (waste from electrical and electronic equipment) directive requires end of life equipment to be collected for recovery, recycling and reuse by end 2003 [44].

2.2 Economical Drives

Nowadays, the 'green' image has been increasingly recognized as an important marketing element. Similarly, proper recovery options such as direct reuse or remanufacturing may he economically attractive because they bring real benefits in some occasions [18]. Coupled with the rapid development of e-commerce and the boom of online retailers and the mailing business. And in order to attract more potential customers, liberal return policies have been widely adopted. Companies have to bear enormous losses from huge returned products of customers. According to estimates, reverse logistics costs in the U.S. exceeded 37 billion dollars in 1999, which on average account for approximately 4 percent of total logistics costs. This also means the costs of reverse logistics are estimated to be one half of the percentage of the total U.S. GDP. The size, scope, and impact of reverse logistics vary by industry and channel position as well as by the type of distribution channel. However, it is clear that the overall amount of reverse logistics activities and costs are large and still growing. And product returns have a large proportion of reverse activities with an average of 6 percent of the sales, although this varies from industry to industry and from season to season. For example, during the 1999 holiday season, approximately 25 percent of all on-line purchases were returned [54, 47].

The challenges of how to reduce wastes and recover the value from used products for further utility and how to manage returned products, add customers' value, improve the relationship with customers and strengthen a company' s competitive advantages, make reverse logistics become a contemporary area of focus among managers and researchers of this field.

3 Connotations of Reverse Logistics

Connotations of reverse logistics dates back to 1992.The conception of reverse logistics was defined by CLM (Council of Logistics Management) as:

The role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective included all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal [8].

Referring to the Council of Logistics Management's definition of logistics, Rogers and Tibben-Lembke (1999) gave the definition of reverse logistics as:

The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal [47].

In 2003, RevLog (the European working group on reverse logistics) described reverse logistics as:

The process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal [8].

The explanation of reverse logistics in a narrow sense emphasizes the recovery processes of reuse, remanufacturing and recycling for a used product. The definition of reverse logistics in a broad sense also includes resource reduction and efficient handling of returned or rejected products from consumers [6].

Efficient and effective reverse logistics is believed not only to bring direct benefits for a company, such as decreased resource investment levels, reductions in storage and distribution cost and recaptured value of recovered products, but also to result indirectly profitable business opportunities, including improved customer satisfaction, closed customer relationship and coincidence of environmental legislation [2].

4 Comparing Reverse Logistics with Forward Logistics, Closed-loop Supply Chain and Green Logistics

4.1 A Comparison with Forward Logistics

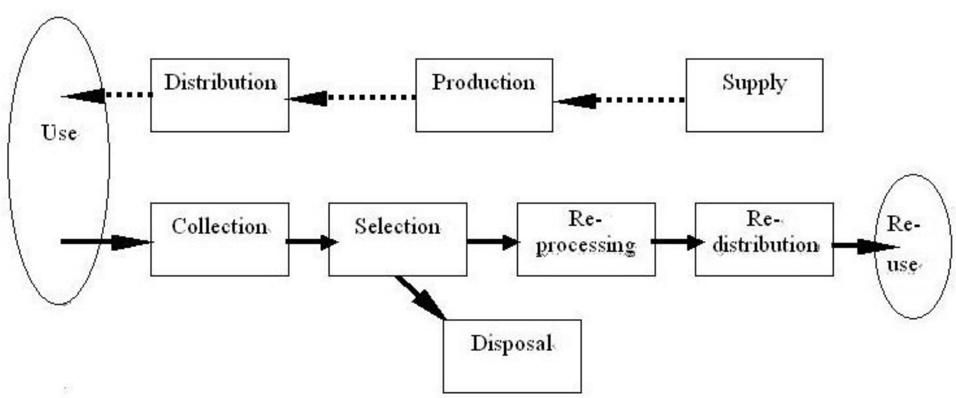

Figure 1: Reverse and forward logistics chain

Fig.1 illustrates a typical recovery chain integrated reverse logistics and traditional forward supply chain [18]. In the diagram, the general activities in the reverse and forward logistics chain are given. The direction of reverse logistics is drawn in the figure with solid lines while the forward direction delineated with dashed lines. It is showed in the figure that the direction of the forward physical flow is from raw material to end user and the main activities comprises material supply, components manufacturing or assembling and products distribution, while the direction of reverse logistics is opposite and the activities involved are also complex. The processes of reverse logistics consist of collection, inspection/separation, reprocessing/disassembly, redistribution and disposal stages.

4.2 A Comparison with Closed-loop Supply Chain

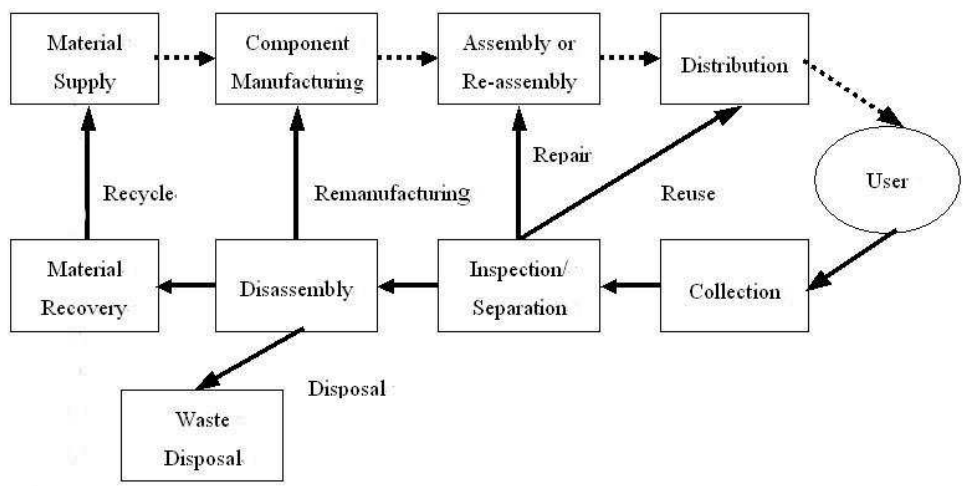

Figure 2: Closed-loop supply chain

Fig. 2 shows the structure of a typical closed-loop supply chain, in which the material flows in a closed way [33, 63]. The flow of reverse logistics is drawn in the figure with solid lines while the forward flow delineated with dashed lines. It also depicts the main processing options in reverse logistics, which are reuse, repair, remanufacturing, recycling and disposal. The conception of closed-loop supply chain is derived from the combination of both forward and reverse logistics because it considers supply chain in a holistic viewpoint. Closed-loop supply chain management encompasses all the contents of reverse logistics, involving all business functions and decisions with respects to the adaptation of business strategy, marketing, quality management, information systems, logistics and the like within the closed material flows. The primary targets for closed-loop supply chain management are limiting emission and residual waste. While aiming at providing customer service at low cost. Moreover, the term of closed-loop supply chain emphasizes the importance of coordination of forward logistics flows and reverse logistics flows since there is a strong interaction between the two [33].

4.3 A Comparison with Green Logistics

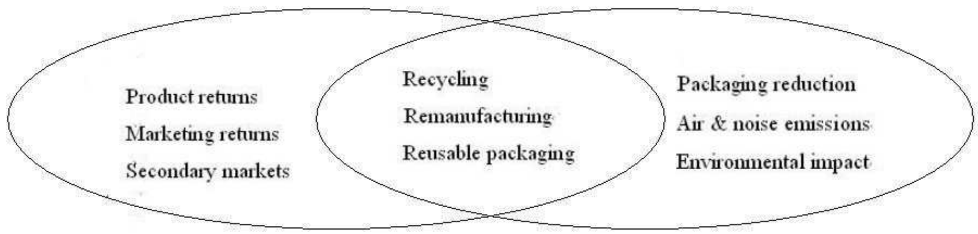

Figure 3: Comparison of reverse logistic and green logistics

Fig.3 gives a comparison between reverse logistics and green logistics. At the same time, the differences and the overlap between the two conceptions are presented in the figure. The overlap means there are some activities applied both to reverse logistics and to green logistics, such as recycling, remanufacturing and reusable packaging [47]. Reverse logistics differs from green supply chain as the latter concentrates on environmental impact of all logistics activities especially the activities involved in traditional forward logistics [8]. The environmental issues in green logistics are reduced consumption of natural resources, air emissions, congestion and road usage, noise pollution, and both hazardous and non-hazardous waste disposal. So green logistics investigate supply chain with respects to environmental and ecological activities while reverse logistics emphasizes more on the profitability of strategic recovery options.

4.4 A Comparison with Waste management

There is a difference between reverse logistics and waste management. The primary purpose of waste management is to collect and process waste or the products without value for recovery. In short, waste management concerns managing waste efficiently and effectively. Reverse logistics focuses mainly on the returned physical flow that contains some value from proper recovery options.

4.5 A Comparison with Sustainable conception

The conception of reverse logistics also differs from sustainable development. However, reverse logistics can be viewed as a part of it. A report by the European Union defined sustainable development as: meeting the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, reverse logistics can be viewed as the implementing of sustainable development at the company level since proper reuse or remanufacturing or recycling activities in reverse logistics rightly meets the requirement of sustainable development [8].

5 Distinct Characteristics of Reverse Logistics

5.1 High Uncertainty

In reverse logistics system, supply is typically considered as an exogenous variable since the timing, quantity, quality of the returned products may be difficult to control. Therefore, supply uncertainty in a wide sense appears to be a major distinguishing factor between product recovery and traditional production- distribution networks. On the contrary, supply in the forward supply chain usually can be controlled according to the system's needs [18]. The demand for products is completely decided by the customers. So, one can easily forecast the demand and the balance between supply and demand could also easily be controlled in a traditional supply chain.

5.2 Complexity in Operation

There is more uncertainty and complexity in reverse logistics system than in forward supply chain because the recovery processes and options of reverse logistics system are complicated and varies in view of life cycles and characteristics of products, resources required and capacity of facilities and so the like. According to a survey [47] in the U.S. companies, the primary activities and functions in reverse logistics include: remanufacturing, refurbishing, recycling, landfill, repackaging, returns processing and salvage. Literature also indicates that a firm' s reverse logistics activities are directly affected by at least four environmental forces: customers, suppliers, competitors and government agencies [6]. So, it is hard for companies to make a strategic decision on recovery options and to operate reverse logistics system efficiently and effectively.

5.3 Implementing barriers

Although in some industries, reverse logistics has become a critical factor to make a difference in fierce competition, quite a number of managers still regard reverse logistics system as less important than forward production- distribution supply chain in terms of costs, asset valuation and potential revenues [54]. Therefore, finance and human resource allocated to implementing reverse logistics is often very limited. In addition, the support from corresponding reverse logistics network and powerful management information system is scarce. All these factors make reverse logistics difficult to implement and manage.

6 Previous Studies on Reverse Logistics

6.1 Qualitative Analysis

From the literature available, quite a few authors investigated reverse logistics using qualitative analysis. The common areas of interest among scholars addressed the following questions:

Why do companies pursue reverse logistics? The first driving factor is economics and that is also the most important reason that companies are willing to devote to reverse logistics. The benefits may come from reduced use of raw materials or product components, added value from product recovery, decreased disposal costs, improved customer satisfaction, green image and the like [8]. Another driven force is various environmental legislations imposed on manufacturers. For instance, in Europe, packaging regulation and WEEE directive force OEM to take the whole life cycle responsibility of their products.

Who assumes reverse logistics activities? That is a strategic decision on considering whether or not a company should outsource their tasks in reverse logistics to a professional service provider in order to achieve core competitive advantages. Actors executing reverse logistics activities may be suppliers, manufacturers, and retailers in forward supply chain or professional third party providers.

What activities are involved in reverse logistics? Generally, the common activities are collection, inspection, separation, re-processing, disposal and re-distribution. Among them re-processing is the actual transformation of a take-back product into a usable product again [18]. There are different transformation forms such as re-packaging, cleaning, repair, remanufacturing and recycling.

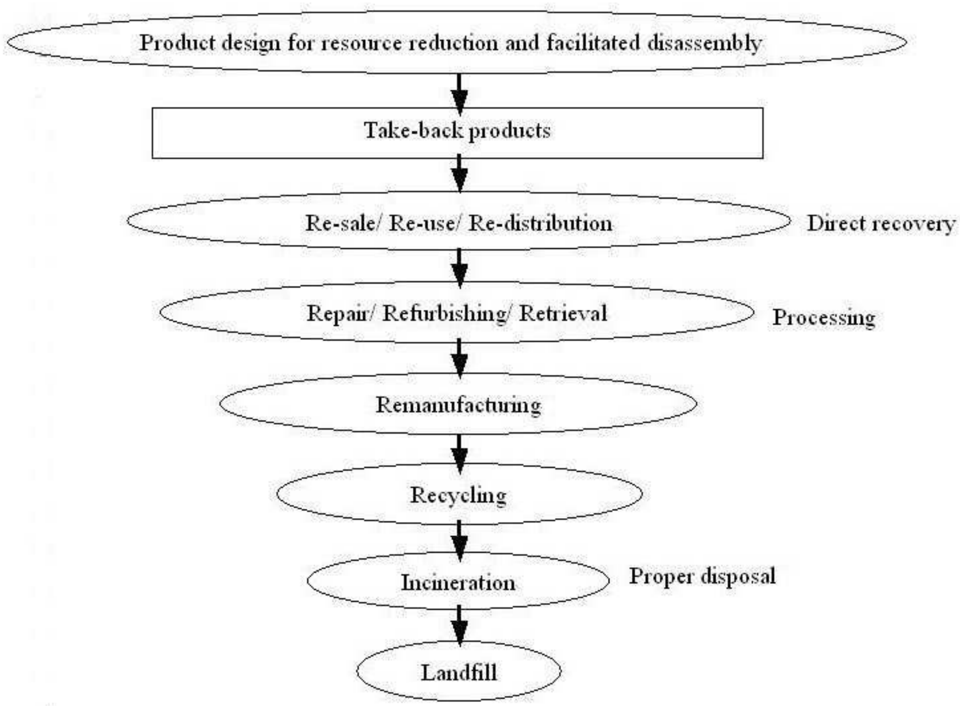

Figure 4: The reverse logistics hierarchy

What recovery options will a take-back product face? Recovery options may be classified as two kinds: direct recovery and process recovery. If the take-back products' condition is as-good-as-new, then they can be directly recovered through re-use, re-sale and proceed to re-distribution. For process recovery, there are more complex processes involved such as repair at product level, refurbishing at module level, remanufacturing at component level, retrieval at selective part level, recycling at material level, and incineration at energy level [56]. The common recovery options may be summarized from various publications as: reuse, repair, remanufacturing, recycling and disposal. Disposal usually encompasses incineration and landfill. Fig.4 presents a typical hierarchy of recovery options [6]. It points out that product design for resource reduction and facilitated disassembly is the priority among other recovery options since resource reduction should be the ultimate goal in the reverse logistics processes. Once the resource reduction option has been exhausted, the firm should attempt to maximize direct recovery, then followed by processing recovery. For the proper disposal options, incineration should be preferred to landfill because the former is also a kind of method for energy recapturing.

Classification for reverse logistics	**Driven forces**	**Processes**	**Products**	**Referenced cases**
Manufacturing returns:				
◆Raw material surplus	Economics	Recycling/Reuse	Ferric scrap/	[30]
◆Production wastes/byproducts	Legislation	Remanufacturing	Pharmaceutical	[52]
◆Unqualified products			materials	
Distribution returns:				
◆Recalls for safety/health problems	Economics/	Recycling/	Monitor	[35]
◆Outdated/obsolete stock adjustment	Legislation	Repair/Resale/	Consumer	[21]
◆B2B commercial returns(unsold products/wrong or damaged deliveries)	(liability)	Remanufacturing	Industrial goods	[4]
Returns after distribution	Economics	Reuse/	Pallets/	[1]
◆Used distribution items	(Legislation)	Recycling	Packaging	[14]
Customers' B2C commercial returns:				
◆Reimbursement guarantees for	Economics	Resale/	Clothing/	[10]
unsatisfied new products	(liability)	Reuse	Commercial goods	[43]
Customers' service returns:	Economics	Repair/	Machines/	[31]
◆ Update/repair demands	(liability)	Retrieval	Circuit boards	[12]
Customers' after-use returns			Electronic appliance/	[50]
◆End-of-use returns	Economics/	Remanufacturing/	Sand/Batteries/	[3]
◆End-of-life returns	Legislation	Recycling	Carpet	[41]

Table 5: Classification of reverse of logistics

How can one classify take-back or returned products in reverse logistics? There are all kinds of product categories related to reverse logistics system, such as consumer or industrial goods, construction wastes, household wastes, packaging, distribution items, production by-product, electronical equipment, electronic appliance and so on. Table.1 gives a general classification for take-back or returned products that occur frequently in view of reasons for return and product varieties.

6.2 Case Study

It is summarized from related literature. Case studies on reverse logistics usually focus on following decision-making contents: reverse logistics network structure, relationship, inventory management, planning and control and information and technology (IT) for reverse logistics [17]. The following statements give a further explanation to these aspects:

Case studies on reverse logistics network (e.g. [3, 7, 11, 34, 41, 52]) concentrate on the network characteristics and establishment under conditions of different recovery options; Case studies on relationship (e.g. [24, 59, 60]) surveys applications of various incentive tools including refund options, buy back options, lease or rent contracts, bring-pick up systems, social responsibility, acquisition price and so on; inventory management (e.g. [10, 20, 58]) deals with varied efforts to handle returned or used products facing different recovery options; Case studies on planning and control of recovery activities [22, 35, 51] discuss coordination of returned or used products' planning and controlling with new products' distribution and production; Case studies on information technology [15, 39, 43] focus on IT' supporting functions for reverse logistics during different stages (product development, distribution and marketing) of the life cycle of a product [9]; The entry and development potential of third-party reverse logistics providers was discussed by Krumwiede [37] and Spicer [53].

6.3 Quantitative Study

One method applied to quantitative study is simulation. In view of complexities of reverse logistics system, adapting the method of system simulation can rapidly and conveniently appraise various comprehensive reverse logistics networks under different scenarios. Thus, the optimized network structure may be decided. Furthermore, parameters and variables' impact on the structure of reverse logistics system, robustness and sensitivity of the network structure can also be analyzed through simulating the system. Some pragmatic simulation software supporting reverse logistics network design has been developed in a few developed countries recently. For example, in 1998 Bernd E. Hirsch introduced a system simulation software namely LOCOMOTIVE logistic planning tool [25]. Based on life cycle approach, the tool can be used to evaluate the environmental impacts on reverse logistics and estimate the cost of different production schemes. Another example is the Disassembly Model Analyzer (DMA), which was developed in order to assess the economics of disassembly for complex products. It is capable of producing optimized demanufacturing plans for very complex products as complicated as a photocopier modeled with well over 1000 parts [53].

Quite a few of mathematical models are proposed in various literatures to optimize reverse logistics system. From an operational point of view, various decision problems of reverse logistics are concentrated mainly on network design, inventory management and production planning.

Determining the number and location of recovery facilities is a central task in the network design problems. Except few stochastic models (see [40]), most authors propose a mixed integer linear program (MILP) model that differs little from traditional MILP facility location models. The purpose of modeling is to minimizing total logistics cost under the constraints of balance of supply and demand, facilities capacity and the integral or non-negative parameters. For a more detailed reference see: ([3, 5, 26, 28, 34, 36, 41, 42, 52, 55]). In 2001, Fleischmann [21] analyzed the detailed characteristics of reverse logistics network.

Two kinds of mathematical models in literature are usually developed to solve inventory management problems of reverse logistics, which are deterministic models (see [13, 32, 45, 46, 49, 63]) and stochastic models (see [19, 27]). For the former, demands and returns are known in advance. By contrast, the latter treat demands and returns as stochastic processes. The objective of inventory management of reverse logistics is to control external component orders and the internal component recovery process to guarantee a required service level and to minimize fixed and variable costs [17].

A third area in reverse logistics modeling is production planning and controlling. The models' main purposes are to control the trade-offs between costs for disassembly and repair and the material value of the recovered components and to plan recovery operations. The referred publications are: [22, 29, 38, 61].

7 Conclusion

Whatever the economical reasons or the legislation reasons, reverse logistics is now becoming so significant that it is no longer a ' black office' task. It must be investigated as a part of the overall supply chain design, especially in some industries like computer business, where life cycles are nearly as shorter as grocery life cycles. The speedy handling and disposition of returns is now recognized as a critical strategic factor for companies [44].

In this paper, the main contents and distinct characteristics of reverse logistics are presented by comparing them with traditional forward supply chain. A deeper understanding of reverse logistics system may be achieved through investigating practices, simulations and models of reverse logistics system. In short, reverse logistics is still a new researching field, although a lot of achievements have been made in recent years. For instance, the influence of return flows on supply chain management is a topic that may be studied more deeply [17]. In addition, the literature on reverse logistics is not adequate and comprehensive approaches and mathematical models are rare. Therefore, it deserves deliberation that some valuable mathematical optimization models and algorithms (see [57]) might be applied to describe and solve the complex reverse logistics problems.

There are a few issues in this area that still deserve to be further explored. The promising exploration are stated as follow: improving and enriching existent forecasting techniques to effectively control uncertainties of returned products on timing, quantity and quality; developing proprietary information management system adapted to reverse logistics; establishing mature market for recovered products matching with reverse logistics system; configuring dynamic and long period operational network for reverse logistics; deeply investigating different reverse logistics participants' strategic decision structure, driven factors and the corresponding impact on these participants.

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Authors' addresses:

Wang Bei
School of Management, Xi'an Jiaotong University, Xi'an city, 710049, China
e-mail: wangbei2000@yahoo.com

Sun Linyan
School of Management, Xi'an Jiaotong University, Xi'an city, 710049, China
e-mail: lysun@mail.xjtu.edu.cn