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Novel multi-objective resource allocation and activity scheduling for fourth party logistics

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ABSTRACT

In order to reduce logistic costs, the scheduling of logistic tasks and resources for fourth party logistics (4PL) is studied. Current scheduling models only consider costs and finish times of each logistic resource or task. Not generally considered are the joint cost and time between two adjacent activities for a resource to process and two sequential activities of a task for two different resources to process are ignored. Therefore, a multi-objective scheduling model aiming at minimizing total operation costs, finishing time and tardiness of all logistic tasks in a 4PL is proposed. Not only are the joint cost and time of logistic activities between two adjacent activities and two sequential activities included but the constraints of resource time windows and due date of tasks are also considered. An improved nondominated sorting genetic algorithm (NSGA-II) is presented to solve the model. The validity of the proposed model and algorithm are verified by a corresponding case study.

1. Introduction

As a result of globalization, many companies refocus their activities to their core competencies and outsource services that are not crucial to their business and no longer need to be managed exclusively to third parties. This movement has had a consequence: the explosive growth of logistics outsourcing services during the 1990s. In addition to reducing costs, and improving the quality of service provided, outsourcing logistic activities could reduce the investment in assets, while increasing operational flexibility and allow greater focus on the core activity of the business. As a result, logistic activities for logistics providers have been growing in complexity and diversification as demonstrated in [28]. Carbone and Stone [4] have shown that the scope and the geographical range of third party logistics (3PL) has been enlarged and extended to the global market. More and more companies have recognized that no firm has all the capabilities in terms of both resources and activities offered to achieve its goals in logistics provision and interorganisational co-operations among 3PLs are becoming more common as demonstrated in [10]. As demands from customers are hardly met by a single 3PL, an integrator between customers and 3PLs is highly demanded. Therefore, fourth party logistics (4PL) was coined and trademarked by Andersen Consulting as demonstrated in [9]. The 4PL is a supply chain integrator that assembles and manages the resources, capabilities, and technology of its own organization with those of complementary service providers to deliver a comprehensive supply chain solution. The function of a 4PL is to act as a single interface or connection between the client and multiple logistics providers, being responsible for hiring other 3PLs and managing the logistics process end-to-end as demonstrated in [17]. The largest opportunity for the 4PL's success will come from effectively implementing multi-company logistics. The multi-company logistics will form a data pool. The 4PL controls the information and assigns logistic tasks to appropriate 3PLs. The 4PL can reach economies of scale by consolidation of logistic demands, reduce investments on logistic facilities by optimal resources allocation and therefore, reduce logistics costs and improve the quality of its services by optimal scheduling of logistic activities. It could optimize logistic operation on a large scope more effectively than any individual participant. Generally, a 4PL has very limited logistic resources and can hardly meet all demands of customers, nor quick response to short-term changes in customer demand patterns. Therefore, it is necessary for a 4PL to make full use of resources belonging to 3PL providers.

Sheu [30] has regarded logistic resource allocation as the mechanism of allocating logistic resources such as containers, vehicles, warehouses and distribution centers etc. to process certain logistic activities. Allocation of logistic resources defines the feasibility of reducing costs for a 4PL by enhancing the resource utility. 4PL has been urgently requested with the capability of allocating 3PL providers' resources efficiently and effectively. Logistic activities scheduling refers to the mechanism of making an optimization scheme of processing logistic activities under various objectives e.g. minimal operation cost or finishing time etc. It includes allocating

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logistic resources, sequencing of logistic activities and determining the starting time and finishing time of each activity. The resource allocation and scheduling of logistic activity are critical techniques for the successful implementation of 4PL.

Based on the literature review in Section 2, it can be concluded that studies, in terms of incorporating resource allocation into scheduling of logistic activities, are rather limited in previous literature. There is a lack of a general model of resource allocation and scheduling which considers the joint cost and time between two adjacent activities for a resource to process or two sequential activities of a task for two different resources to process for a 4PL. Furthuremore, the research on algorithm of multi-objective optimizing of resource allocation and scheduling is very limited. The computational efficiency under large-scale network flow conditions for 4PL also remains to be a difficult challenge. The main purpose of this paper is to build a general multi-objective model which considers the joint cost and time between two adjacent activities and two sequential activities for a 4PL to assign logistic activities to the resources of appropriate 3PLs and to find an optimal schedule for the activities and resources, and therefore, contribute to the cost reducing and services quality standards.

The remainder of this paper is organized as follows. The related research works on resource allocation and scheduling of logistic activity are discussed in Section 2. The research problem is described in Section 3. The proposed model of logistic activities scheduling is presented in detail in Section 4. An improved nondominated sorting genetic algorithm (NSGA-II) is designed to solve the proposed model in Section 5. A computational study is presented in Section 6 to demonstrate the feasibility of the proposed method. Section 7 summarizes the concluding remarks.

2. Literature review

As mentioned before, there are great potential advantages for a 4PL to reduce logistics cost and improve service level. However, bringing 4PL into the supply chain raises the cost versus value questions. It has not been clarified what kind of value is created by a 4PL aside from 3PLs and whether the value is large enough to justify itself. Until now, the distinction between 3PL and 4PL has not always been straightforward as demonstrated in [28,15]. However, Hertz and Alfredsson [14] have noticed the potential advantages of 4PL and try to put it into practice. From the perspective of logistics providers, a 4PL is very much like a logistics alliance in some sense as demonstrated in [4,23,36]. In order to clarify the concept, Liu and Ye [25] have proposed an operation mode of 4PL based on eco-non-profit organization and Liu and Li [22] have proposed a Nash equilibrium model of the benefit distribution between a 4PL and 3PL. In the following of this paper, a 4PL is regarded as an integrator that has no resources of its own and only assembles and manages resources, capabilities, and technology of other 3PLs to deliver a comprehensive logistics solution to customers, as shown in Fig. 1. Its main function is to coordinate logistics operations from a whole system and to assign the logistic activities to the appropriate 3PLs to reduce operation costs and improve services.

It is obvious that the successful implementation of 4PL requires advanced information technology. There is a tremendous amount of data which might affect some decision making of 4PL. Li et al. [20] and Bourlakise and Bourlakis [3] have studied the software platform to facilitate the success of 4PL. As the 4PL must outsource logistic activities to different 3PLs, it is important for a 4PL to choose and evaluate its members. Krakovics et al. [17] has designed a system for a 4PL firm to evaluate the performance of 3PLs and many others such as Jharkharia and Shankar [16] have studied the selection of logistic service providers. Currently, research on logistics network design for a 4PL is rare. However, the research on dynamic network design for 3PL [26] and reverse logistics [18] can be adopted by 4PL because the network design for 4PL has the same research problems including the dynamics and uncertainty for the network design in the research of reverse logistics network. Li et al. [21] has studied the distributed system within the hub-and-spoke network of 4PL in e-Commerce and proposed a routing optimization model for 4PL with minimal transport costs and penalties caused by early and late delivery, and then assigned the transportation jobs to appropriate 3PLs according to their bids. Until now, the research on 4PL, especially on the core operational techniques such as the consolidation of logistic tasks, the optimization of resource allocation and activity scheduling, and algorithms for large size and the complicated problems etc., are very limited.

Consolidation is the process of grouping different shipments from suppliers into a large shipment at the consolidation point. The motive behind consolidation is to reach scale economies through better utilization of a vehicle's capacity and therefore, reduce operation costs. Tyan et al. [32] has developed a mathematical programming model to assist the evaluation of consolidation policies of an integrated global 3PL company. The global 3PL implemented combinations of inventory and vehicle consolidation strategies to maximize the utilization of expensive transportation such as aircraft and to minimize the system-wide cost. Liu and Zhang [24] have proposed a consolidation algorithm based on clustering to group the transportation tasks for reverse logistics alliance and integrate the research with vehicle assignment and vehicle route planning. Consolidation operation can be integrated with resource allocation and regarded as an enrichment of vehicle routing problems (VRP) in some cases.

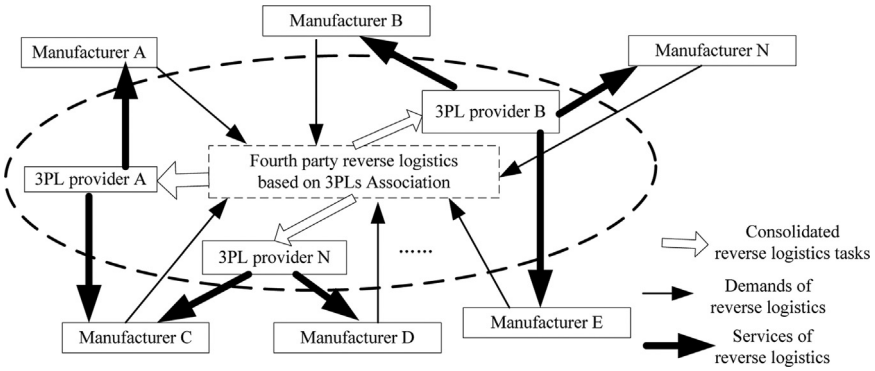

Fig. 1. Relationship between 4PL and 3PLs.
Source: Liu and Ye [25]