Asia-Pacific Journal of Science and Technology: Volume: 22. Issue: 02. Article ID.: APST-22-02-02. Research Article

APST

Asia-Pacific Journal of Science and Technology

https://www.tci-thaijo.org/index.php/APST/index

Published by the Faculty of Engineering, Khon Kaen University, Thailand

Vehicle routing problem for freight forwarding

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Abstract

This paper reveals a current business situation where several types of subcontracting transportation are used for delivery services in forwarding companies. Each subcontracting option contains different cost structure and constraint set that make more complex in transportation planning. This problem comprises new aspects which extend the traditional vehicle routing problem (VRP). A simulated annealing (SA) technique is proposed for simultaneously solving the combination of optimization problems in vehicle routing and scheduling.

Keywords: VRP, Subcontracting, Transportation planning, Multi-transportation modes, SA

1. Introduction

A large number of companies give high attention to minimize their transportation cost of goods because it is considered as a major share of the total logistics cost as shown in Figure 1. This leads to numerous attempts to develop solution approaches and techniques to solve vehicle routing problem (VRP) for over several decades. Most of the existing models seeks to find an optimal route as a standpoint of logistics companies that provide transportation service using their own truck. However, the models from shippers' standpoint is very limited. As a standpoint of shippers, transportation cost is determined based on the tariff rate given from the logistics company depending on the transportation distance and the size of the truck used. In Japan, the tariff rate used to be regulated fixed rate by Ministry of Land, Infrastructure and Transport. Regulations on the transportation cost was relaxed in 1990 and transportation cost can be set freely between a shipper and a logistics company based on the free-market principles. Even after the relaxation of regulation, however, in most cases negotiations are conducted based still on the regular tariff rate from the ministry.

To our best knowledge, Refs [2-4] are only models to consider the subcontracting issues. Refs [2-4] consider the vehicle forwarding problem considering four options used on the Germany as (a) avehicle from own fleet, (b) a vehicle from subcontractor paid on tour basis, (c) a vehicle from subcontractor paid on daily basis and (d) requests forwarded to an independent carrier. Among those options, options (a), (b), (c) are modeled as a linear cost function depending on the transportation distance and the size of trucks used, where option (a) consider both fixed and variable cost, (b) consider only variable cost, (c) consider only fixed cost. The option (d) is modeled as a concave function. This paper introduces two types of subcontracting transportation modes used in Japanese tariff structure, in each of which cost rate is step function. Utilization of own fleet or renting vehicles in a long period to fulfill the requests is defined as self-fulfillment or long-term subcontracting while engaging the external carriers is called short-term subcontracting. The short-term subcontracting consists of two types: tour-oriented and flow-oriented as shown in Figure 2. A simulated annealing (SA) technique is proposed for simultaneously solving the combination of optimization problems in vehicle routing and scheduling.

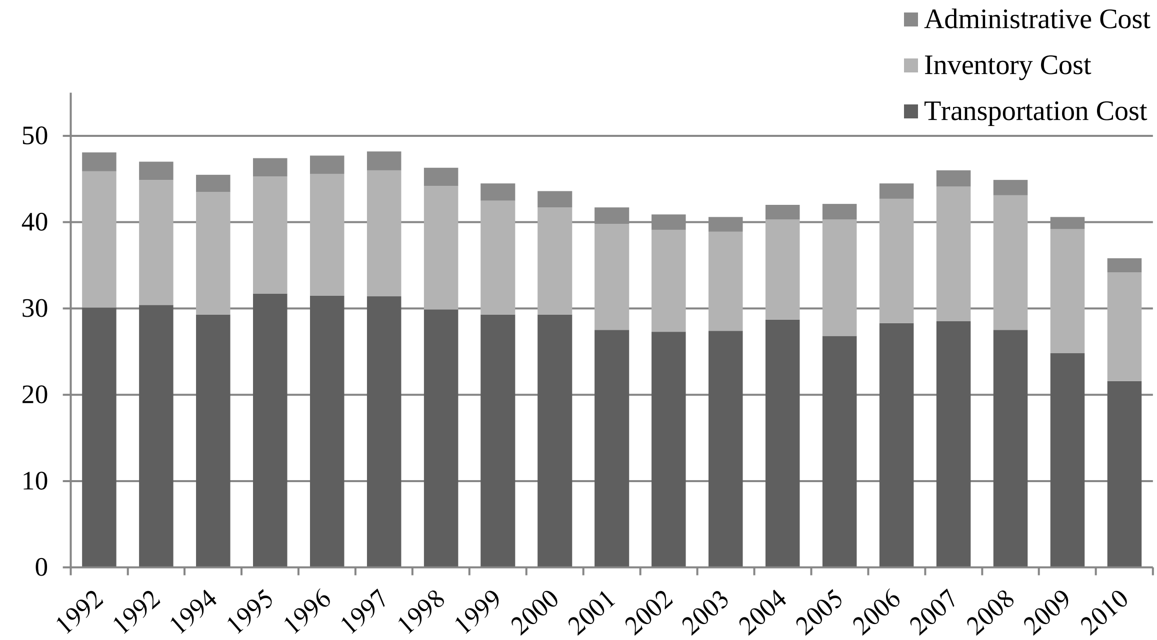

Figure 1 Breakdowns for Logistics Cost Between 1992 and 2010 [1]

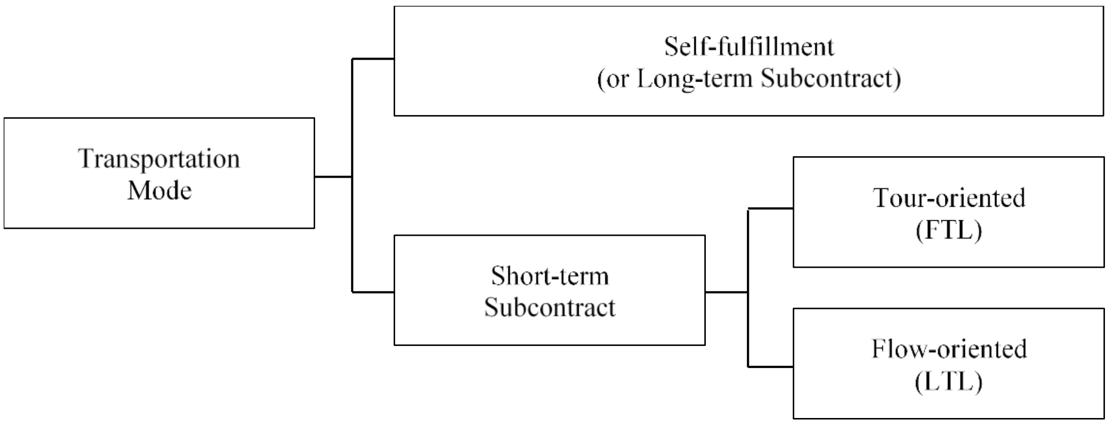

Figure 2 Transportation Modes

Table 1 Comparison of Transportation Modes

Subcontracting Mode		Characteristics			
		Fixed cost	Variable cost	Capacity	Operation time
Long-Term (Self-fulfillment)		Rental fee	Fuel	Yes	Yes
Short-Term	Tour-oriented	Tariff-based		No	Yes
	Flow-oriented	Tariff-based		No	No

2. Materials and methods

2.1 Subcontracting options

The first transportation type is self-fulfillment, which the company uses own trucks. It also includes long-term subcontracting, such as monthly contract of truck rental, which the company could perform the transportation planning in a similar way as the own vehicle fleet by signing long-term contracts with the subcontractors who provide up to an agreed number of vehicles. In this category, the vehicles are stationed in one of their depots, and fulfill pick-up and/or delivery requests with round routes.

The second type is tour-oriented short-term subcontracting which the subcontractors are involved for full truckload shipment (FTL). In this category, trucks are rented during specified short-term period T (e.g., T = 24 hours) to fulfill transportation requests with round routes, and are then returned at their original locations. Since the truck is rented within specific time period and has to be returned at the origin point, operation time constraints (OTC) are to be imposed. A rental fee is calculated separately for each route as regards the fleet size and the travel distance specified in tariff table. This tariff table provides a list of agreed fixed tariff rates under non-linear consideration of loads and lengths of the tours that the subcontracting company charges for its delivery services. The tariff rate per load travel is higher than the cost rate of the first transportation mode as it covers a part of the fixed costs of the subcontractor.

The third type is flow-oriented short-term subcontracting. In this category, transportation requests are fully outsourced to the external carriers so the forwarding companies are not responsible for the vehicle scheduling. As is the same with tour-oriented subcontracting, an outsourcing fee is extracted from the tariff table according to the corresponding amount of goods to be transported and length of the transportation, but the rate is higher than the tour-oriented type. This type is advantageous especially for transport requests with tight constraints. Another attractive feature of this mode is that there are many more sections of truckload and travel distance. Hence, it is appropriate to fulfill less-than-truckload (LTL) transportation requests that have the much smaller order quantity for the fleet capacity, yet are difficult to combine with other orders. Comparison of transportation modes is presented in table 1.

2.2 Solution methodology

The problem is to simultaneously determine customer requests to vehicles, number of vehicles, travel distance and travel time per route, and the corresponding sequence of serving customers for each vehicle so that the all customer demands are satisfied and overall transportation cost is minimized. Given delivery depots where trucks pickup demand orders within time windows, known locations, demands, time windows, and loading and unloading time of customers, tariff tables for both tour and flow-oriented subcontracting which specified capacity of vehicles and travel distances, customers' demand and travel distance cannot exceed section limit of truckload quantity and travel distance in tariff table, and vehicles must return to the origin within the time limit specified in rental condition for tour-oriented subcontracting type. The amount of payment for the transportation fee to the subcontractors is calculated by based on a fixed tariff rate per load and distance. The main objective is to construct a vehicle routing and scheduling with lowest possible fulfillment cost without violating any constraints. In this study, simulated annealing algorithm was selected as the basis for developing technique for the VRP with short-term subcontracting transportation mode, since it has been applied to a wide variety of highly complicated combinatorial optimization problems including the VRP and has been proved that it could solve difficult problems and generally gives an acceptable good solution in a relatively short time.

In this study, we generate the initial solution set with piston routes then apply standard SA procedure combined with local search to solve the VRP with short-term subcontracting problem. A random neighborhood structure which includes two types of trial moves, i.e. insert and swap, is used for improving the current solution by checking for best feasible positions of a customer in all routes. The insert move is carried out by randomly removing a customer from one route and putting it into another route. The flowchart showing the implementation of VRP with subcontracting using SA is shown in Figure 3.

3. Results

We have analyzed the forwarding company in Japan using the short-term subcontracting mode of transportation for its delivery operations. The company receives a varying number of orders from its customers each day and plans the shipment of these daily variations of volume of transportation requests on a monthly basis. In order to ensure that enough resources will be provided profitably for the fulfillment, the company has to make decision on the selection of requests whether to be performed by using the tour-oriented or the flow-oriented short-term subcontracting. The aim of this computational analysis is to point out that the proposed SA algorithm could generate solutions for the VRP with subcontracting transportation modes. A real-problem data set is applied for computational analysis. The company has distribution center located in Tosu to serve 44 customers located around Kyushu area. The depot has business hours from 7:20 a.m. to 1:20 p.m., and there is time window for each customer.

The data of total customer daily demand for one month is 3,088 requests which accounted for almost 2,300 tons. The tariff tables for both service of tour and flow-oriented are referred from the Ministry of Land, Infrastructure, Transport and Tourism. Then a daily fulfillment plan for whole month is generated including the numbers of trucks required for both subcontracting modes and the routing for tour-oriented type using the SA heuristic. The number of vehicle used, total transportation distance and time, and total fulfillment cost of an initial state and after improvement are summarized and presented in table 2. The number of truck and total travel distance could be reduced around 24.5% and 8.9% respectively. The travel time of each route consists of the travel time between two stops and the loading/unloading time of each stop. The total travel time is improved 9.3% from the initial solution. The total cost could be reduced by 12.2%.

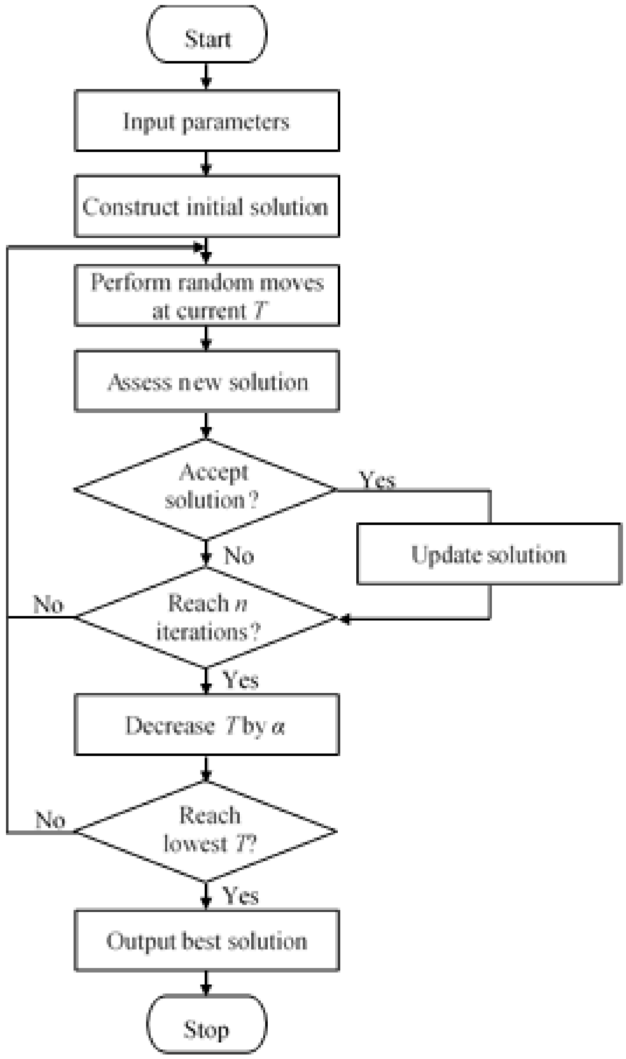

Figure 3 Flowchart of SA Implementation

Table 2 Computation Result

	No. of Vehicle	Total Distance (km)	Total Time (min)	Total Cost (¥)
Initial State	1,088	119,222	412,223	29,014,340
Total Resource Usage	821	108,631	373,955	25,472,510
- Tour-oriented	222	48,204	141,790	9,908,860
- Flow-oriented	599	60,427	232,165	15,563,650
%Improvement	24.5%	8.9%	9.3%	12.2%

4. Conclusions

This paper addressed an extended and more practical version of the VRP. We presented a practical complex situation of current business in the forwarding companies where an integrated transportation approach is used to fulfill the transportation requests. We proposed the simulated annealing approach for the process of constructing an entire fulfillment plan and the solution of combinatorial optimization problem in the VRP with short-term subcontracting mode with the objective to minimize the overall transportation delivery cost.

5. References

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