A New Supply Service Model for Retail Delivery Businesses

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**Abstract.** This study proposed a new delivery model that reduces both the company’s delivery cost and the customer’s stock cost, without any inconvenience to customers. Today, the retailing company offers red-carpet delivery services such as high-frequency and short lead-time delivery, leading to high operational costs and environmental burdens. So the transportation sector requires service companies to be environmentally friendly while maintaining delivery quality.

**Introduction**

As awareness of global environmental problems grows direct order retailers are increasingly being asked to find ways of contributing to reductions in greenhouse gas emissions. With the transportation sector responsible for about 7% of total CO\(_2\) emissions in Japan, improving the efficiency of transportation and delivery operations to reduce their environmental impacts is critical [1, 2]. Particularly, the mail order business, a steadily growing segment of the retail industry, had a 2008 delivery-cost-to-sales ratio of about 12.9%, compared to 8% or less for other retail companies. Thus, there is much room for improving efficiency [3]. Mail order firms have focused their efforts on high-quality logistics services such as shorter lead-time delivery and just-in-time delivery, along with high-frequency deliveries. However, consumers are becoming increasingly aware that such delivery practices will raise levels of greenhouse gas emissions. Thus, mail order firms should reconsider their conventional practice of prioritizing customer convenience via high-frequency deliveries and create a new delivery service model.

Mail order firms, which can acquire customer information more easily than other businesses, analyze their customers’ purchasing behaviors using data mining systems. Ishigaki et al. [4] created a consumer action model using large-scale commodity purchasing history data and customer questionnaire data for a general mail order company. For optimum delivery routing, studied as the vehicle routing problem (VRP), various studies have examined limited loading capacities, limited time frames, and other conditions [5–10]. The abovementioned studies attempted to optimize the VRP and the optimum stock problem within a single company. Few studies have evaluated the economy and convenience of both customers and mail order companies in designing a specific delivery service model.

This study uses a scientific method to create a delivery service model capable of meeting the following three requirements:

- Providing customers with a stock management service for commodities delivered at high frequencies in order to reduce customers’ stock management and order/acceptance costs
- Avoiding compromising customers’ convenience, allowing them to obtain as much as they require when they need it.
- Optimizing the delivery operations of mail order companies to reduce their delivery costs.

**In New Delivery Model for Daily Consumable Supplies**

A periodic supply service is offered to customers for specific commodities. It includes a stock management service, to maintain customers’ stocks at optimum levels, in addition to the conventional delivery service.
The periodic supply service is expected to provide three benefits to customers. First, stock costs can be reduced by maintaining stocks at optimum levels. Second, the labor costs of ordering and accepting commodities can be reduced by avoiding wasteful orders. Third, less frequent deliveries will help mitigate their impacts on the environment and thus assist in meeting the social requirement for environmentally friendly operations. Promoting a periodic supply service to customers will also provide mail order companies with a direct benefit by reducing their delivery costs. In addition, delivery dates and delivery timeframes will become available to delivery staff in advance, enabling them to plan optimum deliveries. Thus, a Win-Win relationship will be created between customers and mail order companies.

To ensure the smooth execution of the periodic supply service, delivery plans drawn up by a scientific method should be provided to delivery vehicle drivers in a form easy for them to execute. We thus constructed a periodic supply service execution support system as a tool for supporting smooth service execution. This system consists mainly of (A) a milk-run delivery planning system and (B) a delivery plan modification system.

The milk-run delivery planning system develops the initial delivery plans as a basis for daily operations. It develops delivery instructions in accordance with the initial delivery plans in order to help smooth their operation.

The delivery instructions provide information such as delivery routes for delivery staff to follow, estimated delivery quantities for each customer, and other notes relevant for each customer. The delivery plan modification system modifies the delivery plans according to the latest information collected by delivery vehicle drivers for customer’s stock variations. Figure 1 provides an overview of the execution support system.

Mail order companies calculate the optimum delivery frequencies for each customer with the milk-run delivery planning system in order to offer each one a periodic supply service. Commodities subject to a periodic supply service are to be periodically consumed and frequently delivered. Once customers accept an offer of a periodic supply service and once the customers subject to a service are decided, System (A) is continuously operated to develop a specific delivery plan for each customer. Basic delivery plans are quarterly. Delivery schedules, on either weekly or biweekly bases, are output as delivery instructions. Delivery staff members execute periodic delivery services in accordance with the delivery instructions and collect information on customers’ latest purchasing trends. They also visually check customers’ stocks at the end of each day, and check whether they have any temporary demands for conferences or other events. The data collected by delivery staff are input into the database and fed back into the delivery plans for the following day(s). As delivery staff gain experience and accumulate more data, the system becomes better able to work out each customer’s purchasing policy, demand variations, and possible temporary demands for various events: the more the system is used, the more intelligent it becomes.
Execution Support System

In developing delivery plans for customers with this system, customers’ stocks are first estimated before a stock management service is offered to them. Actually, the proposed service model requires that customers’ stock estimation become more accurate by having delivery staff collect actual data on the stocks. However, we set the assumption that their daily consumption will remain constant for a fixed period of time. It is required to solve the following two problems: (1) deciding on which customers will be subject to the service and their delivery frequencies and (2) deciding the delivery routes. As one decision influences the other, it is usually difficult to optimize both problems at the same time.

We have solved both problems in the following way: First we determine which customers will be subject to the service and their delivery frequencies. For their delivery routes, certain fixed initial values are set. Once the customers subject to the service and their delivery frequencies are decided, we recalculate their optimum delivery routes. And we compare the initial parameters with those of the newly output delivery routes. If any large discrepancies in parameters appear between them, we consider the initial values as unrealistic, replace them by inputting the latest output data, and then repeat the above steps to approach the optimized delivery route. This approach is shown in Figure 2. Figure 3 is a flowchart of a milk-run delivery planning system.

Step 1. Develop database and set parameters

In this step, we initially develop purchase history database for each customer by aggregating the shipping data. The database includes two tables. The one is shown as Table 1 which element is consolidated by each customer. It consists of the following four elements of a customer; total quantities of purchases, number of purchasing day, the average daily consumption during a quarter year, and geographic data of address for delivery. Secondly we set following initial values on delivery routes. Maximum number of customers which can be delivered with one tuck in one day and Number of visits to customers in a quarter.

Step 2. Calculate optimum purchasing frequencies for consumptions

For each customer, an optimum purchasing frequency T, which refers to the number of deliveries that would minimize the customers’ total purchasing cost is calculated. Total purchasing costs Call are defined in Equation (1).

\[
C_{\text{all}} = C_{\text{stock}} + C_{\text{deti}} + C_{\text{order}} + C_{\text{env}}
\]

Stock cost \(C_{\text{stock}}\) is defined as the space rent cost for the maximum storage space used for stocking the commodities. Maximum storage space is calculated by total volume of purchasing within a quarter year V by the number of visit times t. As shown in Equation (2) and Equation (3).

\[
C_{\text{stock}} = N_{\text{max}} \times S_1 \times P_{\text{ground}} \times d
\]

\[
N_{\text{max}} : \text{Maximum number of units for stock keeping space on user’s site [units]}
\]
$S_1$: Area required for stock keeping per one unit per day [m$^2$]

$P_{ground}$: Daily rent fee per m$^2$ [JPY/(m$^2$ * day)]

d: days of sampling duration [day]

$N_{max} = \frac{V}{t} + N_{safe}$  \hspace{1cm} (3)

$V$: Total volume of ordering units within a quarter [unit]

$N_{safe}$: Number of units of safety stock [units]

t: the number of delivery times [times]

Delivery cost $C_{deli}$ is calculated by multiplying the average delivery cost of one delivery $P_{track}$ by t. As shown in Equation (4),

$C_{deli} = \frac{P_{track}}{m} \times t$  \hspace{1cm} (4)

$P_{track}$: Track usage charge [JPY/(unit * day)]

$m$: The number of customers [unit * day]

Order acceptance cost $C_{order}$ is calculated by multiplying the labor cost for average order acceptance hours by the number of delivery times (or order times) as shown below.

$C_{order} = time_{order} \times P_{staff} \times t$  \hspace{1cm} (5)

$P_{staff}$: Labor cost per hour [JPY/hour]

Environmental impacts $C_{env}$ is obtained by Equation (6)

$A_{co2}$ is obtained from the guideline of Agency for Natural Resources[25].

$C_{env} = L \times \frac{t}{\sum_{Customer}C_{Customer}} + f \times A_{co2}$  \hspace{1cm} (6)

$L$: Drive range distance of a track [km]

$f$: Fuel cost per l [km/l]

$A_{co2}$: Coefficient for converting the CO$_2$ to JPN [JPY/m$^3$]

$C_{deli}$ and $C_{env}$ are consists of two parts; one is proportional to t and the other is constant member. $C_{stock}$ is also consists of two members; one is proportional to $V/t$ and the other is constant. Equation (1) can be expressed as equation (7) by consolidated to $V, t$ with using coefficient $\alpha, \beta, \gamma$.

$C_{all} = \alpha \frac{V}{t} + \beta t + \gamma$  \hspace{1cm} (7)

Figure 4 illustrates the relationships among total cost $C_{all}$, stock cost $C_{stock}$, order cost $C_{order}$, delivery cost $C_{deli}$, and delivery times t, where V is 5,000. $C_{all}$ is represented by a downward projecting curve, by which we can easily determine the number of delivery time t that will incur the minimum $C_{all}$.

**Step 3.** Decide which customers will be subject to the service by optimum purchasing frequencies
We divided customers into groups by the calculated optimum purchasing frequencies. Customers are classified by the size of total purchases within a certain period of time. Customers are classified into three groups using the following thresholds:

- **Level 1:** quantities that require one or more delivery times a week.
- **Level 2:** quantities that require one or more delivery times two weeks and less than one times a week.
- **Level 3:** except above.

Customers subject to the service are selected according to their purchasing frequencies. The purchases of the selected customers are delivered at a frequency that will incur the minimum total cost among the three delivery frequencies.

**Step 4.** Decide the delivery routes by the customers’ geographic location. We develop delivery routes that will ensure optimum deliveries to the customer’s subject to the service. As the customers’ stock costs have already been optimized, we need merely consider the optimum deliveries in developing delivery routes to them, which is an application problem of VRP. We solve the issue as follows. Allot M units of the customer to the Track of the N unit, and determine the sequence of visiting customers for weekly route. M is given initial value with delivery times, and N is calculated at Step 3. The VRP requires exponentially increasing calculation times to search a solution when the number of customers is large.

It is important to provide a certain combination of M and N within a practical calculating time. In addition to that, the main uncertainty of delivery efficiency is traffic jam, so it is not critical to dare search for optimum distance of delivery routes. We adopted a quasi-optimum solution for this step. In actual delivery operations, vehicle drivers change their own delivery routes according to the traffic congestion. Quasi-optimum delivery routes are sufficient for delivery vehicle drivers because they are familiar with road networks and can select their own delivery routes according to their circumstances.

Genetic algorithm optimization has been applied in supply chain system and vehicle routing problem, then we use genetic algorithm to search for the solution. In planning delivery routes, each delivery vehicle should have a loading rate of \((100-a)\)% so that it can respond flexibly to customers’ demand variations. \(a\) is a demand variation buffer. The search results are output as several delivery routes for weekly or biweekly execution according to the input data. Plural delivery routes are allocated to customers receiving two deliveries a week.

**Conclusion**

This study had analyzed customer purchase history of photocopier paper by mail order, clarified problems in customer’s purchasing behaviors and delivery process. Further provided a logistics design system for new service model which is adaptive to each customer’s purchasing activities. Based on customer’s supply and demand this system determines frequency and volume of customer’s procurement, and it provides the combination of logistics routes under real condition. The logistics design is verified with the real cost condition.

**References**


