Feasible Studies of Assembling Service of Knocked-down Furniture in Delivery Business

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Abstract
In Japan, the Internet mail-order services for office equipment are available and prevalent. Many sets of furniture and fixture in offices are selling well and some of them that need to be assembled are called as knocked-down furniture. A delivery of knocked-down furniture is cumbersome because it needs an additional assembling work to decline the delivery efficiency. Furthermore the violent demand fluctuations of delivery order through the Internet make the delivery problem more difficult. This paper discusses the efficiency and cost of delivery for knocked-down furniture with violent demand fluctuations. The efficient assembling operation in delivery service according to the properties of a set of knocked-down furniture is proposed and examined by computer simulations based on the real data from one actual Internet mail-order services company.

Keywords: Delivery service, Demand fluctuation, Cost calculation, Discrete simulation, Vehicle routing and dispatching problem.

1 INTRODUCTION

Recent years, the Internet mail-order services have been rapidly growing in consumer products. In Japan, the Internet mail-order services for office equipment are available and prevalent. Many sets of furniture and fixture in offices are selling well and some of them that need to be assembled are called as knocked-down furniture such as a desk, a chair, a rack, a shelf and so on. A delivery of knocked-down furniture is cumbersome because it needs an additional assembling work to decline the delivery efficiency. Furthermore the violent demand fluctuations of delivery order through the Internet make the delivery problem more difficult [1].

This paper discusses the efficiency and cost of delivery for knocked-down furniture with violent demand fluctuations. The real data offered from an actual Internet mail-order service company is analyzed for improvement of delivery operation. And the delivery simulator is implemented to examine the details of delivery based on the real data. Then the efficient assembling operation in delivery service according to the properties of a set of knocked-down furniture is proposed and examined by the delivery simulations.

2 DELIVERY BUSIBNESS OF KNOCKED-DOWN FURNITURE

2.1 An electric commerce company

Japan has a larger population and smaller land area than almost other countries in the world. Due to high population density, almost retail shops, which are nationally-known stores or local stores, have the only small trading area and the retail delivery services had not been highly developed in Japan. Around 2000 the situation changed after many companies had started new electric commerce businesses. Purchasing various kinds of products via the Internet has been widely prevalent and this has supported the rapid growth of retail delivery service.

About 20 years ago, a certain company (hereinafter called as Company A) started the retail business dealing with office equipment and supplies. The Internet and information technology have supported the rapid growth of the Company A. The company has the large site of the Internet where customers can search and purchase more than 260,000 items, and has some distribution-center warehouse for delivery the items now. The Company A nevertheless does not own a delivering truck and entrust all the delivering works to other delivering companies. That is to say, the business model of the Company A is very similar to the well-known American electric commerce company *Amazon.com, Inc*.

A set of knocked-down furniture and fixtures, which is also call as ready-to-assemble furniture for offices, is the line of business of the Company A. For the customer of Company A, the assembling of knocked-down furniture before installation is in charge of the deliverer. The Company A has a plan to own delivering trucks in the future, so the company has concerns the delivering items, especially knocked-down furniture.

For this research, the three kinds of dataset are offered from the Company A. Those datasets are the transaction data, the master data of items and the master data of customers. The transaction data is the order transaction data on purchase during one year in almost all the 23 wards of Tokyo Metropolitan city. The master data of items is the dataset of all items that the Company A. The master data of items include the data about standard time of assembling, packed size before assembling and finished size after assembling of the every sets of knocked-down furniture. The master data of customers is the dataset of all the Company A’s customers in the region. The some discussions made in this paper are based on the data.

2.2 Approach of assembling service

There are two ways to deliver a set of knocked-down furniture to customers: one is assembling before the delivery and the other is assembling at the delivery destination. The former is named as pre-assembly way and the latter as post-assembly way hereinafter.

The each ways has some advantages and disadvantages. The major advantage of pre-assembly way is that it is possible to deliver more customers by one truck than that in post-assembly way because it doesn’t need assembling works at destinations. Furthermore the assembling time in pre-assembly way generally needs shorter than the one in post-assembly way, when assembling the same set of knocked-down furniture. The reason of higher assembling efficiency in the pre-assembly way is believed that the working conditions for assembling at the company's workshops are much better than the customers' offices. Nevertheless, the major disadvantage of pre-assembly way is that it needs more capacity in a delivering truck than that of post-assembly way because an assembled set of knocked-down furniture on board are larger than packed one. The major advantage and disadvantage of post-assembly way is the opposite of pre-assembly way. The major advantage of post-assembly way is that it needs less capacity in a delivering truck than that of pre-assembly way because the assembling sets of knocked-down furniture on board are larger than packed one. Nevertheless, the major disadvantage of post-assembly way is that it can deliver less customers by one truck than that in pre-assembly way because the it needs assembling works at destinations.

At present almost all the sets knocked-down furniture are assembled in the post-assembly way by the entrusted delivery companies.

3 DATA ANALYSIS

Figure 1 shows the locations of all the customers in the data from the Company A. The plotted area is covered several wards in the Tokyo Metropolitan area. The each dot indicates a customer. The each dot is colored with four colors that indicate the annual purchase amounts of the customers.

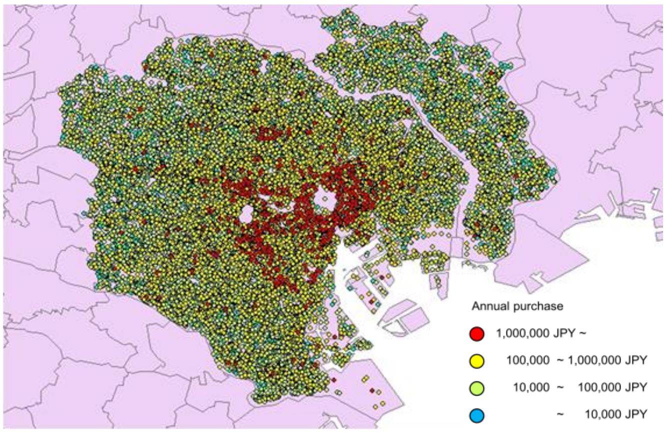

Figure 1: Locations of customers in Tokyo area

Figure 2 shows the daily deliver results of the items in the office furniture category in a certain ward of the Tokyo Metropolitan area (hereinafter called as Area B) during a certain year. The Area B is a typical sales area in Tokyo Metropolitan city. The Company A has 4,733 customers out of approximately 25 hundreds business offices in the Area B. Therefore the dissemination ratio of the Company A in the Area B is 20 percentages, and the ratio is very close to the average of the Tokyo Metropolitan area. The horizontal axis of the diagram indicates the day in a year. The vertical axis of the diagram indicates the delivered volume that is presented as the Japanese volume unit. The Japanese volume unit system is conventionally used in transport industry in Japan, so the unit is also used in the paper. The one unit equals $2.8 \times 10^{-2} m^3$, which is based on the traditional Japanese measuring system. The violent fluctuation of the daily delivery volume can be found in the Figure 2.

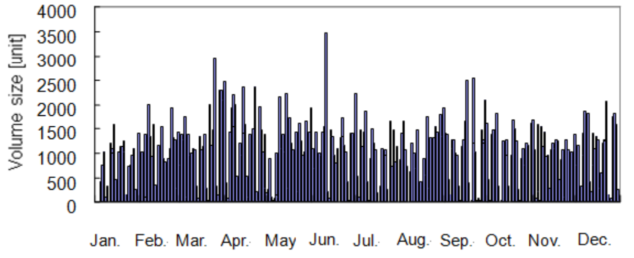

Figure 2: Delivery results of Area B

Figure 3 shows the bubble chart of all the sets of knocked-down furniture that the Company A deals. The each plotted bubble indicates a subcategory in the office furniture category, which is according to the Company A's code of item classifications. The bubble size depicts the number of sets in the subcategory. The horizontal axis of the chart indicates the size ratio between before and after assembly. The vertical axis of the diagram indicates the standard assembling time of the typical set in the subcategory. Some subcategories of office furniture need more than 30 minutes to assembly, and some other subcategories need almost no time to assemble.

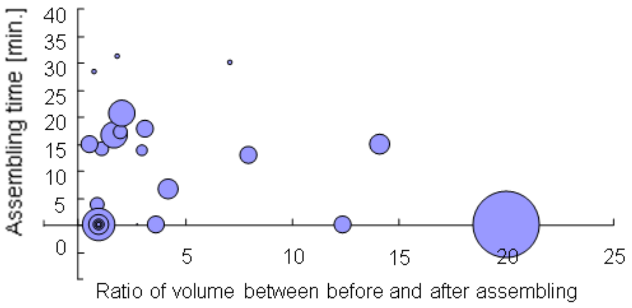

Figure 3: Properties of knocked-down furniture (subcategory base)

Figure 4 shows the diagram of properties of all the sets of the office furniture for delivery. The each plotted dot indicates a set of furniture. The horizontal axis of the diagram indicates the size difference between before and after assembly. The size difference is presented as the Japanese volume unit. The vertical axis of the diagram indicates the standard assembling time. The sets of knocked-down furniture in the right lower zone are appropriate for post-assembly way, because they need less assembly time and less transport capacity. The sets in the left upper zone are appropriate for pre-assembly way, because they need more assembly time but the necessary transport capacity remains the same.

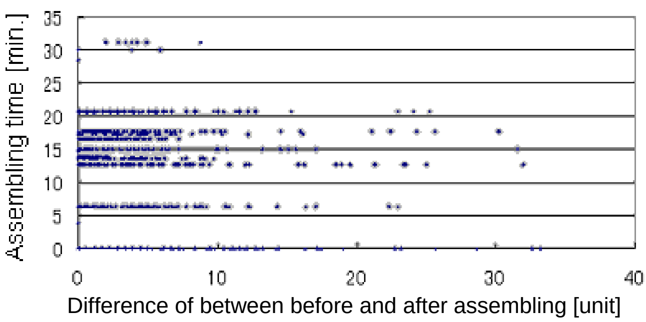

Figure 4: Properties of knocked-down furniture (set base)

The cost of entrusting delivery of the Company A consists of the transportation cost and the assembling cost. The transportation cost is either 285 JPY per volume unit or 58,500 JPY/day per truck. The assembling cost is 73.5 JPY per minute. The costs are the average figures from the survey interviews of the Company A, and the reason why the average figure is used is that the actual costs slightly differ depending on the entrusted companies in their contracts.

4 SIMULATIOM SYSTEM

4.1 Assumptions of case

The delivery operations are modeled and simulated to find ways to cut the costs using the transaction data of the first half of the year in the Area B. For simplicity, some assumptions are introduced as below.

Assumptions of delivery jobs

A delivery truck starts the distribution center, visits each customers of the day and returns the center after finishing all deliveries. The truck visits the same customer only once and never returns to the center while delivering in one day.

The working time for delivery consists traveling time, unloading time and assembling time at destinations. The loading time into a truck at the distribution center is neglected. The traveling time is determined by the delivery route distance and the constant traveling speed 15 kilometers per hour [2]. Traffic jams on the route and other detailed conditions are not considered. The unloading time includes not only unloading time itself from the truck but also moving time from the parking area to the customer's address. The unloading time at one destination is always the same, ten minutes, which is near average figure in the field surveys of the Company A.

All the trucks have the same carrying capacity of 400 Japanese volume units, which is commonly size of delivery trucks used in Japan.

Assumptions of cost calculation

If the Company A owns a delivery truck and employs drivers, the costs are given as follows. The depreciation expense per one truck is 4,110 JPY (Japanese yen) per day, which is calculated from the price for a new vehicle of 15 million JPY, and its amortization period of ten years. The fuel charge of the trucks is 30 JPY/km, which is calculated from the price of light diesel oil of 150 JPY/liter, and the gas mileage of five kilometer per liter. The labor cost for a delivering truck is 30,000 JPY/day for two workers who are a driver and a delivery assistant. And the labor cost is treated as the fixed rate whether the drivers work overtime or not in this paper.

When entrusting delivery labor, the transportation cost is either 285 JPY per volume unit or 58,500 JPY/day per truck, and the assembling cost is 73.5 JPY per minute as described in the Chapter 3.

If the pre-assembly method is adopted in the delivery, the assembling work is assigned to the workers at the distribution center. Accordingly the assembling time is not added to the working time for delivery but the assembling cost is added on the basis of 73.5 JPY per minute in the pre-assembly method.

4.2 Algorithm

The number of day-to-day customers of delivery changes according to the number of purchase orders that the company can't control so the workloads of delivery changes every day. Therefore the number of necessary delivery trucks is calculated from the dataset of daily delivery orders, which include addresses of destination, distance of traveling, number of purchase orders, delivery packages and so on. The gradual approach is taken to determine the values of delivery variables.

First the maximum number of deliver destinations per truck n_{dest} is determined tentatively. The cost-minimum n_{dest} is determined after finishing some trials of the procedures described in this subsection.

Second the daily necessary number of delivery trucks for the Area B, n_{truck}, is determined from the number of daily delivery orders and n_{dest}.

Third the every delivery destinations are separated into groups according to the geographical proximity and then the groups of delivery destinations are assigned to each delivery trucks. The simple *k-means* clustering method is applied to group and assign the delivery destinations. In the clustering method, the number of trucks n_{truck} is regarded as the number of clusters k, and the each delivering truck is handled as the center of cluster.

Then the routing of assigned destinations for each truck is calculated by the 2-opt method [3]. The 2-opt method is a simple local search algorithm for solving the traveling salesman problem whose main idea is searching a better route for swapping. At the swapping procedure in the paper, the shortest routes can be selectively replaced because the shortest routes are found in the Delaunay edge calculated from the Voronoi diagram [4]. In the paper, the distance of route is approximately calculated from multiplying a length of Delaunay edge by a certain factor, not from the real distance of road.

Final the trial simulations run and then the results of each truck are obtained. After the trial and error approach of changing n_{dest}, the cost-minimum n_{dest} is selected to satisfy the two conditions: one is that the average of delivery time of all trucks is approximately eight hours a day and the other is that few truck works more than ten hours a day. The former condition indicates the standard working hours per day, and the latter condition indicates that the within two overtime hours for each truck is permitted per day.

The algorithm is coded by the programming language Java and implemented in the personal computer.

5 COMPUTER EXPERIMENTS

The optimum policy of delivery operations for knocked-down furniture is investigated in this paper. The demand fluctuations, in other words the daily workload of delivery changes depending on the number of orders and locations of delivery destinations, make the optimization more difficult. The some feasible policies for delivery operations are assessed by using of the daily data of delivery demand in the Area B during a half year.

5.1 Reference Case

Before trying of some options of delivery policy, the reference case is calculated. In the reference case, all the packages are delivered by the Company A's own trucks in the post-assembly way.

The cost-minimum n_{dest} is determined as eight from the results of trial simulations, changing n_{dest} from six to eleven destinations. The n_{dest} as eight is near number of approximately ten destinations, which is found by the fieldworks about the actual delivery cases of the post-assembly way in the two entrusted companies.

The results of the reference case are as fellows. The n_{dest} is eight destinations per truck a day, a total of 2,811 trucks and a total of 20,721 hours are necessary during this half year for delivery, and the average of loading ratio of all the delivering trucks is 12 percentages. The last loading ratio seems to be very low. The reason of low percentage is that the number of the delivering destinations is relatively few for truck capacity. But the actual loading ratio is approximately ten percentages that is found in the fieldworks of some cases of delivering only knocked-down furniture, so the both of calculated and the actual ratios are very similar. The total costs calculated from the simulation results are shown in Table 1. The cost of delivery by Company A's own trucks is found to be less expensive than the costs of entrusting delivery.

Table 1: Total costs in reference case

	Total cost [10^3 JPY]
Delivery all packages by the Company A own trucks	98,956
Entrusting delivery works to the others on basis of truck charter	217,942
Entrusting delivery works to the others on basis of package size unit	103,708

5.2 Improvement by hybrid assembling

As mentioned above in the Chapter 3, some sets of knocked-down furniture are more appropriate for post-assembly way than pre-assembly way, and the others are more appropriate for pre-assembly way than post-assembly way. Therefore the concept of thresholds that divide all the sets of knocked-down furniture into two groups, and each set are classified into either the pre-assembly group or the post-assembly group. In this subsection, the four cases of threshold are assessed as follows.

Case1: entrusting criterion

In the case1, the threshold is determined from the two entrusting costs: the transportation cost of 285 JPY per volume unit and the labor cost 58,500 JPY/day (=122 JPY/min.) per truck. The transportation cost of a set of knocked-down furniture is depending on the conveying volume unit, which is calculated from either packed before assembly or assembly finished. The assembling labor cost for the set of knocked-down furniture is depending on the assembling time. When the transportation cost is higher than the assembling labor cost, the set is classified into the post-assembly group. And when the transportation cost is lower than the assembling labor cost, the set is classified into the pre-assembly group.

Case2: in-house criterion

In the case2, the threshold is determined from the two delivery costs by Company A's own trucks described in the Subsection 5.1: the transportation cost of 80 JPY/unit (= 35,204 JPY / 400 unit per truck) and the labor cost 35,204 JPY/day (=88 JPY/min.) per truck. The transportation cost of a set of knocked-down furniture is depending on the conveying volume unit, which is calculated from either packed before assembly or assembly finished. The labor cost of the set is depending on the assembling time. When the transportation cost is higher than the assembling labor cost, the set is classified into the post-assembly group. And when the transportation cost is lower than the assembling labor cost, the set is classified into the pre-assembly group.

Case3: assembly emphasis in-house criterion

The case3 is a variation of the case2. All the conditions are the same to the case2 except the labor cost. The labor cost is up to double 176 JPY/minute, because the actual assembling time in the post-assembly way is often longer than the standard assembling time.

Case4: all in pre-assembly criterion

In the case4, all the sets of knocked-down furniture are assembled in the pre-assembly way.

The thresholds of the four cases are depicted in the Figure 5 and the results of the simulations are shown in the Table 2. The total cost of delivery in the pre-assembly way is less expensive than the one in the post-assembly way, which is the present delivery system. And the total delivery costs of the proposed hybrid approach of pre-assembly way and post-assembly way considering the properties of knocked-down furniture are less expensive than the one in the pre-assembly way.

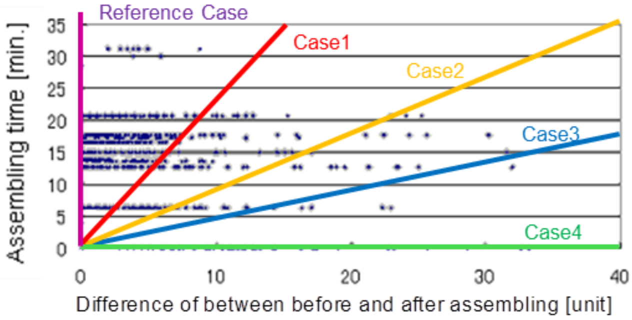

Figure 5: Criteria for assembly way

5.3 Improvement by hybrid entrusting

In the Subsection 5.2, all the delivering trucks are assumed to be owned by the Company A, but the cost of out-of-service trucks and out-of-service worker are not calculated when the delivery demands are small. In this Subsection, it is assumed that the Company A has the fleet of trucks, and the excess demands of deliver capacity are entrusted to the other delivery companies. The cost-minimum fleet size of the delivery is surveyed by simulations. By the way, the Case2 criterion in hybrid assembling in the Subsection 5.2, which is the cost-minimum criterion, is used for the delivery within the Company A's capacity in the simulation.

The results are shown in the Table 3. The cost-minimum fleet size of trucks is nine and the costs of the fleet size around nine are found to be very close.

6 CONCLUSION

In this paper, the assembling service in delivery business of knocked-down furniture with violent fluctuations of demands is discussed as fellows.

- Analysis of the actual delivery data of sets of knocked-down furniture
- Implementation of the delivery simulator based on the actual delivery
- Examination of cost improvement for delivery operations by simulation

Especially, the practicable course of action to minimize the total delivery cost is proposed, which is a choice between pre-assembly way and post-assembly way according to the properties of a set of knocked-down furniture.

Table 2: Results of hybird assembling cases

	Reference case (post-assembly)	Case1 (entrusting criterion)	Case2 (in-house criterion)	Case3 (assembly emphasis in-house)	Case4 (pre-assembly)
Maximum destinations per truck a day	8	18	24	26	26
Average of necessary trucks (total of trucks)	15.7 (2,811)	7.8 (1,394)	6.1 (1,086)	5.7 (1,021)	5.8 (1,039)
Average Distance of traveling [km/ truck per day] (total distance of traveling)	36.4 (102,289 km)	36.5 (51,029 km)	40.6 (44,114 km)	42.6 (43,460 km)	52.2km (54,212k m)
Average delivery time [hours/ truck per day] (total of delivery hours)	7.4 (20,721 h)	7.2 (10,065 h)	7.2 (7,865 h)	7.0 (7,101 h)	6.8 (7,051h)
Loading ratio [%]	12	28	41	50	84
Cost of pre-assembly [10^4 JPY]	—	2,766	3,456	3,858	4,202
Cost by owned truck [10^4 JPY]	9,896	4,919	3,837	3,614	3,707
Total cost [10^4 JPY]	9,896	7,685	7,293	7,472	7,908
Cost ratio	1.000	0.777	0.737	0.755	0.800

Table 3: Results of fleet size optimization

Fleet size of trucks	0	5	8	9	10	15	20	25	30
Cost of delivery in-service [10^4 JPY]	0	2122.5	3388.5	3810	4233	6330	8266.5	9232.5	9373.5
Cost of out-of-service [10^4 JPY]	0	3	13.5	16.5	21	51	238.5	1365	3298.5
Total cost of delivery [10^4 JPY]	0	2125.5	3402	3828	4252.5	6381	8508	10597.5	12672
Entrusting transportation cost [10^4 JPY]	4716	2100	1312.5	1102.5	921	279	19.5	0.15	0.15
Entrusting assembling cost [10^4 JPY]	4999.5	2770.5	1969.5	1747.5	1548	697.5	196.5	30	0.45
Total Entrusting cost [10^4 JPY]	9714	4870.5	3282	2850	2469	976.5	214.5	30	0.45
Total cost [10^4 JPY]	9714	6996	6683	6677	6720	7352	8721	10628	12672

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