STUDY ON LOCATION PLANNING OF DISTRIBUTION FACILITIES

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abstract: This study presents a methodology that utilizes available freight attraction rates which determines the reasonable number of public distribution centers, along with their locations and sizes by analyzing cost trade-off between transportation and facility costs of the distribution center. An interactive approach is used in which an optimization program, the METRO (MEta Truck Routing Optimizer), serves as a tool for investigating location decisions. The methodology is applied using Tokyo Metropolitan Region as a case. Since some of the commodities such as sand and gravel, and petroleum products are not suitable for distribution center usage, the study will only focus on sixteen selected basic consumer items.

1. INTRODUCTION

Changes in the industrial structure, diversified consumer demands, and advances in the field of technology have resulted to Just-in-Time (JIT) type of physical distribution which decreased truck loading rates and caused more frequent delivery of trucks. The development of public distribution centers is an attempt by the public sector to change the existing method of delivery to consolidated delivery in order to increase the loading factors of trucks. Distribution centers serve as a central facility for consolidating goods and concentrating the usage of heavy vehicles on expressways to prevent them from circulating in urban areas. The provision of public distribution centers has been proposed by the Japanese Ministry of Construction to reduce traffic congestion and improve the quality of the urban environment.

2. METHODOLOGY AND COST FORMULATION

The methodology has the following assumptions: 1) demand regions are represented as points and are assumed to be located at the centroids of each zone, 2) proportion of goods that utilizes public distribution centers is given and target goods can be handled simultaneously at distribution centers, 3) distribution centers are to be located in demand areas, and no restrictions on goods handling capacity, 4) Euclidean distances are used, and delivery from the facility to the customer is by direct transport, 5) inbound costs are excluded from the cost trade-off analysis since their sensitivity to the number of distribution centers is very limited.

Transport distances are calculated based on the results of the METRO (Fig. 2). Facility costs for each distribution center is given by: $F_c = [\{(C_l \times a_l)/(y_l \times d)\} + \{(C_b \times a_b) / (y_b \times d)\}] \times P^{\alpha}$ where C_l, C_b, are land and construction prices, respectively, a_l, a_b, are land and building areas, P is the number of distribution facilities, and α is the facility expansion factor which considers increase in land area as the number of facilities increase. Total cost can be expressed as:

$$Total\ Cost = \sum_{i=1}^{m} f_i\, c(x_j,x_i) \quad + \quad \sum_{j=1}^{p} F_{cj}\,(x_j)$$

where f_i is the delivery frequency, $c(x_j,x_i)$ is the delivery cost from the distribution center to the customer, F_{cj} is the facility cost, and x_j is the location of the distribution center.

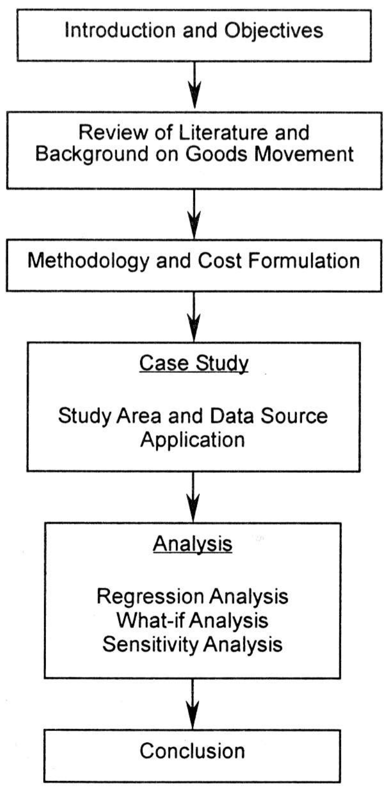

Figure 1 – Flowchart of the study

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3. CASE STUDY

A case study was done to locate public distribution centers in the Tokyo Metropolitan Region. Data was taken from the 1994 Goods Movement Survey of the Comprehensive Transport System Study for Tokyo Metropolitan Region. In the study, additional 12 regional distribution facilities are suggested to be built as a supplement to the five existing public distribution facilities located in Adachi, Itabashi, Keihin, Kasai and Koshigaya. Therefore, in total, the number of public distribution facilities planned for the Tokyo Metropolitan Region is 17.

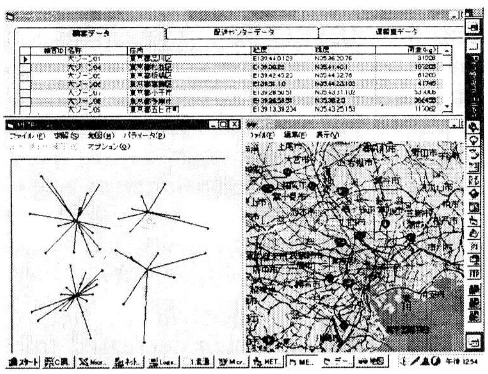

Figure 2 – Sample output of the METRO

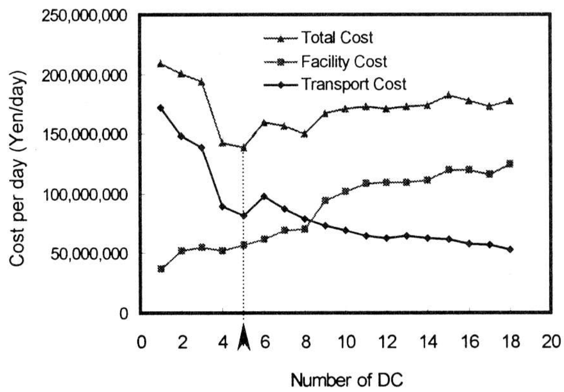

Figure 3 - Cost vs. number of distribution centers (Base case)

From the cost-trade-off analysis in Figure 3 for the base case (existing condition), it can be seen that the optimal number of distribution facilities is 5. However, cost comparison in Table 1 will reveal that the difference in the total cost between 4 facilities to 5 facilities is only 2.9%. Moreover, once there are more than 16 distribution facilities, there is little opportunity to reduce transportation cost. This means that adding more distribution facilities provide little added benefit. Figure 4 shows the locations and respective sizes when number of facilities is 5.

Table 1 - Comparison of costs and average travel distances as the number of DC increases (Base case)

No. of DC	Transport Cost	% change from optimal	Facility Cost	Total Cost	% change from optimal	Average Customer Travel Distance
1	172,084,941	224.9	36,913,848	208,998,788	51.1	52.0
2	148,543,658	180.5	52,019,876	200,563,534	45.0	40.0
3	138,939,857	162.3	55,406,838	194,346,695	40.5	35.0
4	89,663,848	69.3	52,730,360	142,394,208	**2.9**	27.5
5	81,303,310	53.5	57,021,634	138,324,943	**0.0**	24.5
6	98,132,573	85.3	61,522,301	159,654,874	15.4	22.5
7	87,375,075	65.0	69,556,345	156,931,420	13.5	20.0
8	79,289,438	49.7	70,761,601	150,051,039	8.5	19.0
9	73,457,546	38.7	94,124,117	167,581,663	21.2	18.0
10	69,753,032	31.7	101,540,112	171,293,145	23.8	16.5
11	64,977,736	22.7	108,456,987	173,434,722	25.4	15.5
12	62,447,759	17.9	109,037,955	171,485,714	24.0	14.5
13	64,318,416	21.4	108,961,615	173,280,032	25.3	14.5
14	62,816,659	18.6	110,891,237	173,707,896	25.6	13.5
15	61,920,127	16.9	120,157,324	182,077,451	31.6	13.0
16	57,694,188	8.9	119,890,730	177,584,918	28.4	12.0
17	56,715,629	7.1	116,406,559	173,122,188	25.2	12.0
18	52,965,004	0.0	124,335,185	177,300,189	28.2	10.5

Facility No.	Location: *Region*	Location: *City Name*	Size (ha)
1	Yokohama	Izumi	39.5
2	Saitama	Urawa	76.1
3	Saitama	Matsuyama	6.2
4	Chiba	Chuo	18.2
5	Ibaraki	Ushiku	9.8

Figure 4 – Location plan & sizes when DC = 5

The behavior of the transport and facility cost curve when plotted against the number of distribution centers can be approximated by ***Regression Analysis***. Figure 5 shows the estimated costs based on regression.

What-If Analysis and ***Sensitivity Analysis*** are done to evaluate alternative scenarios such as increase in loading factors due to consolidation at distribution centers, increase in the demand of consumers, and changes in parameter values. These are considered to understand its effect in the design of locating distribution centers.

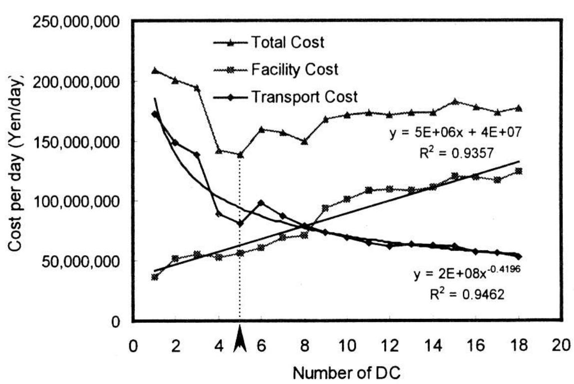

Figure 5 – Approximate regression lines

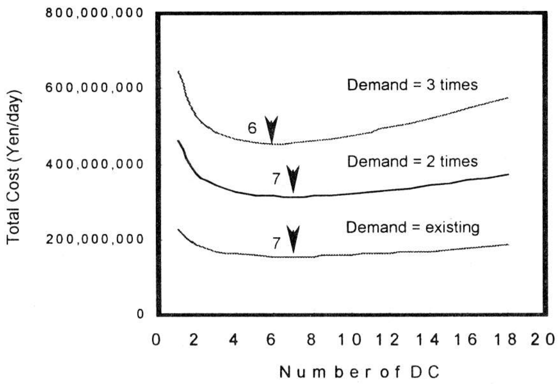

Figure 6 (a) – Sensitivity as demand increases

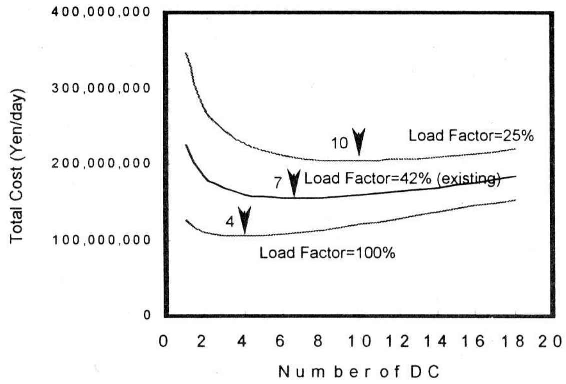

Figure 6 (b) – Sensitivity as load factor increases

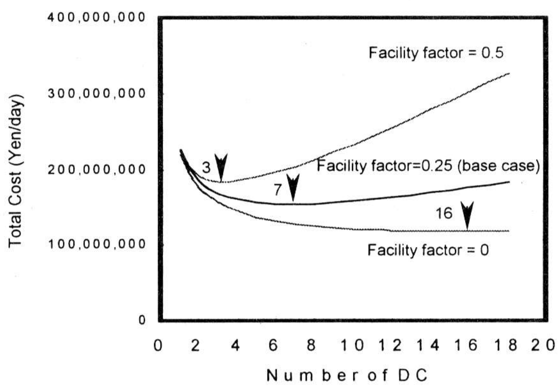

Figure 6 (c) - Sensitivity facility factor increases

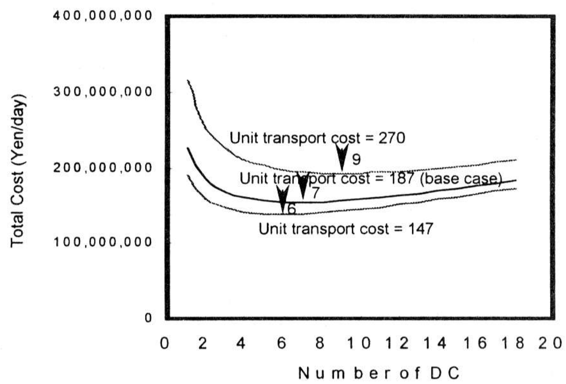

Figure 6 (d) – Sensitivity as unit transport cost increases

Figure 6 (a)-(d) shows the sensitivity of total cost to the number of distribution centers after estimating the behavior of the total cost by regression analysis. It is remarkable that the total cost function is very flat around its minimum. This implies that the solution can be an optimal range of values and not a single value alone. In Figure 6 (a), as the demand for distribution center increases, the optimal number of distribution centers remains nearly the same since both the transport and facility costs are affected almost on even terms by an increase in size. An increased demand will increase the amount of goods that will be handled at distribution centers thus expanding the facility area. Similarly, the amount of goods that needs to be transported will increase resulting to a higher transport cost. In Figure 6 (b), as truck load factors increase, the optimal number of facilities decreases. For a load factor of 100% which can be realized by freight consolidation, the optimal number of distribution centers decreases to only 4. However, for a load factor of only 25%, the optimal number of facilities increases to 10. This means that freight consolidation should be properly incorporated in the distribution center to efficiently control distribution costs. Sensitivity curves in Figure 6 (c) shows that as the facility factor increases, total cost becomes sensitive to the number of distribution centers. A higher facility factor will decrease the optimal number of distribution centers due to the steep change in facility cost. For a facility factor of zero, the optimal number of facilities is 16. This is reduced to 3 distribution centers when the facility factor is increased to 0.5. Figure 6 (d) shows that, as unit transport cost decreases, the number of distribution centers also decreases and the total cost becomes more sensitive around this optimum. Changes in travel speeds affect unit transport costs. An increase in travel speed from 15 kph to 20 kph results to lower unit transport costs thus decreasing the optimal number of distribution facilities from 7 to 6. Conversely, a decreased travel speed of 10 kph will result to higher unit transport cost thus increasing the optimal number of distribution centers to 9. The results can be viewed in this way, an increase in travel speed results to higher levels of customer service thus making the number of facilities minimal. However, with the decrease in travel speed, there will be a corresponding decrease in the amount of service level. Thus, to counter this effect additional distribution facilities are needed to maintain or improve existing customer service standards.

From the analysis, there is no distinct suitable number of distribution facilities and that this number changes as model parameter values changes. However, it is clarified that as the number of distribution facility increases to 16, there is little opportunity to reduce transportation cost and that adding more distribution facilities provide little added benefit. Thus, it can be said that the maximum number of distribution facilities should not be greater than 16. The benefit of supplying the maximum number of facilities is its certainty to increase customer service levels as reflected by a reduced travel distance from the distribution center to the customer. As the need to deliver goods to the right place, at the right time and in the desired condition becomes more and more important due to Just-in-Time and other customer requirements, the provision of 16 distribution facilities may be justified to improve customer service standards. Therefore, the result of this study more or less corresponds to the recommended number of facilities in the 1994 Comprehensive Transport System Study for Tokyo Metropolitan Region of 17 distribution facilities. Figure 7 shows the location of the proposed sixteen distribution facilities.

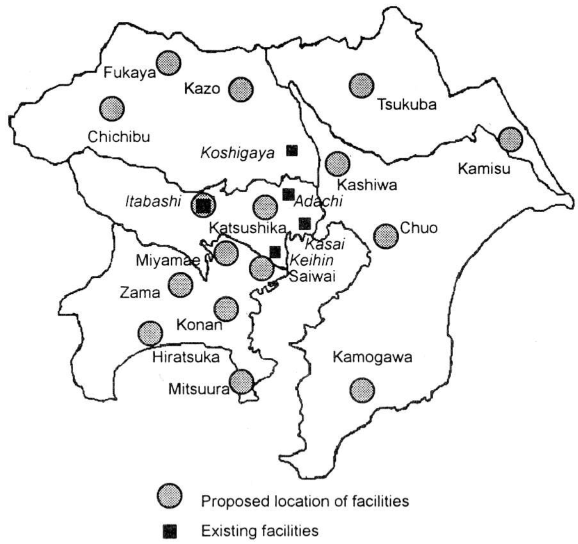

Figure 7 – Location of proposed facilities

4. CONCLUSION

The study discussed the actual utilization of the procedure in urban planning. Given a data set obtained from the Goods Movement Survey of Tokyo, the study was able to provide suitable locations for new public distribution centers that would minimize transport and facility costs. The most significant requirement of the location model is that it identifies sensible facility locations. As long as the locations are adequately dispersed far apart and serve customers within a reasonable distance or time, transportation cost will be approximately the same. On the contrary, the combined effect of taxes, local labor, and zoning factors which are not easily incorporated into facility location models is so huge that they are extremely sensitive to small changes in facility locations. Further improvement can be done by incorporating actual transportation links which consider existent road traffic conditions since suitable sites for distribution facilities are those locations near expressways and interchanges. It should be kept in mind that the results of the study are merely a guide to urban planning decision making. Nevertheless, the study can provide good initial solution to start a detailed analysis of a locational decision and compare and evaluate alternative distribution facility sites. Developing countries that are experiencing numerous problems due to inefficient goods movement may benefit from the study by incorporating distribution center planning to their urban transportation plans.

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