AN ANALYSIS ON THE DISTRIBUTION CHANNEL OF CONSUMPTION GOODS AND EFFECT OF COOPERATIVE PICKUP AND DELIVERY SERVICE

Yoji TAKAHASHI
Professor
Dept. of Information Eng. & Logistics
Tokyo University of Mercantile Marine
Etchujima, Koto-ku, Tokyo #135, Japan
Fax:+81-3-5245-7366

Tetsuro HYODO
Associate Professor
Dept. of Information Eng. & Logistics
Tokyo University of Mercantile Marine
Etchujima, Koto-ku, Tokyo #135, Japan
Fax:+81-3-5245-7386

Hirohito KUSE
Professor
Dept. of Information Eng. & Logistics
Tokyo University of Mercantile Marine
Etchujima, Koto-ku, Tokyo #135, Japan
Fax:+81-3-5245-7369

abstract: This study aims to suggest a methodology to evaluate the effect of the cooperative pickup and delivery service. The concept of distribution channels is introduced and an empirical study using actual goods movement survey data is examined. Finally the possibility of the cooperative pickup and delivery with distribution business centers (DBCs) is discussed.

1. INTRODUCTION

Goods movement is one of the most essential activities in urban areas as a part of commercial transactions. In that respect, cooperative pickup and delivery service could be effective as a means of decreasing truck traffic which causes serious traffic congestion and air pollution in urban areas.

This paper aims to introduce the situation of goods movement and traffic problem in Tokyo so as to show the importance of analyses of goods movement (Chapter-2). In Chapter-3 and 4, we focus on the distribution channels that are one of the important attributes of goods movement for cooperative pickup and delivery. Various distribution channels of comsumer goods are analyzed by type of industry and facility in the Tokyo Metropolitan area. Moreover, an empirical analysis of the efficiency of spatial arrangement in the distribution business centers (DBCs) is studied. Finally the role of the DBCs for cooperative pickup and delivery is examined.

2. GOODS MOVEMENT AND TRAFFIC PROBLEMS IN TOKYO METROPOLITAN AREA

2.1 Characteristics of freight transportation and traffic service in Japan

By 1990, there were 35.4 million passenger cars and 22.27 million trucks. Though the number of trucks is only one-third of the total, the share of trucks in [vehicles × kilometers] has exceeded one half of the total (Fig.-1).
Although traffic conditions in urban areas have worsened largely due to the increased number of automobiles, this problem has been exacerbated by additional truck pickup and delivery services. Traveling speed in urban areas has considerably decreased; 30 km/h in

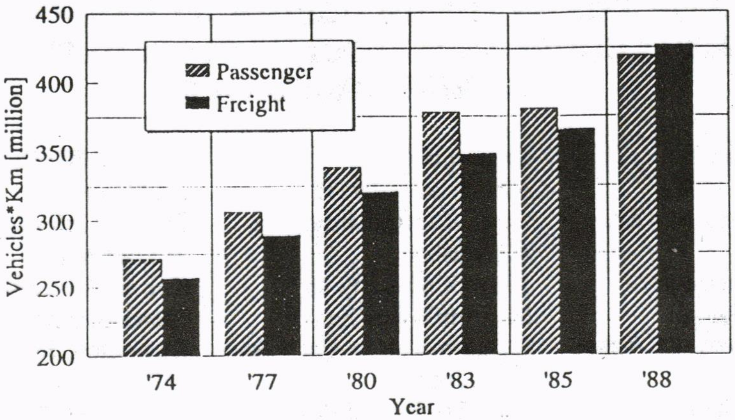

Fig.-1 Average vehicle × Km of passenger car & truck

built-up areas and only 20 km/h in densely inhabited areas (Fig.-2).

Since constructing roads in urban areas requires considerable amounts of time and funds, the efficiency of truck services will definitely decrease in the future if the problem of traffic congestion is not resolved.

As a consequence of economic growth and a rise in income, consumers' demand has become more sophisticated and diverse than ever. Because of increased popularity of the JIT (Just-In-Time) type delivery, there is a corresponding demand for transportation by delivery services. As a result, forwarders and carriers have faced a remarkable increase of transportation cost and have tried to construct logistics centers to cope with it (Fig.-3).

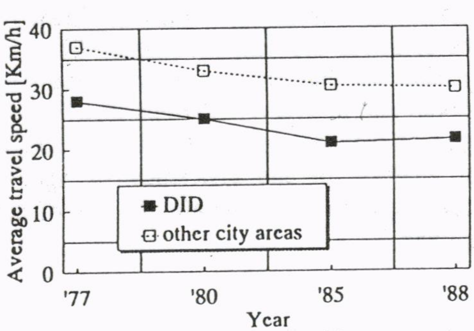

Fig.-2 Average speed in D.I.D. and other areas

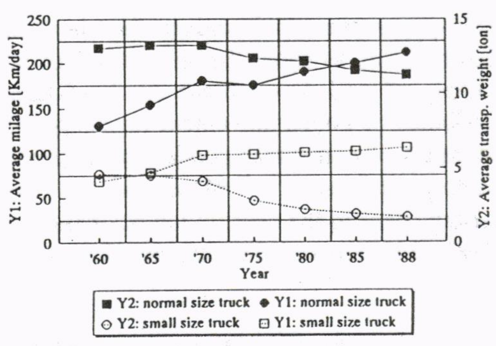

Fig.-3 Average mileage and transp. weight of small & normal size truck

2.2 The concept and role of Distribution Business Center (DBC)

The rapid growth of the Japanese economy started in the mid 1950's and resulted in concentrations of population and industries into major cities, like Tokyo and Osaka. In addition to this, motorization has been causing serious urban problems such as traffic congestion, air pollution and traffic accidents. In particular, trucks are troublesome as they account for one half of the vehicles on the road, and truck trips are mainly generated by wholesalers, warehouses, and carriers usually located in urban areas. These logistics business, which are classified as small business, can hardly relocate their facilities to enlarge and modernize because of shortages of funds. In order to solve these problems, the concept of Distribution Business Centers (DBCs) was created in the beginning of the 1960's and the Act concerning Development of the Distribution Business District was enacted in 1966. Since then, Distribution Business Centers (DBCs) have been developed as main logistics facilities in the districts. The significance of DBCs in urban areas is summarized as follows:

1) Logistics facilities, which are relocated in the outskirts of the cities, contribute to decrease traffic in built up areas.
2) The sites where logistics facilities used to be located can be utilized in other ways.
3) DBCs developed in the outskirts of the cities can function as new city cores.
4) Modernization of the logistics systems and facilities, together with the cooperation of small enterprises, can be achieved in the process of relocation.

As traffic problems in built up areas of major cities are serious, DBCs should be arranged in the outskirts of built up areas so that they can cover different service areas under better traffic conditions. Consequently, DBCs should be located in sites where we can easily access the interchanges of highway networks, as well as to harbors and airports. DBCs, which have been developed in the public sector and are based on the master plans, has become more important for the truck service. The concept and role of DBCs is shown by Fig.-4.

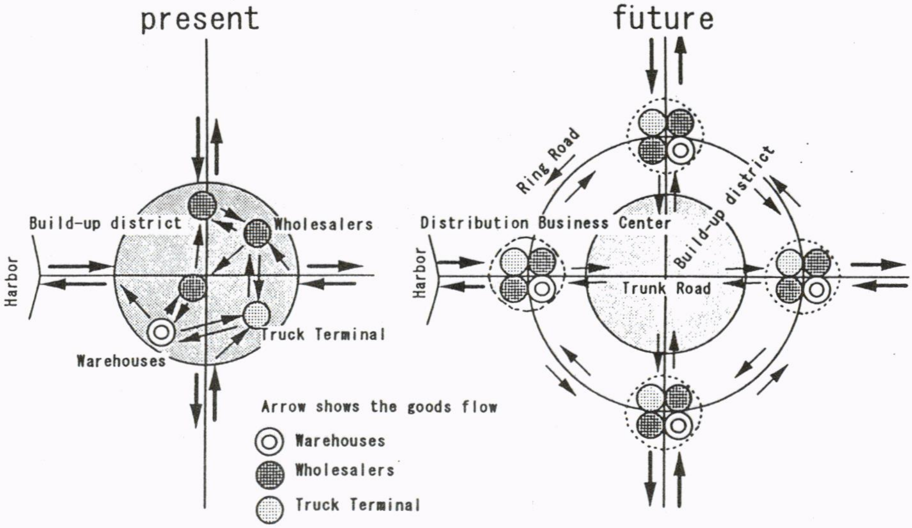

Fig.-4 Concept and role of DBC

2.3 The master plan of DBCs in Tokyo metropolitan area

According to the Tokyo Metropolitan Area Plan in 1969, Omiya, Chiba, Tachikawa and Yokohama, which are located within 30 km of the center of Tokyo, should be developed as sub-city cores, in order to convert the Tokyo metropolitan area into a multi-cored city (Fig.-5).

For that purpose, the Metropolitan Region Connection Roads were planned outside of these four cities so that they could become core cities in the Tokyo metropolitan area while being independent cities. The plan intends to establish four or five DBCs along this ring road so as to reorganize goods flow in the Tokyo metropolitan area (Fig.-6).

The master plan of DBCs in Tokyo was provided by the Act concerning Development of the Distribution Business District. The plan aims to construct about 10 DBCs in five different directions outside of the developed areas in Tokyo (north, east, south, south-west and north-west). Each DBC, whose size is approximately 100 ha, has enough capacity to allow the activities of distribution, storage and trading in each service area. Each DBC is usually consists of a truck terminal, a wholesale market, a container depot, warehouses, loading and unloading spaces and related processing facilities like offices, shops for carriers and wholesalers.

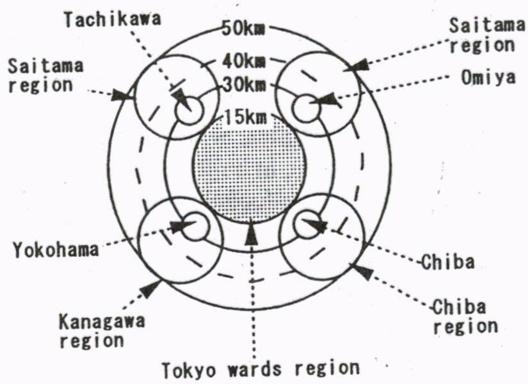

Fig.-5 The plan of Metropolitan Tokyo

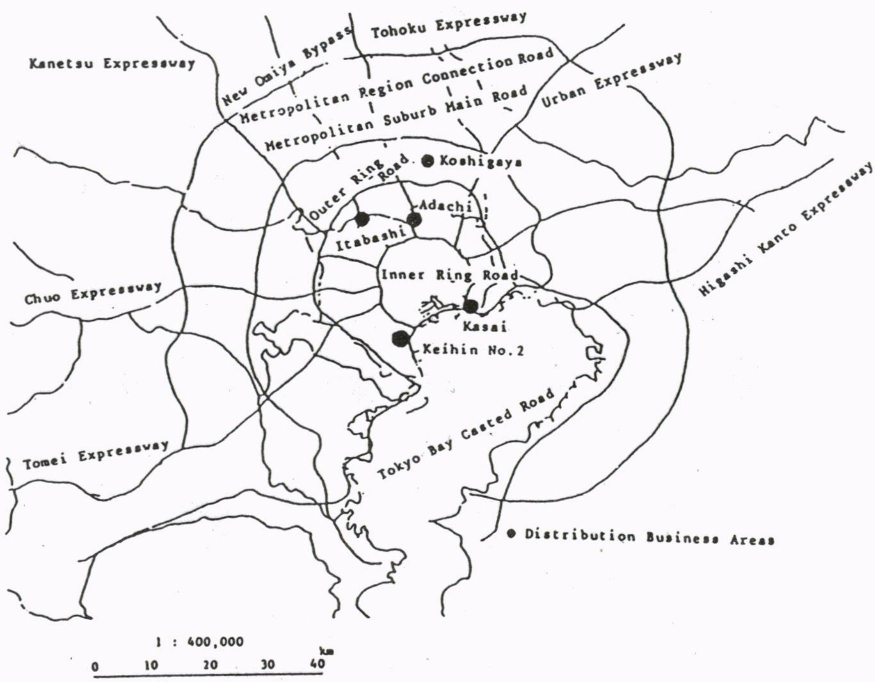

Fig.-6 The arrangement plan of DBCs in Tokyo

3. DISTRIBUTION CHANNEL CHARACTERISTICS IN TOKYO METROPOLITAN AREA

3.1 Objective and Scope

The Distribution channel generally consists of commercial transactions and physical distribution. And the physical distribution has two attributes, which are industries and facilities. (Fig.–7)

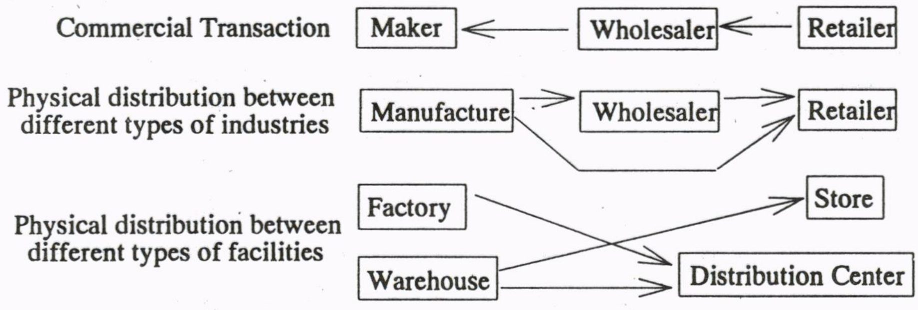

Fig.–7 : Variation of the Distribution Channels

The conventional analyses have focused on the spatial distribution of goods movement, however, the variation of the distribution channels is also very important for the analysis of the physical distribution mechanism. Because our research has shown that analyses of distribution channels is one of the necessary conditions of cooperative pickup and delivery.

In this chapter, we analyze the physical distribution not only as a flow between industries but as a flow between facilities. The possibility of the cooperative pickup and delivery service is examined through these two kinds of distribution channels. We use the data from 'Goods Movement Survey in Tokyo Metropolitan Area' conducted in 1982 for this study.

3.2 Physical distribution between industries and between facilities by item

3.2.1 Classification of item, industry and facility

The Goods Movement Survey in the Tokyo Metropolitan Area used 50 items of goods, 15 types of industries and 18 types of facilities. We classify item, industry and facility to simplify the analysis. The classifications of the data are shown in Table–1.

3.2.2 Characteristic of physical distribution between industries by item

The classification method of our study is as follows:

1) To calculate the number of freight by items and distribution channels between five types of industry (see Table–1). The maximum number of the channels is 25 (=5 × 5). The number of freights of i–th channel and j–th item is represented by A_{ij} (i=1,2,...,25, j=1,2,...,50).
2) To calculate the ratio of A_{ij} to the total freight of j–th item (= B_j), the ratio is defined as C_{ij}.
3) To choose the channel in each item of which C_{ij} is highest, and to group the items in principal distribution channels heuristically.

Table-1 Classification of item, industry and facility

item	type of industy	type of facility
type 1 items grain, vegetables & fruit, the rest of farm products, marine products, stock farm products, type 2 items general machines, electrical appliances, transport machines, precision machines, type 3 items textile goods, food, publishing & printed matters, furniture & equipment, kitchen ware, clothing&personal belongings & footware, stationery & instruments, hobby & sporting goods, the rest of daily necessities	type 1 industries agriculture & forestry & fisheries, the building industry, the chemical industry, the steel industry, the metalworking industry, type 2 industries raw materials wholesalers, product wholesalers, warehouses type 3 industries retailers type 4 industries service, official business, electricity & gas & water, department, land transportation business, the rest of transportation business type 5 industries final consumers	type 1 facilities land of agriculture & forestry & fisheries, constructions sites, factories type 2 facilities wholesale markets type 3 facilities deep freeze, refrigerator, tank, silo, oil tank, warehouses, collection & delivery centers, disposal of goods centers type 4 facilities offices, restaurants, hotels, amusement facilities type 5 facilities schools & welfare facilities, residence facilities type 6 facilities reclaimed grounds, parking lots

Table-2 Principal distribution channels between industries by item

	items	principal distribution channels between different types of industry (%)
(A)	vegetables&fruit	maker→retailer(41) retailer →retailer(22) wholesaler→retailer(16)
	general machines	maker→maker(22) wholesaler→maker(16) wholesaler→wholesaler(16)
	precision machines	maker→maker(26) wholesaler→retailer(12) retailer→retailer(11) wholesaler→wholesaler(10)
	textile goods	maker→maker(31) maker→wholesaler(14)
	publishing&printed matters	maker→wholesaler(14) maker→service(13) maker→maker(11) retailer→consumer(11) service→service(11)
(B)	marine products	wholesaler→wholesaler(30) wholesaler→retailer(29) retailer→retailer(15)
	stationary&instruments	wholesaler→retailer(24) wholesaler→wholesaler(11) retailer→consumer(10)
	clothing&personal belongings	wholesaler→retailer(25) retailer→consumer(25) service→service(14)
(C)	rest of farm products	retailer→retailer(36) retailer→consumer(25) wholesaler→retailer(12)
	stock raising	retailer→retailer(32) wholesaler→retailer(29) retailer→consumer(17)
	transport machines	retailer→retailer(23) wholesaler→retailer(16) maker→maker(15)
(D)	clothing&personal belongings	wholesaler→retailer(25) retailer→consumer(25) service→service(14)
	electrical machines	retailer→consumer(31) maker→maker(17)
	grains	retailer→consumer(66) retailer→retailer(23)
	food	retailer→consumer(33) retailer→retailer(15) retailer→maker(12) wholesaler→wholesaler(11)
	furniture	retailer→consumer(53) wholesaler→retailer(11)
	the rest of daily necessities	retailer→consumer(24) wholesaler→retailer(16)

Table-2 shows the principal distribution channels by item, and the value in parentheses indicates the ratio ($=C_{ij}$). Four different types of distribution channels are derived by the classification process. Fig.-8 shows the principal channels between facilities. The bold lines indicate the highest and the second highest ratio in each group ((A)-(D)).

Group A: The distribution channels "maker --> retailer", and "maker --> wholesaler" and "maker --> maker" show high ratios (C_{ij}) in this group. General machines, precision machines and textile goods are the main items in this channel.

Group B : The channels "wholesaler --> retailer" and "wholesaler --> wholesaler" show high ratios in this group. Marine products, stationery and instruments are the main items in this channel.

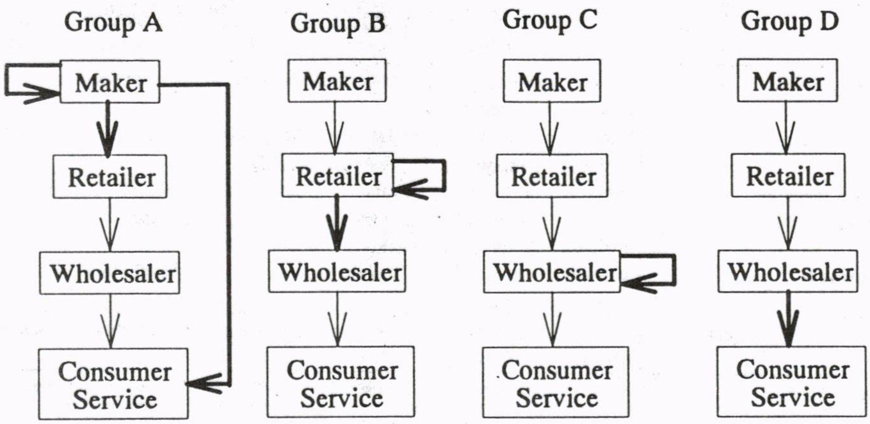

Fig.-8 Diagram of principal distribution channels between industries

Group C : The channels between different types of retailers and "wholesaler --> retailer" show high ratios in this group. Stock raising, the rest of farm products and transport machines are the main items in this channel.

Group D : The rest of the items are put together in this type.

3.2.3 Characteristic of physical distribution between facilities by item

The procedure for classification of physical distribution between facilities is just the same as that of industries which is mentioned in 3.2.2. The result of classification is shown in Table-3 and Fig.-9. The five groups are derived from the procedure as follows.

Group X: Vegetables, fruit, general machines, transport machines, precision machines and textile goods are main items in this group.

Group Y: Stationery and instruments are main items in this group.

Group Z: Marine products are main items in this group.

Group U: Furniture, clothing and personal belongings are main items in this group. The channels "warehouse --> business facilities", "business --> residence facilities" and "warehouse --> residence facilities" show high ratios in this group. This is why it is necessary to store these items for a time.

Group V: The rest of farm products, electrical appliances, publishing & printed matters and the rest of daily necessities are put together in this group.

3.3 Characteristic of distribution channels by industry, facility and item

The items which are classified by industry and facility are arranged in cross-table (Table-4). Most items in Group A (general machines and precision machines) are classified as Group X as far as facilities are concerned, and there is a close relationship between Group D and Group V. The cross-table would represent that distribution channels are classified into two different groups, i.e. manufacturing type and commercial type.

In this chapter, we clarify that the physical distribution in Tokyo Metropolitan Area can be categorized as Table-4 according to distribution channels by industry, facility and item. The distribution channels is are the most important attributes to be considered when we realize cooperative pickup and delivery service of different items. It seems that the classification results can apply to the examination of possibility of the cooperative pickup and delivery service of different items.

Table-3 Principle distribution channels between facilities by item

	items	principal distribution channels between different types of facility(%)
(X)	vegetables&fruit	factory→business(32) business→business(23) warehouse→business(13) business→residence(11)
	general machines	business→business(16) warehouse→factory(14) warehouse→business(14) business→factory(13) factory→factory(12)
	transport machines	business→business(26) warehouse→business(12) factory→factory(10)
	precision machines	business→business(20) factory→factory(16) warehouse→warehouse(13) business→factory(13) warehouse→business(10)
	textile goods	warehouse→business(17) warehouse→warehouse(15) factory→warehouse(14) business→business(12)
(Y)	stationery&instruments	business→business(28) warehouse→warehouse(20) warehouse→business(19) business→residence(12)
(Z)	marine products	market→business(30) business→business(18) warehouse→business(13)
(U)	stock raising	warehouse→business(46) warehouse→residence(17) business→business
	furniture	warehouse→residence(35) business→residence(23)
	clothing&personal belongings	business→business(37) warehouse→residence(17) business→residence(15) warehouse→business(11)
(V)	grains	business→residence(68) business→business(22)
	the rest of farm products	business→business(36) business→residence(30)
	electrical machines	business→residence(38) factory→factory(13) business→business(12) warehouse→business(10)
	food	business→residence(30) business→business(17) factory→business(14) warehouse→business(12) business→factory(10)
	publishing&printed matters	business→business(37) business→residence(19) factory→business(12)
	the rest of daily necessities	business→business(39) business→residence(24) warehouse→business(11)

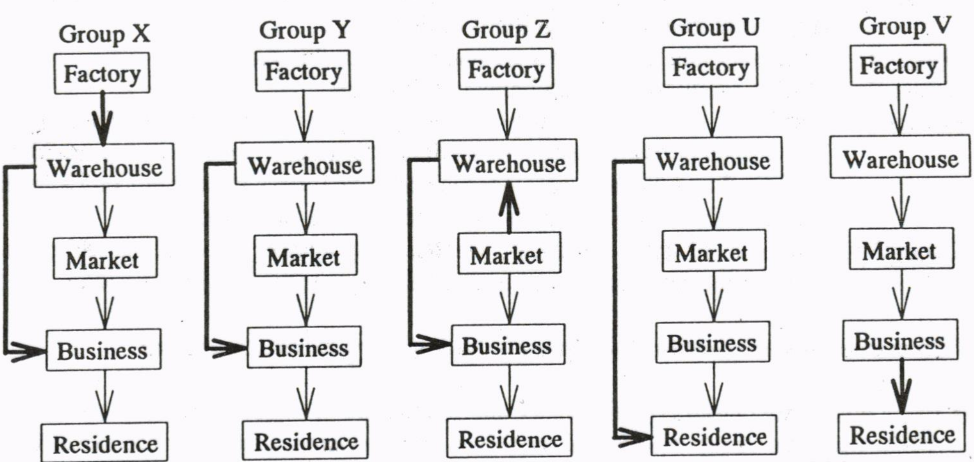

Fig.-9 Diagram of principal distribution channels between facilities

Table-4 Distribution channels by industry, facility and item

	(X)	(Y)	(Z)	(U)	(V)
(A)	vegetables&fruit general machines precision machines textile goods				publishing & printed matters
(B)		stationery & instruments	marine products	clothing & personal belongings	
(C)	transport machines			stock raising	the rest of farm products
(D)				furniture	grains electrical machines food the rest of daily necessities

4. FEASIBILITY ANALYSIS OF DISTRIBUTION BUSINESS CENTERS (DBCs)

4.1 Methodology for evaluation of efficiency of physical distribution

Our surveys show that distribution business centers (DBCs) could improve the loading factor of pickup and delivery service trucks. Freight to similar destinations can be consolidated at DBCs and delivered by the same trucks. The consolidation will be done more easily when freight has the same type of distribution channel.

The freight transportation route between i–th origin and j–th destination depends on the total cost (transportation cost, storage cost, transshipment cost) and time (lead time, line-haul time) Here we assume the followings:

1) The route, at minimum cost is chosen. We assume that the cost of freight transportation can be calculated by [the number of freight × line–haul time]. Transshipment cost and storage cost are not taken into consideration here.
2) The truck size, for delivery service without DBCs, is assumed to be small. As for the truck size for delivery with DBCs, the one between 'origin --> DBC' is assumed to be large and the one 'DBC --> destination' is assumed to be small .
3) The loading factor of trucks from DBCs to destinations is higher than that of trucks from origins to DBCs owing to the consolidation effect at DBCs.

The direct route (route–A) is faster than the route via DBC (route–B), however, route–A may cost more than route–B because of lower the loading factor.

The cost by route–A is represented as follows:

$$C_{ij} = \frac{\theta \cdot \mu \cdot F_{ij} \cdot T_{ij}}{\alpha \cdot \beta} \tag{1}$$

θ : the cost of the pickup and delivery by a truck per a minute, μ : the average weight per one freight [ton/freight], F_{ij} : the number of freight between i–j, α : the loading capacity of the truck from i–th origin, β : the loading factor of small size truck, T_{ij} : the time from the i–th origin to the j–th destination.

And the total cost of freight transported into the j–th destination without DBC is

$$CT = \sum_i C_{ij} \tag{2}$$

The total cost of the route–B (via DBC) is described as follows:

$$C'_{ij} = \theta \cdot \mu \cdot F_{ij} \cdot \left(\frac{T_{im}}{\omega \cdot \beta} + \frac{T_{mj}}{\alpha \cdot \gamma} \right) \quad (3)$$

T_{im} : the time from i–th origin to DBC, T_{mj} : the time from DBC to j–th destination, ω : loading capacity of large size truck, γ : loading factor of truck with consolidation

Here $\alpha<\omega$, $\beta<\gamma$. If the freight is shipped between i–j at the cost minimum, the actual transportation cost (C''_{ij}) is defined as follows:

$$C''_{ij} = \min\{ C_{ij} \ , \ C'_{ij} \} \quad (4)$$

From the equation (1)–(4), the total cost of freights into the j–th destination with DBC is derived as

$$CT' = \theta \cdot \mu \cdot F_{ij} \cdot \sum_i \left[\min\left\{ \frac{T_{ij}}{\alpha \cdot \beta} \ , \ \frac{T_{im}}{\omega \cdot \beta} + \frac{T_{mj}}{\alpha \cdot \gamma} \right\} \right] \quad (5)$$

Finally, the reduction rate of transportation cost with/without DBC is defined as follows:

$$R = \frac{CT - CT'}{CT} \quad (6)$$

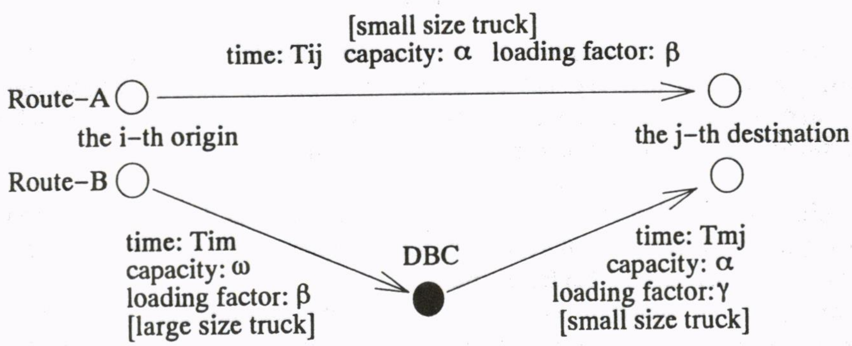

Fig.–10 The conditions for a direct route and a route via DBC

4.2 Empirical analysis of distribution business centers in the Tokyo Metropolitan Area

The consolidation at DBCs causes a reduction in the total traffic volume. In this section, we analyze the effect of the DBCs around Central Business District (C.B.D.) in the Tokyo Metropolitan Area. The following conditions are supported:

1) We focus on the freight from non–ward area of Tokyo to Ginza, because existing DBCs are located in the fringe of wards in Tokyo. We also focus on freight only to Ginza district because it is the central commercial area in Tokyo.
2) We calculate the effect of DBCs in the present situation, in which we have four Public Truck Terminals in Tokyo, i.e. Keihin, Adachi, Itabashi and Kasai (see Fig.–6).
3) Each truck routes is chosen so as to minimize the transportation cost.
4) Loading capacity of small size truck is half of that of large size truck ($\alpha=\omega/2$). From the past research (Yoshimoto (1993)), $\beta=0.58$ and $\gamma=0.95$ are supported.

And we use the reduction rate *'R'* (equation–(6)) as an index of the DBC effect. The result of the calculation is shown in Table–5.

The result shows that the total traffic volume is reduced by 13.6% and the DBC in Keihin district is most effective for the freight to be delivered to Ginza district.

The calculation does not consider the consolidation between different distribution channels, therefore it shows the maximum reduction rate. As a matter of fact, there are many distribution channels which does not have compatibility with each other. It is necessary to combine the analysis of distribution channels with the detailed transportation cost analysis.

Table-5 Difference in total cost [freight*min.] with/without DBCs

		without DBCs	with DBCs
Direct		1,782,052	851,453
D	Keihin	- - -	384,785
B	Adachi	- - -	9,958
C	Itabashi	- - -	81,044
	Kasai	- - -	212,451
total		1,782,052	1,539,691
R		- - -	13.6 %

Table-6 compares the total cost of freight which has the same distribution channel at each DBC to the total freight via each DBC. 40.1% of freight, which uses DBC in Keihin, has the same kinds of distribution channels; on the other hand, DBC in Kasai does not have the same channel. This result suggests that cooperative pickup & delivery can be more easily realized in Keihin than in Kasai.

Table-6 Rate of freight which has the same distribution channel

		number of freight	rate of same channel
Direct		21,980	- - -
D	Keihin	7,258	40.1%
B	Adachi	139	100.0%
C	Itabashi	1,853	38.6%
	Kasai	4,290	0.0%
total		35,521	- - -

5. CONCLUSION

The results of our study are summarized as follows:

1) We clarified the attributes of goods movement from the point of distribution channels. The principal distribution channels are derived from the analyses. They could be the indices of cooperative pickup and delivery service between different items.
2) We supported evaluation methodology to examine the efficiency of DBCs, and indicated the validity by empirical study. The result shows that existing DBCs reduce the total cost of transportation by more than ten percent.
3) As the result of 1) and 2), we showed the possibility of introducing efficient

cooperative pickup and delivery service with DBCs.

Further topics to be studied are as follows:

1) Other freight attributes, such as loading time (like Just–In–Time), temperature condition or tolerance of freight and so on should be studied. These attributes are also important for cooperative pickup and delivery service of different items.
2) This paper mainly focused on the evaluation of the methodologies and we dealt with the OD–pairs which concentrated on only one destination (Ginza district) for an empirical study. Feasibility studies the all OD–pairs should be examined for the arrangement of DBCs in the Tokyo Metropolitan Area.
3) Our methodology consists of simple procedures and it would have applicability to other cities. However, it needs detailed goods movement survey. It is desired to establish the effective survey method of goods movement.

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