NEW URBAN FREIGHT TRANSPORT SYSTEM

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INTRODUCTION

Freight transport in Japan is divided among trucks, railways, ships, and planes, with the share of trucks increasing every year. Urban freight transport in particular mostly depends on trucks. However, city traffic is fraught with problems: traffic congestion, environmental problems -- including noise and air pollution, a transport labor force shortage, rising fuel prices, and so forth. Thus, circumstances related to truck traffic will become increasingly severe from now on.

Under these circumstances, from the development and diversification of industries and the national way of life, just-in-time delivery has spread and small-lot, frequent delivery has been introduced. In addition, work rationalization and distribution cost reduction as well as faster and punctual transport are strongly required.

Against this background, rising land prices, etc., have made it very difficult to tackle the present problems of truck traffic and future problems of increasing transport demand and changes in transport quality by only utilizing the existing approach of improving roads in cities. Thus, a new urban freight transport system must be introduced to replace truck traffic and thus solve the problems of traffic congestion, traffic environment, and labor and energy shortages.

Taking the 23 wards of Tokyo (hereinafter referred to as the "Tokyo Ward Area") as an objective region for system introduction, freight transport that can be switched over to the new system and the effects of constructing such a system were studied.

1. Problems with Truck Traffic

Problems related to truck traffic are reviewed here and the need for a new freight transport system described.

The share of truck traffic -- in terms of tons and freight -- in the three major metropolitan areas has been increasing over the past 10 years. Even in the highly congested Tokyo Metropolitan Area, truck traffic had an 85% share (freight base) in 1982. The major share of truck traffic has been confirmed as being not only for short distances, such as mobility within urban areas, but also long distances -- of over 500km.

Table 1 shows changes in vehicle-kilometers on municipal and higher-rank roads in the Tokyo Ward Area. As shown in the table, the number of vehicle-kilometers increased 8% during the 17 years from 1971 to 1988, while vehicle-kilometers of trucks increased 23% during the same period. In addition, vehicle-kilometers of trucks constituted about 53% of total vehicle-kilometers in 1988.

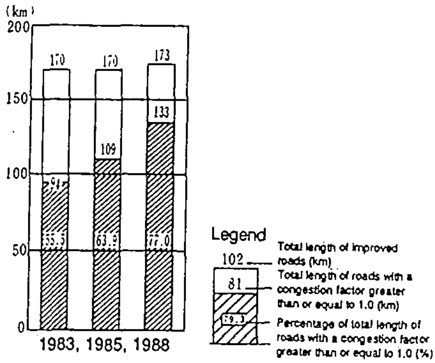
Figure 1 shows the state of congestion of national roads in the Tokyo Ward Area. According to this figure, the share of the total length of roads with a congestion factor greater than or equal to 1.0 among the national roads has increased, reaching 77% in 1988. In addition, in 1988 average travel speed at peak time in the Tokyo Ward Area was approximately 15km/h, and the proportion of the total length of roads on which travel speed was under 25km/h climbed to slightly over 90%.

Table 1 Changes in Vehicle-Kilometers on Municipal and Higher-Rank Roads in the Tokyo Ward Area

(Million vehicle-kilometers/12 hours)

	'71	'74	'77	'80	'83	'85	'88
Passenger cars	13	13	12	13	14	14	14
Trucks	13	14	14	15	15	15	16

Source: Road Traffic Census, Ministry of Construction



Source: Road Traffic Census, Ministry of Construction

Fig. 1 Changes in Congestion of National Roads in the Tokyo Ward Area (5.5m or over in width after improvement)

Regarding automotive exhaust, while the maximum allowable quantity of NO_x emitted from passenger cars has been improved (lowered) to one-tenth or one-twentieth of the 1966 level, that of trucks has only been lowered to only one-half. NO_x emission of diesel automobiles, predominantly trucks, touches the level of 3.5g/km/vehicle, which is extremely high and is 15 times the level of passenger cars.[1)] Moreover, the number of diesel automobiles is increasing.

In 1988, transportation's share of total energy consumption in Japan was 22%, of which consumption by passenger cars accounted for 40%, buses 2%, and trucks 44%. Such consumption was conspicuously high, accounting for 86% of transportation as a whole; the growth rate has also been high. Trucks also have a high proportion of energy consumption compared to their proportion of the traffic volume. This tendency is conspicuous among privately owned trucks.

Statistical data issued by Ministry of Labor indicate that average actual labor hours per month for all industries were 176.8 in 1986 and 179.1 in 1988. In comparison, truck drivers -- particularly those in the transportation industry (an industry considered ill-suited for reducing working hours) -- work over 200 hours, owing to the driver shortage. Furthermore, the average age of truck drivers is increasing year by year, leading to a growing trend in aging truck drivers.

Following the growth of truck traffic, distribution base functions have been put together as a countermeasure for reducing distribution costs through transport rationalization. However, existing facilities must be expanded or additional terminals constructed to keep pace with urbanization and increased cargo volume, terminal sites are becoming scarce, owing to the lack of land and rising land prices.

2. Characteristics of Truck Movement in the Tokyo Ward Area

Table 2 shows changes in total volume of freight traffic generation and absorption and total freight frequency in the Tokyo Ward Area. As shown in this table, while freight weight volume has decreased approximately 20% for the 10 years from 1972 to 1982, freight frequency has increased approximately 37% and weight per freight movement fell by half during the same 10 years.

Composition classified by rank of loading weight per truck in the Tokyo Ward Area is bipolarized as under 500kg (44% of all) and 8 tons or over (38% of all) for each origin-destination pair (within the Area, from the Area to outside it, and from outside the Area to the Area itself).

Table 2 Changes in Freight Transport in the Tokyo Ward Area

	1972	1982	1972/1982
Traffic Generation (1000 tons/day)	531	427	0.804
Traffic Absorption (1000 tons/day)	774	620	0.801
Freight Frequency (1000/day)	790	1,085	1.373
Weight per Freight (tons)	0.67	0.39	0.582

Source: Freight Traffic Survey in the Tokyo Metropolitan Area (1972, 1982)

Table 3 Freight Traffic Volume in the Tokyo Ward Area

(unit: 1000 trips/day)

	Within the Area	From within the Area to Outside it	From the Outside to the Area	Total
Traffic Volume	1,659	250	246	2,155
Share (%)	77.0	11.6	11.4	100.0

Source: Freight Traffic Survey in the Tokyo Metropolitan Area (1982)

According to Table 3, which shows freight traffic volume in the Tokyo Ward Area, traffic within the Area occupies about 80% of all, indicating heavy internal traffic. In addition, major traffic lines appear among the zones along coastal regions. Small automobiles constitute 75% or more of the automobiles used in such freight traffic. However, between Shinagawa and Ohta, use of small and large automobiles is equivalent, as gravel transport occupies slightly over 70% of the ton-base traffic volume between the two places.

Table 4 shows traffic volume in the Tokyo Ward Area classified in terms of goods. The table shows that major trips are ones for light and miscellaneous industry-related goods -- such as publications/printed matter, chemicals, garments/personal belongings, and paper/pulp -- and that small trucks are the major transportation mode.

Classifying loaded traffic volume by trip purpose, "sales, distribution, and delivery" accounts for 770,000 trips per day and "stocking, purchase, and collection" for 100,000. These statistics indicate that truck traffic only for goods transport occupies slightly over 80% of loaded truck traffic volume within the Tokyo Ward Area (1,070,000 trips per day).

Figure 2 shows trip time distribution from loading to unloading in terms of truck traffic within the Tokyo Ward Area. The highest figure falls in the 30-45-minute rank. The over-60-minutes rank is also comparatively high. A survey of freight traffic for light and miscellaneous industrious goods or "sales, distribution, and delivery" shows the same results.

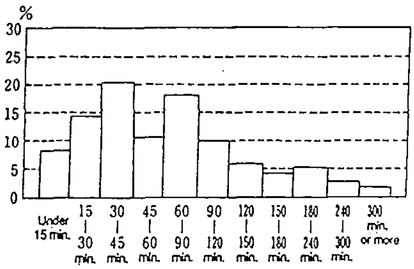
Many major distribution facilities -- such as airports and their related freight facilities, public truck terminals, and warehouses -- in the Tokyo Metropolitan Area are concentrated in the areas along Tokyo Bay.

Table 4 Goods-Based Traffic Volume in the Tokyo Ward Area

(1000 tripes/day)

Top 10 Goods	Traffic Volume	Top 10 Goods	Traffic Volume
Food	153	Metal Products	43
Publications/Printed Material	73	Livestock Products	48
		Electrical Appliances	35
Chemicals	68	Total	612
Cereals	55	Percentage of Total Loaded Traffic Volume (%)	(57.0)
Garments/Personal Belongings	53		
Paper/Pulp	50	Total Loaded Traffic Volume	1,073
Stationery/Musical Instruments, etc.	44		

Source: Freight Traffic Survey in the Tokyo Metropolitan Area (1982)



Source: Freight Traffic Survey in the Tokyo Metropolitan Area (1982)

Fig. 2 Distribution of Trip Time for Truck Traffic in the Tokyo Ward Area

3. Image of the New Urban Freight Transport System

A considerable volume of truck traffic must be switched to the New Urban Freight Transport System to solve problems of traffic congestion, traffic environment, and labor and energy shortages. For these purposes, the New Urban Freight Transport System must fulfill the following criteria:

(1) To meet diversified demands related to lots, sizes, and goods;
(2) To meet demands for "many origins and many destinations";
(3) To automate unloading at depots for collection and delivery and transshipment along routes;

(4) To adopt speedy, punctual, and economically efficient "just-in-time" delivery;
(5) To collect freight at and deliver it to densely placed depots; and
(6) To improve the environment by switching from the existing diesel automobiles to electric cars.

As an example of an underground freight transport system that meets the aforementioned criteria, a network with as many routes as the existing subways (underground railways) and extending a total length of 300km will be planned throughout Tokyo's 23 wards. Basically, shuttle operation would be adopted at every route, but railway-like operation capable of branching would be partially employed. Vehicles would be propelled by linear induction motors. In addition, parts of the routes would be extended to the vicinity of expressway interchanges in suburbs or to distribution facilities, such as airports and harbors (Fig. 3).

Goods are packed in containers and conveyed by vehicles. Containers are as large as the bed of a small truck -- 1.7m wide x 1m high x 2m long -- and there are also half- or quarter-size containers. Tunnel cross-sections consist of double trucks with a diameter of about 5m.

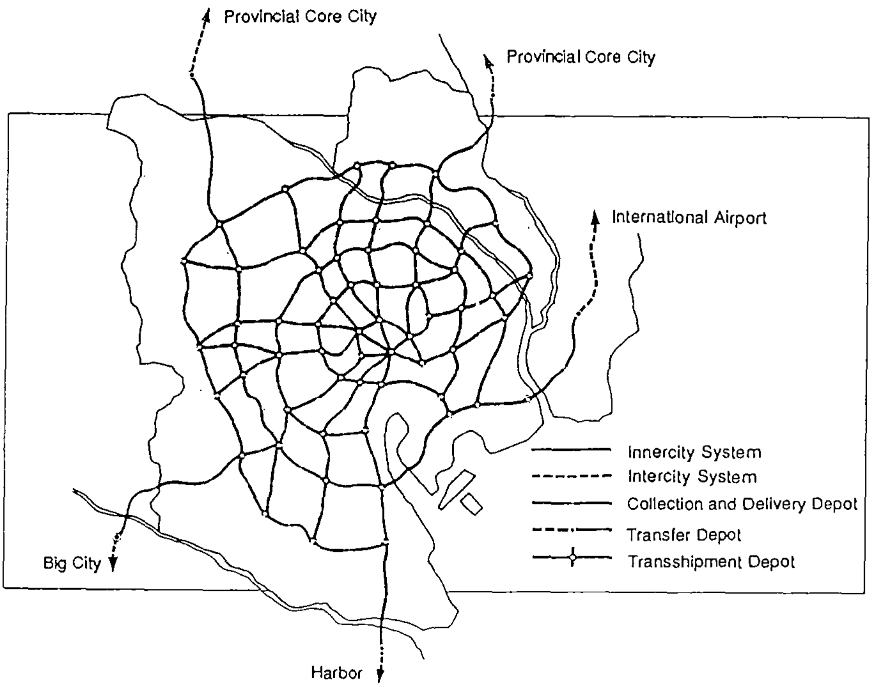


Fig. 3 Image of the New Urban Freight Transport System Network

Depots (collection and delivery facilities) are placed as densely as the existing subway stations: every 2 kilometers. The number of depots is about 150, and depots are constructed using underground roads or facilities where there is large demand (e.g., large buildings and department stores).

There are three kinds of depots: first, collection and delivery depots, which act as an interface between road and underground transport; second, transfer depots placed along routes: and third, transshipment depots between intercity and innercity freight transport systems. Electric cars are used for collection and delivery from depots.

Quantity of truck volume that could be switched over to the New Urban Freight Transport System (which has the aforementioned functions) by introducing it to the Tokyo Ward Area was estimated, based on the following conditions:

(1) Dangerous goods; tall, wide, heavy, and thick goods; and fresh concrete were excluded;
(2) Freight trips for "sales, distribution, and delivery" and "stocking, purchase, and collection" would be switched over to the new system; and
(3) Long trips -- those exceeding 60 minutes -- would be switched over to the new system.

Based on these conditions, results of calculations using survey data on freight transport in the Tokyo Metropolitan Area (1982) are shown in Table 5. The table shows that approximately 30% of the total traffic volume of the Tokyo Ward Area could be switched over to the new system. Estimated volume includes traffic whose origin and/or destination is within the Tokyo Ward Area.

Table 5 Volume that can be Switched Over to the New Urban Freight Transport System (traffic volume in terms of loaded goods)

Traffic Volume in Terms of Loaded Goods (trips/day)	
Agricultural Products	57,075
Gravel/Surplus Soil	1,923
Cement	4,797
Metal/Machines	74,063
Light and Miscellaneous Industry – 1	109,360
Light and Miscellaneous Industry – 2	212,625
Waste	693
Other	7,476
Unloaded Vehicle Traffic Corresponding to Traffic Switched Over	171,804
Total	639,379
Ratio to Truck Traffic Volume in Tokyo's 23 Wards	(29.2%)
Truck Traffic Volume in Tokyo's 23 Wards	2,187,965

To investigate the transport capacity of the New Urban Freight Transport System, truck traffic that could be switched over to the new system (approximately 30% in all) was distributed to the network (total length: approximately 320km) of main municipal and higher-rank roads. Results are shown in Fig. 4. This calculation was made by simply distributing traffic to the shortest route.

Provided that a system container is capable of holding approximately 1 ton of goods, it is assumed that a 20-car train could be operated with minimum headway of 30 seconds. This would mean that maximum transport capacity would be about 37,000 vehicles/12 hours/section when converted to truck capacity.

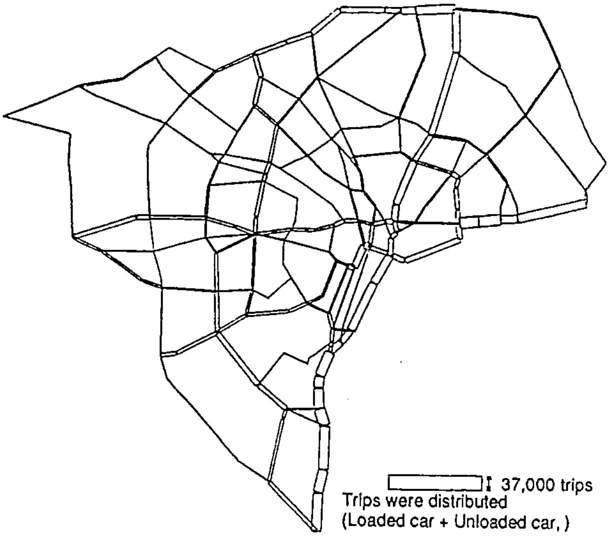


Fig. 4 Results of Traffic Distribution (Tokyo Ward Area; traffic was distributed to the shortest route)

Comparing this traffic capacity to the distribution results shown in Fig. 4 reveals that about 13 sections have insufficient traffic capacity, of which insufficiency exceeds 20% in only 5. Excessive demand could be diverted other routes in the network.

In this new system, electric cars are used for collection and delivery to meet door-to-door traffic needs. In addition, container packing, temporary storage, and loading/unloading will be automated. Figure 5 shows an image of a depot and Figure 6 an image of introduction to underground road space.

Construction of this system would begin with routes along major distribution terminals, such as airports, harbors, and truck terminals, which could be utilized even when only some of the routes and facilities have been completed.

Construction cost of the New Freight Transport System described above was estimated in reference to the construction cost of a subway with linear induction motors in Osaka. The cost of constructing a 320km-long network was thus estimated to be approximately 5 trillion yen. Table 6 shows the breakdown. Land purchase cost was not included in this estimate because the new system would be constructed underground, in the land beneath roads.

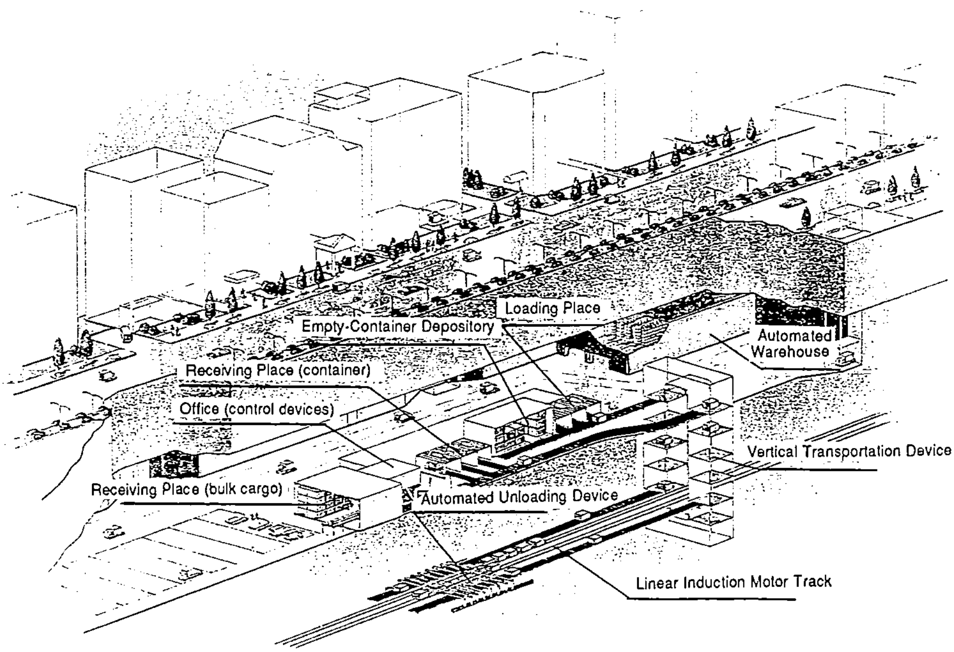


Fig. 5 Image of a Depot

Table 6 New Urban Freight Transport System Construction Cost Estimate

Item		Construction cost (100 million yen)
Infrastructure	Tunnels	15,700
	Depots	5,900
	Planning and Supervision	4,400
	Subtotal	26,000
Others	Tracks	6,400
	Buildings	8,000
	Vehicles	2,100
	Planning and Supervision	3,500
	Interest	2,300
	Subtotal	22,300
Total		48,300

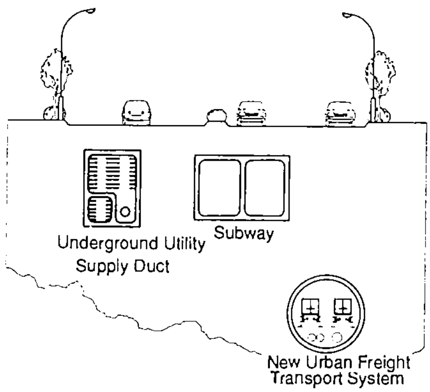


Fig. 6 Image of Introduction to the Underground Road Space

4. Effect of Implementing the New Urban Freight Transport System

Examination results from the previous section show that an estimated 30%, approximately, of truck traffic could be switched over to the new system. Hence, it was assumed that 30% of the 16 million vehicle-kilometers in Tokyo Ward observed in the 1988 road traffic census shown in Table 1 could be switched over to the New Freight Transport System. As the ratio of vehicle-kilometers that could be switched over to the new system to total vehicle-kilometers cannot be estimated, it was assumed to be the same as the trip ratio presented above. This assumption is likely to lead to slight underestimation. As shown in Table 1, a 30% decrease in truck vehicle-kilometers would result in a 16% decrease in total vehicle-kilometers. The likely direct effect in the case of such a decrease is shown in Table 7.

The effect of increased travel speed was estimated from the relationship between annual average travel speed and the congestion factor, which was calculated via simulation.[2)] A rise in traveling speed of approximately 40% would constitute conspicuous improvement. A 16% decrease in traffic in the Tokyo Ward Area would basically be equivalent to the state of traffic during All Souls' Day (August 13-15), a Buddhist holiday, and would mean that there would be little traffic congestion. As shown in Table 7, the environment, driving labor force, and energy, would be greatly improved. In addition, the total 20-year benefit of travel cost and travel time saving would be an estimated 9 trillion yen.

Table 7 Presumable Direct Effects

Congestion (increase in travel speed)	Speed will increase 1.38 times (average speed per day of 15km/h would rise to 21km/h).
Environment (NOx emission)	Twelve-hour NOx emission would fall to 76.1%. (This estimate considers only the effects stemming from reduced traffic volume. Reduced NOx emission resulting from a decrease in the number of stops related to relieved congestion was not included.)
Driving labor force	A labor force equivalent to 76,000 truck drivers (27%) would be reduced.
Energy	Energy consumption would decrease to 80.5% of the pre-introduction level. (Electric power consumed by the new system and electric cars for collection and delivery were included.)
Travel cost	As the effect of increased travel speed would extend to passenger cars, the travel benefit would amount to approximately 1.040 million yen/12 hours for all types of automobiles. (However, the benefit for truck traffic to be switched over to the new system has not been taken into account.)
Travel time	For all types of automobiles, the estimate is approximately 1.310 million yen/12 hours. (However, the benefit from switching truck traffic over to the new system has not been taken into account.)
Total benefit	2.350 million yen/12 hours or 700 billion yen/year. Should this annual benefit continue every year, the 20-year cumulative benefit would be 9.160 billion yen - assuming a 5% discount rate.

The following indirect effects were presumed: (1) comprehensive rationalization of distribution activities; (2) reduction of commodity prices; (3) incentive for industries to engage in various industrial activities; (4) effective use of freight terminal sites and promotion of suburban site locations; and (5) improved punctuality.

Furthermore, a new intercity freight transport system will be separately studied, and the more efficient system will be constructed by connecting the New Urban Freight Transport System and the intercity transport system.

5. User Questionnaire Survey

A questionnaire survey concerning the new Urban Freight Transport System was administered to 500 companies: 440 shippers listed on the Tokyo Stock Exchange and 60 shipping companies with branches or offices in the Tokyo Metropolitan Area. Responding were 112 of the former companies (26.5%) and 16 of the latter (26.7%).

Table 8 shows the problems with truck freight transport according to the results of the questionnaire survey. Shippers pointed out increased traffic costs as the major problem with truck transport -- regardless of industry --, followed by road congestion and rising land prices. In contrast, shipping companies cited road congestion and arranging for delivery staff as the top problem.

Table 8 Problems with Truck Freight Transport

Order	Manufacturers	Wholesalers/Retailers	Others	Shipping Companies
1	Increased traffic cost 61 (100.0)	Increased traffic cost 18 (94.2)	Increased traffic cost 28 (100.0)	Road congestion 15 (100.0)
2	Road congestion 60 (98.4)	Rising land prices 18 (94.2)	Road congestion 27 (96.4)	Arranging for delivery staff 15 (100.0)
3	Urgent/specific-time delivery 57 (92.4)	Road congestion 18 (94.2)	Fluctuations and increased volume 27 (96.4)	Increased traffic cost 15 (100.0)
4	Small-lot/frequent shipping 55 (90.2)	Urgent/specific-time delivery 17 (89.5)	Arranging for delivery cars 23 (82.1)	Concern over traffic accidents 13 (86.6)
5	Fluctuations and increased volume 55 (90.2)	Small-lot/frequent shipping 16 (84.2)	Arranging for delivery staff 23 (82.1)	Fluctuations and increased volume 13 (86.6)
6	Arranging for delivery cars 51 (83.6)	Fluctuations and increased volume 16 (84.2)	Small-lot/frequent shipping 21 (75.0)	Urgent/specific-time delivery 13 (86.6)
7	Arranging for delivery staff 48 (78.6)	Arranging for delivery staff 14 (73.6)	Urgent/specified-time delivery 21 (75.0)	Rising land prices 10 (66.7)
8	Rising land prices 44 (72.1)	Arranging for delivery cars 14 (73.6)	Rising land prices 20 (71.4)	Delivery area limitations 8 (53.3)
Number of replies submitted	61	19	28	15

* Figures are for the number of companies answering "major problem" or "problem." Multiple answers were permitted. (Figures in parentheses represent percentage of number of replies.)

Table 9 shows requests related to the new system. As the table indicates, shippers request low freight charges most and strongly look forward to shorter transportation time and punctual arrivals. Shipping companies most look forward to solving the driver shortage.

Table 9 Requests Related to the New Urban Freight Transport System

Order	Manufacturers	Wholesalers/Retailers	Others	Shipping Companies
1	Low freight charge 48 (82.8)	Punctual arrivals 17 (89.5)	Low freight charge 22 (84.6)	Countermeasures to the driver shortage 9 (69.2)
2	Shorter transport time 41 (70.7)	Low freight charge 15 (78.9)	Shorter transport time 22 (84.5)	Punctual arrivals 9 (69.2)
3	Punctual arrivals 40 (69.0)	Shorter transport time 15 (78.9)	Punctual arrivals 19 (73.1)	Shorter transport time 9 (69.2)
4	Countermeasures to the driver shortage 32 (55.2)	Countermeasures to the driver shortage 5 (26.3)	Countermeasures to the driver shortage 12 (46.2)	Low traffic charge 8 (61.5)
5	Improved traffic environment 11 (19.0)	Improved traffic environment 2 (10.5)	Improved traffic environment 2 (7.7)	Improved traffic environment 4 (30.8)
Number of replies submitted	58	19	26	13

* This questionnaire had respondents rank the prescribed 5 items. Number of replies for what turned out to be the top three items is shown in this Table. Figures in parentheses are the percentages of number of replies.

In response to the question of whether they would use the new distribution system if it was implemented, 24.6% answered that they would actively and 56.8% possibly use it. It thus seems that approximately 80% of the companies answering are prepared to use it.

6. Conclusions

(1) To drastically solve such problems as traffic congestion in cities, the traffic environment, and truck driver and energy shortages, the New Urban Freight Transport System proposed here would not only be effective but a definite necessity as well.

(2) Approximately 85% of freight is conveyed by trucks, and 53% of total vehicle-kilometers in the Tokyo Metropolitan Area are run by trucks. Moreover, truck transport has sharply increased due to recent business prosperity and demand for just-in-time delivery. To solve the problems of traffic congestion and environmental deterioration caused by trucks, a new freight transport system must be introduced.

(3) If the new system was introduced, approximately 30% of truck trips could be switched over to it.

(4) Construction of the new system underground in the Tokyo Ward Area would cost approximately 5 trillion yen, provided that the system is approximately 320km long, has double tracks in its 5m-diameter tunnels, about 150 depots, automated loading/unloading devices, vehicles propelled by linear induction motors, and containers of a maximum size of 1.7m x 1m x 2m. System capacity would be sufficient for accepting diverted traffic demand of approximately 30% of truck trips.

(5) Implementing the system proposed herein in the Tokyo Ward Area would increase travel speed by approximately 40%, remarkably relieving traffic congestion. In addition, NO_x emission would fall to 76%, consequently improving the environment. As for truck drivers, the system would be equivalent to a labor force of 76,000 people, easing the labor shortage. Energy consumption fall about 20%, and the total 20-year benefit in travel cost and travel time savings would reach an estimated 9 trillion yen, approximately.

(6) This system is outstanding in terms of punctuality and is applicable to just-in-time delivery. Automated devices have been introduced to it. Accordingly, this system contributes to rationalization of a whole range of distribution activities.

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