A Proposal of Metropolitan Area Deep Underground Distribution Tunnel

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ABSTRACT

The Kyoto Protocol went into effect in Japan in February 2005. In addition, environmental preservation has become a vital issue in the physical distribution area, including carbon dioxide reduction.

Tokyo is a densely populated region, requiring a large volume of commodities. It is the core of a metropolitan area with numerous physical distribution bases, including Tokyo Bay, which handles the largest amount of foreign trade containers within Japan, and Haneda Airport, which has been enlarged with more functions following additional expansion and internationalization. Under these circumstances, innovation in physical distribution is essential in the Greater Tokyo metropolitan area, to achieve more effective physical distribution, become more competitive in the international market and improve daily lives and the environment.

In February 2006, the Tokyo metropolitan government set up the “Integral Physical Distribution Vision: Physical Distribution Innovation Beginning from Tokyo.” This plan states that effective utilization should be studied in depth, for underground as well as surface space.

In 2001, a special measure law concerning the public use of deep underground space was put into effect. This law specifies the potential utilization of deep underground spaces for diverse structures, such as roads, railways and essential infrastructure.

With the current situation in mind, this paper discusses a preliminary study on the feasibility of a new physical distribution system utilizing underground space.

1. FACTORS AFFECTING PHYSICAL DISTRIBUTION IN THE METROPOLITAN AREA

1.1 Metropolitan Area as the Center of Our Nation’s Economic Activities

The population of Tokyo now accounts for nearly 10% of Japan’s total. In the metropolitan area (the 8 prefectures consisting of Tokyo, Ibaraki, Tochigi, Gunma, Saitama, Chiba, Kanagawa, and Yamanashi), as many as 30% of the national population reside. In terms of percentages of the nation’s gross product, the area’s figures are high, with Tokyo registering 17% and the metropolitan area as a whole showing 40%. The same applies to annually compiled commodities sales, manufactured goods shipment volumes, and so on. With such high percentages in the metropolitan area, it is quite clear that Tokyo and its surrounding regions represent the very center of Japan’s economic activities and, at the same time, of mass consumption.

1.2 Increasing Coverage of Physical Distribution in the Metropolitan Area

The volume of physical distribution in the metropolitan area is such that, according to the 4th
Survey on Physical Distribution (fiscal 2003), approximately 1.26 million tons/day of freight moves within the Tokyo’s urban districts (excluding Yamanashi) while as much as 0.87 million tons/day of freight passes between Tokyo’s urban districts and the regions outside them. A comparison from the results of the 2nd Survey (fiscal 1982) indicates that, while the freight within Tokyo’s urban districts has remained unchanged, that from outside them (including from overseas) has increased ([1], Figure 1).

Fig. 1. Volume of Freight Movement in the Tokyo Metropolitan Area (net movement).

1.3 Tokyo Port’s Role and Its Increasing Importance

Ever increasing globalization has accordingly caused the volume of import and export freight to rise. With a mass-consumption area right behind it, Tokyo port has an increasingly important place among businesses due to the cargo volume. As illustrated by Figure 2, the volume of overseas trade containers handled at Tokyo port has been growing year on year, exceeding 3 million TEU for the first time in Japan in 2003. The volume is steadily increasing, as indicated by the changes and estimates in the volume of freight by overseas trade containers found in the Tokyo Port 7th Revised Harbor Plan, suggesting the importance of promptly consolidating facilities to meet demand.

1.4 Addressing Issues Surrounding the Global Environment

The Kyoto Protocol (treaty) binds the signatory industrial countries to the reduction of greenhouse gases. The treaty came into effect in February 2005, committing our nation to a reduction of 6%, with the 1990 figure serving as a benchmark, for the period from 2008 to 2012.

In line with the requirement, the “Goal Achieving Plan for the Kyoto Protocol” was approved in Japan in April 2005 during a Cabinet meeting to set forth the target reduction levels to be imposed on emissions in various fields. According to the Plan, the transportation category is assigned the target of reducing the increase in carbon dioxide emissions from energy sources to 15.1% by fiscal 2010 with fiscal 1990 serving as the year of reference. The growing number of passenger cars and so on, however, already triggered an increase of about 20% in the year 2002 (with 1990 as the year of reference), requiring us to devise further measures through nationwide efforts.

2. CURRENT BASES AND NETWORK OF PHYSICAL DISTRIBUTION WITHIN THE METROPOLITAN AREA

2.1 Freight Articles within the Metropolitan Area
Where articles of freight transported in the Tokyo metropolitan area are concerned, Reference 1 shows us that, while such heavy items as ceramic/chemical and metal industry products have a considerable share in terms of total freight tonnage, daily necessities (e.g. farm and marine products/food industry products, daily articles, and miscellaneous light-industry commodities) and machine industry products account for about 60% in terms of the number of total freight vehicles (Figure 3).

Figure 3. Composition of Freight for Physical Distribution (net movement)

Fig. 3. Composition of Freight for Physical Distribution (net movement)

2.2 Major Items and Physical Distribution in Action

a) Electrical Equipment

Personal computers, communications devices, and other electrical equipment are the main Japanese exports, and they are usually transported from their production sites to harbors and airports (e.g. Tokyo port, Yokohama port, Narita airport). In Tokyo, the Tama region serves as the metropolis’s principal site of production, and the goods are moved, for export, to Tokyo and Yokohama ports through specific routes, including National Highway 16 and Fuchu Kaido. There is a lack of land locations suited the efficient transportation and
storage near harbors (Figure 4).

b) Transportation Machinery

Although the production of transportation machinery, including automobiles and their associated parts, is shifting overseas, considerable production still remains in Japan and is exported, with wide-ranging related industries. In addition to Northern Kanto, where factories are concentrated, many production sites for transportation machinery are found in the region extending from Saitama to Kanagawa through Tama, resulting in a large volume of physical distribution in these areas.

The production of transportation machinery calls for the transportation of parts and materials in large volumes among related industries. Often, such transportation takes place between sites in Saitama, Tama, and Kanagawa, where factories are concentrated, moving the items in a North-South direction through specific routes (e.g. National Highways 16, 129 and Fuchu Kaido).

2.3 Bases of Physical Distribution and New Developments in Site Location

a) Site Conditions of Distribution Facilities in the Metropolitan Area

According to Reference 1, the spread of distribution bases, newly built in the year 1990 and thereafter, is heavy in such fringe areas where highways are consolidated, such as near Tsurugashima-to-Ome and Atsugi, in addition to harbor areas and the region extending between the north of Tokyo and south of Saitama (Figure 5). As for the scale of these facilities, the more recent they are, the larger they tend to be, illustrating the preference for large-scale facilities and encouraged by the need for increased physical distribution efficiency, as indicated, for example, by the need for reduced inventories. Further, of the wide-area distribution facilities, those large in scale (with a site area of 3,000 m² or more) and handling a large volume of freight per vehicle (5 t/vehicle or more) are mostly found in the bay area and fringe areas along National Highway 16.

b) Acceleration of Consolidation for Distribution Bases in the South West of Tokyo

In the “Comprehensive Vision for Physical Distribution” (draft) provided herein as Reference 5, the Tokyo metropolitan government sets forth its intention to study the ideals of distribution bases in the Tama area by obtaining an accurate understanding of their relationship with existing wide-area distribution facilities and demand, in view of progress in the consolidation work on trunk roads. It further refers to its plan to decide on basic policies pertaining to the consolidation of distribution bases suited to regional characteristics and in collaboration with the municipalities concerned.

2.4 Distribution Network and its Current State

In the metropolitan area, road consolidation is under way for 3 loop and 9 radial lines as shown in Figure 6 as part of its expressway network. Currently, although consolidation work on the radial expressways is more or less complete, a number of portions remain uncompleted along 3 loop lines, i.e. the Metropolitan Inter-city Expressway (Ken-O expressway), the Tokyo Outer Ring Road (Gaikan expressway), and the Metropolitan Central Ring Line (Chuo Kanjo line): such portions as on the Central Ring Shinjuku line and Shinagawa line as well as south of Oizumi and Misato of the Gaikan expressway remain to be completed, and completion also remains pending for most portions other than the Tsurugashima-to-Akiruno segment.

According to Reference 1, the delay in consolidating expressway loops has resulted in freight vehicle traffic imposing heavy loads on general roads in the outskirts (e.g. National Highways 16 and 129), causing congestion. The fact has resulted in inefficient transportation and significant loads on the environment because of freight vehicles.

3. ISSUES TO ADDRESS FOR EFFICIENT PHYSICAL DISTRIBUTION

The delay in road consolidation and the presence of bottlenecks along the routes taken by large freight vehicles are among the many issues cited in connection with road networks, together with those relating to the functions of harbors and airports being compromised by the ever-increasing
volume of international freight. In addition, the lack of suitable land for newly establishing distribution bases and congestion during shipments in various areas are also often cited as elements hindering efforts made by businesses to facilitate physical distribution.

4. PROPOSAL FOR UNDERGROUND DISTRIBUTION TUNNELS

4.1 Establishment of Distribution Networks and Distribution Bases Equipped with New Functions

We propose a grand scheme for an underground distribution tunnel route as part of undertakings intended to accommodate increases in the volume of container freight in Tokyo port and for the formulation of wide-area distribution networks. Within the “Comprehensive Vision for Physical Distribution” (Reference 5), we have focused our attention on programs to establish distribution bases in the South West area of Tokyo, where the consolidation of expressways is underway, and have come to the conclusion that, rather than attempting to eliminate the bottlenecks between Tokyo port and the distribution bases in the area, the creation of a new route will be significantly more effective, selecting a Hachioji-to-Oi route as shown in Figure 7. We further propose the establishment of facilities equipped with integrated distribution functions at intermediary bases of operations, thereby increasing efficiency through functional integration.

Fig. 7. Detour Movement Pattern of Relay Freight after Consolidation of Bases.

Fig. 8. Plan View of the Route.
4.2 Studies on a Possible Transportation Route

a) Assumed Conditions

(1) Large international containers will be transported, of which the maximum dimensions will be as follows: 20 ft in length, 9.5 ft in height, and 8 ft in width.

(2) The underground transport system, in principle, will be unmanned.

(3) The underground transport tunnel will pass below ground at super deep underground levels (depth of 40 m or more).

(4) Intermediary bases will be near a junction with an expressway.

(5) The tunnel will have a circular cross section, and the extra space will be used to arrange other infrastructure.

b) Planned Route

The decision is taken to connect a point near the Oi container wharf to a distribution base near the Hachioji North interchange of the Metropolitan Inter-city Expressway over a distance of about 50 km, in line with the Super Deep Underground Law, via an underground tunnel 40 to 60 m deep. The route will be more or less straight, and the areas near interchanges along the route that connect to major roads will be furnished with the intermediary bases.

Figure 8 shows a plan view of the tunnel, while Figure 9 shows its cross sectional view.

c) Ground Condition of the Tunnel Route

The Super Deep Underground Law applies to (1) an underground level of 40 m or more or (2) an underground level of 10 m or more from the top of the supporting ground (top of the Tokyo gravel layer), whichever is deeper. In the area shown in Figure 9, a line at an underground level corresponding to -40 m from the ground surface or -10 m from the Tokyo gravel layer will be drilled. All routes that were studied were planned within the Kazusa layer group.

Fig. 9. Cross-sectional View.

According to References 7 and 8, the Kazusa layer group consists mainly of sandstone/mudstone with the irregular appearances of sandstone in the form of quasi-lumps.

4.3 Studies on Transportation Systems

a) Objectives of an Underground Distribution System

An underground distribution system will be introduced, thereby ensuring on-time operation, reducing environmental loads, and easing the traffic congestion around harbors. The introduction is also likely to result in improved work conditions as well as decreased traffic accidents attributed to freight vehicles. Its benefits further include a reduction in carbon dioxide, the utilization of idle land in the harbors, and enhancement of the harbor area landscape.
b) Reduction of Loads on the Environment Imposed by the Transport System

- Transportation by Railway
  If the energy consumption efficiency per ton-km of transportation by railway is 100, it will be 1,709 by private truck. If the carbon dioxide emission per ton-km from transportation by railway is 100, it will be 3,551 by private truck. Compared with container transport via large trucks, transport by rail along tunnels will significantly contribute to reducing the environmental load.

- Transportation by Vehicles
  The introduction of travel by electrical means, based on a power collection method or by means of storage batteries (lithium-ion), as well as unmanned operation, will generate no automobile exhaust (carbon dioxide and nitrogen oxide) and also enhance safety.

- Transportation by Air Capsules
  Transport by air capsules is free from frictional resistance between the tubular route and the capsules, demonstrating its superiority, particularly in the field of super deep/long distance transportation.

5. SUMMARY

The results of outline studies have led to a high degree of feasibility regarding the realization of a distribution route that utilizes underground space, in line with the application of the Super Deep Underground Law, being confirmed. Currently, detailed studies are underway with financial support from Japan Keirin Association to prepare estimates of its economic effects simultaneously with studies on the volume of physical distribution on the planned route, new distribution systems, and items possibly calling for deregulation of regulatory requirements/revision of laws. In terms of additional work, there is also a need for a study concerning combination of facilities (e.g. communications facilities) capable of responding to large-scale disasters.

REFERENCES


The Tokyo Metropolitan Government. October 2005, Comprehensive Vision for Physical Distribution (draft)

