UTILIZATION OF THE DEEP UNDERGROUND SPACE IN TOKYO

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ABSTRACT

Our research group has been working on projects related to the utilization of deep underground spaces. We have proposed several projects since the 1970s and examined their effectiveness. An outline of the latest project that aims at effective utilization of deep underground is presenter in this paper. The way effective implementation of the project can be achieved is also discussed. These projects are major public- works and need to receive higher budget priority. Accordingly, it is very important to work out new public- works schemes. This paper focuses on the results of feasibility studies and shows how the project can be realized by integrating urban disaster prevention with urban environment improvement.

1. INTRODUCTION

In 2001, the law on Deep Subterranean Utilization went into effect in Japan. In Japanese civil law, land ownership theoretically encompasses the space from the sky to the deep underground. According to the law, a space that is deep enough underground does not violate the rights of private above-land ownership. The kinds of environmental problems and urban disaster mitigation facing Tokyo are now becoming global problems, and technological city planning should be encouraged. We focus on the deep underground space as the last precious unused space, that the Mega city Tokyo has left to it.

2. UTILIZATION OF THE DEEP UNDERGROUND SPACE

2.1 Problem of infrastructure network system in Tokyo

The area of Tokyo has been defined by a 60-km radius, but this is currently rapidly growing to become a 100km radius. With this expansion, all of the infrastructure, such as the electric power network, the communications network, the water supply, drainage, and gas pipelines, have extended without order or preconceived plan, just tending to follow the outward sprawl of the city. It is difficult to maintain such a complicated infrastructure network. In particular, in an emergency, it would be not possible to back up the metropolitan network where the infrastructure consists of numerous congested routes. Damage from the next big earthquake, especially a strong local earthquake centered on Tokyo that is forecast to occur at the beginning of the 21st century, could cause three times the damage inflicted during World War II. Once one part of the network shuts down, other parts become overloaded and also slow down. Finally, it would result in a functional shutdown of the entire system. Tokyo cannot continue to depend on this large area network given this situation. If parts of the lifeline, such as electricity, gas, information transmission, traffic, and so on, were to be interrupted, damage would occur not just to the families and enterprises directly affected, but also to the nation as a whole.

2.2 Principles for using the deep underground

The ideal future use of the region can be clarified by formulating a long-term, phased plan for the infrastructure before the suprastructure is constructed. The means of utilizing the deep underground space is one of the key technologies that will allow sustainable development of the Asian mega cities with adequate margins of safety and security. Proper use of the deep underground is an important proposal for Japan. Public welfare must be the first consideration before embarking on the use of the deep underground, followed by a consideration of how private projects will be puesued. A pilot project must be done first and as soon as possible, from the viewpoint of technology and sociology. This would ensure that a sound base for supporting the various demands of the big city, especially in emergencies, could be established.

3. DEEP UNDERGROUND SPACE NETWORK PROJECT

3.1 System of the deep underground infrastructure

We have proposed a deep underground space network project to alleviate problems in Tokyo regarding both disaster prevention and urban environment improvement. The underground system is composed of a vertical tunnel that connects the surface of the earth with the deep underground base, and a horizontal tunnel that joins each of the underground bases.

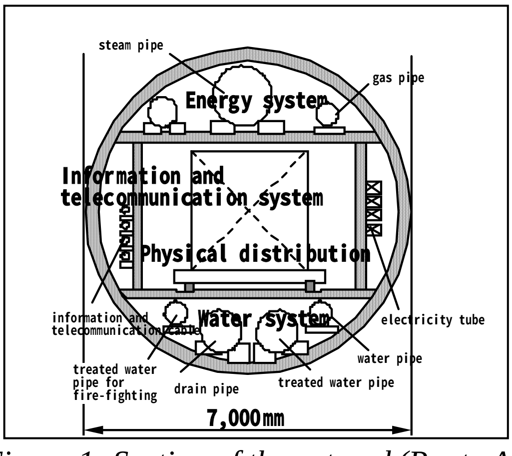

Figure 1: Section of the network(Route A)

The horizontal tunnel is a multipurpose underground conduit, as shown in the illustration (Figure 1). The routes and functions of the Tokyo network being proposed are shown in Figure 2.

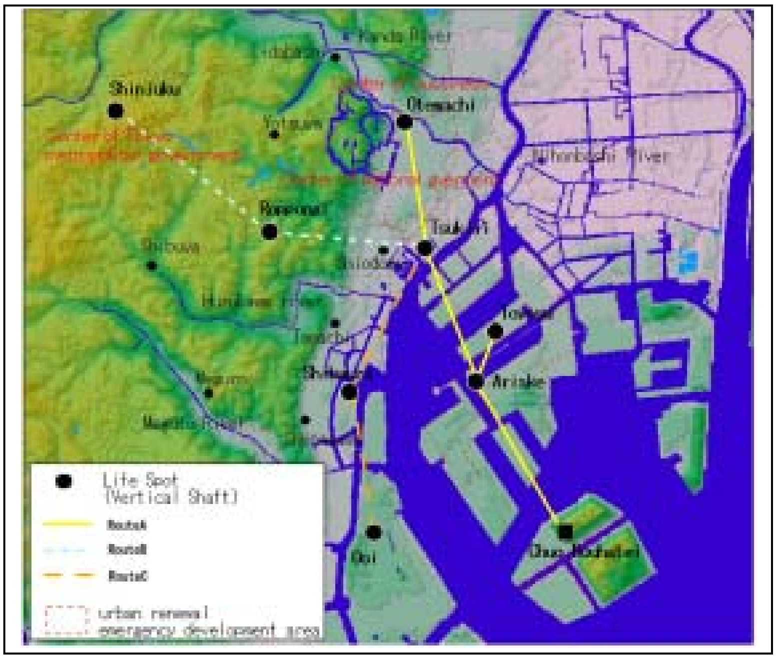

Figure 2: Routes of the Tokyo network

►Total length of the network: 27km （vertical shaft included）

►RouteA 11.9km
（Otemachi-Tsukiji-Ariake-ChuoBouhatei、Ariake-Toyosu）
- ▪Function: energy (steam)、treated water、information and telecommunications、physical distribution
- ▪ Diameter of the tunnel: 7m
- ▪Construction cost of the tunnel: 35.8 billion Yen （NATM method 3billion Yen/km 、Between Ariake and Toyosu submerged tunneling method 4billion Yen/km）
- ▪Construction cost of the vertical shaft 8.4billion Yen
- ▪Construction cost of the inside facility 12.4billion Yen

►RouteB 7.8km
（Shinjyuku-Roppongi-Tsukiji）
- ▪Function: energy(steam)、treated water、information and telecommunications
- ▪ Diameter of the tunnel: 4m
- ▪ Construction cost of the tunnel: 7.2billion Yen （NATM method 0.9billion Yen/km）
- ▪Construction cost of the vertical shaft: 1.8billion Yen

■Construction cost of the inside facility: 4.1billion Yen

►RouteC 6.8km
（Tsukiji-Shibaura-Ooi）
■Function: energy(steam)、treated water、information and telecommunications
■Diameter of the tunnel: 4m
■Construction cost of the tunnel: 9billion Yen（submerged tunneling method 1.3billion Yen/km）
■Construction cost of the vertical shaft: 0.8billion Yen
■Construction cost of the inside facility: 3.5billion Yen

3.2 Outline of the project

We worked out the outline and the scale of the project, which has been designed based on the conditions and assumptions listed below.

1. By including future re-development projects, the net floor-area ratio in this area increases by up to 125% compared to the present.(Increases in total floor area in this area comes to 3.6 million ㎡)
2. Supply targets are new buildings to be constructed as part of future re-development projects in three areas in the center of Tokyo (Otemachi, Roppongi, Shinjuku) with a total floor area of 3.6 million ㎡.
3. To use high-temperature thermal energy from the Shinagawa electric power plant, systemic change is necessary.
4. Three sewage- treatment plants in Tokyo (Ochiai, Shibaura, Ariake) have the capacity to supply enough treated water.

■Construction cost of the vertical shaft: 0.8billion Yen
■Construction cost of the inside facility: 3.5billion Yen
■Time for completion: 3years
■Business period: 30years
■Extinguishment period: tunnel 75years、inside facility 15years（remaining value 10%）
■Land cost: 0yen/year （free rental）
■Cumulative income from all businesses: 15billion Yen/year
Breakdown heat supply 10billion Yen（2280TJ）、treated water supply 3.8billion Yen（24.8million t）、physical distribution （1.2billion Yen）
■Total income from all businesses 8.5billion Yen/year

3.3 Evaluation of the external economic effect

The external economic effect of this deep underground space network project was analyzed, and then, based on the results the application of PFI scheme to the project was studied.

The main functions of the deep underground infrastructure in the event of an emergency are as indicated below.

■securing of redundancy of lifeline
■reservoir of drinkable water
■securing a transportation route for essential materials
■transport and removal of rubble without using roads
■backup for information infrastructure

By providing these services through a deep underground infrastructure, business and administrative activities will be maintained and be able to continue functioning smoothly in a time of emergency. The precious value and benefit of these kinds of things are difficult to measure. They make it possible to supplement or provide an effective alternative to the current preparations of Tokyo Metropolitan Government for an emergency water supply, emergency food and the basic necessities of life. Accordingly, we defined the efficacy of disaster prevention as being equal to the current budget of Tokyo Metropolitan Government for emergencies.

►The effect of disaster-prevention: 6billion Yen

The following three operations, heat supply, treated water supply and physical distribution were then focused on, and an attempt was made to quantify the magnitude of the advantageous effects and public benefit on a daily and steady basis. The external economic effects for the following two items were then calculated.

■reduction in the amount of energy consumed by using high-temperature thermal energy from the electric power plant effectively(Heat supplied to the three areas totaling 10 million m^2 including the addition of 3.6 million m^2 floor area)

► The effect of energy saving: 90billion Yen

■decreases in CO_2 emissions in conjunction with reduction in the amount of energy consumed is 180,000t/year (value of the transaction in the markets is 10,000yen/t-CO_2)

► The effect of reduction of greenhouse gas emissions (CO_2): 30billion Yen

Total external economic effect（evaluation period 30years）amount to 126 billion Yen.（present value accounting, rate reduced ４%）

3.4 Evaluation of business plan by applying PFI scheme to the project

Based on the magnitude of its external economic effects, it was decided that public defrayment should be one third of the total cost of the project. A business plan was then simulated and a cash flow analysis was conducted.

►Evaluation of business plan（evaluation period 30years）
▪PFI（BTO type）
▪form of business organization: nontaxable corporation
(special-purpose company)
▪ investment: 83billion Yen
equity capital 16billion Yen
public defrayment 28billion Yen
(one third of the total cost of the project)
debt loan 39billion Yen
▪ profit and loss
total incomes（thirty years） 447billion Yen
heat supply 300billion Yen
treated water supply 112billion Yen
physical distribution 35billion Yen
total expenses -261.9billion Yen
administrative and maintenance expense
0.3（billion Yen/year）×30（years）＝ 9billion Yen
heat supply
6（billion Yen/year）×30（years）＝180billion Yen
treated water supply
1.5（billion Yen/year）×30（years）＝ 45billion Yen
physical distribution
0.5（billion Yen/year）×30（years）＝ 15billion Yen
nonlife insurance premium
0.04（billion Yen/year）×30（years）＝ 1.2billion Yen
interest charge 11.7billion Yen
business interests 185.1billion Yen
debt loan -39billion Yen
net profit for investment 146.1billion Yen

According to the simulation, this business will yield a fair return (146.1 billion Yen) on the initial investment (16 billion Yen).

4. CONCLUSION

The feasibility study clearly showed that the deep underground space network project has considerable potential to improve the urban environment and enhance disaster prevention in Tokyo as a provision of social overhead capital. How a major project such as this one is to be financed is always a problem. In this paper, it was demonstrated how the project could be made feasible by integrating urban disaster prevention projects with urban environment improvement projects based on external economic effects. How to evaluate the external economic effects for disaster prevention is our challenges for the future.

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