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Evacuated tube transportation routes: go through overhead, on ground, shallow underground or deeply underground?

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Abstract

Just like current railway and highway, evacuated tube transportation will extend all over the world. There are four possible ETT route schemes, namely going through overhead, on ground, shallow underground and deeply underground. It's significant to analyze characteristics and performance of each one scheme and to decide which one is the best route scheme. ETT tubes could be deeply imbedded into underground in the whole region where ETT routes go through. It's possible to have most of ETT route segments overhead or on ground. It's difficult to have most of ETT route segments exactly in the shallow underground because of the terrain fluctuation. Based on the comprehensive consideration about the primary construction cost, land occupying, climate temperature affect, factitious destroying, vacuum keeping, inspecting, maintaining and overhauling, the overhead scheme of ETT route should be the optimized one.

Keywords: evacuated tube transportation, route, overhead, ground, underground

1 Introduction

With a partial vacuum surroundings, Evacuated tube transportation (ETT) will be the fastest traffic mode on earth in the future, possible over 6000km/h, and low energy consumption, no air pollution, no noise and relatively safe[1-2]. ETT network will extend all over the world. As for the ETT route, there are four possible schemes, *e.g.* going through overhead, on ground, shallow underground and deeply underground. Dispute about which one is the best route scheme exists around us. This paper specifically describes four schemes and analyzes the performance of each one. Some conclusions are put up in the end.

In fact, besides the deeply underground scheme which could be imbedded into the deep underground in whole route range, other three route schemes are not absolute. The overhead scheme only indicates that the majority of ETT route segments are overhead, inevitably going into underground tunnel when going through mountains, and need to be paved on ground when going through a local high terrain. The ground scheme means that the majority of ETT route segments are on ground, inevitably going into underground tunnel when going through mountains, and must be supported upon piers when going over a river or a local low terrain.

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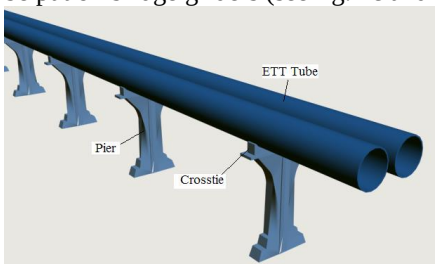
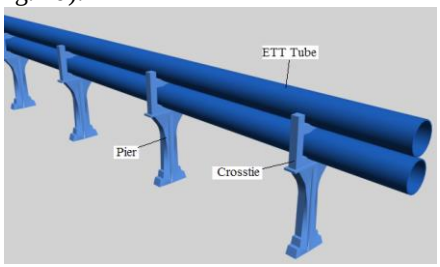
2 Four different route schemes to construct ETT

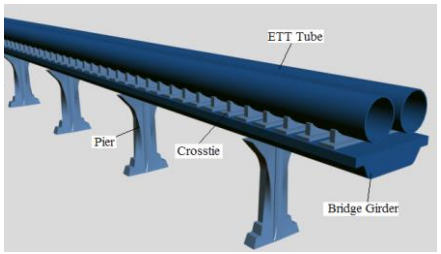
Fig. 1 shows the overhead schemes, namely the tubes are mainly upheld overhead by piers. Daryl Oster claims it's the better ETT route mode [3-4]. Specifically, two (or more) tubes can be arranged on a level (see fig. 1a) or vertically (see fig. 1b). If accepting tubes with low intensity, then tubes should be put on bridge girders (see fig. 1c and fig. 1d).



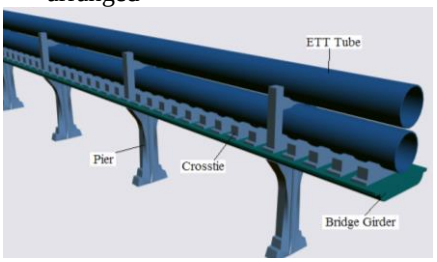
a. Tubes on a level and directly on piers



b. Tubes directly on piers but vertically arranged



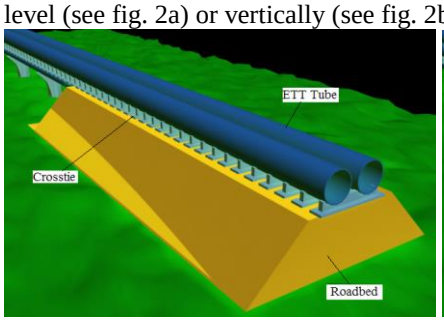
c. Tubes on a level and on bridge girders



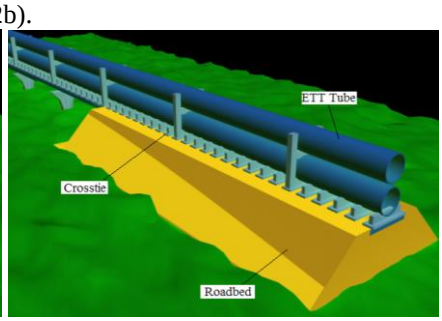
d. Tubes vertically arranged and on bridge girders

Figure 1: Overhead schemes

Fig. 2 shows the ground scheme in which the ETT tubes are mainly put on the roadbed artificially built on the ground surface. It's feasible to arrange tubes on a level (see fig. 2a) or vertically (see fig. 2b).



a. Tubes on a level and on roadbed



b. Tubes vertically arranged and on roadbed

Figure 2: Ground schemes

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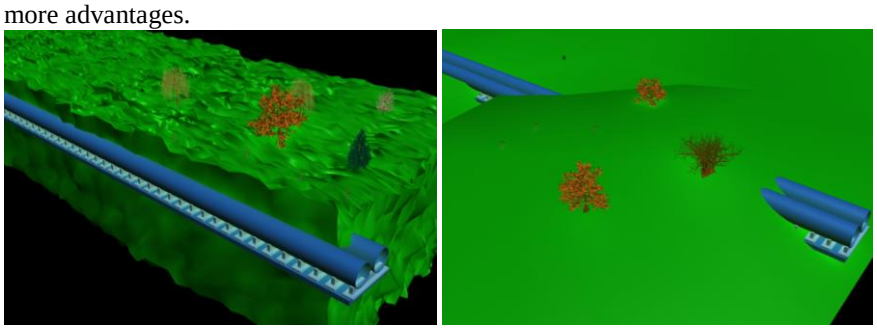
Fig. 3 shows the shallow underground scheme where the tubes are imbedded by excavating the ground surface. Except in some cities, almost all landforms are fluctuant, so even in plain regions, it's not realistic to hope to uniformly imbed the tubes in shallow underground such as 2~6m deep. Tubes would be certainly imbedded deeply underground in some places, and go through bridges (overhead) in other places. Although in some place where ETT route goes on the ground surface as shown in fig. 3b the tubes could be imbedded by filling earthwork, it's clearly unreasonable. You have no reason to specially imbed tubes by moving soil from nearby which could be on ground originally and with more advantages.

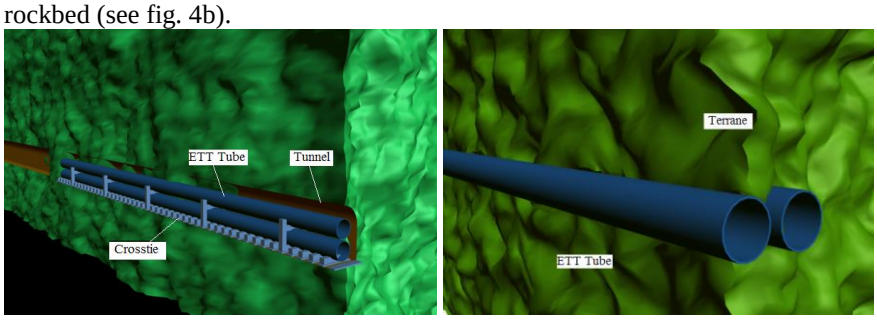


a. Whole tube segments in shallow underground

b. Some tube segments comes on the ground surface

Figure 3: Shallow underground scheme

Fig. 4 shows the deeply underground scheme. It's really possible to put tubes deeply underground in all regions where ETT routes go through. Swissmetro designed their scheme with the tubes deeply underground at all [5-6]. There may be two specific deeply underground schemes. One is that tubes are put into the tunnel dug early (see fig. 4a), another is that tubes are directly imbedded in the rockbed (see fig. 4b).



a. Tubes in a tunnel

b. Tubes directly imbedded in the rockbed

Figure 4: Deeply underground schemes

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3 Characteristics of the above four ETT route schemes

According to various parameters and performance aspects, the characteristics of four ETT route schemes are compared in table 1. Some performance aspects with same parameters or same index, such as factitious destroy risk and terrorist attack happened inside ETT tube (in fact in trains), are not considered here. The numerical value in table 1 is the factor indicating the performance, for example, 5 indicating the best performance and 0 indicating the worst case.

Table 1: Four ETT route schemes comparison

	Overhead	Ground	Shallow underground	Deeply underground
Construction cost	4/low	5/low	4/high	0/extremely high
Land occupy	2/high	0/extremely high	3/low	5/no
Vacuum equipment install	4.5/easy	5/easy	3/ difficult	2/ difficult
Airproof check	4.5/easy	5/easy	1/very difficult	0/extremely difficult
Airproof cope	4.5/easy	5/easy	1/very difficult	0/extremely difficult
Maintenance cost	4.5/low	5/very low	1/high	0/very high
Temperature stable	0/bad	0/bad	4/good	5/best
Climate affect	0.5/serious	0.5/very serious	4/little affect	5/no affect
Factitious destroy risk	1/high	0/very high	4/low	5/no
Terrorist attack	1/high	0/very high	4/low	5/no
Evacuate in urgency	4.5/easy	5/easy	1/very difficult	0/extremely difficult
Succor	4.5/easy	5/easy	1/very difficult	0/extremely difficult

When ETT routes go through overhead or ground, tube diameter can be allowed very small, such as less than 2m. In this case, it’s possible to check airproof, cope with leakage and maintain tubes outside the tubes, no necessary going into tubes. And, the tube can be made into an openable structure [7], further facilitating inspecting, maintaining and urgent succor. These advantages are impossible or very difficult to be attained for underground tube scheme.

Tube diameter is the most important factor to decide the ETT construction cost, thus the cost of the overhead tubes (or ground scheme) with the small diameter would be much less than that of deeply underground routes. In addition, the expenditure to dig tunnel is much more than that of bridge building, so that another huge cost would add on the deeply underground scheme.

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Although the construction cost of ground scheme is less than that of overhead, with increasing continuously in land price, the total cost of ground scheme would be more than that of overhead scheme. And, the tubes on ground are apt to being destroyed by human and flood.

4 Conclusions

By the above describing and analyzing, some conclusions come out as following:

(1) The overhead scheme is the optimized one among four ETT route schemes. Especially in the primary stage of ETT development, it should be firstly considered to build ETT route on overhead.

(2) The experience to construct current high-speed railway, maglev and highway has proven that the transportation route on overhead is more reasonable than on ground surface. The overhead scheme is more fit to ETT route with the light load and small section.

(3) Because of the terrain fluctuation, it is impossible to uniformly have ETT route shallow underground. Therefore, the shallow underground scheme is a bogus proposition, and afterwards nonsense to discuss its advantages or disadvantages. If the tubes must be able to be inspected and maintained outside tubes, then it would be prohibited to cover tubes directly with soil, and it means that it wouldn't be permitted to imbed any tube segment shallow underground.

(4) In the far future, when ETT gets full-scale development and when people see that ETT construction cost is really not so high, the deeply underground scheme can be another option.

In addition, four ETT route schemes have been specifically drawn and listed in this paper, which would be the base and reference for further studying ETT routes.

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