Vacuum Tube Transport: An Effective Solution to Global Transport Dilemma

ZHANG Yaoping1,2
1Institute of Vacuum Tube Transport, Xijing University, Xi’an 710123, China
2Institute of Evacuated Tube Transportation, Southwest Jiaotong University, Chengdu 610031, China

Abstract: Cars, trains, planes and ships are important parts of modern civilization, but they are also the main makers of the global greenhouse gas effect, climate warming, air pollution, noise pollution and marine pollution, and the largest one to consume petrochemical energy. In addition, car accidents lead a great number of casualties every day, and it is a serious threat to human life and safety. Luckily, vacuum tube transport could reach ultra-speed, and possess some special qualities such as low energy consumption, low pollution, low noise and relatively safe, construction cost not high. It will take on a majority of transportation mission of passengers and freight in long distance, reducing the usage proportion of long-distance highway, railway and flight transport, so that it is highly prospective to radically solve the global transportation dilemma by vacuum tube transport.

1. Introduction

Today, transportation could be thought very developed and highly modernized. Aircraft flying in the blue sky, can reach any corner of the earth in one day; CRH high speed trains run at more than 300km per hour, galloping in the vast land of China. Trips from most of the Chinese province department cities to the capital city Beijing can be completed in 8 hours; highways extend in all directions, city loop roads and freeways pervade like the spider web; the car civilization really brings the travel convenience and the high efficiency to people all over the world. In addition, people also hope that supersonic aircrafts and magnetic levitation trains (Maglev) would create the higher speed.

Anyway, compared with the highly developed information technology (IT), the traffic speed has lagged. Based on the pursuit history to the high speed travel, the relaying of speed dream and the journey demand at the present era, we can be sure the people wouldn’t completely satisfied with the speed of the high speed train, Maglev train and supersonic aircraft, but also expecting the higher speed. This is the dream! The dream has been greatly contributing to the promotion of human science and technology development. Speed dream, will still be an important part of the Chinese dream and the world dream.

It should be seen that today's transportation civilization is companied with the grim reality confusion. It is consuming a lot of energy resources, destroying the environment, producing pollution and threatening the safety of life. Transportation is also the largest consumer of fossil fuels, with a large proportion of carbon emissions and greenhouse gas emissions. Cars are also the biggest makers of casualty all over the world, killing more than 1.24 million people worldwide each year [1].

Therefore, it is necessary, with the scientific wisdom to find a way and explore the route for solving the traffic plight. Technical analysis and scientific research have shown that the high speed maglev transportation in vacuum tube transport (VTT) has a unique excellent performance, which is expected to solve a series of problems in the current transportation [2-4].

2. Global transport dilemma situation

2.1 Dilemma 1: Human beings are looking forward to the higher speed for travelling

For the natural biological community, with the birth of them, there are two ways to travel. One is walking and running by the limbs, another one is flying by the wings. For human beings, as the spirit of the nature, the greatest regret is they have no wings and can’t fly by themselves. Ever since, the dream of flying has been one of the most intense desires of human beings, and has always been looking forward to it. Until the Wright brothers invented the plane in 1903, human beings, with their own wisdom, finally fly up by using the tools.

The flying dream is essentially the expectation for fast travel, free spanning obstacles and moving high efficiently. In the expectation process, human beings first learned to ride (ride cattle and ride horse, etc.), and then invented the roller and the vehicle, created boats. With the development of modern industrial revolution, manpower vehicles and boats were replaced by the motor vehicles and vessels which could reach faster speed and attain higher efficiency.
In a long era of riding, the Chinese nation not only conceived the idea of flying dragon, but also was ever striving to find the swift horse (Qianlima) in the real world. At the time when the train had just been invented, it was driven by the steam engine and its speed was slower than a horse. With the principle of speed potential, it was followed by the internal combustion engine, electric locomotive, high-speed train and maglev, the speed record was updated time and time again, from tens of kilometers per hour to more than 500km/h today. As for automobile development from ordinary highway to freeway, and then to racing car, the speed is also faster and faster. Obviously, the human desire for speed has never stopped.

Today the transport tools have been modernized. However, is the speed of travel already fast enough or not? Has it achieved the degree to be satisfactory for people or not? Has been able to meet the demand of economic and social development? These questions about the travel speed need to be examined and evaluated. On the freeway, accidents happen frequently due to the drivers often drive long time in fatigue. Even if for the high-speed trains, 8 hours is required to run over 2000km, so that passengers on train always feel sleepy. For thousands of kilometers of intercontinental travel, the aircrafts need to spend more than ten hours. Almost all people who suffered from travel mentioned the above, wouldn’t be satisfactory to the speed of cars, trains and aircrafts at present. From the perspective of economic and social development, traffic speed has become a constraint factor. Compared with the highly developed information technology, the transportation speed is obviously lagging behind. Therefore, it is necessary to develop a more rapid traffic model.

2.2 Dilemma 2: transportation is the highest energy consuming sector

Transportation is such an industry to occupy large amount of resource and consume large amount of energy. With the transport volume of passenger and cargo increases year by year, transportation energy consumption also increases year by year. In 2005, Chinese total energy consumption was 235,997 million TCE (converted tons of standard coal), the total amount of oil consumption is 325 million tons, in which the energy consumption and oil consumption of transportation, storage and postal sector were 166.72 million TCE and 107 million tons respectively, accounting for 7.06% and 29.84%. In 2011 the national total energy consumption is 3480 million TCE, the total oil consumption 440 million tons, of which the transportation, storage and postal energy consumption was 285.36 million TCE and oil consumption 160 million tons [5], respectively accounting for 8.2% and 36.4%.

In 2009, the global crude oil production was 399,448 million tons, the aviation sector consumes 142.9 trillion tons of oil, accounting for 3.58%; this year the total supply of crude oil in China was 18.962 million tons, the aviation industry consumes 2.71 million tons of oil, accounting for 1.43%. In 2009 the global maritime transport consumed 18.586 million tons of oil, accounting for 4.65%; in which Chinese maritime industry consumes 9.64 million tons of oil, accounting for 5.08% of China consumption.

In 2010, the total mileage of the electric railway in China is 42 thousands km, and the power consumption is 56.9 trillion kWh, which accounts for 1.36% of the total amount in this year. In 2014, Chinese railway mileage exceeded 112 thousands km, including electrified railway, the total mileage has exceeded 65 thousands km, in which Chinese high-speed railway over 16 thousands km[6], ranking first in the world. This year Chinese electrified railway consumed power 88 trillion kWh.

According to the statistic data from United Nations Statistical Division (UNSD), in 2012, the total energy consumption and the part by transport in some countries are as shown in Table 1[7]. The final energy consumption of United States, China, India and Russia ranked on top, respectively 56548972, 54831204, 21080980 and 16474788 (Tera-joules). The energy consumed by transport in these four countries account respectively for 45.15%, 15.16%, 4.82% and 25% of their total energy consumption.

<table>
<thead>
<tr>
<th>Country</th>
<th>Final Energy Consumption (Tera-joules)</th>
<th>By transport %</th>
<th>Road</th>
<th>Rail</th>
<th>Domestic</th>
<th>Aviation</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>56548972</td>
<td>45.2</td>
<td>5374010</td>
<td>503926</td>
<td>738004</td>
<td>1063766</td>
<td>633358</td>
</tr>
<tr>
<td>China</td>
<td>54831204</td>
<td>15.2</td>
<td>802482</td>
<td>160323</td>
<td>177595</td>
<td>1523302</td>
<td>653358</td>
</tr>
<tr>
<td>India</td>
<td>21080980</td>
<td>4.8</td>
<td>2035550</td>
<td>257769</td>
<td>277750</td>
<td>3076735</td>
<td>704554</td>
</tr>
<tr>
<td>Russia Federation</td>
<td>16474788</td>
<td>25.2</td>
<td>3369744</td>
<td>51705</td>
<td>2246108</td>
<td>503926</td>
<td>309888</td>
</tr>
<tr>
<td>Brazil</td>
<td>8966294</td>
<td>37.6</td>
<td>2276885</td>
<td>58451</td>
<td>3250849</td>
<td>257769</td>
<td>407888</td>
</tr>
<tr>
<td>Germany</td>
<td>8054549</td>
<td>27.1</td>
<td>2146108</td>
<td>58451</td>
<td>1250849</td>
<td>407888</td>
<td>245888</td>
</tr>
<tr>
<td>Australia</td>
<td>3120153</td>
<td>21.1</td>
<td>1236072</td>
<td>58451</td>
<td>704554</td>
<td>309888</td>
<td>399888</td>
</tr>
<tr>
<td>South Africa</td>
<td>2849896</td>
<td>24.7</td>
<td>704554</td>
<td>246108</td>
<td>107351</td>
<td>309888</td>
<td>399888</td>
</tr>
</tbody>
</table>

Table 1. Total energy consumption and part by transport in some countries in 2012 (Terajoules)
2.3 Dilemma 3: vehicles has been the most serious one of the environmental pollution sources

2.3.1 Air pollution

The situation of greenhouse gas effect, global warming and carbon emissions and the atmospheric environment is getting worse and worse, which is seriously damaging the earth home. By estimation, 19 percent of black carbon emissions in the world come from the transportation sector, with a relatively large share coming from diesel vehicles [1].

Table 2 World Carbon Dioxide Emissions, 1990, 2005 and 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Million metric tons from oil use</th>
<th>Percent of emissions</th>
<th>Million metric tons from oil use</th>
<th>Percent of emissions</th>
<th>Million metric tons from oil use</th>
<th>Percent of emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>United States</td>
<td>4,989</td>
<td>44%</td>
<td>5,985</td>
<td>44%</td>
<td>5,361</td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>471</td>
<td>48%</td>
<td>620</td>
<td>49%</td>
<td>552</td>
</tr>
<tr>
<td></td>
<td>Mexico/Chile</td>
<td>302</td>
<td>77%</td>
<td>461</td>
<td>66%</td>
<td>534</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>1,054</td>
<td>65%</td>
<td>1,241</td>
<td>52%</td>
<td>1,245</td>
</tr>
<tr>
<td></td>
<td>Australia/New Zealand</td>
<td>298</td>
<td>38%</td>
<td>438</td>
<td>55%</td>
<td>441</td>
</tr>
<tr>
<td></td>
<td>Russia</td>
<td>2,393</td>
<td>33%</td>
<td>1,548</td>
<td>25%</td>
<td>1,633</td>
</tr>
<tr>
<td></td>
<td>China</td>
<td>2,293</td>
<td>15%</td>
<td>5,490</td>
<td>16%</td>
<td>9,595</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>573</td>
<td>28%</td>
<td>1,182</td>
<td>27%</td>
<td>1,808</td>
</tr>
<tr>
<td></td>
<td>Africa</td>
<td>659</td>
<td>46%</td>
<td>978</td>
<td>43%</td>
<td>1,105</td>
</tr>
<tr>
<td></td>
<td>Total World</td>
<td>21,487</td>
<td>42%</td>
<td>28,054</td>
<td>40%</td>
<td>33,186</td>
</tr>
</tbody>
</table>

Resources from: Transportation Energy Data Book (Edition 34), September 30, 2015[8].

The U.S. accounted for 23.2% of the World’s carbon dioxide emissions in 1990 and 16.2% in 2005 and 2014. At the same time, China accounted for 10.7% of the World’s carbon dioxide emissions in 1990, 19.6% in 2005 and 28.9% in 2014.

In China and its Cities, the blue sky has become a luxury, and haze days have been so normal. One of the main air pollution sources is the car and plane. According to the national environmental statistics bulletin (2002-2012) [9] and the website information of China National Statistics Bureau[1], we can get the total emissions of nitrogen oxide, smoke (powder) and dust as well as emissions of the motor vehicle are shown in table 3.

Table 3 China's total emissions and motor vehicle emissions unit: million tons / year

<table>
<thead>
<tr>
<th>Year</th>
<th>NOX emission</th>
<th>Total emission</th>
<th>Vehicle emission</th>
<th>%</th>
<th>Smoke dust emission</th>
<th>Total emission</th>
<th>Vehicle emission</th>
<th>%</th>
<th>CO emission (Vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>16.4</td>
<td>9.86</td>
<td>2.77</td>
<td>16.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>16.2</td>
<td>9.01</td>
<td>2.82</td>
<td>17.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>16.9</td>
<td>8.47</td>
<td>3.17</td>
<td>18.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>18.5</td>
<td>8.29</td>
<td>2.90</td>
<td>15.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>24.0</td>
<td>12.78</td>
<td>6.37</td>
<td>26.5</td>
<td>0.63</td>
<td>4.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>23.4</td>
<td>12.34</td>
<td>6.40</td>
<td>27.4</td>
<td>0.62</td>
<td>5.0</td>
<td></td>
<td></td>
<td>3471.7</td>
</tr>
<tr>
<td>2013</td>
<td>22.2</td>
<td>12.78</td>
<td>6.41</td>
<td>28.9</td>
<td>0.59</td>
<td>4.6</td>
<td></td>
<td></td>
<td>3439.7</td>
</tr>
<tr>
<td>2014</td>
<td>20.8</td>
<td>17.41</td>
<td>6.28</td>
<td>30.19</td>
<td>0.57</td>
<td>3.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Nov. 28 to Dec. 1 of 2015, China, especially its capital Beijing, suffered the most serious air pollution in its record. Fig. 1 is a screenshot from the website of Ministry of Environmental Protection of China (MEP) [9]. It shows that the main pollutant PM 2.5 reached 498 μg/m³ by 19:00 on 2015-11-30 in Beijing.
According to the report from the MEP website, on Dec.1, 2015, haze engulfed an area around 550,000 km², rendering 27 out of the 70 cities in this region heavily or seriously polluted. Specifically, four cities Beijing, Shijiazhuang, Dongying, and Binzhou were seriously polluted, and 23 cities including Xingtai, Langfang, Linyi, Zibo, and Handan were heavily polluted. Beijing was hit the hardest by the haze, with AQI reading as much as 476 and mean daily reading of PM2.5 up to 464 μg/m³. The mean daily reading of PM2.5 in all of the 12 monitoring stations under the national monitoring program was above 250 μg/m³, and among others, at Guchengzi Station, the peak hourly reading of PM2.5 was up to 741 μg/m³.

Dec.7, 2015, Xinhua News reported that some officer of the Ministry of Environmental Protection of China claimed they had find the main source of PM2.5 in some cities such as Beijing, Hangzhou, Guangzhou and Shenzhen is vehicles[10-11].

2.3.2 Noise pollution
Besides air pollution, another modern plague is the noise pollution. The source of most city noise worldwide is mainly transportation system, motor vehicles, aircraft and trains. High noise levels would cause cardiovascular effects in humans and an increased incidence of coronary artery disease. Noise pollution affects both health and behavior. Chronic exposure to noise can damage psychological health, cause hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects [12-13].

By “2014 Nanjing Environment Situation Bulletin”, mean traffic noise of Nanjing was 67.2 dB in urban, 67.6 dB in suburb. In 2013, mean traffic noise of Nanjing was 68.4 dB in urban and 66.8 dB in suburb. All these noise value in two years exceeded allowable value. In all city environmental hot telephone, complaints about noise pollution from residents account for the most percentage, mainly the complaints for traffic noise. Traffic noise has been the first pollution source of Nanjing noise pollution [14].

In some areas in Beijing where subway, railway and high speed main road go through and exist at the same time, traffic noise is affecting and disturbing residents living there. Especially these areas along to subway line 13, line 5 and Batong line that is on ground, traffic noise problem is outstanding specially. Some residents have litigated the municipal subway company as well as real states companies to the local court. Building 10 located in Taixiangyuan on the west side of Zhichun Road is about more than 10m far from the subway line 13, and railway S2 line close to subway line 13. In the house in Building 10, residents couldn’t almost listen to the normal TV sound when the train goes by. Even if in the hot summer, residents have to keep windows closing. Especially when both the subway train and railway train go by at the same time, and they whistle
screamingly, residents couldn’t almost bear the combined noise [15].

Dr. Tian Feng studied noise annoyance situation of Beijing-Shanghai High-speed Rail section in Anhui. The results indicate that 86.2% of the samples are exposed to the noise exposure level above 70 dB; 81.4% of the living environment has been interfered by high-speed noise, 32.1% of which has reached a serious or rather serious degree. Significant differences exist in terms of the variety in age, hearing status, body health, building sound insulation effect and exposure sound level; 35.8% samples rise earlier, 35.3% samples prolong sleep, 49.6% awaken more during nights, 35.3% are severely disturbed in sleeping, the running traffic between 8 pm to 8 am producing great disturbances onto sleep quality of residents along. He pointed out the significant difference boundary lies in 300 -400 meters, so the influence scope of 200 meters prescribed in present technical specification is unrepresentative [16].

Aircraft and airport noise are complex and difficult global problems which have been studied for decades and are still the focus of many research efforts today. It is bringing harm to human beings. The aircraft noise mainly includes the act device noise and aerodynamic noise. Its harm relates to impact on the inside cabin and outside cabin. The outside noise impact directly interferes to flight line along and airport around, especially when aircrafts take off or get down. Generally the aircraft noise level is on 90–110 dB and the avion noise level is on 130 dB.

2.4 Dilemma 4: transport safety situation is austere

Automobile vehicle has been the killer which seriously threatens life safety. In China, total 3906164 road traffic accidents were reported in 2010, including 219521 accidents which related to casualty, made 254075 persons wounded and 65225 persons death, direct economic loss 930 million CNY. Total 210812 road traffic accidents were reported in 2011, including 237421 accidents which related to being wounded, made 62387 persons death [17]. Table 4 shows the death number in road accidents of some countries in the past ten years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Nation</th>
<th>P. R. China</th>
<th>United States</th>
<th>Russia</th>
<th>India</th>
<th>Brazil</th>
<th>South Africa</th>
<th>Worldwide</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


High-speed railway is rather safe, but it is vulnerable in some aspects. A bird can stop a high-speed train sometimes.

In addition, airplane is another vulnerable transportation tool and accompanies with safety risk. In 2010, 28 flight disasters led 828 people death all over the world.

In 2014, many flight disasters happened. On March 8, MH370 of Malaysia pranged and 239 people on board died. On July 17, MH17 of Malaysia was shot down and 298 people on board died. On July 23, GE222 of Taiwan got down emergently and 48 people died. On July 24, AH5017 of Algeria pranged and 116 people on board died. On Aug. 10, one Iran airline pranged and 48 people died. On Dec. 28, one airline of Asia Flight pranged in sea and 162 people on board died.

3 , VTT is the only way to run at ultra-speed on the ground

Transport means in running would be thrown the resistance $F$. 

$$ F = F_r + F_a + F_v $$

In Eq. (1),

$F_r$ is rolling resistance, $F_a = mgf_r$. In which $m$ is vehicle mass, $g$ is acceleration and $f_r$ is rolling friction coefficient. For motor vehicles and high-
speed railway trains, \( F_r > 0 \). For airplanes and VTT trains, \( F_r = 0 \).

\( F_a \) is aerodynamic resistance, \( F_a = \frac{C_d A \rho v^2}{2} \), in which \( C_d \) is aerodynamic resistance coefficient, \( A \) is front face area, \( \rho \) is air density and \( v \) is running speed. For motor vehicles, high-speed trains and airplanes, \( \rho \) is constant, and generally \( \rho = 1.225 \text{ kg/m}^3 \). For maglev trains running in VTT tube, \( \rho \) could be selected by demand and it would be much less than 1.225kg/m³.

\( F_s \) is the combined force by both internal frictional resistance and bearing rolling resistance. For motor vehicles and high-speed trains, \( F_s > 0 \); for airplanes and VTT trains, \( F_s = 0 \).

Therefore, running resistance of VTT maglev trains would be less than that of motor vehicle, high-speed railway trains or airplanes.

For motor cars running on road, speed wouldn’t be very fast because they are restricted by some factors as following. (1) Resistance between tires and ground is great; (2) Vibration of cars running ground is great, faster the cars run, more serious the vibration; (3) Aerodynamic drag restrict the motor vehicle speed; (4) Due to emergent response speed restriction from drivers, motor vehicles speed isn’t allowed to be very fast. All these restriction factors don’t exist for VTT, thus VTT train speed could be much faster than road vehicles.

Due to rail-wheel coupling restrict and aerodynamic drag, running speed on high-speed railway shouldn’t exceed 400km/h. For maglev train, mechanical friction is eliminated, but aerodynamic drag would rise with the speed square, namely \( F_a \sim v^2 \). The test speed of Japan Yamanashi Maglev reached 603km/h, but it isn’t feasible on economic to operate in reality, for overcoming the huge aerodynamic drag at so high speed would consume tremendous power energy. And, the aerodynamic noise and vibration would also be close to the mechanical limit, thus its speed shouldn’t be increased further more. For VTT, maglev trains will be put into the tube where gas is exhausted, and aerodynamic drag is eliminated or decreased greatly. Therefore, maglev train speed in VTT tube could reach very high.

As for the airplane flying at troposphere are restricted by aerodynamic drag so that its speed doesn’t exceed 1000km/h. The speed of the supersonic airplane flying at higher space and in rarefied atmosphere could reach 2000km/h or more, but at that speed the aerodynamic noise and vibration would be too high, oil consuming too high so that it isn’t right to popularize supersonic airplane as mass transport means. It is just for these reasons, France “Concorde” supersonic airline had exited from market in October 2013.

Therefore, only VTT, breaks through the above various restrict factors to speed, so that VTT speed could reach extreme high. At beginning, VTT speed should be 600–1000km/h, 1% atm low air pressure environment could meet the basic requirement for small aerodynamic drag. At the second stage, VTT speed would be supersonic, about 1000–3000km/h, and 1% atm low air pressure environment could meet the basic requirement. At the third stage, VTT speed would be faster, about 3000–6000km/h, and 0.1% atm (less than 10Pa) low air pressure environment could meet the basic requirement.

When VTT speed is more than 4000km/h, most global travel could be finished in 3 hours. At the fourth stage, VTT speed would be hypersonic, about 6000–10000km/h, and vacuum in VTT tube should be much less than 10Pa, then almost all travel worldwide could be finished in 2 hours. At the fifth stage, VTT technology with speed over 10000km/h will be studied, creating the highest speed for ground travel of human beings and realizing space travel on earth.

It’s clear, only VTT, is the exclusive effective way to realize hypersonic travel on earth.

4. VTT energy consuming is least

Power energy consuming \( Q \) of vehicles consists of two parts.

\[ Q = Q_a + Q_f \quad (2) \]

In Eq. (2) \( Q_a \) is energy consuming for accelerating, \( Q_a = f_a \cdot t \), \( f_a = ma \), in which \( m \) is the vehicle mass, \( a \) is acceleration. For certain distance and acceleration, \( Q_a \) is decided by the times of accelerating. Given travel distance 1000km, which is the smallest reasonable distance for VTT, VTT train normally needs one time of accelerating. But road motor vehicle needs 10 times of accelerating at least to run through 1000km. Thus road vehicle energy consumption for accelerating is much higher than that of VTT train.

\( Q_f \) is the energy consuming for traction, \( Q_f = Q_f(F_{f\text{ric}}, F_{\text{aero}}) \), and \( Q_f \) is proportional to rolling friction drag \( F_{f\text{ric}} \) and aerodynamic drag \( F_{\text{aero}} \), namely \( Q_f \sim (F_{f\text{ric}}, F_{\text{aero}}) \). For VTT, the rolling friction drag \( F_{f\text{ric}} \) is 0, and aerodynamic drag \( F_{\text{aero}} \) is much less than that of road vehicle. Thus the energy consumption to keep VTT maglev trains running will much less than that of road vehicle. Although it is necessary for VTT to create vacuum at beginning and it consumes much energy, tube vacuum environment could be kept long time. Thus
operation to exhaust for VTT tube is seldom, maybe one time for several months or even more than one year, so that we have reason to think the total energy consumption of VTT would be much less than road vehicles.

Airplane in flying and VTT maglev train in running is acted by only aerodynamic drag $F_a$, $F_a = \frac{1}{2} C_d A \rho v^2$. Energy consumption $Q$ is proportional to $F_a$, and $F_a$ is proportional to air density $\rho$, then $Q$ is proportional to $\rho$, $Q \sim \rho$. Air density $\rho$ in VTT tube could be decreased to very low, much lower than airplane, therefore, energy consumption $Q$ of VTT would be much less than that of airplane.

Because both mechanical resistance and aerodynamic drag are eliminated, energy consumption consumed by vehicles in VTT tube would be extreme low. It is mainly consumed at the stage to accelerate or decelerate vehicles. In addition, it would consume little energy to overcome the left aerodynamic drag. With the optimized comprehend effect, unit equal energy consumption of VTT would be much less than that of railway, motor vehicle and airplane [19]. Here suppose high temperature superconductivity maglev is used in VTT, so that the energy consumption for levitating the maglev train could be neglected.

However, VTT has a special energy consumption to create the vacuum environment for tube, that isn’t necessary for railway, road vehicle and airplane. If setting the pump station every 2km, available pumping speed 1000L/s, tube diameter 2m, rated vacuum 1% atm, then the necessary pumping time is 482 minutes[20]. If exhausting for VTT tube each day or each week, then the total energy consumption to create vacuum would be very high, so that VTT loss the advantage to consume extreme least energy. In fact, existing technology has been able to keep vacuum situation for long term. For example, loading-man spacecraft flying in vacuum environment 10^4 Pa, the airtight of spacecraft shell could be kept for long term. The vacuum of thermos bottles and vacuum flask is about 10^{-1} Pa, approximately equal to that of VTT, could be kept long term as long as you don’t break it. Therefore we can say vacuum could be kept long term, and we can believe that vacuum environment of VTT tube could be kept long term with the current technology level. It means that the unit energy consumption to create vacuum for VTT tube would be tiny.

Artificial satellite and spacecraft can fly for dozens of years without any driving power and energy consumption. It profits from the space environment without resistance. Similarly, VTT vehicles will run in vacuum tube without aerodynamic and friction resistance, so that it will consume tiny energy. Therefore, we claim that transportation and travel wouldn’t certainly consume large amount of energy. As long as we change old thoughts and technology route, open creative thoughts and make use of creative wisdom, it is highly possible to find transportation tools and travel mode which consume only a little energy. We claim, VTT will bring out hyper speed transportation and travel on earth with only tiny energy consumption. On the sense, vacuum, could be thought as one kind of energy source which is completely clear and low cost. Vacuum, is also an energy treasury, and would save a great amount of petrifaction energy source for human beings, as long as we make use of it properly.

5. VTT is the transportation means with extremely low emission and pollution

Exhaust emission $P$ of transportation tools is proportional to energy consumption, $P \sim Q$. By the above analysis, unit energy consumption of VTT would be less than 1/100 of airplane, less than 1/50 of motor car. Then, the harmful exhaust emission of VTT will be less than 1/100 of airplane, less than 1/50 of motor car.

Maglev train running in VTT tube consume a little electricity power, not consuming petro oil, so it doesn’t emit CO$_2$, CO$_x$, NO$_x$, hydrocarbon and particulate matters, not like motor cars, airplanes and gas engine. Except for emitting air from tube to outside when creating vacuum, VTT doesn’t emit any matter to outside tube when operating. Therefore, VTT is a clear transportation mode with almost zero emission and zero pollution.

With some advantages such as hyper speed, low cost, good safety and low carbon emission, VTT could replace more than 50% of passenger and freight turnover finished by current motor vehicles, railway and airplanes. It means that VTT could reduce half of current carbon emission of transportation activities. With VTT operation, a low carbon environment and a non-haze sky could be expected.

Except for exhaust gas produced by fuel combustion, passengers or drivers on train or cars possibly throw garbage out, so that environment along line would be polluted. VTT train is a closed airtight shell, and will run in a completely closed airtight tube, thus no any things could be thrown out or dropped along to VTT line. No anything could be thrown into inside tube too.

Because of long travel time, lavatories are always set on passenger train carriages and airplanes, even on some long-distance bus. It leads the inside environment of train, airplane or long-distance bus to be bad, emitting bad smell. For VTT, right design schedule should have any VTT travel be finished in 3 hours. At beginning when VTT speed is low (600-1000km/h), only run “short-distance train”
VTT is higher than that of motor cars. Tube wall, thus the constituent safety performance of also with all directional restrict and safeguard from that time, SWJTU began VTT research.

6. VTT is relatively safer

Airplane flying in space faces to several dangerous factors. Due to lacking of holding protection, airplane would drop down to earth from high space in the case it wrecks, leading to fatal crash, surviving probability very low. As a transport tool running on earth, VTT wouldn’t face to risk to fall down. Airplanes are brittle for weather when taking off, getting down and flying, and couldn’t take off or get down in bad weather with heavy fog, rain, snow or strong wind. It’s possible for airplane in flying to be stricken by thunder, while VTT wouldn’t be affected by any weather factor such as winding, raining or heavy fog. VTT vehicles running in tube wouldn’t be stricken by thunder any time. Airplanes tend to become aims hijacked by criminals and terrorist, because airplanes are easy to be hijacked and are easy for terrorist to achieve their purpose. Criminals and terrorist could drive airplane to some places they want to go. VTT vehicles run along to fixed route and are operated automatically, so it isn’t worth for criminals and terrorism to hijack VTT vehicles. In fact, it is impossible for VTT to be hijacked like an airplane.

By key factor analysis method, we can see that the airplane is the most unsafe transport means. However, by fatal crash death based on the passenger turnover, airplanes are thought as the safest transport means. We have to point out that airplanes embody the safety based on the most strict safe safeguard. It is clear, if no strict safeguard, airplanes would be the most unsafe at all.

A flying bird can bump an airplane or a CRH train, but it’s impossible for a bird to bump a VTT train which runs in the tube. Motor car is driven by human, no fix rail for it, so that the optional and non-restrict characters make road motor vehicles become the most main killer in transportation. VTT vehicle is operated automatically, not only with rail restrict, but also with all directional restrict and safeguard from tube wall, thus the constituent safety performance of VTT is higher than that of motor cars.

Almost all mechanical failures are aroused by vibration. Besides jounce vibration from route unsmooth, the other main vibration of motor car, train and airplane is the aerodynamic vibration. Because of no aerodynamic vibration, almost no mechanical failure would happen on Satellites and spacecrafts flying in space vacuum environment, so that they could safely fly for dozens of years in space. VTT vehicles run in vacuum tube without aerodynamic vibration or only a little, much less than that of motor cars, trains and airplanes in running or flying, thus failure probability of VTT vehicle will be less than that of motor car, train and airplane.

7. Origin Idea and research history

VTT origin idea could be traced to two early U.S. patents, “Vacuum Railway” (US1336732, May 23, 1919) applied by Robert Ballard Davy[21] and “Vacuum Tube Transportation System”(US2511979, June 20, 1950) applied namely by Robert. H. Goddard (His wife applied after his death)[22].


The formal research on VTT started in 1974 when Germany engineer developed the concept of a Swissmetro to provide high-speed travel between Switzerland's principal urban and rural areas. 1981. The project receives the support of a group of professors at the Swiss Federal Institute of Technology in Lausanne (EPFL), who carry out a study of the feasibility of the project. 1985, interest in the project is shown at a political level, with support for the project in Parliament by Robert Ducret (Geneva) and in the National Council by Sergio Salvioni (Ticino). 1999, Presented the final results of the Main Study[25]. Up to now, Swissmetro hasn’t been built and relative research step almost stops.

In the early 1990s, America engineer Daryl Oster started to be engaged in VTT research and development. He applied U.S. patent “Evacuated Tube Transport” (US5950543)[26] in 1997 and created ET3.com Inc. in Florida in 1999. From that time, modern VTT research had got going.

Zhang Yaoping created relationship with Daryl Oster in 2001 and began his research on VTT. With the invitation from Zhang Yaoping and Prof. Wang Jiasu, Daryl Oster and his wife arrived at Beijing on Dec. 4, 2002. Afterwards, they visited Southwest Jiaotong University (SWJTU) and a cooperation agreement on VTT study was signed between ET3.com Inc. and SWJTU (see Fig.2). However, that agreement wasn’t carried out effectively. Anyway, from that time, SWJTU began VTT research.
2006, research project “Basis Study on Evacuated Tube High-speed Maglev Transportation” was funded by National Natural Science Foundation of China (No. 50678152) which is presided by Zhang Yaoping. It means VTT research is concerned and supported by China authority and government. With effort of Zhang Yaoping. Institute of Evacuated Tube Transportation and Institute of Vacuum Tube Transport were created respectively in SWJTU in 2006 and in Xijing University in 2009.

Chinese VTT research is progressing. Some main universities which study on VTT in China are SWJTU, Xijing University and Qingdao University of Science and Technology. A HTSM VTT prototype was built in SWJTU in 2014. However, China government is spreading HSR and wants to market HSR to more other countries, so that VTT research and development is blocked at present. Because some politicians are afraid that VTT would disturb their HSR marketing plan.

8. Conclusions

By the above analysis, transportation problems have been the most serious challenge to human beings. Cars, trains, airplanes and ships are the symbol of modern civilization, but they are also the producers of air pollution, noise pollution, marine pollution, carbon emission and fatal accidents. People worldwide have paid much effort to solve these problems, but the effect isn’t ideal. With economic growth, transport dilemma in developing countries became more serious. How to overcome all the above problems and dilemma radically, bringing human beings out from the current dilemma? We can get a significant conclusion: building VTT and having maglev run in the vacuum tube so as to carrying out ultra-speed travel on earth, while reducing energy consumption to least, substantially reducing air pollution and noise, realizing zero emission, and reducing transport casualty accidents by all dimension restrict and high order.

The primary oppugning for feasibility of building VTT is if the construction cost would be too expensive. As for the reply to this oppugning, at first we should see that high technology doesn’t certainly mean high cost. The science and technology development history has made know that the final case is often reversed to the perceived case on the cost at the beginning. High technology with prospective potential is always with of traits to reduce social comprehensive cost and increase social comprehensive efficiency. With highly automatization and integration, tube cross-section of VTT can be very small for equal shipping ability, so that its construction cost wouldn’t be higher than that of HSR and freeway. This would be right similar to that the cost of integrate circuit is less than transistor, CMOS chip cost less than circuit board, and SPC exchange cost is less than that of the wiring logic control switch.

Therefore, we are sure that VTT will be an effective solution to transport dilemma of human beings.

Acknowledgements

The work is supported in part by a grant from the Scientific Plan Funding of Shaanxi Province Education Department (No. 14JK2167) and Teaching Reform Project 2016 of Xijing University (JGGH1608).

This work was supported in part by a grant from the National Science Foundation.

References


