# Magplane China Pre-Feasibility Studies

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ABSTRACT: Pre-Feasibility Studies are being carried out to assess the potential for deployment of Magplane in China. One high volume route previously studied for various competing technologies has been chosen to also give a comparison with the Magplane System. The initial route chosen is a high speed connector along the Jing-Jin-Tang (Beijing-Tianjin-Tanggu) Corridor between the Beijing and Tianjin airports. The traffic flow in that corridor is anticipated to be 130 million people and 91 million tons cargo per year by 2020. The studies address the social and economic development of the regions, passenger and freight flow estimates, a comparison of Magplane with other modes of transport (highway, railway and other maglev), return on investment and construction related issues.

## 1 INTRODUCTION

Because the Magplane project is still in the experimental stage, this pre-feasible research [1] studies the corridor between Beijing and Tianjin as a "hypothetical route" to provide a reference case for the feasibility of the Magplane project [2].

We assume that a Magplane line is constructed along the existing highway with the guideway elevated over the highway, with the line passing through Beijing, Tianjin and Hebei Province with the whole length of 130 kilometers.

The Beijing and Tianjin transportation corridor is one of the synthesis transportation corridors with the most complete infrastructure, the highest technical level, the most powerful comprehensive transportation capacity, and the busiest passenger and cargo transports. At present, the corridor mainly includes the Beijing-Tianjin-Tanggu highway and the Beijing-Tianjin section of Beijing-Shanghai railroad. Additionally, the Beijing-Tianjin second highway and the Beijing-Tianjin intercity railroad, which are under construction, will be completed and open to traffic in 2007.

(1) **Beijing-Tianjin-Tanggu highway.** The whole length of this road is 142 kilometers, in which Beijing-Tianjin section is 130 kilometers. The designed traveling capacity for cars is 55,000 vehicles per day on average (maximal traveling capacity). At present the utilization is above 85%.

(2) **Beijing-Tianjin section of the Beijing-Shanghai railroad.** This section is 137 kilometers long. In 2003, the unidirectional passenger flow density was 17.46 million people/year. The utilization of Beijing-Tianjin section has surpassed 90%.

(3) **Beijing-Tianjin second highway.** At present the second highway is being constructed between Beijing and Tianjin, and is estimated to be completed and open to traffic in 2007.

(4) **Beijing-Tianjin intercity railroad.** The whole length of this line is 115 kilometers long, and the total investment of this project is 12.34 billion Yuan. At present, the line has been constructed with the designed speed of 250 kilometers/hour. It is estimated to be put into use in July 2008, and is anticipated to achieve the goal of a travel time of half an hour between Beijing and Tianjin.

(5) **Beijing-Shanghai passenger transportation line**. The whole length of this line is 1,300 kilometers long, in which the Beijing-Tianjin portion is constructed with a design speed of 250 kilometer/hour. At present the line is under construction and is estimated to be completed and open to traffic in 2010.

According to the traffic census materials and the transportation investigation, the total quantity of passenger transportation demands on Beijing-Tianjin corridor was 115.85 million people in 2005.

## 2 TRANSPORTATION DEMAND FORECAST

There are many cities along the Beijing-Tianjin corridor with medium and small towns spread throughout; there is a dense population and frequent passenger flows. With the implementation of a developmental strategy to build up a comparatively well-off society in China, the national economy in this area will develop rapidly. The urbanized level will be greatly enhanced and the economy development and inhabitant's cultural living standard will increase continually. The request of the people for transportation quality will increase, and transportation effectiveness is anticipated to improve. In the future, a large quantity and a large range of short distance passenger transportation demands among the cities and countryside and between the cities in Beijing, Tianjin and Hebei areas will develop.

(1) According to the forecast shown in Table 1, the passenger transportation demands will reach 176.27 million people in the Beijing- Tianjin corridor in 2010 with the average yearly growth rate of 8.8% during the 2005-2010 period. The demands will reach 320.955 million people in 2020 with the average yearly growth rate of 6.2% during 2011-2020 period The demands will reach 487.751 million people in 2030 with the average yearly growth rate of 4.3% during 2021-2030 period. The forecast results indicate that in the future the passenger transportation demands in Beijing-Tianjin-Tanggu corridor will be exuberant, the development speed rapid, and the passenger transportation demand will likely be greater than predicted.

Table 1: Passenger Transportation Demands in the Future in BeijingTianjin corridor
(Units: Ten Thousand people)

| Year | 2005 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| Transportation capacity | 11584.8 | 17627.0 | 32095.5 | 48775.1 |

(2) The supply characteristic of each kind of transportation mode and the passenger transportation market share of the road, the railroad and the high-speed railroad are listed in Table 2. The Magplane share of the total is estimated to be in the range of 18% of the corridor transportation capacity.

(3) According to the forecast shown in Table 3, the bidirectional passenger exchange capacity, which the Magplane will address, will reach 30 million people/year in 2011 between Beijing and Tianjin, and will increase progressively with 6% growth rate per year thereafter. It will reach 50.68 million people in 2020 and 90.77 million people in 2030.

Table 3: Transportation capacity forecast for bidirectional passenger flows between Beijing and Tianjin
(Units: Ten thousand people/year)

| Year | 2010 | 2020 | 2030 |
|---|---|---|---|
| Passenger transportation capacity forecast in the corridor | 17627 | 32096 | 48775 |
| Passenger transportation capacity forecast for Magplane | 3173 | 5777 | 8780 |

## 3 COMPARISON OF TECHNICAL AND ECONOMIC CHARACTERISTICS OF PRINCIPLE TRANSPORT MODES

Different transport modes have different technical and economical characteristics. Several of these factors have been objectively evaluated and result in some large differences between each transport mode. Factors include among others: the running speed, the transportation capacity, the operation condition, the transportation cost, the security, comfortableness, and convenience. Each mode has its own advantages and disadvantages. For the Beijing-Tianjin passenger transportation route, the technical and economical characteristics of three main transportation modes: the highway, the railroad (that mainly will be a passenger transportation special line), and the Magplane maglev system are compared in Table 4.

Table 2: Unit fare, characteristic and market share for each mode of transportation

| | Magplane | Railroad | Road | Railroad passenger transportation line | High-speed railroad |
|---|---|---|---|---|---|
| Average ratio of the price (Yuan/Kilometer) | 0.68 | 0.12 | 0.25 | 0.5 | 0.5 |
| Average running speed (Kilometer/hour) | 400 | 130 | 100 | 250 | 250 |
| Market share | 18% | 12% | 35% | 20% | 15% |

Table 4: Comparison of Economic Characteristics of Highways, Railroads and Magplane

***Operational Speed***

Highway: Operational speed up to 100 km/hr [Evaluation – Fast]

Railway: The speed of ordinary railroad is 70-160 km/hour; intercity railroad and passenger transportation lines are typically 250 km/hour. [Evaluation - Faster]

Magplane: Intercity from 400 to 500 km/hr [Evaluation - Very Fast]

***Transportation Capacity***

Highway: Passenger transportation per vehicle 50 maxi- mum [Evaluation – low]

Railway: Generally every train carries 1800 people [Evaluation- large]

Magplane: Can flexibly organize into individual or multi-car; maximum unidirectional 30,000 passengers/hr [Evaluation – large]

***Flexibility:***

Highway: [Evaluation – good]

Railway: Often restricted by topography and physical surroundings [Evaluation – less good]

Magplane: Evaluation – good

***Construction Investment:***

Highway: Construction cost of the highways in Beijing-Tianjin area is about 80 – 150 millon yuan/km [Evaluation - comparatively high]

Railway: Ordinary railway construction is 30 – 60 million yuan/km; passenger transportation lines and high speed rail is about 100 million yuan/km [Evaluation – comparatively low]

Magplane: Construction cost approximately 120 million yuan/km without land [Evaluation – high]

***Operations Cost:***

Highway: Road transportation is about 3.6 times that of ordinary railway [Evaluation – high]

Railway: The freight volume is large, the transportation density is high and the unit cost is low [Evaluation – comparatively low]

Magplane: According to calculations, the unit passenger transportation cost for magnetic levitation transportation system with the speed of 450 km/hour (that is, the transportation cost per person in the same time to the same distance) is equal to 2/3 of that of high-speed rail with the speed of 300 km/hour. [Evaluation – Comparatively high]

***Energy Cost:***

Highway: Unit energy transportation cost is comparatively high [Evaluation - high]

Railway: Unit energy transportation cost is comparatively low [Evaluation - comparatively low

Magplane: At a speed below 300 km/hour the energy consuming of the magnetic levitation train is 1/3 less than that of high-speed rail train [Evaluation – low]

***Availability of service:***

Highway: Can achieve gate to gate transportation [Evaluation – high]

Railway: Passengers spend some time and expense to arrive at or depart from the railway station [Evaluation – comparatively high]

Magplane: Hard to enter the center of the city, and passengers spend some time and expense to arrive at or depart from the station [Evaluation – Normal]

***Land Occupied*:**

Highway: The use of area for a highway is 2.5 – 3 times that of a railway at the same transportation capacity. [Evaluation – high]

Railway: Less area than highway [Evaluation – comparatively low]

Magplane: Use of elevated guideway minimizes area occupied [ Evaluation – comparatively low]

***Comfort:***

Highway: [Evaluation – normal]

Railway: [Evaluation – comparatively good]

Magplane: Advanced intelligent transportation system; stable at take off, landing, and operation. [Evaluation – good]

## 4 COMPARISON OF US MAGPLANE, JAPANESE EXPRESS AND GERMAN TRANSRAPID

The Magplane, Japanese and German maglev trains individually represented three kinds of typical maglev technologies; their main technical characteristics are compared in Table 5.

## 5 THE ECONOMIC AND TECHNICAL ADVANTAGES OF MAGPLANE

The Magplane system optimizes each kind of transportation resources by integrating the multiple technical characteristics. It has not only relative low construction and operation cost, but also the realized unification of high speed, large passenger capacity, and the merging of the urban short-distance transportation and intercity long-distance transportation system. Consequently, Magplane provides an organic whole solution to the complicated city transportation system environment.

The Magplane uses a non-contact levitation, guidance, and propulsion system, and may well become the fastest ground passenger-traffic tool available in the world. It has the advantages of high speed, strong climbing ability, low energy consumption, low operational noise, safety, comfort, no on-board fuel requirement, and less pollution. In addition, elevated guideways and small curving radius take less land.

The Magplane uses independent, passive vehicles that can be coupled when necessary for additional capacity. When the vehicles move, the on-board permanent magnets induce currents (eddy currents) in the trough-like aluminum sheet guideway to realize levitation. The long stator coil located on the center of the guideway and the on-board permanent magnets constitute the linear synchronous motor. The Magplane appears like a wingless plane flying 10 centimeters above the aluminum trough. Aerodynamics parts on the top of vehicles control the flight dynamics. Taken all together, Magplane is simpler than the German electromagnetic maglev and Japanese superconductivity maglev systems. The main technical advantages lie in:

(1) Magplane uses permanent magnets to realize levitation and does not need activation and a real-time servo control system. It avoids the electric power demand of conventional electro-magnets or the complex cooling systems for the superconducting magnets, and the passive stability guarantees safe, comfortable, and stable high-speed operation. The large operating gap reduces the route investment, reduces the energy consumption, and makes it simple to operate and maintain the guideway.

(2) Magplane is a high-level intelligent transportation system, with stable take-off, landing, and operation. If the power fails it will automatically decelerate, with high safety reliability, and good comfortableness. It uses a real-time, high-speed, effective dispatch system to change the demand to accommodate the passenger flow of the transportation system and to enable the real-time local transportation intelligent link and dispatch between urban and intercity transportation.

(3) Magplane can be accelerated to high speeds within a short distance and will achieve levitation once reaching the speed of 20 km/h with the normal levitation gap of 10 cm. The intercity running speed is 480 km/h, and the intra-city travel speed is 120 km/h. The distance between two urban neighboring stops would typically be 1.2 km.

(4) Magplane is an elevated guideway transportation system, with small curving radius and strong

Table 5: Characteristic comparisons of Japanese, German, American maglev technology

| | Japan | Germany | USA |
|---|---|---|---|
| Guideway Structure | U type | T type | U type |
| Levitation mode | Repulsion type | Attraction type | Repulsion type |
| Levitation Gap | 150-200mm | 7-8mm | 100-150mm |
| Propulsion | LSM | LSM | LSM |
| Guideway magnets | Conventional excitation | Conventional excitation | Conventional excitation |
| On-board magnets | Superconducting excitation | Conventional excitation | Rare earth permanent magnets |
| Magnetic Fields | High | Middle | Low |
| On-board excitation electricity consuming | Highest | Middle | No |
| Areas of magnetic poles | Least | Middle | Largest |
| Vehicle weight | Heaviest | Middle | Lightest |
| Vehicle electricity consuming | Highest | Middle | Lowest |
| Maximal speed per hour | 550km | 500km | 550km |
| Vehicle Construction | Most complicated | High precession | Comparatively simple |
| Guideway manufacture | Comparatively hard in techniques | Hard in techniques | Easy in techniques |
| Engineering implementation | Complicated | High requirement for precession | Easy to be implemented |
| Cost per km | \$1200 million | \$35 million | \$20 million |
| Switch | Mechanical | Mechanical | Electromagnetic |
| Switching speed | About 5-8 minutes | About 8-16 minutes | 0 |
| Service mode | Point to point | Point to point | Multiple points |
| Suitable transportation line | With less switch | With very little switch | No limit |
| Headway | 5-8 minutes | 8-16 minutes | >20 seconds |
| Passing capacity | Middle | Low | High |
| Maximal slope of the guideway | 8% | 12% | 35% |
| Curving radius | Largest | Large | Smallest |
| Maximal climbing capability | ≤8% | ≤12% | ≤24% |

climbing capacity, and can be constructed along the existing road to reduce the land area requirements.

(5) Magplane does not use any onboard fuel. It has no waste gas, no air pollution, low running noise, and no magnetic pollution to the passenger and the peripheral environment As a result, it belongs in a class with the cleanest and most environmentally friendly transportation systems.

(6) Magplane uses the most advanced non-mechanical movement electromagnetic switching technology. As a result, it not only makes the switching simple and reliable, but also reduces the construction expense of the line and stations. Therefore, it can completely change the traditional mechanical rail switch of the railway and the very complex, unwieldy, high-cost German and Japanese maglev switch concepts.

(7) Magplane can integrate the urban and intercity transportation. The line network which consists of multi-aisle platform and the multiple host and branch guideways can switch like the highway. It is suitable for the main intercity line with large service density as well as the large transport capacity required for the intracity applications. The headway can be reduced to 1 minute, with minimum distance of 1.2 km between two neighboring stations. The one-way transportation capacity can reach 30,000 person/hour in an urban system. The system will have a low operation cost.

(8) The aluminum sheet portion of the guideway is light weight, with low fabrication precision requirements because of the large levitation gap which can reduce the construction cost of guideway by a significant amount. The entire construction system includes the guideway, the Magplane vehicles, the control system and the stations (but not the land). The total construction cost is low, with each kilometer expense being 20 million US dollars, (165 million RMB) and can be reduced as the technology and manufacturing base in China matures.

## 6 INVESTMENT BENEFIT ANALYSIS OF THE AMERICAN MAGPLANE

We assume that this "hypothetical" project will begin in 2008, complete the construction and the installment in 2010, accomplish the commissioning tests in 2011, and be put into service in 2012.

The total construction investment includes static investment, the land, interest during the construction period, and the basic preparation fees. We make the assumption that the construction funds originate from two parts: the innate capital and the domestic loans, in which 50% are the innate funds, and 50% are bank loans with 7% loan interest rate.

The total construction investment for the project is estimated to range from 20.2 to 26.3 Billion Yuan depending on the unit cost of construction in China for the Magplane system. The relative breakdown of the total investment is shown in Table 6.

The return on investment over the range of construction investment, and the various assumptions used for passenger flow, operating expenses and travel fares has been estimated using economic models at the Institute of Comprehensive Transportation. At the low end of the range, the internal revenue rate (IRR) of the Magplane project in the Beijing and Tianjin corridor is 8.85%, the FNPV is 6.63 billion Yuan, and the investment recycling time is 14.2 years. At the high end of the range, the internal revenue rate (IRR) is 7.16%, the FNPV is 3.29 billion Yuan, and the investment recycling time is 16.3 years.

Table 6: Relative Investment Cost

| | | % |
|---|---|---|
| 1 | Construction Investment | 100.0 |
| 1.1 | Static Component of Investment | 86.4 |
| 1.1.1 | Line Project Investment | 74.3 |
| 1.1.1.1 | Mechanical Guideway | 31.9 |
| 1.1.1.2 | Civil Engineering | 8.1 |
| 1.1.1.3 | Magnetic Switches | 3.7 |
| 1.1.1.4 | Electrification and propulsion | 18.2 |
| 1.1.1.5 | Communications and Control | 1.7 |
| | subtotal | 63.5 |
| 1.1.2 | Vehicle Purchase | 1.3 |
| 1.1.3 | Other costs including land | 7.4 |
| 1.1.4 | Basic Preparation fees | 5.9 |
| 1.2 | Dynamic Component of Investment | |
| 1.2.1 | Preparation fees | 9.3 |
| 1.2.2 | Loan Interest | 4.3 |
| 2 | Capital | 0.8 |
| 3 | Capital for the project | 100.8 |

The above estimates indicate that the interior financial revenue rate of the project is better than the fiducial financial revenue rate, and the financial net gain value is greater than zero, showing that the project is feasible from a financing point of view.

## 7 RELATED QUESTIONS ABOUT PROJECT CONSTRUCTION

Because the Magplane guideway can be constructed over or beside the highway, the project should be coordinated with the departments of road planning and construction to obtain the most social efficiency.

## 8 ACKNOWLEDGEMENT

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## 9 REFERENCES

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