

THE TOBU KYURYO LINE (POPULAR NAME:LINIMO) A MAGNETIC LEVITATION SYSTEM

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Abstract

The Tobu Kyuryo Line will be Japan's first railway service that adopts a normal conductive system levitated by the attractive power of magnets and propelled by a linear induction motor. This paper describes the background, linear planning, methods and structures and potential effects of the Tobu Kyuryo Line as well as the outline of the 2005 World Exposition, Aichi, Japan.

1 Introduction

Nagoya Eastern Hill Region of Aichi Prefecture, where the line is being planned and constructed, was designated as the Aichi Academic Research and Development Zone, featuring ongoing residential areas as well as other cultural and recreational facilities. The area adjacent to Prefectural Highway Chikaraishi-Nagoya Line including the City of Toyota and Nagakute Town, hosts a great number of public and private universities, research institutes and recreational facilities. Overall, the area is being planned to play a key role to the entire zone.

The Tobu Kyuryo Line contributes a great deal to vitalization of its adjacent areas as well as serves as an arterial transportation system to the areas.

Moreover, the Tobu Kyuryo Line is projected as a transportation artery for visitors to the 2005 World Exposition, Aichi, Japan since the Youth Park Area, a main ground for the Expo, is near the line. The line is also expected to promote global exchanges through its state-of-art magnetic levitation technology for the first practical application in Japan.



Figure 1.1: Vehicle

2 Aichi Prefecture

Aichi Prefecture is located in the center of the Japanese archipelago. It extends 94km from north to south and 106km from east to west. It accounts for about 1.4% of the country or 5,154km². It hosts the country's fourth largest population, about 7.13 million people, followed by Tokyo, Osaka and Kanagawa Prefecture.



Figure 2.1: Location map of Aichi Prefecture

Nagoya Urban Area (prefecture capital: City of Nagoya) has contributed a great deal to our economic and social development as one of three main metropolitan areas including Tokyo and Osaka Urban Areas. The prefecture has the headquarters of world's famous Toyota Motor Corporation and has contributed as a core area of industry and technology.

In 2005 the prefecture will hold a Japanese international exposition and will open an international hub airport, Chubu International Airport.

3 Nagoya eastern hill region

The region is located east of the City of Nagoya and abounds in natural environment. It has hilly terrain, sloping from northeast to southwest.

Although in the past it was a sparsely populated farming area, the region has developed as a satellite city for Nagoya Urban Area with ongoing extensive housing development since Japan's high-growth era. This is because it is within 10-15km from the City of Nagoya. The region's population has increased by 14.9% during the past 10 years though the population of entire Nagoya area remains unchanged.

Designated as a core district of the Aichi Academic Research and Development Zone of Aichi Prefecture, the region also features many academic institutes including Aichi Prefectural University and public and private research institutes such as Aichi-ken Agricultural Research Center, Toyota Central R & D Labs, etc. as well as recreational facilities including the Aichi Youth Park and Toyota Automobile Museum. In the near future this region will plan to build the Science and Technology Exchange Center.

Contrary to these developments, the region has a severe traffic situation although railway services connecting to Nagoya City Center - Nagoya Railway Seto Line in the north and Nagoya Railway Toyota Line in the south - are available. The region lacks a high-speed surface transport system because the previously mentioned railways are over 10km apart. Under these circumstances, the region's main modes of transportation are cars or buses, which cause heavy traffic congestion in main highways including Prefectural Highway Chikaraishi-Nagoya Line, and near Fujigaoka Station of Nagoya City Subway Higashiyama Line. Therefore, it is very important to secure a smooth transportation system to alleviate this traffic congestion and to reinforce the link between the region and Nagoya City Center. A new high-speed surface transport system, connecting between Fujigaoka Station and Banpaku-Yakusa Station of Aichi Loop Railway, is being constructed.

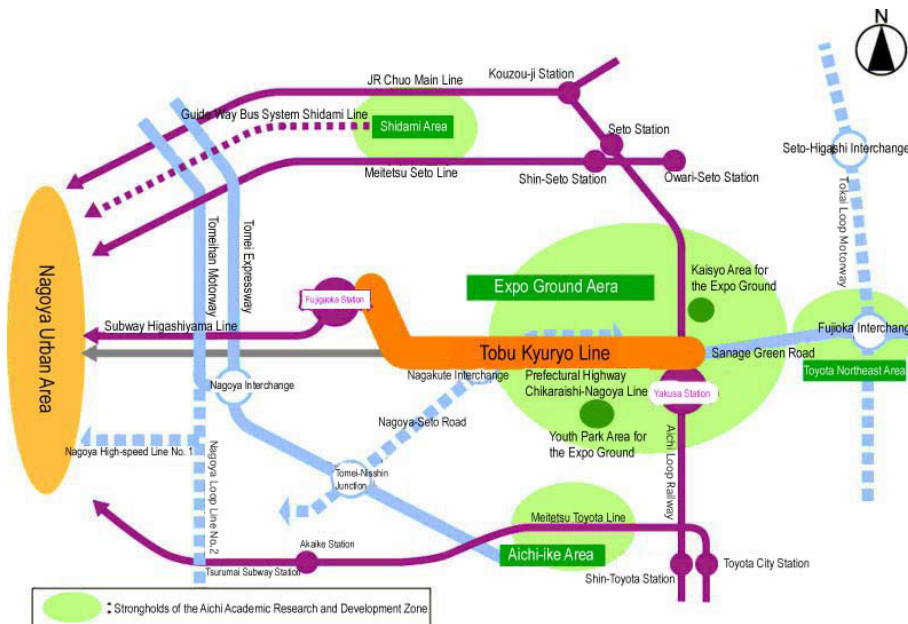


Figure 3.1: Transportation network around the Tobu Kyuryo Line

4 Project planning of the Tobu Kyuryo Line

4.1 Background

In January 1992 the Council of Transportation Policy projected the Tobu Kyuryo Line to be built as a medium-capacity transport system by target year 2008. Later, the Government of Japan conducted various studies on the line and as these results decided the project as state-subsidized in April 1999. As for a model to select, new transport system, straddle-type monorail and magnetic levitation system were examined in view of their cost performance and adaptability for the concept of the region's development, environment, etc. From the evaluation results, magnetic levitation system was selected as the most suitable. In February 2000, Aichi Rapid Transit Co., Ltd., the operating body of system infrastructures and the Tobu Kyuryo Line, was founded. They started project procedures in line with City-Planning and Zoning Law, Traffic Law and environmental assessment, and completed the procedures by the end of March 2002. The construction work started in 2003.

Table 4.1: Background of the Tobu Kyuryo Line

1989 - 1992	A study was conducted on Technical Evaluation Methods for Magnetic Levitation Railway (Ministry of Transport). The results revealed that HSST-100 system with a maximum operating speed of 100km/h would be safe and reliable enough as a city public transport means.
January 1992	The Council of Transportation Policy projected the Tobu Kyuryo Line to be built as a medium-quantity transport system by target year 2008.
1999	The Government of Japan decided the project as state-subsidized. Magnetic levitation system was selected.
February 2000	Aichi Rapid Transit Co., Ltd., the operating body of system infrastructure and the Tobu Kyuryo Line, was founded.
February 2000 through March 2002	Aichi Rapid Transit Co., Ltd. conducted various studies and did administrative procedures.
April 2002	Started construction for the entire line.
March 25 through September 25, 2005	The 2005 World Exposition, Aichi, Japan will be held.

4.2 Outline of the project

Name	Tobu Kyuryo Line (Popular Name: Linimo)	
Route	From Fujigaoka (eastern terminal of Nagoya Subway No. 1) to Banpaku-Yakusa (Aichi Loop Railway)	
Operation length [Construction length]	8.9km [9.15km]	
Number of stations	9 stations (underground: 1; ground: 1; elevation: 7)	
Structure	Double-track line and elevated (underground)	
Running method	Normal Conductive Magnetic Levitation System Linear induction motor propulsion	
Maximum Operating Speed	100km/h	
Capacity	244 people/unit (1 unit 3-car)	
Operation number	About 220 units round trip/day (About 20 units round trip/hour at peak)	
Opening target	March 2005	
Operating Body	Infrastructure	Aichi Prefecture City of Nagoya
	System Infrastructure	Aichi Rapid Transit Co., Ltd. (Quasi-public sector)
Project Cost	Total	About 90 billion yen
	Infrastructure	About 54 billion yen
	System Infrastructure	About 36 billion yen

4.3 Linear plan

Plane linear is set as a route, which will be built along Prefectural Highway Chikaraishi-Nagoya Line (30m wide; 4-lane) to fit to the road alignment with high-level piers on medians, provided that a curve radius is over 75m. Due to difficulty in securing an introductory space, it will be of underground structure at the starting point.

Longitudinal linear is set to fit to road longitude, provided that filling necessary for underground sections and clearance limit under the high-level road are secured, and the maximum slope of the main line is under 6%. Because the region is hilly, the difference in elevation of the rail surface is about 130m.

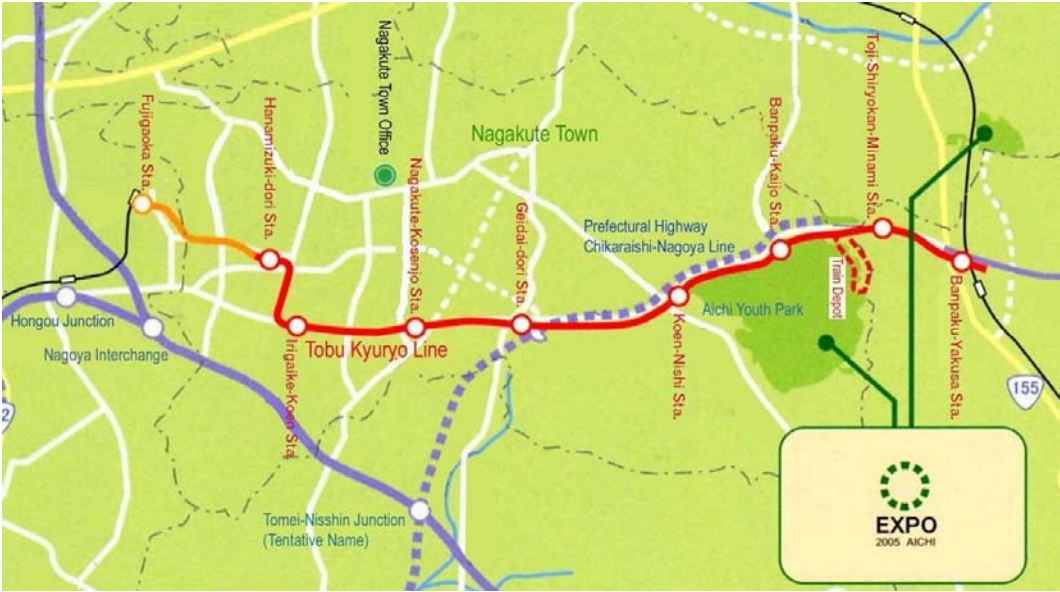


Figure 4.1: Route map of the Tobu Kyuryo Line

4.4 About structures and works of infrastructure

4.4.1 Underground structure

Because in the section between Fujigaoka Station and Hanamizuki-dori Station, roads have only a 16m width and are already aligned along adjacent land, underground structure is to be adopted due to difficulty in widening of roads and building of structures. Fujigaoka Station section and crossing sections are to be excavated by the open work. For other sections, tunnel structure of double-circle sections of 6.5m in diameter is to be constructed using double-circle shield tunneling (Figure 4.2).

4.4.2 Gate-shape pier structure

An elevated structure, crossing road shoulders, is adopted partly because in the section between Hanamizuki-dori Station and Irigaiki-Koen Station, roads has only 20m width and 3.6m by 3.6m rain pipes are buried under the center of the road; and partly because building of piers at the center of roads is difficult.

Since shops, offices and hospitals are built along the line, RC floor compound steel rigid-frame box girder structure, using steel gate-shape (Figure 4.3) bridge piers with a 40-50m interval, is adopted taking into consideration surrounding environment, landscape and cost performance.

This section also features the adoption of PC well foundation work to the pier foundation. Using this method, cylindrical PC well blocks (3.5m in diameter; 2.5m in height) are pressed for excavation. This method is selected in order to minimize road traffic constraints, noise and vibration because of heavy traffic in the section.

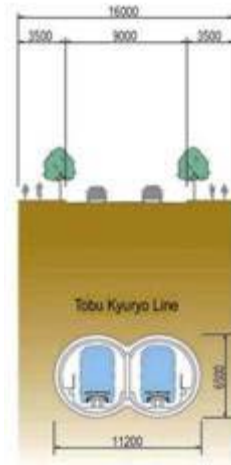


Figure 4.2 :Cross-section view of underground structure

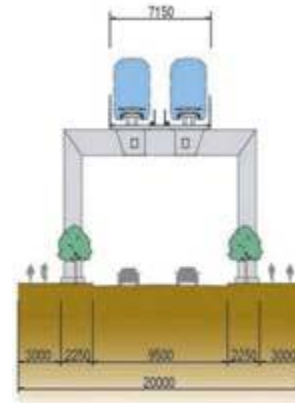


Figure 4.3:Cross-section view of gate-shape pier structure

4.4.3 T-shape bridge pier structure (basic structure)

An elevated structure with T-shape (Figure 4.4) pier is mainly adopted between the section from Irigaie-Koen Station to Banpaku-Yakusa Station. Out of the substructure work, cast-in place piles with the All-Caisson work are adopted for foundation work. And for stable ground sites direct foundation work is used. Bridge piers consists mainly of RC structure. However, for sites with piers of about 15-20m height (i.e. the section between Science and Technology Exchange Center Station and Banpaku-Yakusa Station), SRC structure, combining bars and beams, is adopted to make pillar sections slim. Also, pillar section shape is octagonal, considering its visibility and landscape.

As for the superstructure work, PC midair floor girder bridges with a 30m span are adopted in normal sites. And RC floor compound steel with a 40-50m span is adopted on special sites, i.e. crossings.

4.4.4 Stations

The Tobu Kyuryo Line will have 9 stations, of which can be categorized into underground (Fujigaoka Station), ground (Hanamizuki-dori Station) and elevated (other 7 stations). Of the elevated stations, those built on mediums (Irigaie-Koen, Nagakute-Kosenjou and Science and Toji-Shiryokan-Minami Stations) adopt steel bridge piers of a racket-shape section of the main structure.

Geidai-dori, Koen-Nishi, Youth Park and Banpaku-Yakusa Stations are to be built on the south side of Prefectural Highway Chikaraishi-Nagoya Line, and will have RC rigid-frame structure.

Also, station squares are to be provided for Nagakute-Kosenjou, Banpaku-Kaijo and Banpaku-Yakusa Stations, considering the region's convenience. There shuttle buses arrives and departs, and spaces for park and ride are provided.

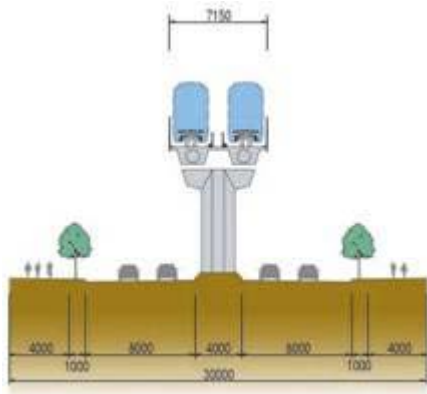


Figure 4.4 :Cross-section view of T-shape bridge pier structure



Figure 4.5 : Image of Irigaike-Koen Station

5 Project effects

The following effects can be achieved through the project of the Tobu Kyuryo Line:

■ Time saving:

In Nagoya Eastern Hill Region, introducing the Tobu Kyuryo Line, there is only one bus service available for the region's public transport system. Currently, about 740 Meitetsu buses run roundtrip all day from Fujigaoka Station, the end of Subway Higasiyama Line, to the Tobu Kyuryo Line. Due to traffic congestion in Fujigaoka area, however, it decreases its service quality including punctuality each year.

After its opening to traffic, the Tobu Kyuruo Line will shorten a peak travel time of about 40 minutes (from Fujigaoka to Banpaku-Yakusa) down to about 15 minutes.

■ Curbing road congestion:

Prefectural Highway Chikaraishi-Nagoya Line is the only arterial highway in the east and west, and has traffic congestion problem with cars from the City of Toyota, the City of Seto, Fujioka Town and the Tomei-Nagoya Interchange. Also, there is traffic congestion all day with buses around Fujigaoka Station.

These road congestions are expected to be reduced.

■ Responding to development plans:

Although development plan of the region includes land readjustment and transfer of universities, there is only one bus service available for the region's mass transport system. The bus service will not serve for increasing public demands in the near future.

A rapid and punctual transport system will be secured to respond to local demands and is expected as an indispensable infrastructure to serve as a central district for the development of the Aichi Academic Research and Development Zone.

■ Alleviating environmental concerns:

In view of improvement for global environment and energy resources savings, the line can use clean energy and has an energy saving effect. Also the line is a city transport magnetic levitation linear motor car and has small noise and vibration, which minimize pollution.

■ Transporting visitors for the 2005 World Exposition, Aichi, Japan:

As a railway transport artery, the line is projected to transport about 33% of the total projected visitors: 15 million for the 2005 World Exposition, Aichi, Japan. Also, the line is expected as one of the Expo's attractions since it adopts a new system, magnetic levitation.

6 The 2005 World Exposition, Aichi, Japan

6.1 Outline of the 2005 World Exposition, Aichi, Japan

On the 15th day of December 2000, the 2005 World Exposition, Aichi, Japan was officially approved and registered by the BIE (the Bureau of International Expositions) to be held in the City of Seto, Nagakute Town and the City of Toyota. In Aichi Prefecture the 2005 World Exposition, Aichi, Japan will be held with its theme, "Nature's Wisdom," during a six-month period starting from March 2005.

Using all of the experiences, knowledge and wisdoms that the human race has so far acquired, the Exposition of Global Harmony aims at realization of a new form of culture and civilization. This is based on "Nature's Wisdom (splendid mechanism and life force in nature)." And a 21st century social model will be created through various opinion exchanges with people all over the world.

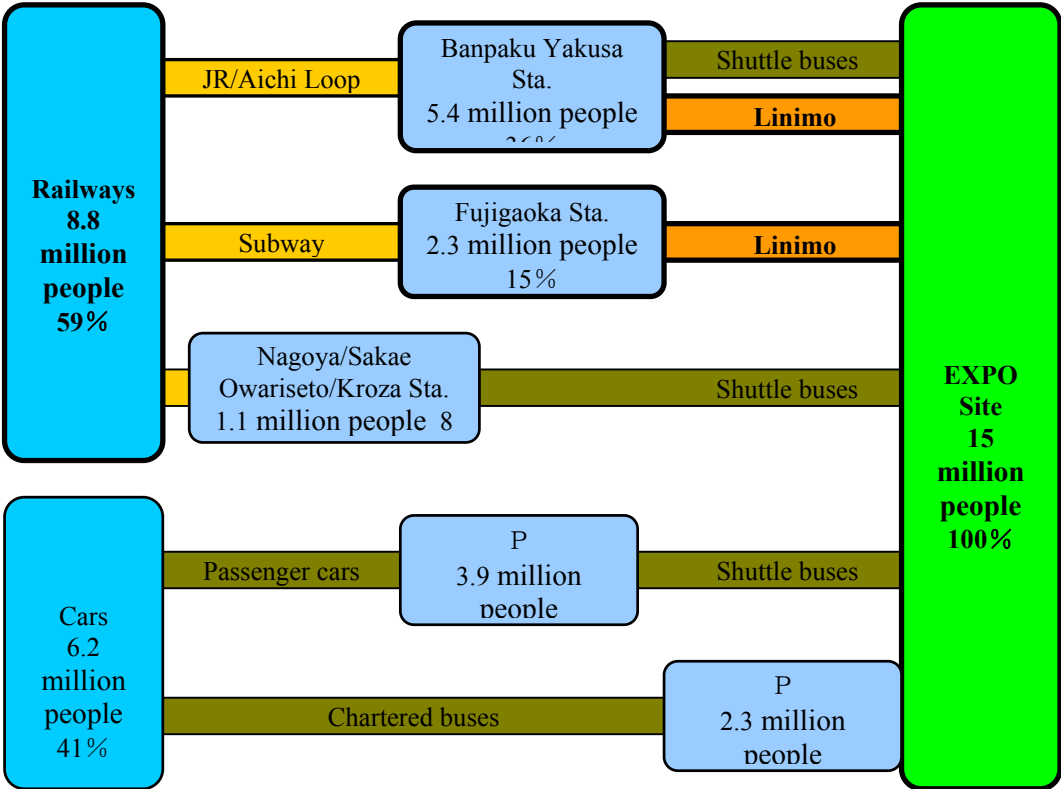
Nagakute Town is planned as the main ground for the Exposition of Global Harmony in the Youth Park Area, and the City of Seto will serve as its sub-ground in Seto Area.

The Youth Park Area is to be developed as a zone where visitors can experience a grand intercultural symphony from all the participating countries, international organizations, private companies and citizens. An attractive central zone, composed of Global Common, Global House and Global Harmony Concourse, is to be built to enhance the exposition and meet visitors' satisfaction. The Youth Park Area accommodates large-scale exhibition sites for various BIE official events and national days of participating countries and a state guesthouse for VIPs from abroad.

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- Title: Official: The 2005 World Exposition, Aichi, Japan
Abbreviated: EXPO 2005 Aichi, Japan
 - Theme: "Nature's Wisdom"
 - Sub-themes: 1) "Nature's Matrix"
2) "Art of Life"
3) "Development for Eco-Communities"
 - Duration: March 25 through September 25, 2005 (185 days)
 - Location: Nagoya Eastern Hills (Nagakute Town, Toyota City, and Seto City)
 - Project cost: Construction cost: 13.5 billion yen
Operation expense: 5.5 billion yen
 - Projected number of visitors: 15 million people
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6.2 Access to the Expo 2005 Aichi site



7 Concluding remarks

The Tobu Kyuryo Line of about 9km in total length is being constructed to open to traffic by the opening of the 2005 World Exposition, Aichi, Japan in a three-year construction period. Since the start of the construction, two and a half years have passed safe and sound in cooperation with the Government of Japan, local municipalities and relevant government ministries and agencies. Because the line adopts a new system, enough time for its trial runs is needed and a shorter construction period is expected.

The author sincerely hopes that during the 2005 World Exposition, Aichi, Japan, starting from March 25th 2005, visitors will enjoy using the Tobu Kyuryo Line. He would like to acknowledge the assistance, support and efforts of the staff of Aichi Prefecture Government as well as others, and will be glad if this paper is any help to the people concerned.