The Shanghai No. 1 Subway Line

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The Shanghai No. 1 Subway Line runs north-south from Shanghai Railway Station to Jinjiang Playground. The total length of the line is 16.1 km servicing 13 stations. Construction commenced on 19 January 1990 and was completed on 10 April 1995. The Line garnered the prestigious Gold Cup Highest Honors in the category of metropolitan construction projects from the Construction Ministry.

Project Background

Shanghai has 13 million residents with an additional transient population of approximately 3 million workers and visitors. It is the industrial, economic and financial centre of China. The downtown area is characterized by overcrowding due to extremely high population density, narrow streets and back alleys, and inevitable traffic jams. In recent years, Shanghai's transportation problems have negatively affected the pace of economic development.

A subway was first proposed for Shanghai in 1956. On 8 December of that year, the initial Shanghai Subway Planning Report was presented by the City Administration Transportation Office to the Shanghai City People's Council for consideration. An interesting point in the report mentioned that the subway would not only speed transportation but would be of strategic use in the event of war for evacuating the civilian population and for moving troops.

In 1964, the Tunnel Engineering Bureau did some secret test of subway construction work for research and planning. The tests, carried out to examine design ideas and develop relevant construction techniques, were headquartered at Hengshan Road in downtown Shanghai. They included digging a 660-m tunnel. In addition, a prototype station was built below Hengshan Park. The subway project was halted shortly afterwards with construction coming to a complete halt in the mid-1960s in the chaos of the Cultural Revolution.

After China's implementation of economic reform, and the policy of opening up to the outside world in the early 1980s, the Shanghai subway construction plan was put back on the agenda. On 14 August 1986, China's State Council approved the Proposal Concerning Construction of Shanghai City Subway Line from Xin Long Hua Station to Shanghai Railway Station.

The proposal stated that the main objective of the new subway would be diversifying traffic flow. According to the proposal, Shanghai City alone would be responsible for raising the necessary capital through financing schemes and borrowing.

The State Council gave its official stamp of approval on 19 January 1990, paving the way for the commencement of construction.

Different Type of Traffic Congestion in Shanghai *(EJRCF)*

Directing Construction

Building a subway is a large-scale project involving complex considerations of design, traffic flow, traffic disruption, dislocation of residents, and relocation of businesses; it requires close cooperation with the city administration as well as access to vast amounts of power and utilities such as water, construction materials, construction equipment, and other resources. Thus, an undertaking of such large scale requires strong leadership and powerful direction.

Shanghai created the Shanghai No. 1 Subway Line Construction Leadership Group led by the Vice-Mayor of Shanghai City. The members of the small group included top officials of all relevant administrative bodies impacted by the plan. The Shanghai City administration appointed the Shanghai No. 1 Subway Construction Board of Directors. The Board was given responsibility for quality and safety, and to obtain capital for the construction. To facilitate development of businesses related to the construction, the Board of Directors created the Shanghai Subway General Company.

The General Company was under the supervision of the Shanghai City Engineering Management Bureau, which in turn was under the Shanghai City Construction Committee Group. The Board of Directors and the General Company were in fact two names for one body responsible for public bidding on projects, signing contracts, and smoothing relationships; this unitary group was divided into two separate entities like two sides of the same coin to reflect both government and corporate functions. The General Company brought together more than 40 companies and construction units to work on the project through public bidding.

Cut and Cover Construction of Shanghai No. 1 Subway Line *(Author)*

Funding

Why did the plans to construct a subway in Shanghai meander back and forth for over 30 years with no progress? The key reason was lack of funds. This changed in 1986 when Jiang Zemin, then Mayor of Shanghai, suggested borrowing foreign capital to fund the project. A sum of US$3.2 billion was earmarked for modernizing the Shanghai economy; part of the funds would be used for investment in industry, part would be used for city infrastructure development including the subway, airport, telecommunications, bridges and other projects. According to this plan, profits garnered from the investment in industry would service the interest and eventually repay the principle.

The subway was budgeted to cost US$300 million. Thus, participation was viewed by many countries as the 'contract of the century'. Not only did participation represent a foot in China's open door, but it also offered the lure of getting a head start on the competition in the Chinese market. The project served as an investment magnet for more than 60 firms involved in subway construction from 12 countries around the world. Bidding sparked fierce competition in the political, economic and technology arenas.

Germany, France, Japan and the USA were the main competitors; in the end, Germany won the contract. The German government put up DM460 million in loans (US$230 million) to be repaid at an annual interest rate of 0.75% over 30 years with a 10-year grace period. The money was earmarked especially for buying 16 trainsets with a total of 96 cars, electrical generators, transformers, communications equipment, station equipment, overhead power lines and escalators. The American government committed to loans totalling US$23 million, 40% of which was an outright grant primarily for signalling systems, safety and alarm systems, water-cooling equipment, waterproofing materials, etc. The French government provided US$21.5 million in funds of which 54% was in the form of a loan at 2% annual interest over 40 years with a 10-year grace period. Export credits comprised the other 46% and seven shield tunnelling machines were bought from FCB Corporation of France. Shanghai City was to provide capital for housing relocations, compensation, restructuring utilities, and building and decorating stations.

Shanghai Railway Station *(Author)*

Construction

The Shanghai No. 1 Subway Line runs north-south through urban Shanghai. Most sections of the line were dug using shield tunnelling machines through water-saturated compressible and slippery ground or soft, clayey soils.

The line cuts through a crowded downtown area of small streets. At the narrowest point, the route was restricted to a width of 20 m, leaving little room to work around existing buildings at ground level, or to get past existing underground pipes and utility cables.

Because of ground quality and environmental factors, all the subway stations have a continuous underground tunnel wall. The wall, which protected the structure during digging of the foundation, now serves as a permanent part of each structure. A cross section of each station shows the geometry of double pillars dividing the space into three sections and single pillars dividing the space into two sections. The spaces are connected by a rib-like structure. Ground settlement is dealt with in two ways: by anti-floating tendency, or by ground stabilization.

Special techniques were used to control subsidence when digging the stations. Theory, survey measurements and experience were combined to solve problems. The foundation subsidence was controlled to within 3 cm.

When construction reached the bustling business district of Huaihai Road, the city government requested that construction be accelerated to shorten the road closure period. A reverse construction method was used to dig the underground foundation. Work progressed in two stages: In the first stage, the upper station level was dug, and the roof, continuous walls and ceiling were built and covered. In the second stage, work continued underground on the intermediate structures and the base plate. The road closure was reduced from 18 months to less than 11 months by using this method. The two-stage process increased the construction pace, and limited business losses by allowing above-ground traffic to resume as soon as possible.

The subway construction inconvenienced residents and caused business losses due to road closures and changes in traffic flow in vital business areas. But considering the long-term interests of local residents, it was possible to win widespread cooperation and support and construction stayed on schedule.

The average underground station on the No. 1 Line is 230-m long and between 20- and 24-m wide. Each station has two levels. The upper level is devoted to the station hall, with three to five entrances/exits leading to the street above. The hall contains ticket machines, wickets and public telephones. The lower level is devoted to the platforms and tracks. The

Xin Long Hua Station *(Author)*

platforms are 186-m long and 8- to 14-m wide. The two levels are connected by escalators and stairways. The interior decoration of each station is unique, with wall paintings being the primary ornamentation.

Tunnels

Long tunnel sections connect the stations; the line is composed of 10.02 km of double track. Cylindrical tunnels are used for 9.27 kilometers, and rectangular tunnels for 0.75 kilometers. The tunnels were constructed using pressure shield tunnelling machines from FCB Corporation. Steel-reinforced slabs and concrete columns are used for support. The shield has an inner radius of 5.5 meters, and an outer radius of 6.2 meters.

Various techniques were used to ensure that ground subsidence stayed within the range of +1 to -3 cm during digging. Laser technology was used to direct the flow of pressurized liquid concrete used in construction of the tunnel base plate. At the same time, state-of-the-art techniques were used to simultaneously ensure a strict system of auditing and strong environmental protection.

The double-track tunnel was completed on 25 May 1994, setting speed records with a daily rate of 23.5 meters, a weekly average of 115 meters and a monthly rate of 387 meters.

After successful completion of tunnelling, track laying commenced using pressurized welding to form seamless track. The longest seamless track is 6.38 km, ensuring a smoother journey, reducing noise, and increasing stability, safety and comfort for commuters.

Electrical Engineering

Power

The Shanghai No. 1 Subway Line has two 110-kV transformer stations and seven 33-kV sub-stations. Principal equipment was produced by Siemens Corporation and AEG Corporation of Germany. Huadong Songbiandian Engineering Company and the Railway Ministry Electrification Department took charge of installing electrical systems and adjusting electrical equipment.

The line uses crossbow current collectors to draw power from overhead lines. Power monitoring and control equipment made by Siemens Corporation was installed and put into operation by 1994.

Telecommunications

The telecommunications system uses fiber optic cables, computerized switching equipment, program controllers, public address and broadcast systems, surveillance TV cameras, and a radio communications system. Most of the above-mentioned systems are already in operation. In 1994, the line underwent the first actual subway operation tests well ahead of schedule. The technicians installed a temporary communications network to carry them through the interim period, making it possible for trains to run throughout the system.

Signalling

The line relies on an automatic train control system (ATC) from GRS Signals Company and Casco Signals Company of the USA. Signalling work involved three main areas: installing trackside equipment, installing equipment in cars, and setting up the signalling control centre.

Security

Both the fire prevention and security systems were imported from two American companies. The 1,301 chemical-based fire extinguishing system was produced by Sinplex Corporation. It is a central system backed-up by peripheral systems at each dual-level station. The entire system is monitored and controlled by computer.

Environment Control

The environment control system was fully installed, tested and fine-tuned by 12 December 1994. It maintains the quality of the environment in the tunnels and

People's Square Station *(Author)*

Control Centre *(Author)*

stations. Environment control means complete control of temperature, humidity, noise, air flow and air quality. The aim is to give people in the subway maximum comfort. In an emergency, the environment control system is designed to provide safe dispersion of smoke and evacuation of people from the subway. The entire line is dotted with ventilation and air-conditioning systems. The standard climate control levels at each station are at a temperature of 30°C in the upper level of the station, and 29°C at the platform level. The relative humidity is 65%. The subway cars have air-conditioning.

Water and Drainage Systems

Three types of water system are used: water supply, water drainage, and fire sprinklers. The total piping length is 20 km with 120 water pumps of all types, and 20 water cooling towers.

Miscellaneous

The equipment in the environment control system and water supply and drainage system can be operated by an independent control system from Sauter Corporation of Switzerland and Intellisys Corporation of Canada.

The underground stations will have baffled doors to stop cool air escaping to the street, saving electricity over the long run while increasing fire safety. Forty-eight heavy-duty escalators were purchased from OTIS of Germany. An automatic ticketing system, including ticket machines and wickets will be installed at an unspecified future date after further tests.

Test Operations

The line began various test runs as early as 1992, when the Shanghai City Subway Operations Corporation was formed. Company subdivisions include a passenger section, electrical engineering section, signals section, construction and repair section, train carriage section and control centre. The train carriage section later became independent and set up its own factory. The Corporation sent over 100 people to Germany and other countries for specialized training in operating a subway. Train dispatchers were sent to various railway locations in China for training, and the passenger service personnel were sent to the Beijing Subway General Company for training.

The train carriages were designed and produced by the Germany Shanghai Metro Group (GSMG). The first sample carriage was shipped from Hamburg on 24 September 1992 reaching Shanghai on 30 October. By the year end, a large number of carriages equivalent to nine full trains had been delivered, inspected and adjusted for operation.

While construction of the line was underway, ground transport was disrupted causing numerous difficulties for commuters; the Shanghai City government requested putting the completed southern part of the line into operation as soon as possible and commercial operation started on 28 May 1993 over the southern section. The middle and northern sections started testing movement of trains on 12 December 1994 as construction neared completion. Finally, the entire length was opened on 10 April 1995. The traffic pattern was set at six cars per train with a top operational speed of 80 kph, and a train leaving a station every 8 minutes. All the trains are conductor-operated, and run for 17 hours each day. The ATC is undergoing adjustment and more time will be required before it satisfies operating requirements.

Development of Nearby Areas

According to the original cost calculations, 5 billion Yuan (US$600 million) invested in building and development costs cannot be recovered from subway ticket sales alone. At present, a ticket to ride the entire length of the line is 2 Yuan. (US24 cents) The daily passenger volume is steady ranging from 240,000 to 260,000. Although all this income is used to service the loans, it is insufficient. Consequently, to pay back all the loans, the nearby areas, both underground and above ground, must be exploited by opening profitable businesses, and by selling real estate and advertising space. At present, there are 400,000 m^2 of business and office space in buildings near the line. The space available includes independent business ventures devel-

oped by the line, and various joint ventures. Another 300,000 m² of floor space adjacent to the underground stations is slated for construction.

Advertising revenue from let space in subway stations and from illuminated panels will be used to support operations.

Extending No. 1 Subway Line and Building No. 2 Subway Line

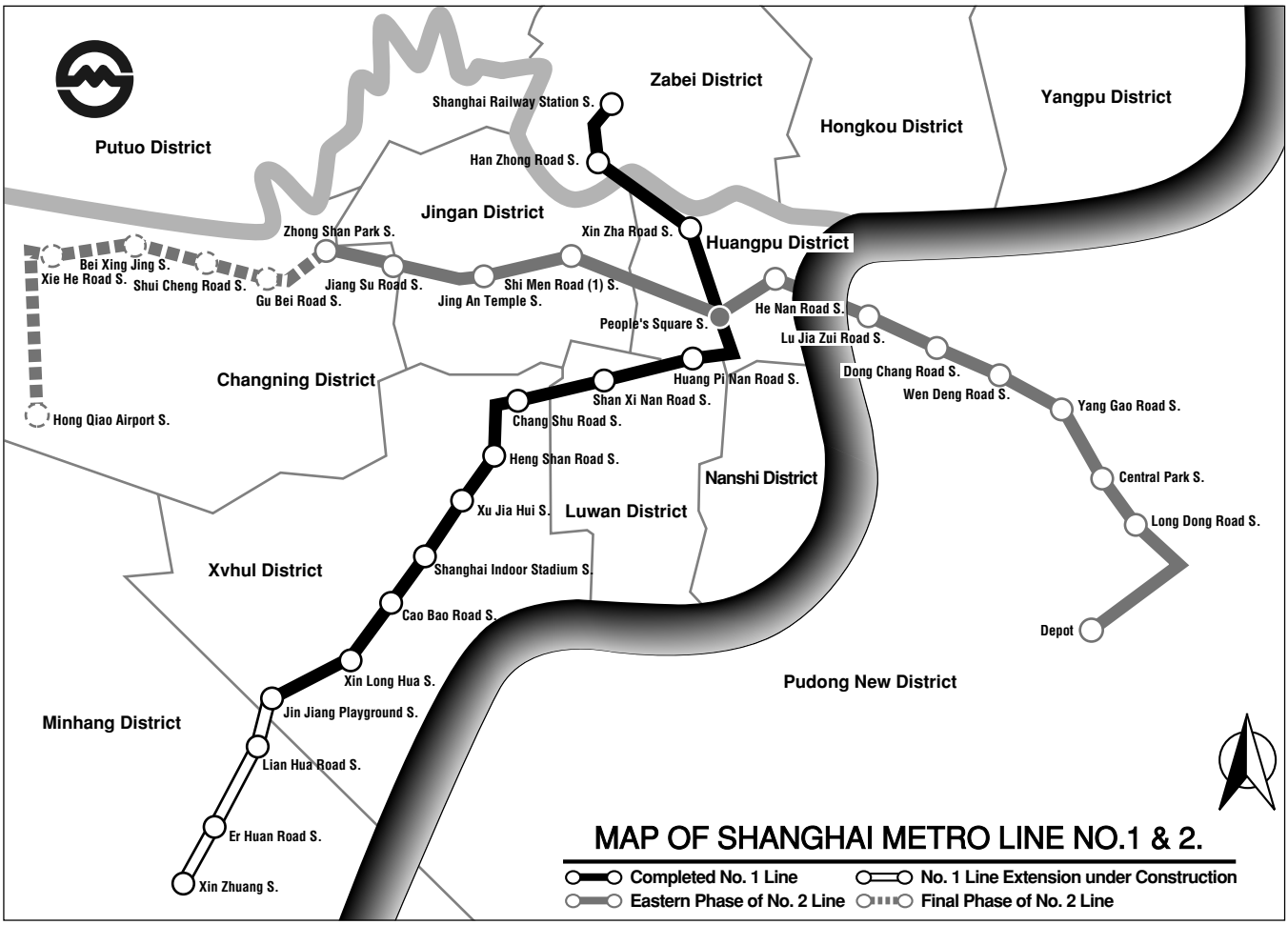
An extension to the No. 1 Line is under construction from the southernmost terminus at Jinjiang Playground to Xin Zhuang Station. It includes three above-ground stations and runs 5.29 km. Development is divided into two areas. The Minhang district, where the southern extension runs, is responsible for financing the macro-construction involving obtaining and clearing land. The General Company is responsible for raising funds for the trains, track and mechanical equipment.

The formal ground-breaking ceremony for the extension was on 24 October 1994 and it is estimated to be completed sometime in the first half of 1997. It will have a positive economic impact on the development of the business districts in southwest Shanghai.

China's State Council approved construction of the Shanghai No. 2 Subway Line on 11 January 1995.

The No. 2 Line will start at Hong Qiao International Airport on the west edge of the city and will service the Hong Qiao Special Economic and Technology Development Zone east of the airport. The line will then continue east along Nanjing West Road going right into the heart of downtown Shanghai to People's Square where it will meet the No. 1 Line. From People's Square, it will run under the busy thoroughfare of Nanjing East Road until it meets the Huang Pu River, passing under the river and entering the Financial Zone in Pudong District on the east bank. From Lu Jia Zui Road Station, it will run to its terminus at Pudong District's Long Dong Road. The total length of the No. 2 Line will be 27 km with 17 stations.

The project is divided into two phases;



Shanghai No. 1 Line Depot *(Author)*

the first Eastern Phase will construct the line from Zhong Shan Park in downtown Shanghai to Pudong District on the east bank of the river. It is expected to cost US$1.5 billion, all of which must be repaid by the City. Shanghai City will repay domestic costs by letting land, by fund-raising foundations, and by developing peripheral areas benefitting from proximity to the new line.

Zhu Rongji, China's Vice-Premier paid an official visit to Germany on 8 February 1996 and signed an intent to enter a bilateral agreement concerning cooperative financing of the Shanghai No. 2 Line. The final contract was signed by late July. The carriages, electrical generators, electrical power equipment, telecommunications systems, etc., will be provided by German companies. ABB Daimler-Benz Transport Company and Siemens Corporation will provide about DM730 million worth of loans. Germany was also successful in becoming involved in construction of the Guangzhou (Guangdong Province) No. 1 Subway.

At the same time, the No. 2 Line also attracted loans at favourable rates from the governments of America and France. Two shield tunnelling machines were purchased for US$9 million from Framatome, a French company. Signal systems, signal boxes, and ticket-vending and ticket-collecting equipment were purchased from America for more than US$50 million.

Six stations on the No. 2 Line are already under construction in the Pudong District. Construction of most of the stations will begin during 1996. The Eastern Phase is slated for completion in 1999. After the Line is fully constructed, it will form a cross-shaped rail network with the No. 1 Line. When the city bus loop is taken into account, the transportation system will be shaped like a box, criss-crossed by the subway system. This configuration should be most beneficial to the transport flow in Shanghai.

Feasibility studies on the No. 2 Line began in 1988. At that time, the Pudong District was not considered in the plan; The original plan called for the line to run from Hong Qiao International Airport to northeast Shanghai reflecting the stress of heavy passenger traffic at that location and time. However, in April 1990, Premier Li Peng announced the opening of the Pudong District to rapid economic development. As a result, the No. 2 Line was re-routed to take the Pudong District into account. News of the future subway service dramatically improved the attractiveness of the Pudong District in terms of investment. (Pudong is already building an international airport, connected by road to the No. 2 Line.) The rapidly developing Pudong District is poised to become a brilliant new window to the world.

Shanghai may have as many as nine subways in the not-too-distant future; full-scale feasibility studies are already underway on the No. 3 Subway Line. We believe that the 13 million people of Shanghai, the city government and foreign investors will all benefit from construction of the subway system. ■

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