Chuo Shinkansen Project using Superconducting Maglev System

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Significance of Chuo Shinkansen Project

Central Japan Railway Company (JR Central) is going forward with the Chuo Shinkansen project using the Superconducting Maglev (SCMAGLEV) system based on the Nationwide Shinkansen Railway Development Act (the 'Act') to sustain the company's mission of operating high-speed railways linking the Tokyo Metropolitan Area (TMA), Chukyo, and Kinki regions, and to ensure the company's business foundation into the future.

More than 50 years have passed since the 1964 opening of the Tokaido Shinkansen serving as Japan's main rail transportation artery. Therefore, we must think of fundamental ways to meet the challenges of aging infrastructure and large-scale natural disasters because it takes a long time to build a new railway line. After the 2011 Great East Japan Earthquake, the need for a new line offering multiple routes across our main transportation artery has become even more important as a precaution against natural disasters. This is why JR Central decided to complete the Chuo Shinkansen as quickly as possible by utilizing SCMAGLEV developed by JR Central, under the assumption that we bear the construction cost. JR Central will operate the Chuo Shinkansen in an integrated manner with the Tokaido Shinkansen.

People's sphere of activities will broaden and business and leisure lifestyles will change, expanding the variety of possibilities using the greatly reduced travel time offered by SCMAGLEV to form a single megalopolis from Japan's three major conurbations of Tokyo, Nagoya and Osaka. And when the Chuo Shinkansen opens to Osaka, there will be room for changes to the Tokaido Shinkansen so the current timetable centred on *Nozomi* services (not stopping at intermediate stations) can switch to one centred on *Hikari* and *Kodama* services (stopping at intermediate/all stations), greatly improving travel times and frequencies from cities along the Tokaido Shinkansen to the three major urban areas.

In promoting this project, we expressed the intent in December 2007 to agree to JR Central being the designated operator and builder for the first phase of the Chuo Shinkansen from Tokyo to Nagoya, followed in April 2010 for the extension to Osaka, taking into account possible prerequisites at each of those points in time. As a result, JR Central decided to build the first section from Tokyo to Nagoya upon making investments required to secure safe and stable transport in operations, enhance competitiveness, and adhere to sound management and stable provision of dividends. Then, after recovering corporate strength, the company will proceed with the plan to build the section to Osaka.

To confirm that the principles of a privately owned company, such as freedom of management and autonomy of capital investment, would not be hindered by application of the Act, we referred fundamental clauses regarding application of the Act to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in December 2007 and received a reply in January 2008 indicating that these principles will not be hindered.

Procedures in Nationwide Shinkansen Railway Development Act

The Act was established in 1970 to develop a nationwide shinkansen railway considering the significance of the functions of an established high-speed transportation network in the comprehensive and universal development across the national territory, thereby contributing to the development of the national economy, expansion of the livelihood of citizens, and regional growth. Even today, Japan's shinkansen network is built based on this Act.

The Act states that the Minister of MLIT shall take into consideration trends in the demand for railway transport, the overriding priority in the national land development policy, and other matters required in effectively developing shinkansen railways, and determine a basic plan that stipulates the routes where construction should be started (Article 4). The basic plan for the Chuo Shinkansen (between Tokyo and Osaka) was determined in 1973. Further procedures in the Act are shown in Figure 1. Of the survey procedures stipulated in Article 5, topographical surveys have been conducted since 1990, and were reported to the MLIT Minister in October

2008. As for the remaining four items for which surveys were instructed in December of that year, the results were submitted to MLIT in December 2009. With that, the Minister consulted with the Transport Policy Council as stipulated in Article 14-2 regarding designation of the operator and constructor and the decision on the development plan (Figure 2). Deliberations commenced subsequently. Those deliberations were held 20 times from various perspectives, and the Transport Policy Council reported that it would be appropriate to designate JR Central as the operator and constructor and that the development plan using SCMAGLEV and a route through the Southern Japan Alps would be appropriate. As a result, the Minister designated JR Central as the operator and constructor between Tokyo and Osaka upon gaining the company's agreement (Article 6), decided on the development plan upon gaining agreement (Article 7), and instructed construction of the line (Article 8).

JR Central started the procedures for environmental assessment of the first stage between Tokyo and Nagoya, released the 'planning stage environmental impact statement' in

Figure 1 Flow of Procedures in Nationwide Shinkansen Railway Development Act

Article 4 — Basic Plan

- Decided in November 1973

Article 5 — Researches and Reports

- Topographical and geological research: Ordered in February 1990
  → Reported in October 2008
- Research on 'the residual 4 items' *Ordered in December 2008
  → Reported in December 2009

Article 14-2 — The Transport Policy Council

- Consulted on February 24, 2010
  → Reported on May 12, 2011

Article 6 — Designation of Operator and Constructor

- Consented on May 18, 2011
  → Designated on May 20, 2011

Article 7 — Development Plan

- Agreed on May 23, 2011
  → Decided on May 26, 2011

Article 8 — Instruction to Construct

- Instructed on May 27, 2011

Environmental Impact Assessment

Article 9 — Construction Implementation Plan

- Submission of Construction Implementation Plan (Part 1) on August 26, 2014
  → Approved on October 17, 2014

Start of Construction

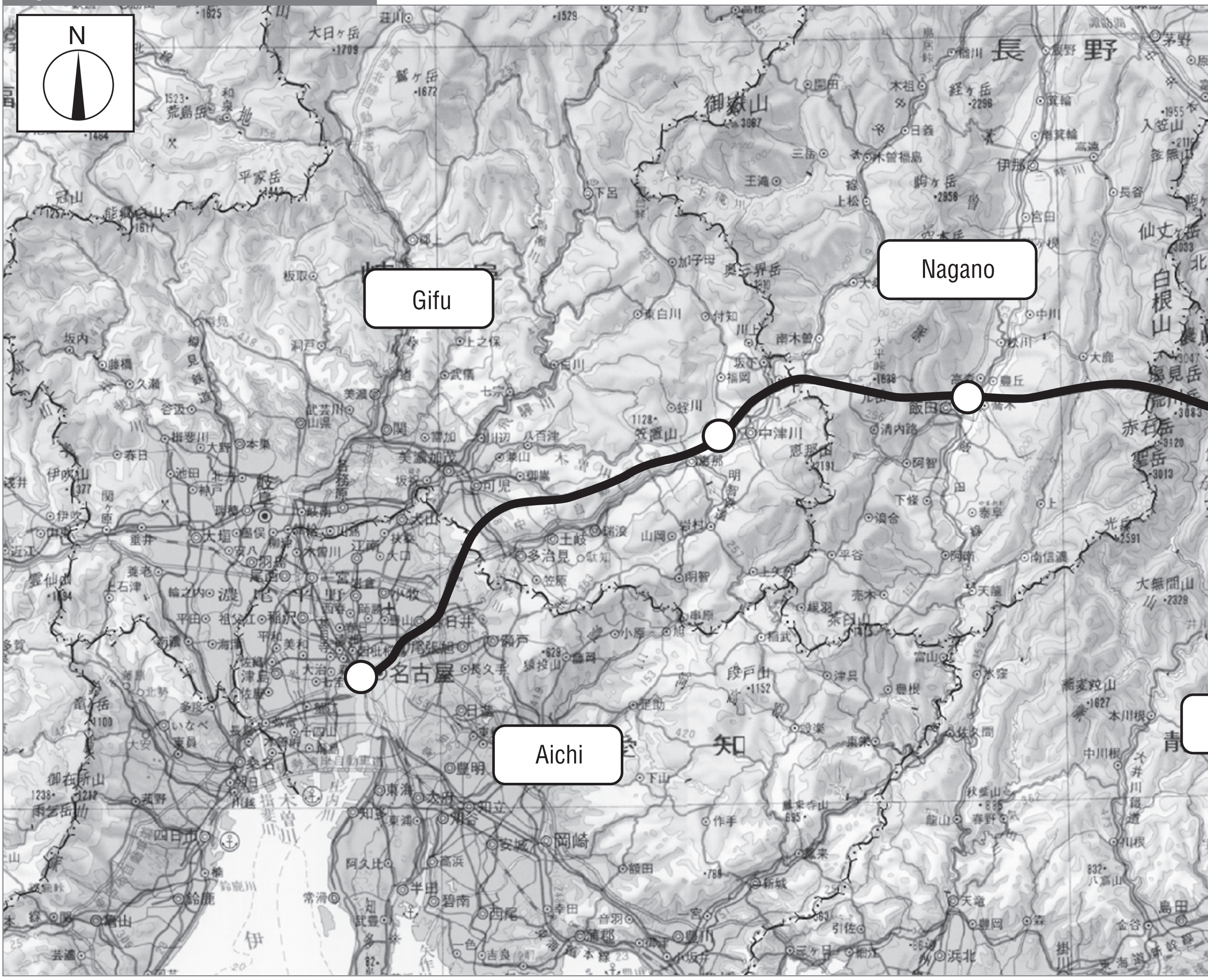
*Research on 'the residual 4 items'
- Items related to transportation capacity in response to the transportation demand
- Items related to the development of facility and rolling stock technologies
- Items related to construction costs
- Other necessary items

Figure 2 Overview of the Development Program

Line to be constructed	Chuo Shinkansen	
Section	Tokyo Metropolis and Osaka City	
Technology used for running	Superconducting Magnetic Levitation Technology	
Designed maximum speed	505 km/h	
Approximate amount necessary for the construction (including expenses necessary for Shinkansen cars)	¥9,030 billion	
Other required matters	Major transit sites	Kofu City or nearby areas, south and central areas of Akaishi Mountains (Southern Alps), Nagoya City regions, Nara City regions

Note: Interest is not included in the estimated construction cost

Figure 3 Route of the Chuo Shinkansen



June 2011 (August for Nagano part), and indicated an approximate route and location of stations (Figure 3). The company then summarized the environmental impact items in the planning stage, and in September of that year announced an ‘environmental impact assessment method document’ and held 58 explanatory sessions. Separate from the environmental impact assessment procedures, explanatory sessions were held 12 times over 2 years in the trackside prefectures about the Chuo Shinkansen plan details, safety, etc.

In September 2013, an ‘environmental impact assessment preparation document’ (the ‘preparation document’) showing the specific route and station locations was announced and 92 explanatory sessions on the preparation document were held. Careful consideration was then made regarding opinions on the preparation document from the governors of the seven trackside prefectures received in March 2014, and an impact statement was produced and sent to the MLIT Minister in April 2014. The Minister’s opinions received in July of that year were considered, and a final impact statement was sent to the Minister and related local governments in August and announced publicly.

At the same time as the environmental assessment procedures, JR Central made preparations to apply for approval of the construction implementation plan based on the Act. The company submitted an application for approval of the construction implementation plan (part 1) between Shinagawa and Nagoya (Figure 4) to the Minister on the same day as the submission of the environmental impact statement and received approval in October.

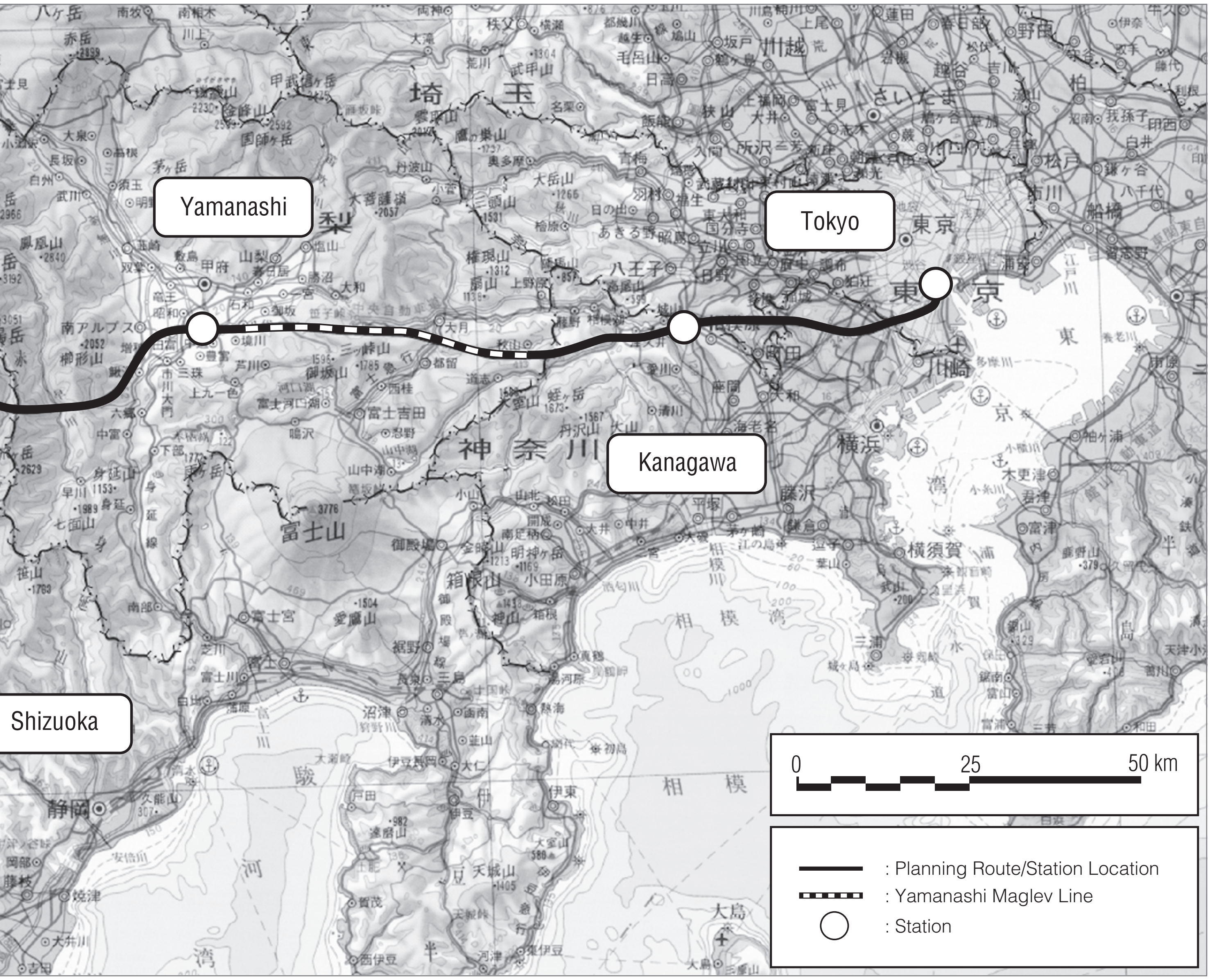


Figure 4 Outline of the Construction Implementation Plan (#1) of the Chuo Shinkansen Section between Shinagawa and Nagoya

Section	Between Shinagawa and Nagoya
Location of the stations	Shinagawa Station, Kanagawa Prefecture Station (tentative name), Yamanashi Prefecture Station (tentative name), Nagano Prefecture Station (tentative name), Gifu Prefecture Station (tentative name), Nagoya Station
Railway length	285.6 km
Construction costs	4,015.8 billion yen (The total planned construction cost is 5,523.5 billion yen (including cost for rolling stock but excluding expenses for Yamanashi Maglev Line already constructed))
Scheduled completion year	2027

Plan Progress Status

Construction

Work such as surveying, design, and land purchase is currently being carried out systematically for the Chuo Shinkansen, which entered the construction phase with approval of the construction implementation plan. Moreover, construction is progressing steadily with emphasis on safety and the environment at the Southern Alps Tunnel where construction is expected to be time consuming and difficult, at Shinagawa Station, at Nagoya Station, and at other locations where preparations have been made.

To date, more than 250 explanatory sessions have been held since October 2014 for trackside municipalities and residents' associations to explain details relevant to the individual communities. Along with carrying out trackbed centre-line surveying to determine the centre line of the track in the six prefectures, preparations for construction are also underway, such as holding explanatory sessions on land purchase to explain items such as compensation.

Construction contracts have also been concluded for the Southern Alps Tunnel, Shinagawa Station, and the like, and some explanatory sessions on construction for residents have been held to cover aspects such as overview of the construction and safety measures. Ceremonies to pray for safety and groundbreaking ceremonies were held for the Southern Alps Tunnel construction (Yamanashi construction area) in December 2015 and Shinagawa Station construction (north and south construction areas) in January 2016, marking the start of full-scale civil engineering works.

The Southern Alps Tunnel, the first full-scale tunnel to pass under the Southern Japanese Alps, will be a long tunnel of approximately 25 km with an overburden (depth from ground surface to top of tunnel structure) of about 1400 m (Figure 5). It will combine Japan's best technologies to overcome what will be very difficult work. Geological surveys have been conducted, but a pilot tunnel will be drilled ahead of and parallel to the main tunnel to confirm the geology. Moreover, construction will use state-of-the-art exploration techniques to bore horizontally from inside the tunnel to accurately confirm the geology ahead. Plans are to bore inclined shafts from seven locations that will become emergency exits and then bore the pilot tunnel and main shaft.

Work at Shinagawa Station involves building underground station structures for the Chuo Shinkansen while supporting the station for the operating Tokaido Shinkansen. Careful attention to safe and stable transport by the Tokaido Shinkansen must be paid to work directly underneath the operating line, and foundation piles and other buried structures will need to be avoided, making this a complex and large-scale project.

Southern Alps Tunnel construction (Yamanashi construction area) safety and groundbreaking ceremony (JR Central)

Use of deep underground

JR Central plans to use the so-called deep underground based on the Act on Special Measures concerning Public Use of Deep Underground (the ‘Deep Underground Act’) in construction between Shinagawa and Nagoya in parts of the TMA and Chukyo region where land use is becoming advanced and complex.

The deep underground is defined either as depths of 40 m or more, which are not ordinarily used for building basements, or as 10 m or more from the top of the bearing layer, a depth not ordinarily used for building foundations. It is assumed that using the deep underground as defined in the Deep Underground Act will negate the need to compensate land owners; so by conducting procedures stipulated in the Deep Underground Act for use in certain projects with public aspects, usage rights can be set without paying compensation in advance. The planned deep underground lengths are 35 km at 40 to 110-m underground in the TMA, and 20 km at 40 to 100-m underground in the Chukyo region.

Any project using the deep underground based on the Deep Underground Act must be approved by the MLIT Minister and JR Central is currently progressing with advance coordination that includes on-site surveys including geological surveys and surveys of properties such as wells, which must be done in the approval application. After these preparations, the company plans to apply to the Minister for approval to use the deep underground.

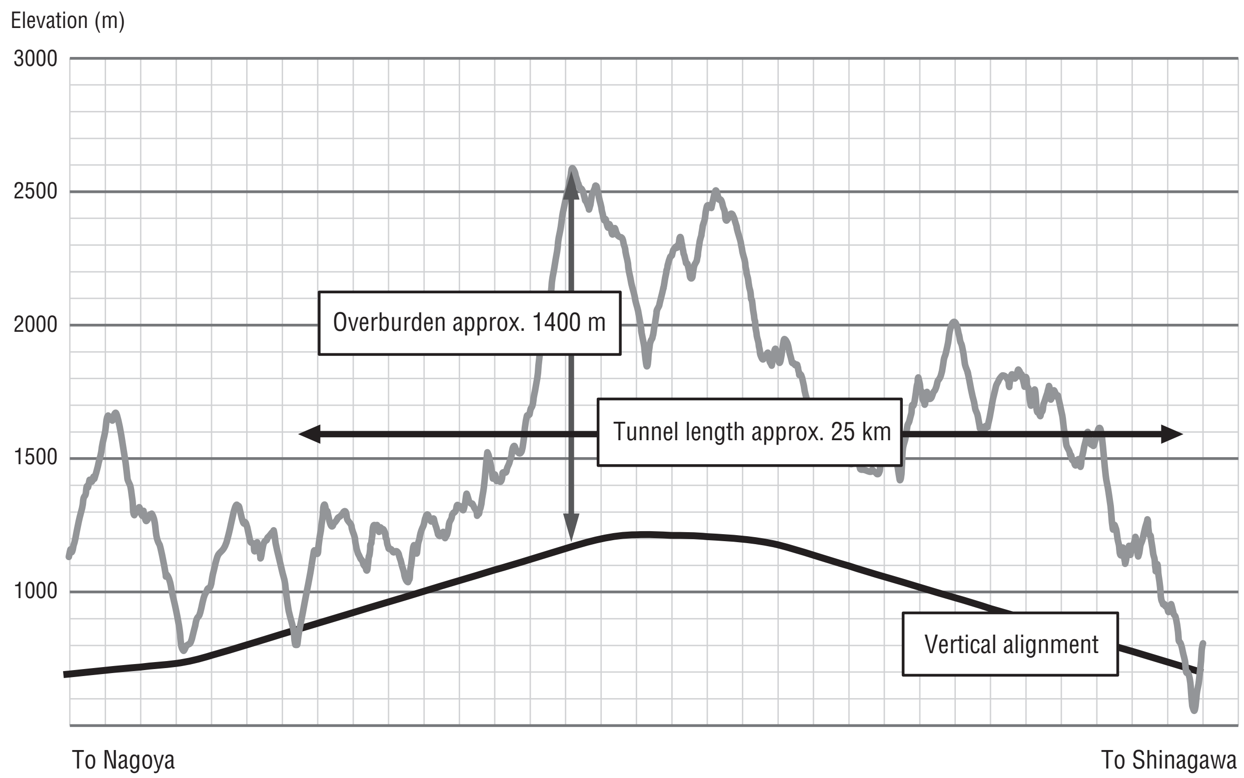
JR Central will continue to work toward completion with an emphasis on construction safety, environmental protection, and partnership with communities while gaining the understanding and cooperation of related parties.

SCMAGLEV Technology

JR Central has been working on development of SCMAGLEV technology since the company’s creation in 1987 because the company sees this technology as best for the Chuo Shinkansen thanks to it being advanced and achieving high speeds.

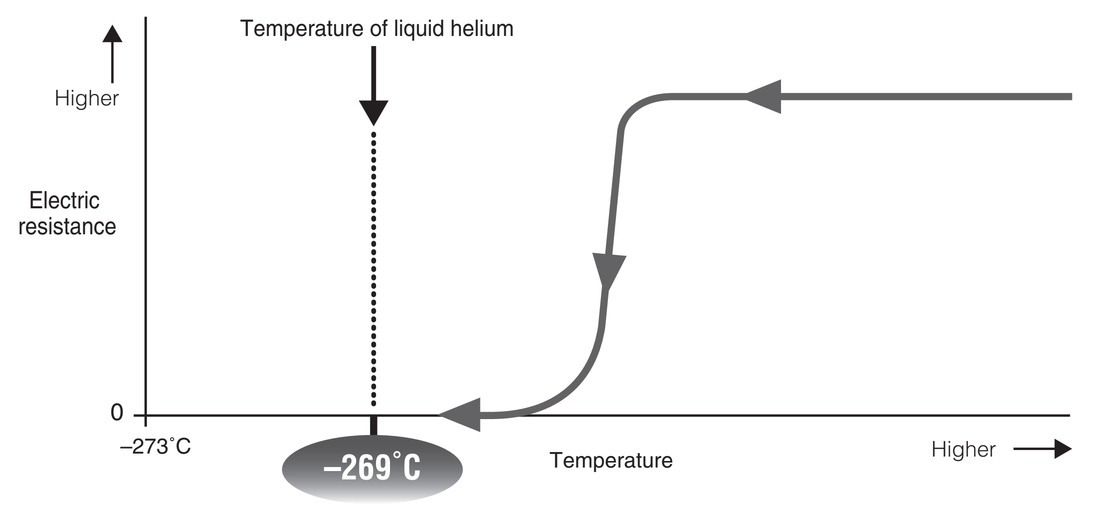
SCMAGLEV is an internationally acclaimed, cutting-edge technology unique to Japan. Unlike conventional railway systems that rely on adhesion between wheel and rail, SCMAGLEV is a contactless system using a magnetic levitation force generated between onboard superconducting magnets and ground coils. This enables stable ultra-high-speed operation at 500 km/h, something not achieved by conventional railways so far. Moreover, it has

Figure 5 Vertical Alignment of Southern Alps Tunnel



Series L0 (JR Central)

Figure 6 What is Superconductivity?



better acceleration and deceleration performance than other high-speed railways, providing even better quality services. And even at ultra-high speeds, SCMAGLEV produces less CO_2 emissions than aircraft, making it environment friendly.

What is superconductivity?

Superconductivity is the phenomenon whereby the electrical resistance of certain materials approaches zero at certain temperatures. When electrical current is applied to a superconducting coil, the current continues flowing almost indefinitely, creating a very large magnetic field. Niobium-titanium alloy has been used for the SCMAGLEV, and the superconductive state is achieved by cooling the alloy to –269°C using liquid helium (Figure 6).

What is a linear motor?

A linear motor is analogous to a conventional type of rotating motor cut open and extended linearly. The rotor inside the conventional motor corresponds to the superconducting magnets in the SCMAGLEV vehicles, while the external stators correspond to the propulsion coils on the ground (Figure 7).

Propulsion system

Passing current through the propulsion coils on the ground generates a magnetic field with north and south poles, propelling the vehicle forward by the attraction of opposite poles and the repulsion of same poles acting between the ground coils and the superconducting magnets (north and south poles arranged alternately) built into the vehicles (Figure 8).

Figure 7 What is Linear Motor?

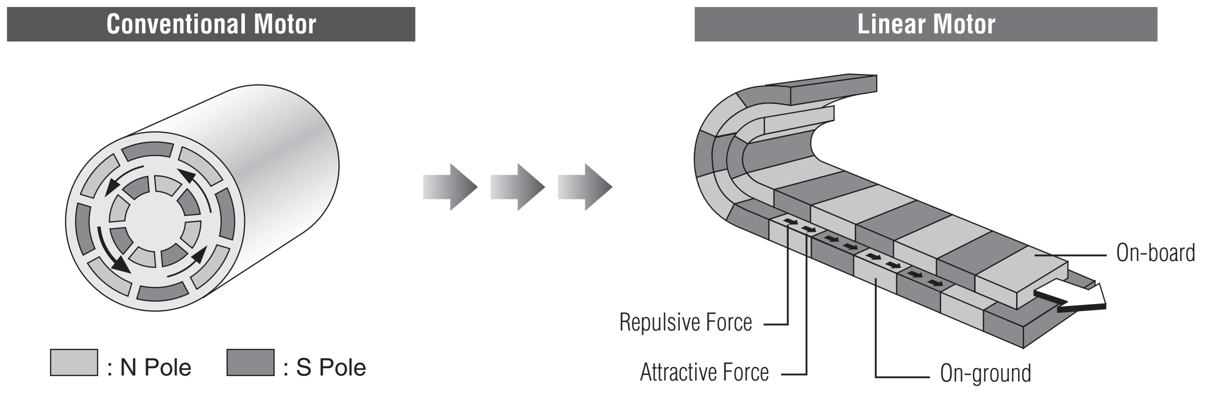


Figure 8 Propulsion System

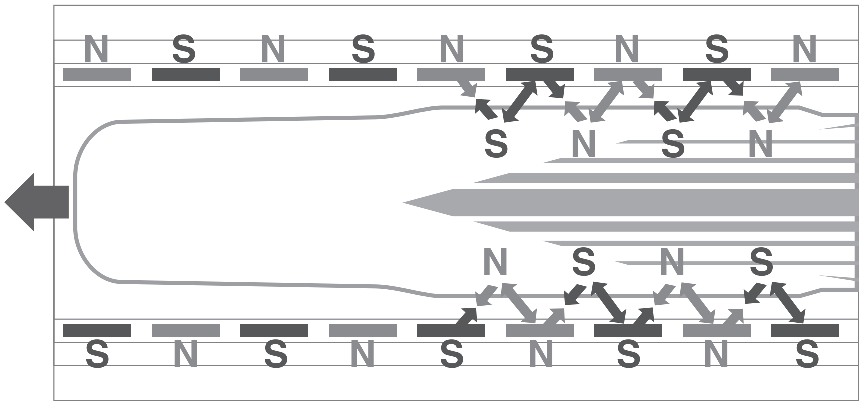


Figure 9 Levitation System

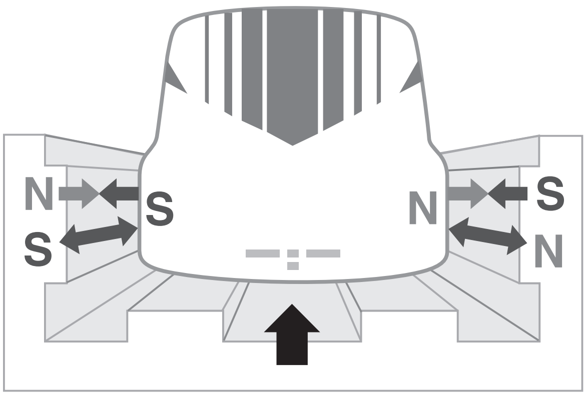
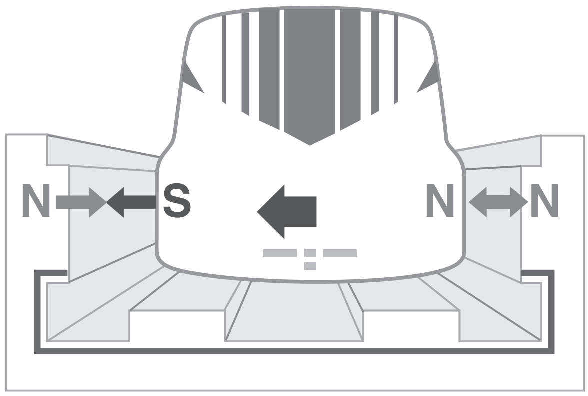


Figure 10 Guidance System



Levitation system

Levitation and guidance coils are installed on both sides of the guideway (Figure 9). When the onboard superconducting magnets pass through these coils at high speed, an electric current is induced in the levitation and guidance coils, causing them to become electromagnets with forces that both push (repulsion) and pull up (attraction) the vehicle (superconducting magnets).

Guidance system

The levitation and guidance coils on both sides of the guideway keep the vehicles in the centre of the guideway at all times by exerting attraction on the far side of the vehicle and repulsion on the near side if the vehicle moves off centre to either side (Figure 10).

Achievements of the Yamanashi Maglev Line

Construction of the Maglev line and technical prospects for practical application

After confirming to the old Ministry of Transport (now MLIT) about the unified operation of the Tokaido Shinkansen and Chuo Shinkansen in June 1990, JR Central decided to bear part of the expenses for facilities such as civil-engineering structures of the Yamanashi Maglev Line that can be repurposed later as part of the Chuo Shinkansen as well as part of expenses for technical developments for practical application. Construction started on the Yamanashi Maglev line in November 1990. The 18.4-km priority section was completed first in March 1997, and the running tests started in April 1997. The first levitated running was achieved in May 1997. The speed was increased gradually, and eventually recorded the maximum design speed of 550 km/h in December. Moreover, to confirm running stability, running tests with five-car trains and passing tests with trains running in opposite directions were performed. Based on the results of these tests, the Ministry of Transport's Maglev Technological Practicality Evaluation Committee (MTPEC) acknowledged in March 2000 that the prospect for practical application of the technology had been reached.

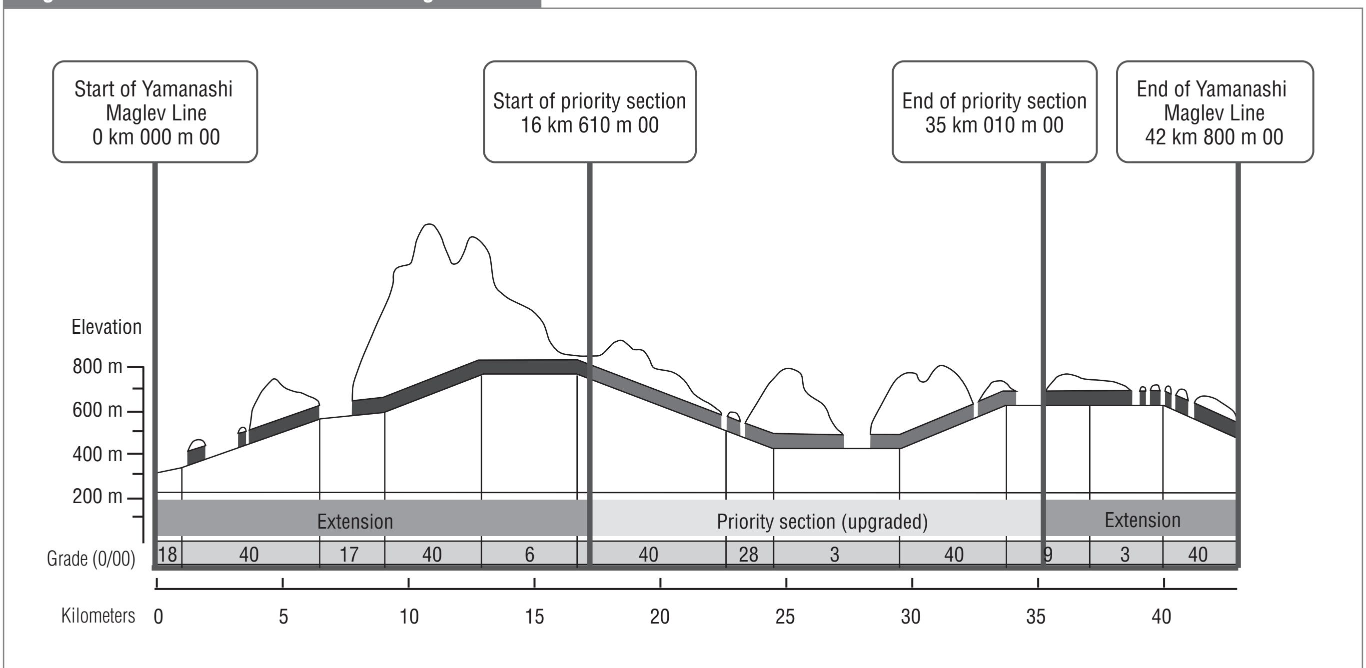
Establishing fundamental technology for practical application

During the 5-year test period from 2000, technical development and running tests went forward with the focus on verification of reliability and long-term durability of the system, cost reduction, and improvement of the aerodynamics of the cars. Specifically, reliability and durability of the vehicles and wayside equipment were confirmed by repeatedly running the train at high speed. As for technical developments in terms of cost-reduction, new forms of guideways with better constructability and maintainability were developed. New vehicles were introduced in order to improve the aerodynamic characteristics, and confirmed reduction of running resistance and improvements to both the onboard and wayside environment. In November 2003, a continuous running test was conducted achieving a cumulative distance of 2876 km in a single day—which is about twice the average daily distance run by JR Central Shinkansen trains. In December 2003, a new world railway speed record of 581 km/h—rewriting its own railway world speed record—was attained during maximum speed increase tests. With these achievements, MTPEC acknowledged that all SCMAGLEV technologies necessary for future revenue service have been established.

Establishing technologies for practical application

With the aim of completing all technologies necessary for practical application, technical development and running tests since 2005 have focused on verification of further long-term durability, technological development for further cost reduction including maintenance cost, and consideration of equipment specifications for actual commercial lines. Environmental countermeasures, emergency responses,

Figure 11 Overview of Yamanashi Maglev Line



and maintenance regime were also clarified and confirmed through running tests. By September 2011 when running tests on the priority section were finalized, the total running distance reached 878,000 km—approximately circling 22 times around the globe—and SCMAGLEV reached the level where all obstacles to commercial operation including safety had been overcome. In July 2009, MTPEC acknowledged and confirmed that the technology required for commercial operation had been established comprehensively and systematically, making it possible to draw-up detailed specifications and technical standards.

An outline for the new vehicle, Series L0 (L Zero), designed under specifications for use on commercial lines was determined in October 2010. In September 2011, MTPEC acknowledged that the technologies of the Inductive Power Collection for on-board power supply had been established to the practical level. In December 2011, the MLIT Minister enacted technical standards for the SCMAGLEV, putting the legal foundations in place.

Completion of the Yamanashi Maglev Line construction and brush-up of the SCMAGLEV technology

In September 2006, JR Central decided to invest ¥355 billion of its own funds to extend the Yamanashi Maglev Line to 42.8 km and update equipment to practical application specifications (Figure 11). Construction was completed in August 2013 and running tests were restarted with commercial-line-specification Series L0 cars. Various tests were conducted and achieved records such as a cumulative running distance of 4064 km in a single day, as well as a new world speed record of 603 km/h, both established in April 2015 (Figure 12).

With vehicles and facilities designed with specification for use on commercial line, we will conduct further long-distance running tests by alternately operating two trainsets, verify and establish a maintenance regime for commercial operation, continue refining the technologies, and further reduce construction, operation, and maintenance costs.

The 42.8-km Yamanashi Maglev Line will become part of the 285.6-km section between Shinagawa and Nagoya,

Figure 12 Progress of the Superconducting Maglev Technology

June 1990	Applied the construction plan of the Yamanashi Maglev Line to the Minister*, which was approved
April 1997	Started running tests at the Yamanashi Maglev Line
March 2000	The Superconducting Magnetic Levitation Technological Practicality Evaluation Committee of the Ministry of Transport acknowledged the technical prospects for practical application
December 2003	Recorded the highest speed of 581km/h by a manned rail vehicle, breaking the world record
November 2004	Conducted a passing test at a relative speed of 1,026km/h
March 2005	The evaluation committee of MLIT acknowledged that 'all necessary technologies for the future service have been established'
September 2006	Decided the investment plan of the upgrading and extension of the Yamanashi Maglev Line
January 2007	Applied the modified construction plan to the Minister, which was approved
July 2009	The evaluation committee of MLIT acknowledged that 'the technologies required for a commercial line have been cyclopaedically and systematically established and it is possible to move forward with detailed specifications and technological standards for revenue service'
December 2011	The Minister established the technological standards of the Superconducting Maglev
August 2013	Completed the extension of the Yamanashi Maglev Line to 42.8km and the upgrading of the facilities and restarted running test by using the new vehicle, Series L0
April 2015	Recorded the maximum daily running distance of 4,064km Recorded the highest speed of 603km/h by a manned rail vehicle, breaking its own world records

* 'The Minister' stands for the Minister of Land, Infrastructure, Transport and Tourism (the Minister of Transport in 1990)

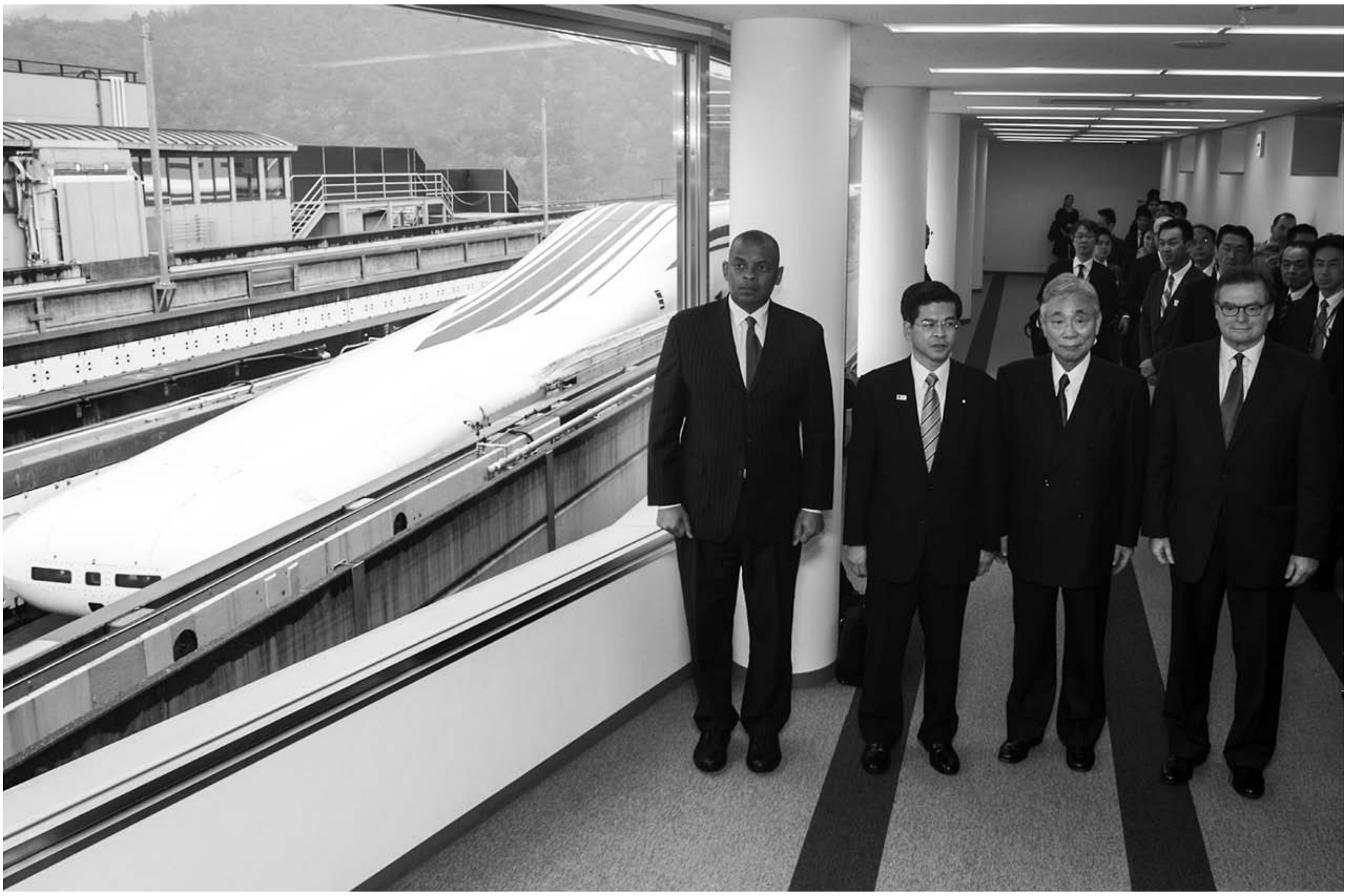
World speed record (JR Central)

Experience Rides (JR Central)

section of the Chuo Shinkansen where Construction Implementation Plan was approved. It will eventually utilize as commercial line when the Chuo Shinkansen opens.

Experience Rides on the Yamanashi Maglev Line

JR Central thinks it is important to offer the 500km/h ride experience to many people as possible. Therefore, we have been offering experience rides on the Yamanashi Maglev Line since November 2014 by adjusting the tight running test schedule. More than 30,000 people have taken the rides, giving feedback such as how comfortable the ride is while experiencing the high completion level of the SCMAGLEV. JR Central continues offering these experience rides in a systematic manner.



US Department of Transportation Secretary Foxx and Japanese Minister of Land, Infrastructure, Transport and Tourism Ishii, observing the Yamanashi Maglev Line (JR Central)

Overseas Deployment of High-Speed Railway System

JR Central offers consultation to overseas high-speed railway projects by utilizing our comprehensive technologies regarding the highest-level high-speed railway system in the world. JR Central believes that overseas deployment of its high-speed railway system will be a meaningful project enabling Japanese manufacturers to maintain and strengthen their technology and skills through expansion of the international high-speed railway market, while also leading to stable provision of equipment, and technological innovation and cost reduction of railway-related equipment.

An SCMAGLEV line is expected to be built to connect Washington DC with New York, and JR Central is currently initiating promotional activities to ensure that the initial section from Washington DC to Baltimore goes ahead with the cooperation of both the Japanese and US governments. Awareness for the project continues to rise on the US side. US Secretary of Transportation and the Governor of Maryland observed the Yamanashi Maglev Line in 2015, and the US government has approved a federal grant of $27.8 million to the State of Maryland.

Conclusion

Construction of the Chuo Shinkansen by JR Central is progressing as a key project for Japan's future by providing an alternate route for Japan's main transportation artery. JR Central will continue to adhere to sound management and stable provision of dividends as a private-sector company as we work toward completion of this project. ■

Mamoru Uno

Dr. Uno is a Director, Senior Corporate Executive Officer and Director General of the Chuo Shinkansen Promotion Division at JR Central.