Tokaido Shinkansen- 50 Years of Evolution – The Fruit of Railway Engineer's Research and Ingenuity

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1. Introduction

Last October the Tokaido Shinkansen marked its 50th anniversary of service since its commencement as the world's first highspeed rail. The Tokaido Shinkansen has served an astonishing 5.6 billion passengers, since its start. The market area connecting three major cities of Tokyo, Nagoya and Osaka has played a vital role in developing Japanese economy and culture. Though its market area only covers just over 20% of the land area of Japan, the area accounts for approximately 60% of Japan's population and GDP.

To serve this globally unique demand structure, the Tokaido Shinkansen has been offering the world highest level of service from various aspects such as safety, punctuality, high speed, comfort, high frequency, large transportation volume, and environmental friendliness, and has been supporting Japan's growth as the main artery of its economy.

2. Safety and Punctuality

Since the start of operation, the Tokaido Shinkansen has maintained its flawless record of no derailments or collisions involving trains in commercial service, and zero accidents resulting in injuries or fatalities to passengers on board. In addition, it has also maintained its unparalleled degree of punctuality, with the record of average delay of less than one minute (0.9 minutes for FY 2013) per train, even including delays due to natural disasters.

The core factor of this safe and stable transportation is the total system based on the fundamental principle of "Crash Avoidance". The key element of this principle are1) an Automatic Train Control system (ATC) which automatically detects train position and control the operation of the system to accurately stop trains running at high speed, and 2) the use of dedicated tracks for high speed passenger trains to eliminate any possibility of collision at level crossings. During the 26 years since the company's establishment in 1987, we have made a total of 2.7 trillion yen of safety related investment (approximately 55% of the overall non-consolidated capital investment), and have implemented a variety of measures for the Tokaido Shinkansen, from both the software and hardware perspective, to enhance the level of safety. The ATC, which plays an important role in the principle of "Crash Avoidance", has progressively evolved by continuously incorporating the latest technology, ever since the Tokaido Shinkansen first went into service. In 2006, we introduced a digital ATC system with one-step brake control, realizing flexible timetable setting and improving riding comfort without compromising safety.

As for the precautions against natural disasters, we have continually adopted the latest seismic technology to the Tokaido Shinkansen. Subsequent to the 1995Hanshin-Awaji Earthquake, we carried out anti-quake reinforcement on elevated track columns, bridge piers, embankments and other engineering structures all the way along the lines, and measures were implemented on bridge girders to prevent bridges from breaking up in case of large earthquakes. These measures were implemented in order to avoid structures from collapsing which would result insignificant long-term interruptions to train services. The necessary seismic retrofitting works was performed and were mostly completed in 2013. Furthermore, although railway structures did not suffer significant damage during the 2004 Chuetsu Earthquake, the Joetsu Shinkansen derailed. This incident led us to implement measures to counter derailment and deviation, which began in 2009. These countermeasures involved a redundant system consisting of "Derailment Prevention Guards" and "Deviation Prevention Stoppers"."Derailment Prevention Guards" are installed along the tracks to prevent derailment wherever possible. Even if a greater-than-anticipated shock causes a derailment, train deviation would be prevented as much as possible by the "Deviation Prevention Stoppers" installed at the bottom of rolling stock bogies. In order for derailment prevention guards to function effectively, additional measures to suppress displacement of civil engineering structures has also been implemented.

There has also been a continuing effort on developing a system which could quickly decelerate and stop trains whenever an earthquake occurs. In 1965, shortly after the service commenced, the world's firstalarm seismometers were installed, which detects earthquake and processes the alarm to output automatically. In 1992, the "Urgent Earthquake Detection and Alarm System (UrEDAS)" was adopted; it detects the initial shock (P-wave) during an earthquake and issues an alarm. Moreover, in 2005, the "Tokaido Shinkansen EaRthquake Rapid Alarm System (TERRA-S)" was developed and introduced, improving the speed and accuracy of the earthquake detection. Since then, the latest knowledge has been integrated and improvements have been made in operations to decelerate and stop trains even earlier and with greater precision in case of earthquakes.

For the civil engineering structures of the Tokaido Shinkansen, in FY 2013, we launched a large-scale renovation, which is planned to take 10 years to complete. We were able to start this renovation project five years ahead of original schedule as a result of unremitting research and development carried out mainly at our Komaki Research Center in Aichi, which established new construction methods to greatly reduce both the interruption of train service during works and renovation costs.

3. High Speed and Comfort

The Series 0 of the Tokaido Shinkansen was the first true highspeed train in the world and was developed with the latest rolling stock technology of the time. Before the commencement of the Tokaido Shinkansen, it took six and a half hours to travel between Tokyo and Osaka by train. The Tokaido Shinkansen, which ran at a maximum speed of 210 km/h, enabled to shorten the travel time to three hours and ten minutes (it took four hours at the time of the commencement of service). In October 1985, the Series 100 was put into service. This rolling stock improved passenger service by introducing the new cabin amenities, double-deck first-class cars and private compartments for the first time for the Shinkansen. (the maximum speed was 220 km/h).

Since the establishment of JR Central in 1987, we began to study and draw plans for speed up and drastic increase of the transportation capacity to reinforce the transportation competence of the Tokaido Shinkansen. First, in January 1988, we started the development of a new type of rolling stock to realize higher speed, with a maximum speed of 270 km/h, which enables to shorten the travel time to two hours and thirty minutes between Tokyo and Shin-Osaka. The Series 300 which commenced commercial operation in March 1992 for *Nozomi* service was the product of this development work, and connected Tokyo and Shin-Osaka in two and a half hours, thus greatly reducing the traveling time. In March 1999, the Series 700 went into commercial operation and realized better ride comfort with larger space and less vibration with a semi-active damping control system

and several other devices(the maximum speed in the Sanyo section is 285 km/h).

As a result of the opening of Shinagawa Station in October 2003 and the completion of making our fleet consist of trainsets with a maximum speed of 270 km/h, the Tokaido Shinkansen made a dramatic rise in the level of service principally of Nozomi trains. This project, which we may also call it the "Rebirth of the Tokaido Shinkansen", was an epoch-making event for JR Central. This project required a total of 15 years of planning and implementation as well as a total capital investment of approximately 800 billion yen (approx. 500 billion yen for new rolling stock, approx. 200 billion yen for improving ground facilities, and approx. 80 billion yen for the construction of Shinagawa Station).

The Series N700 introduced in July 2007 employed a "Body Inclining System" for the first time on Japanese Shinkansen rolling stock in order to increase the cruising speed on the curves which are typical of the Tokaido Shinkansen alignment. As a result, the Series N700 succeeded in reducing the travel time between Tokyo and Shin-Osaka up to five minutes.(the maximum speed in the Sanyo section is 300 km/h). In March 2009, we started on board internet connections via a wireless LAN network using the digitalized train wireless communication system, thus making the Tokaido Shinkansen more convenient for passengers.

The Series N700A started operation in February 2013.It was created by incorporating technology developed at the Komaki Research Center based on the Series N700 as well as using results achieved in running tests with the Series N700 testtrainset. In addition to the Series N700's high level functions, the N700A newly employs the "Central Fastening Brake Disks", "Bogie Vibration Detection System", "Cruise Control System", and several other features. The N700A has achieved further improvements in safety and stability as well as reducing environmental load. Since April 2013, JR Central has started modifying the existing eighty N700 trains, all to improve further safety and reliability by equipping part of the latest functions introduced to N700A. By the end of FY2016, about 80% of all trainsets will be either the Series N700A or the upgraded Series N700.

We are aiming to raise the maximum speed to 285 km/h, which will further reduce the travel time around three minutes by spring of 2015.

4. High Frequency and Mass Transportation

The most significant feature of the Tokaido Shinkansen service is that it provides transport capacity responding to demand by maintaining a certain number of trains as a regular service in the base timetable and arranging extra trains where necessary. Since the opening of the commercial operation, we stimulated transport demand, and improved both rolling stock and ground facilities from both mid and long term perspective in accordance with the trend of passengers demand. As a result, the Tokaido Shinkansen has greatly evolved its transportation system with strong competitive edge in respect of both quality and quantity.

When the Tokaido Shinkansen commenced operation, there were 60 departures per day in a "1-1" hourly timetable with one *Hikari*, stopping only at major stations, and one *Kodama*, stopping at each station. Revisions to the running schedule were made almost annually to accommodate the rapid surge in transportation volume during Japan's high-growth period, including the surge of transportation volume due to Expo '70.

Since the privatization of the Japan National Railways, the Tokaido Shinkansen facilities have been improved continuously, resulting in stable transportation and increased transportation capacity. These improvements included the replacement from a BT feeding system to an AT feeding system, the introduction of a heavy compound catenary system, increasing the cant for more than 240 km on both up and down tracks which correspond to approximately a quarter of the entire line, and reduction of turn-back time at Tokyo terminal station by reducing the conversion time of switches.

In March 1992, *Nozomi* service was launched with two round trips per day, early in the morning and at night, operating a total of four trains. At the same time, the number of daily train departures reached 288which indicated an increase of almost 50trains in less than five years from the establishment of JR Central. During the subsequent period of approximately 10 years, the fleet were progressively replaced to the Series 300 and the Series 700 which was capable of running at a top speed of 270 km/h, while the *Nozomi* which started off four departures a day was incorporated into the patterned timetable to run once an hour, and later twice an hour.

In October 2003, Shinagawa Station was opened after approximately six years of construction work. This improved the accessibility to the Tokaido Shinkansen from the Tokyo metropolitan area, and at the same time the timetable was greatly revised to run seven *Nozomi*, two *Hikari* and three *Kodama* trains every hour. In March 2008, all trains began to stop at Shinagawa and Shin-Yokohama, resulting in even easier access from the Tokyo metropolitan area and greater convenience for passengers.

The construction of a new track, a new platform and two more draw-out tracks from 2 to 4 at Shin-Osaka station was completed in spring 2014, resulting in the "*Nozomi* 10-train timetable" in which it made it possible to operate up to ten *Nozomi* trains per hour during almost all time slots throughout the day. This realized more flexible transportation during peak periods.

5. Environmental Performance

We have actively developed and adopted low-energy type rolling stock to make Shinkansen a further greener transportation mode. The Series 300 which was introduced in 1992 consumed approximately 30% less energy compared to the initial Series 0 (comparison made at 220 km/h operation). In addition, the energy consumed by the current mainstay the Series N700 and N700A is approximately 25% less than that of the Series 300 (comparison made through travel between Tokyo and Shin-Osaka).

Comparing the energy consumption by the Tokaido Shinkansen (the Series N700 and N700A *Nozomi* trainset)to that of an aircraft (B777-200), the energy consumption per seat of a train between Tokyo and Shin-Osaka is 1/8 of that of the aircraft, and also the amount of CO_2 emitted is approximately 1/12. This indicates that the environmental performance of aTokaido Shinkansen trainset is far superior to that of an aircraft.

6. Overseas Deployment

There are many environment-friendly high-speed railway (HSR) construction projects underway worldwide. JR Central is promoting the overseas deployment of HSR systems by leveraging its comprehensive HSR technology, which we achieved through over 50 years of operation, and is at the world's highest level. Overseas deployment of HSR systems maintains and strengthens domestic manufacturers' technology and skills as well as produces technological innovation in railway-related components as a consequence of an extended HSR market.

We have identified the United States as a prime target. Currently, JR Central is promoting a Tokaido Shinkansen-type HSR system, called the "N700-I Bullet", in the State of Texas, and the Superconducting Maglev, "SCMAGLEV" which can run at a maximum speed of 500km/h, for the Northeast Corridor connecting Washington D.C. and New York.

In addition, JR Central agreed with the Taiwan High Speed Rail Corporation (THSRC), to provide high-quality technical consulting services.

7. Conclusion

During the last 50 years, the Tokaido Shinkansen has played the role of a main transportation artery in Japan as a top level highspeed railway in the world, and contributed greatly to the development of the Japanese economy while evolving in various aspects. This technology is the fruit of the efforts and ingenuity made by many engineers of

the Japan National Railways and JR Central, the Railway Technical Research Institute, the JR Central Komaki Research Center of JR Central, and many of Japanese manufacturers who provided high-quality components to us with valuable and superior technology. The Tokaido Shinkansen is indeed the symbol of representative technology of post-war Japan, and the pride of the Japanese people. Here, I would like to express my heartfelt gratitude to all of you who have made strong supports for the Tokaido Shinkansen.

In order to maintain and evolve the Tokaido Shinkansen in the future, we hereby pledge to strive for further refinements from both hardware and software aspects.

Starting Ceremony of the Tokaido Shinkansen First Train
(Provided by Kotsu Shimbun Newspaper)