# India-Japan historical linkages in the field of railway technology

Transition from individual development to cooperative innovation

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*In 1853 the first railway in Asia was opened, it was between Bombay and Thane in India. In 1872 the first railway in Japan between Tokyo and Yokohama was opened, technology of both railways was based on UK. However, both countries made completely opposite decision, India adopted broad gauge (1676mm=5'6"), Japan adopted narrow gauge (1067mm=3'6").*
*Landform, climate, and various kinds of conditions are different between India and Japan, railways of both countries have been developed independently for long years. After World War I, Japan developed railway industry and realized "Make in Japan", rolling stock equipment were exported to India in the 20th century, for example traction motors for locomotives or suburban trains.*
*In the 21st century, many metro lines are opening in India. Most of metro rolling stock are made in Korea, China, or European countries, but approx. 70% of electric equipment of these metro rolling stock are made in Japan. Next step is "Make in India", the factory of electric equipment has been established in India, important equipment with "Japanese quality" have been started to product in India.*
*In 1964 "Shinkansen" between Tokyo and Osaka was opened in Japan as dedicated high speed railway with standard gauge (1435mm=4'8 1/2"). Now in India, design of high speed railway between Mumbai and Ahmedabad is underway, it is also dedicated corridor with standard gauge based on Japanese "Shinkansen" technology. India-Japan linkages in the field of railway technology is getting into close cooperation stage.*

**Opening and development of railway technology**

In 1825, the first railway in the world was opened in UK, it means that history of railway is only 200 years after industrial revolution. Most of countries have own railways, these are based on various condition of climate, society, passenger or goods, size of transportation, and so on. Main facilities for traffic in the world are automobiles, ships, aircrafts, and railways. I really feel as railway engineer that railwaysare "aboriginal traffic". Basic technology can be imported from foreign country, but it should be customized to fit various conditions of each countries or regions.

In 1853 the first railway in India was opened between Bombay and Thane, as the first railway in Asian countries. Figure 1 is the steam locomotive "Fairy Queen" (replica) which was built in 1855 and worked in East India. In 1872 (trail India 19 years) the first railway in Japan was opened between Tokyo and Yokohama. Figure 2 is the first steam locomotive in Japan. Both locomotives were built in UK.

*Figure 1. The early locomotive in India Figure 2. The first locomotive in Japan*

At the opening of railway, India and Japan made completely opposite decision for track gauge, in spite of same technology come from UK (standard gauge 1435mm=4’8 1/2”). India adopted broad gauge (1676mm=5’6”), please refer to Figure 3. Tradition says that it was decided based on opinion of “wider is better” which is suggested by 1st. Marquess of Dalhousie (Governor-General of India).

On the other hand, Japan adopted narrow gauge (1067mm=3’6”), please refer to Figure 4.Reason of this decision is to reduce initial cost for track construction, it is very clear. One of decision maker was Mr. Shigenobu Okuma who was a politician and the founder of Waseda University. He reminisced during his life that “Selection of narrow gauge is my biggest mistake in my life”. I was graduated from Waseda University and then became a design engineer of traction motor for rolling stock, I fully agree with his reminiscence.

*Figure 3. Broad gauge train in India Figure 4. Narrow gauge train in Japan*

From the 19th. to the 20th. century, India and Japan have constructed huge network of railway in the country. Figure 5 and 6 is a symbol of grown up railways in both countries.

*Figure 5. Night view of Mumbai Chhatrapati Shivaji Maharaj Terminus station built in 1887*

*Figure 6. Night view of Tokyo station built in 1914*

Landform, climate, and various kinds of conditions are different between India and Japan, railways of both countries have been developed independently for long years.
Figure 7 is Mumbai suburban train which is running in flood. Japanese train cannot run in flood at all, but Indian train can run in flood up to 100mm water depth on rail top.Rolling stock and signal system are well considered for operation in flood.

Figure 8 is Joetsu Shinkansen high speed train which is running in snowfall. In winter season train catch snows at under floor, and then stuck snows melt and drop. It causes big damage with jumping ballast during high speed running, sprinklers to melt snows are equipped along high speed track in snowfall area. However, it is not requested in India.

*Figure 7. Mumbai suburban train in flood Figure 8.Joetsu Shinkansen train in snowfall*

**Export of rolling stock and equipment from Japan**

In the 19th century, Japanese heavy industry was poor, most of products were imported from foreign countries, UK, Germany, U.S.A., and so on. Electric power in Japan today still have two kind of frequency 50Hz (in east area) and 60Hz (in west area), it is based on historical reason in the 19th century. Generators in power plant were imported from Germany in east Japan area, and from U.S.A. in west Japan area.

Railway industry was in the same situation, rail, wheel set, rolling stock, etc. were imported at the beginning stage. Japanese railway industries were developed step by step, ratio of domestic products were getting higher and higher. Most of import was stopped by World War I, and after that Japanese railway industries completed “Make in Japan 100%”.

After World War II, Japanese railway industries aimed to export products, rolling stock, equipment, and so on. Figure 9 is maker’s plate of steam locomotive by Kawasaki in 1954, I found it in Heritage Museum of C.S.M.T. station in Mumbai. Figure 10 is DC electrified Mumbai suburban train (retired in 2016) which install Japanese equipment (Figure 11). When I joined Toyo Denki (TDK) in 1981, the first training in workshop was assembly work of this traction motor, I remember Indian inspector was walking around in the factory.

*Figure 9. Maker’s plate of steam loco.* *Figure 10.Mumbai suburban train (DC electrified)*

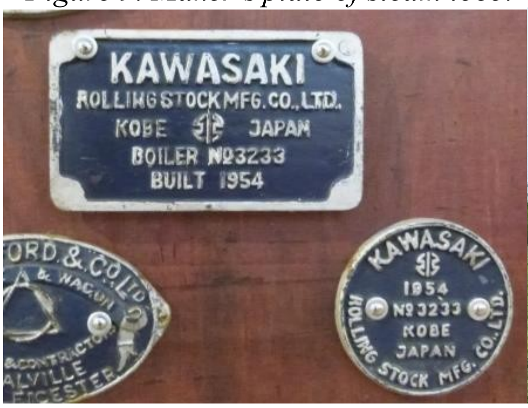
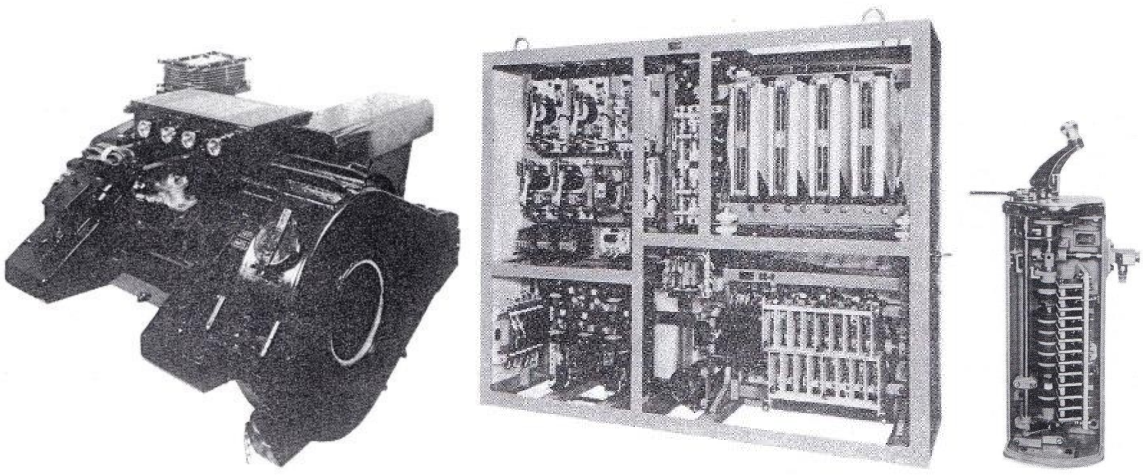




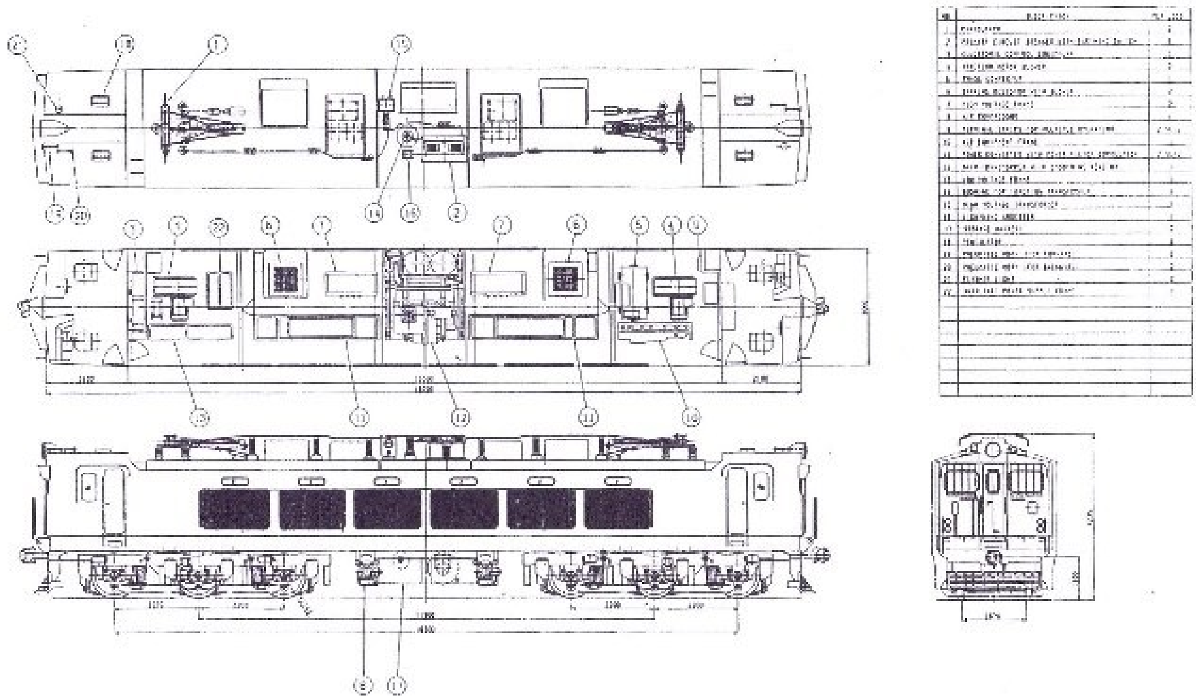
*Figure 11. Traction motor, main controller, and master controller of Mumbai suburban train*



(Toyo 1982)

Table 1 is“Number of Rolling Stock exported from Japan to India”. After 1986 no rolling stocks have been exported from Japan to India, the reason should be development of Indian car builder and loss of price competitive power of Japanese car builder.
Figure 12 is electric locomotive WAG6C by Hitachi in 1985. It is the last rolling stock exported from Japan to India at the moment, but some of equipments (such as traction motors) were continuously delivered from Hitachi to Chittaranjan Loco.Works.

*Figure 12. Electric locomotive WAG6C made in Japan*



(JARI 1988)

*Table 1. Number of Rolling Stock exported from Japan to India (contact base)*

| Year of Contract | Type of Rolling Stock | | | | | | |
|---|---|---|---|---|---|---|---|
| | Steam Loco. | Electric Loco. | Diesel Loco. | Coach | EMU* | DMU* | Goods Wagon |
| \|<br>1952 | | | | | | | |
| 1953 | 165 | | | | | 12 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1954 | 48 | | | | | | |
| 1955 | 164 | 3 | | 50 | 74 | | 1102 |
| 1956 | | | | | | | 135 |
| 1957 | 4 | 10 | | | | | |
| 1958 | | | | | | | |
| 1959 | | 7 | | | | | |
| 1960 | | | 2 | | | | |
| 1961 | | 28 | 4 | | | | |
| 1962 | | 18 | 2 | | | | |
| 1963 | | 45 | | | | | |
| 1964 | | | 5 | | | | |
| 1965 | | | 10 | | | | |
| 1966 | | | 1 | | | | 14 |
| 1967 | | | | | | | |
| 1968 | | | 5 | | | | |
| 1969 | | | | | | | |
| 1970 | | | | | | | |
| 1971 | | | 2 | 13 | | | |
| 1972 | | | 2 | | | | |
| 1973 | | | | | | | |
| 1974 | | | 1 | | | | |
| 1975<br>\|<br>1984 | | | | | | | |
| 1985 | | 12 | | | | | |
| 1986<br>\|<br>2017 | | | | | | | |
| Total | 381 | 123 | 34 | 63 | 74 | 12 | 1251 |

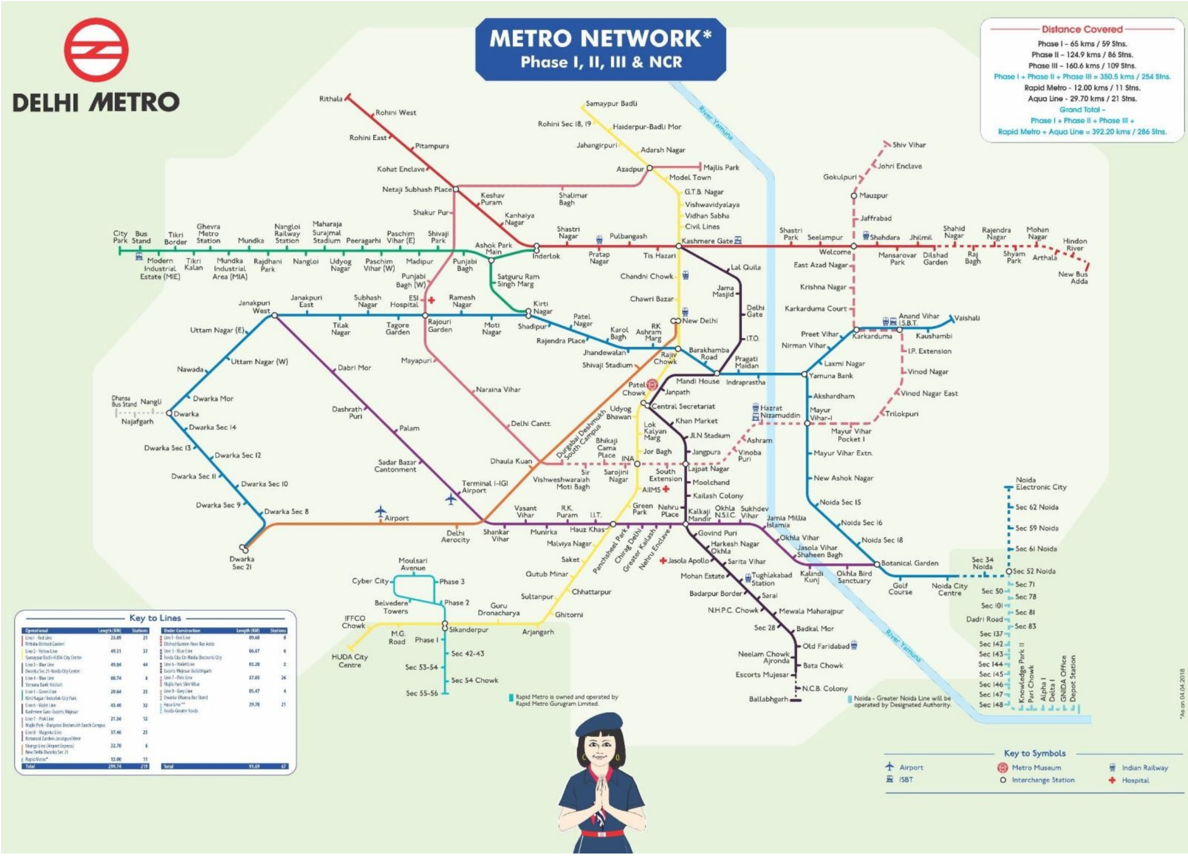
* EMU: Electric Multiple Unit, DMU: Diesel Multiple Unit

(JARI 1977)

**Development of metro technology in India**

The first metro in India is Kolkata Metro opened in 1984. In 2002, Delhi Metro was opened as second metro in India. It was constructed based on Japanese loan, opening of the first line was just on schedule. Key person is Dr. E. Sreedharan, who was MD of Delhi Metro Rail Corporation. He tried to keep construction schedule based on Japanese method for safety, punctuality, and high quality. People concerned metro project call him “Metro man in India”.
Figure 13 is “Delhi Metro Network” this year, total distance is approx. 300km, it is same as metro network in Tokyo (Tokyo Metro + Tokyo Municipal Metro). It was constructed in 90 years in Tokyo, on the other hand only in 16 years in Delhi. It is so dramatic development in metro network.

*Figure 13. Delhi Metro Network*




(DMRC 2018)

Figure 14 is the first rolling stock for Delhi Metro Line 1 (Red Line). It was manufactured by Korea-Japan consortium, completed car was built by Rotem, propulsion system (electric equipment) was provided by Mitsubishi Electric. Air-conditioned metro train with frequent service brought traffic innovation in the capital of India.

Figure 15 is recently opened Line 8 (Magenta Line). Rolling stock manufacturer is same combination as Line 1. Signal system is newest CBTC (Communications-Based Train Control), it is provided by Nippon Signal.

*Figure 14. Delhi Metro Line 1*   *Figure 15.Delhi Metro Line 8*

In the 21st century, new metro lines were opened at many cities in India, please refer to Table 2.Unfortunately there are no completed metro cars by Japanese car builder, but you can find many "Mitsubishi" as electric supplier in Table 2.

*Table2. Existing Metro in India*

| City Name | Opening Year | Operational Length | Track Gauge | Electrified System | Car Builder | Electric Supplier |
|---|---|---|---|---|---|---|
| Kolkata | 1984 | 27 km | 1676 mm | DC750V | ICF<br>ICF | BHEL<br>NGEF |
| Delhi | 2002 | 296 km | 1676/1435 mm | AC25kV | Rotem<br>BEML<br>CAF<br>Bombardier. | Mitsubishi<br>Mitsubishi<br>Mitsubishi<br>Bombardier |
| Bangalore | 2011 | 42 km | 1435 mm | DC750V | Rotem<br>BEML | Mitsubishi<br>Mitsubishi |
| Gurgaon | 2013 | 12 km | 1435 mm | DC750V | CSR | Siemens |
| Mumbai | 2014 | 11 km | 1435 mm | AC25kV | CSR | Mitsubishi |
| Jaipur | 2015 | 10 km | 1435 mm | AC25kV | BEML | Mitsubishi |
| Chennai | 2015 | 35 km | 1435 mm | AC25kV | Alstom | Alstom |
| Kochi | 2017 | 18 km | 1435 mm | DC750V | Alstom | Alstom |
| Lucknow | 2017 | 9 km | 1435 mm | AC25kV | Alstom | Alstom |
| Hyderabad | 2017 | 30 km | 1435 mm | AC25kV | Rotem | Mitsubishi |

ICF=Integral Coach Factory (India), BEML=Bharat Earth Movers Limited (India), BHEL= Bharat Heavy Electrical Limited (India), NGEF=New Government Electricals Factory (India),
Mitsubishi=Mitsubishi Electric (Japan), Rotem (Korea), CSR=China South Rolling Stock (China), CAF=CAF (Spain), Bombardier (Germany/India), Alstom (France/India)

Figure 16 is Mumbai Metro Line 1, car builder is CSR Nanjing Puzhen in China.Figure 17 is Jaipur Metro Pink Line, car builder is BEML in India. Electric equipment such as propulsion system for both metro rolling stock is provided by Mitsubishi Electric. Electric equipmentfor Indian metro, approx. 70% is provided by Mitsubishi Electric.

In 2015 Mitsubishi Electric established own factory in Bangalore to realize "Make in India". Figure 18 and 19 is IREE 2017 (International Railway Equipment Exhibition) in Delhi. Please see Figure 19 maker's plate of traction motor, you can find"ケ"at the lower right. It is stamp of"検査"(inspection), it means samequality management as its factory in Japan.

*Figure 16. Mumbai Metro Line 1Figure 17.Jaipur Metro Pink Line*

*Figure 18. "Make in India" by JapanFigure 19.Quality management by Japan*


In the metro history in India, there is a legendary Japanese woman civil engineer Dr.Reiko Abe (the present post: MD of Oriental Consultants India). She attended metro project in Delhi and Bangalore, she supervised the site of metro construction as tunnel expert. In Japan (India too) woman civil engineer is very rare, but she directly supervised many Indian workers at site to realize safety, punctuality, and high quality based on her various knowledge and experience all over the world.

I have been in Mumbai since 2015. I am working in General Consultancy named "Maple" for Mumbai Metro Line 3 (under construction) project as Rolling Stock Expert. In these 3 years, I have been considering the best rolling stock for Mumbai as Japanese railway engineer based on my knowledge, experience, and watching actuality of India. Fortunately, I have good Indian colleagues to realize it. Figure 20 is the first TBM (Tunnel Boring Machine) lowering ceremony in September 2017. Figure 21 is my Rolling Stock team in General Consultancy "Maple".

*Figure 20. TBMlowering ceremony of MML3 Figure 21.GC Rolling Stock team of MML3*


**Recent technical linkage between India and Japan**

Two big ongoing projects are based on JICA loan with technical linkage between India and Japan. One is DFC (Dedicated Freight Corridor) west corridor project, one more is MAHSR (Mumbai-Ahmedabad High Speed Rail) project, please refer to Figure 23.

DFC project is one of infrastructure development for DMIC (Delhi-Mumbai IndustrialCorridor), loan condition is basically Japan tied. Signal communication system, electric feeding system, track system, and some of civil package are provided by Japan. Back ground of DFC project, that remains unchanged operation of freight train.

*Figure 22. Double stack trainFigure 23.DFC (West) and MAHSR*

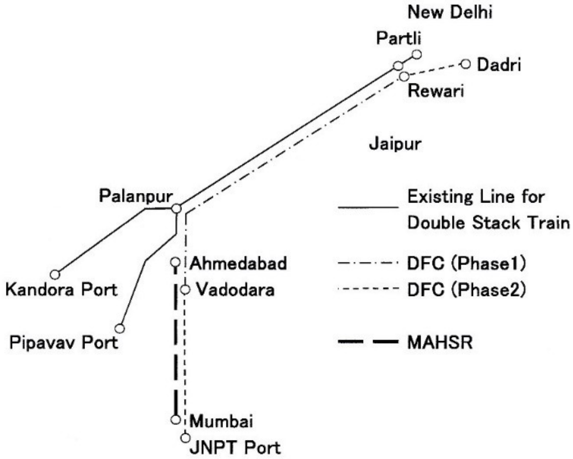
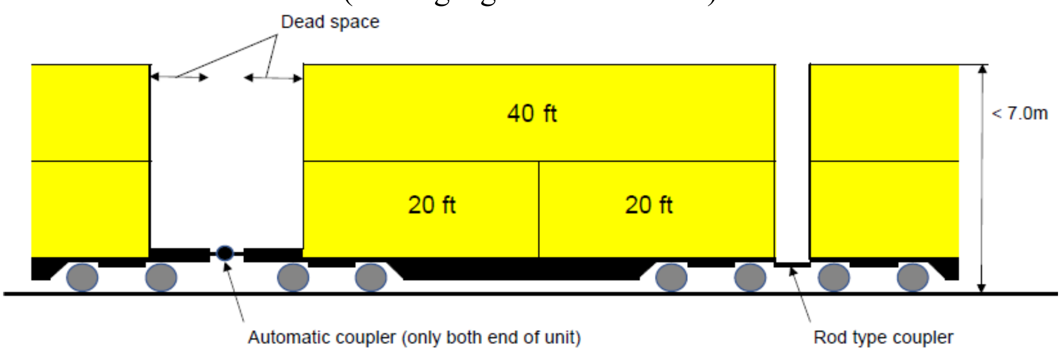



Figure 22 is double stack train with diesel locomotive on existing line, double stack will be applied to DFC (west) with electric locomotive. Before my taking this photo, the train dwelled at station, the driver called me to come into driver's cab. I asked him "what is the departure time?" He replied "I don't know, use this to ask" and he handed me a walkie-talkie with smile. It means that no diagram for freight train, and arrival time (date) of goods is unknown. It should be improved by DFC separated from passenger trains.

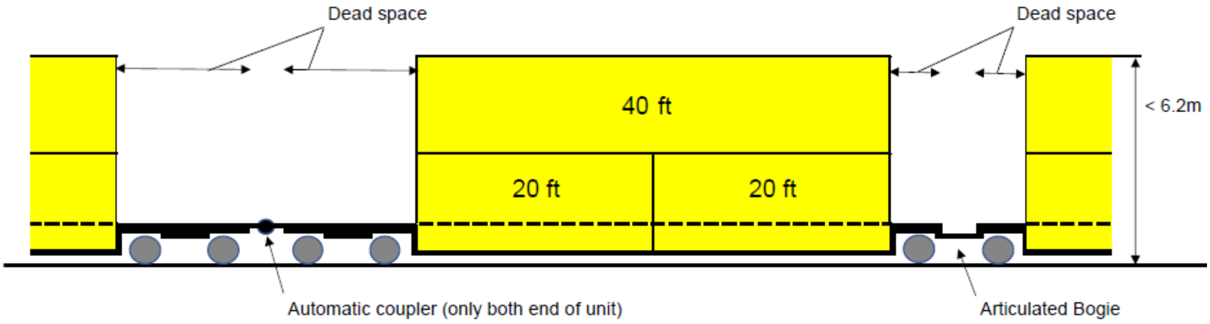
Birth country of double stack train is U.S.A., but it is not electrified. On the other hand DFC is electrified, height of overhead line is approx. 7.5m, it is approx. 2m higher than normal.Figure 24 is comparison between India and U.S.A., Indian double stack train is the highest train in the world, because U.S.A. is using low floor car (well car). Well car in U.S.A. is articulated structure, because of reducing dead space by bogie. On the other hand Indian flat car has advantage of less dead space (both end of 5 cars unit has slight dead space). It can be realized by historical advantage of broad gauge (1676mm=5'6").

*Figure 24. Comparison ofdouble stack train between India and U.S.A.*

India (broad gauge 1676mm=5'6")




U.S.A. (standard gauge 1435mm=4'8 1/2")




MAHSR (Mumbai-Ahmedabad High Speed Rail) is the first high speed rail project in India. JICA loan condition is basically Japan tied, it is also dedicated corridor with standard gauge (1435mm=4'8 1/2")based on Japanese "Shinkansen" technology, design base of rolling stock is Tohoku Shinkansen E5 series (Figure 26). Table 3 is design feature of MAHSR.

*Table3. Design features of MAHSR*

| | | | |
|---|---|---|---|
| Track Gauge | 1435mm | Max. Design Speed | 350km/h |
| Electrified System | AC25kV 50Hz AT feeding | Max. Operation Speed | 320km/h |
| Min. Curve Radius | 6000m | Train Configuration | EMU 10cars (16cars in future) |
| Max. Gradient | 25/1000 | Design Base of Train | Series E5 |
| Center Distance of Track | 4.5m (4.3m in Japan) | Number of Train | 24 |
| | | Number of Operation | 35 (/day/single) |
| Cross Section of Tunnel | 80m² (64m² in Japan) | Train Protection System | Digital ATC |
| | | Train Radio | LCX |
| Axle Load | 17t | Fare Collection | CONCERT (System of IR) |
| Track Structure | Slab Track | | |

*Figure 25. Shinkansen in Museum Figure 26.Shinkansen E5, design base for MAHSR*

In 1964 "Shinkansen" (Figure 25) between Tokyo and Osaka was opened as dedicated corridor with standard gauge (1435mm=4'8 1/2"). "Shinkansen"(新幹線)has no meaning of "high speed", it means "New Main Line". In planning stage, it was decided that new main line wasseparated from existing line to realize high speed train operation. This idea is based on condition of existing line with narrow gauge (1067mm=3'6"), it is technical reason. As I mentioned Mr. Shigenobu Okuma made "mistake" in selection of gauge at the beginning, but there should be no chance to create "Shinkansen" without his "mistake".

On the other hand, Indian railways are broad gauge (1676mm=5'6"), it can be applied for high speed rail, but final decision is dedicated corridor with standard gauge (1435mm=4’8 1/2”), it means no chance to run through into existing line as European countries. I think it is correct decision, because of unsafety condition of existing line in India. Approx. 15,000 people died per year by reckless crossing track. High speed rail should be completely separated from existing line same as metro in India, it is key issue to keep high level safety.

I live in Mumbai, I always watch unsafety condition of Indian Railways. All doors of suburban train are always open in spite of very crowded condition, I know it is method to keep punctual train operation, but it surprises Japanese people. Many passengers don’t use foot bridge, cross track including just before coming train. I think these acts are based on one of Indian philosophy “Jugaad”. It has many meanings, “flexibility” or “Innovation” as positive, “makeshift” or “illegal shortcut” as negative. Unsafety condition of Indian Railway is based on negative “Jugaad”, it must be not applicable for high speed rail.

For MAHSR, I worry about too optimistic reports in Japan, such as “India make decision to use Japanese Shinkansen system as whole package”. I can clearly declare based on my 3 years experience in India, there are no chances to use foreign railway system without any modification in India. It is design and tender stage at the moment, a lot of Japanese railway engineers come to India, they are in tough negotiation with Indian engineers. It is touchstone for adaptability of Japanese railway engineer, if they get success in India, they (including me) have nothing to fear all over the world.

Please refer to Table 3, design features basically follow Japanese Shinkansen, but basic specification for civil is very old to reduce construction cost (unchanged more than 40 years). “Center Distanceof Track” and “Cross Sectionof Tunnel” are modified to reasonable values. According to this condition, rolling stock design especially for shape of top car should be changed. Long nose of E5 series (Figure 26) is result of solution to realize high speed running more than 300km/h with poor civil specification, at the sacrifice of passenger capacity. Shape of top car for MAHSR should be shorter nose and beautiful, much more than E5 series with sufficient passenger capacity.

Needless to say, air conditioner of rolling stock should be customized based on climate of Maharashtra and Gujarat. Interior design of wash room also should be customized based on Indian habit. In Japan, no security check is requested at the entrance of station, we can carry cutlery, alcohol, and so on. In India, security check is mandatory, solution for prohibited goods should be considered, otherwise MAHSR will be inconvenient compare with flight. Many items should be optimized in India-Japan close linkage.

*Figure 27. The break-ground ceremonyof MAHSR Figure 28.Mr.Modi on E5 simulator*


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Figure 27 is the break-ground ceremony of MAHSR in Ahmedabad (Sabarmati) on 14 September 2017. Prime Ministers of India and Japan push the button together, construction machine starts to work at the site of training center in Vadodara. Figure 28, Mr. Narendra Modhi tried to operate Shinkansen E5 series by himself on its simulator in Gandhinagar.India-Japan historical linkages in the field of railway technology is going into close cooperation stage.

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