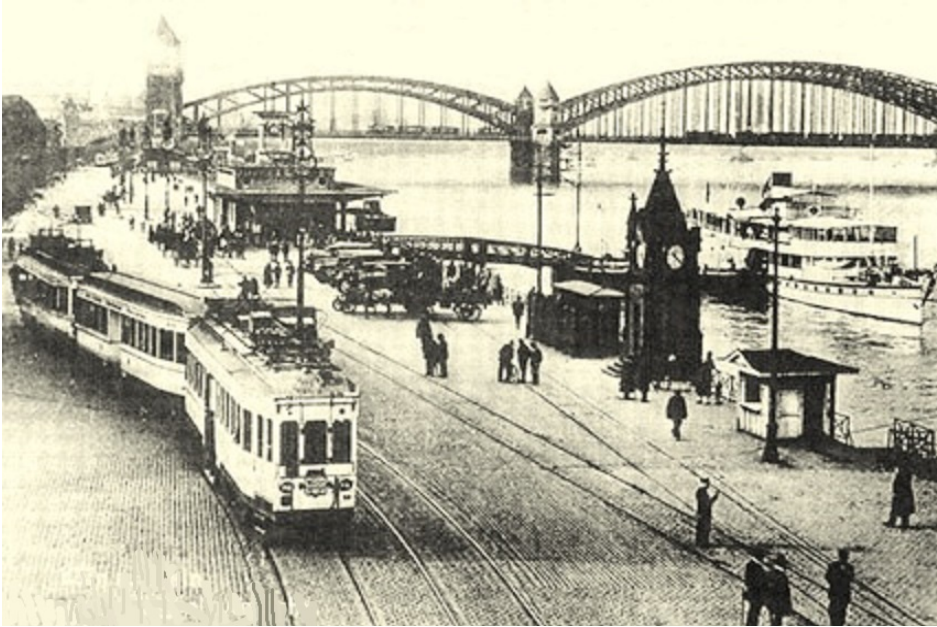


# METRO/TRAM-TRAINS

## The Multi-Talents



**Cologne-Bonn Tram-Train "*Rheinuferbahn*" from 1906,  
Germany**

By Dr. F.A. Wingler, Germany  
January 2021

### **I. Introduction**

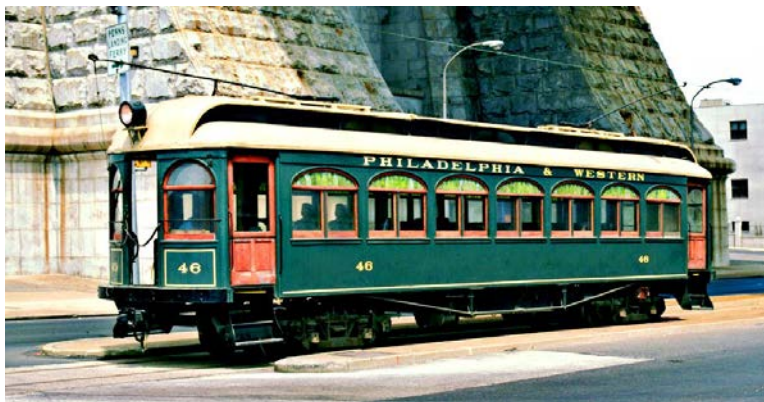
Metro/Tram-Trains are Multi-Talents or Chameleons, that operate locally on the City Rail Networks and as well inter-regional or between cities on Main-Line Railway networks, bringing commuters from one City Center to the next City Center without changing the transport mode. Metro/Tram-Trains operate seamless with one-and-the-same Rail Vehicle on Lines of Metros, Subways, Street Cars, Street Trams, suburban Commuter Rail, Intercity Regional Rapid Transits and Main Line Railways. The system should be unigue, otherwise dual-gauge or gauntlet tracks are needed. Metro/Tram-Trains combine Urban Rail with Regional Rail Transport.

Tram-Trains evolved in Europe from the so-called electric "Überland-Bahnen" at the beginning of the 20<sup>th</sup> Century. One of the first of such transits had been in Germany the Cologne-Bonn electric (1 kV DC) "Rheinuferbahn", starting in the Cologne and Bonn City centers as

Street-Tram and running between the Cities of Cologne and Bonn on the that time private Main Railway Line (Köln Bonner Eisenbahn, founded 1844) for freight trains serving with its wide rail network the regional Rhine harbors, chemical industries, the brown-coal mining fields, electric power stations and agricultural productions.

At the beginning of the 20st Century electric Tram-Trains, called "*Interurbans*" became also popular in the United States of America.

The **Interurban** (or **Radial Railway**) is a type of electric tram-railway, with tram/street car-like light electric self-propelled railcars, which run within and between cities or towns; in cities as street car or tram and between cities as a railway. They were prevalent in North America between 1900 and 1925 and were used primarily for passenger travel between cities and their surrounding suburban and rural communities. Large networks have also been built in countries such as Japan, the Netherlands, Belgium and Poland, many of which have survived to the present day. Interurban as a term encompasses the companies, their infrastructure and the cars, that ran on the rails:



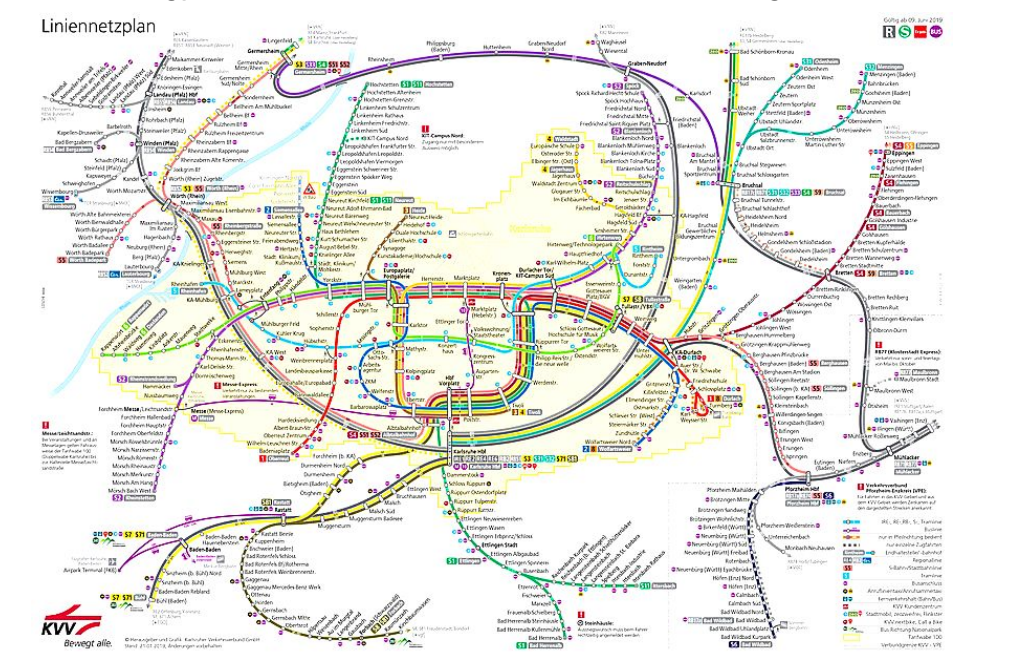
**An Interurban Tram from the Philadelphia & Western Railroad, USA, which survived long in the Interurban Business; pict. by Voogd075 at Dutch Wikipedia**

## **II. Tram Trains in Europe**

### **A. The Karlsruhe Tram-Train Model, Germany – a Success Story**

The most advanced modern Tram-Train system in the world operates currently in the Karlsruhe region, Germany, on a rail network of 533 km, using 354 km railway lines together with the infrastructures of the German Federal Railway. Further modern Tram-Train Networks can be

found in the regions of Cologne, Bonn, Saarbrücken, Stuttgart (Neckar-Alb), Nordhorn in Germany, Cadiz in Spain, Mulhouse and Nantes in France, Linz and Salzburg in Austria, Copenhagen in Denmark and Szeged in Hungary. Cases for combined Metro and Railway systems are the Nagpur and Dehradun-Rishikesh-Haridwar Regions in India.



**Map of the „Karlsruhe Verkehrs Verbund“ KVV**

Modern Thyristor Technology enables nowadays the seamless operation under different electric feeding systems: 650/750/1000 V DC, 15 kV, 16 2/3 Hz AC and 25 kV, 50 Hz AC.



**With the Tram-Train from Karlsruhe Main Railway Station over a 50 km long Main Railway Line to the City of Forbach in the North Black Forest**





**With the Tram-Train from over the German Federal Railway  
River Rhine Bridge to Wörth**

Karlsruhe is a planned city with a structured geometry of its main roads. Unlike than in other cities, there had been no constraints to bring the tramway underground. Karlsruhe is a railway center, and several elder railway lines could be re-activated and a private regional railway network (Albtal Bahn) integrated.



**Tram-Train operating as City Street Car at Karlsruhe**



**Tram-Train running on German Federal Railway Line from the City-Centre of Rastatt to Karlsruhe Main Railway Station**



**New BOMBARDIER *FLEXITY* Tram-Train for Karlsruhe Region**





**Experimental Run of Karlsruhe Tram-Train on German Railway Main Line in the industrial Ruhr Area on the Way to Dortmund Main Railway Station**



**Tram Train connects the City Center of Freudenstadt in Black Forest with the City Center of Karlsruhe over a Distance of 80 km using the German Federal Railway Line**

The Karlsruhe Tram-Train System is a success story and has a role model function for other regions in Germany.

### **B. Tram Trains for Greater Neckar-Alb Area of Stuttgart, Tübingen, Reutlingen, Germany**

A similar system for the greater Neckar-Alb area of Stuttgart, Tübingen and Reutlingen is in the making with a project to re-activate abandoned Railway Lines and to integrate the rail network of the non-governmental regional Hohenzollernische Landesbahn (railway). Previously Stuttgart Tramway operated on Meter Gauge. In the last decades the network had been converted to 1435 mm Standard Gauge:



**Stuttgart LRT U-Bahn (Metro) Tram-Train, Germany**

### **C. The Cologne-Bonn Transit Model**

As in several cities in Germany the City Tramway of Bonn and Cologne had been laid in the Underground operating now section wise as an Underground Metro-Rail. The Lines 16 and 18 connect from Underground Stations the Main Railway Station of Bonn with the Main Railway Station of Cologne. Line 18 operates as a combined Underground Metro, as City Street Tram, Regional Tram on dedicated



and reserved at-grade tracks and as regional Tram-Train Railway between both cities:



**City Tram runs as Underground-Metro Rail at Cologne**



**Line 18 runs in Cologne as City Street Car**



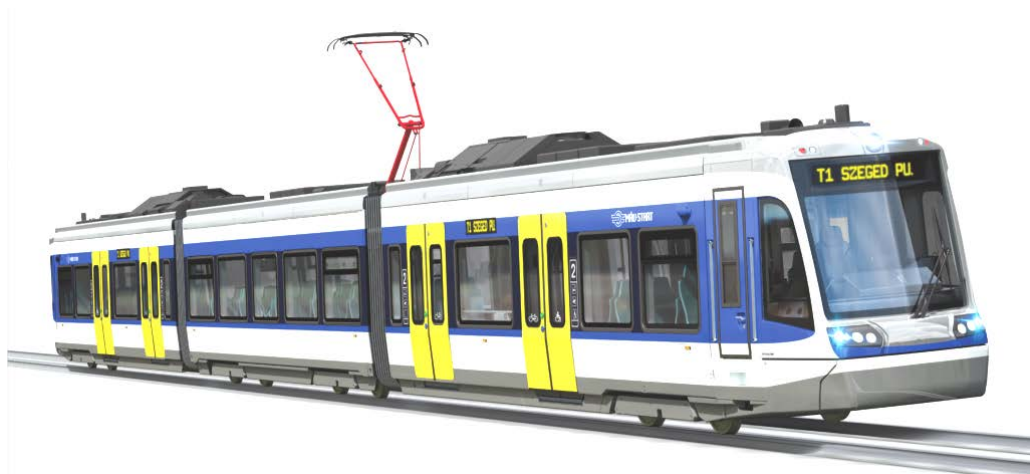


**Cologne-Bonn City Tram on dedicated/reserved Track**



**Line 16 between Bonn and Cologne on Railway Line**

## D. Szeged-Hódmezővásárhely Tram-Train Project, Hungary



The **Szeged-Hódmezővásárhely Tram-Train** is a system under construction in Hungary between two of the most important cities of Csongrád County, Szeged, and Hódmezővásárhely. Construction has begun on 4th April 2018, and is planned to be complete by 2021.

The country's first tram-train project aims to provide a high-quality service for daily commuters between the two cities, which are 25 km apart. Both have inconveniently located railway stations, meaning the majority of public transport commuting is currently by bus. The tram-trains will use 600 V DC electric power on the street-running sections in the two cities, and will be powered by two low-emission diesel power-packs rated at 390 kW on the main railway line. The objective of the project is to provide a high quality public transportation system for passengers commuting every day between the two cities

In May 2017, the Hungarian State Railway Company MÁV-START Zrt. signed a contract with Stadler, for the supply of 8 bi-mode tram-train vehicles to be build in the Valencia Plant, Spain..

The bidirectional and bi-mode Citylink vehicles cover tramway applications and full train operations at 100 kmph. The new tram-trains have been designed according to the latest safety standards and have a capacity over 200 persons.

Citylink is a modular, barrier-free and low-floor light rail vehicle family specially designed for Tram.



### **III. The Gauge Question for Tram-Trains**

For a combined and intermodal City-Tram/Metro and Regional Railway operation the track gauge should be the same, either both system in Meter Gauge, Standard Gauge or Broad Gauge; if not, mixed gauge or gauntlet tracks can be provided. Gauntlet main-line tracks we find in Spain and Bangladesh:



**Mixed Gauge Track in Spain with 1435 mm Standard and 1668 mm (Iberian) Broad Gauge**



**Mixed Gauge Track in Bangladesh with 1000 mm Meter and 1676 mm (Indian) Broad Gauge**

Historically **Spain** operated its Railways, Metro and Regional Trains on Iberian 1668 mm Broad Gauge and on 1000 mm Meter Gauge. With the introduction of High-Sped-Lines, the 1435 mm Standard Gauge entered Spain in 1992.

**Bangladesh** inherited a rail network with Indian 1676 mm Broad Gauge and in 1000 mm Meter Gauge. Bangladesh did not follow as India an "Uni-Gauge-Strategy". For interoperability mixed gauntlet tracks get used.

The **Meter Gauge Harz-Railway** is regional non-governmental Railway in Germany, that operates on a 140 km network still with 12 steam locomotives in operation. The longest 60 km route, the "Harz-Querbahn" runs between the cities Nordhausen and Wernigerode. Nordhausen has a Meter Gauge City Tramway network, that got extended on the Railway Track of the "Harz-Querbahn" up to Ilfeld with bi-mode **Meter Gauge Tram-Train Vehicles**, with electric catenary propulsion within the city and with Diesel-electric propulsion on the railway line.



**Modern Meter Gauge Steam Locomotive in Operation on the Harz Meter-Gauge Rail Network, Germany**





**Meter Gauge Tram-Train Line No. 10 with bi-mode Hybrid Vehicle, Nordhausen-Ilfeld, Germany**

Ferrocarriles de la Generalitat de Valenciana in Spain is a **Meter Gauge Tram-Train System**, operating in the City of Alicante as a Street Tram and outside along the Costa Brava as a Railway connecting Alicante with the Cities of Benidorm and Denia, on an old Railway Line once connecting Valencia with Alicante. Within the City of Alicante the Stadler build bi-mode hybrid "Citylink" Rail Cars run electric propelled with overhead line feeding and regional to Denia with Diesel-electric propulsion:



**Meter Gauge bi-mode hybrid Tram-Train Alicante-Benidorm-Denia, Costa Brava, Spain**

To avoid the Gauge-Dilemma the broad gauge **Cadiz Tram-Train Project in Spain** had been executed with Iberian 1668 mm Broad Gauge. This has involved the construction of 14 km of 1668 mm gauge tramway in the towns of Chiclana de la Frontera and San Fernando, plus adaptation of 10 km of main line track into the city of Cádiz, operated by the Governmental Railway RENFE. The rolling stocks are provided by CAF, Spain:



**Cadiz Tram-Train operated by the Main-Lin Operator RENFE, Spain, into the Hearts of the Cities of Cadiz, Chiclana de la Frontera and San Fernando on Iberian Broad Gauge**



**Cadiz Broad Gauge Tram-Train on RENFE Main Line**



## IV. The Indian Gauge-Dilemma

### A. Historical Background

The first agreement of the Government of India with East Indian Railway Company and Great Indian Peninsula Company in 1849 stipulated that railways in India would be built with the four feet, eight and half inch or 1435 mm British Gauge, nowadays called "Standard Gauge".

*This "Standard Gauge" has spread over the world by the delivery of the first steam locomotives build by **George Stephenson** (9th June 1781 – 12th August 1848), Newcastle, England. With the England Steam Locomotives the 1435 mm Gauge came to Europe (with exception of Russia, Spain and Portugal), to North and Middle America, China, Iran, Ir Iraq, Turkey, Morocco and Egypt. This gauge goes back to the collieries in England with a wheel gauge, which goes back most likely to the Roman carts:*



**Roman Cart Road; "Roman Cart Standard Gauge"**

*This "Roman Gauge" has proved to be the most suitable gauge for High-Speed Railways. When deciding for the dedicated High Speed network*

*for the Shikansen, Japan introduced 1964 the 1435 mm Gauge in addition to the 1067 mm Cape Gauge of the countries rail grid. In 1992 Spain introduced (in addition to the Iberian Broad and Meter Gauge) the 1435 mm Standard Gauge for its High-Speed Network with now over 3000 km, the second longest in the world after China.*

However, soon there were disagreements with Lord Dalhousie favouring a 6 ft (1,829 mm) gauge and Mr. Frederik Walter Simms, the consulting engineer favouring the five feet and six inches gauge:



**James Andrew Broun-Ramsay**  
**"Lord Dalhousie", 1812 – 1860**



**Frederik Walter Simms**  
**1803 - 1865**

In India, the Governor-General James Andrew Broun-Ramsay, 10th Earl of Dalhousie, determined that the wider gauge than 1,435 mm (4 ft 8 1/2 in) standard gauge was more suitable for larger firebox and stability in high winds and long steep gradients.

The debate was finally settled in favour of the five and half feet gauge, called the Indian broad gauge in 1850s, and the first train that ran from Bombay to Thane ran on broad gauge.

That time one thought that the Indian Broad Gauge will evolve as the "Standard Gauge" in South-East Asia. But this did not realize. The Railways in most countries of this region had been constructed with 1000 mm (MG) or 1067 mm (CAP) Gauge. The engineer of the CAP gauge had been in 1862 the Norwegian engineer **Carl Abraham Pihl**:





**Carl Abraham Pihl; 1825-1897**; source: Oslo Museum

The only Indian neighbor country, which adopted the Indian Broad Gauge, was Sri Lanka, although Meter Gauge would have much better suited the topography. Especially on the SL "grueling Upcountry Line" climbing from sea level to the summit at nearly 2000 m, the tight 17-18 Degree Broad Gauge Curves on a ruling gradient of 1 in 44 are a big maintenance problem.

In 1991, India adopted the Project **Unigauge**. Gauge conversion towards Indian broad gauge got underway, replacing narrow gauges and meter gauge.

To achieve long term economic feasibility of railway projects by transporting more cargo and passengers, India's all new railway lines got built with broad-gauge.

In 1871 the Government of India wanted to build cheaper railways for the development of the country. And for regional lines all over India the tighter **1000 mm or Meter Gauge** was introduced. The first MG line was built in 1872 from Delhi to Farukh Nagar. Interestingly, the metric system was not after all adopted until nearly a century later, so the gauge was the only thing in India that was 'metric' for a very long time.

The MG network was especially dense in the west (around Vadodara, and in Rajasthan), in the east/north-east (West Bengal, Assam) and, before Independence, the areas in what is now Bangladesh, and in much of the south of India. Until the late 1980s, the North-Eastern Railway had a completely MG network. The MG networks of northern India (including the north-east via the Assam Rail Link) and southern

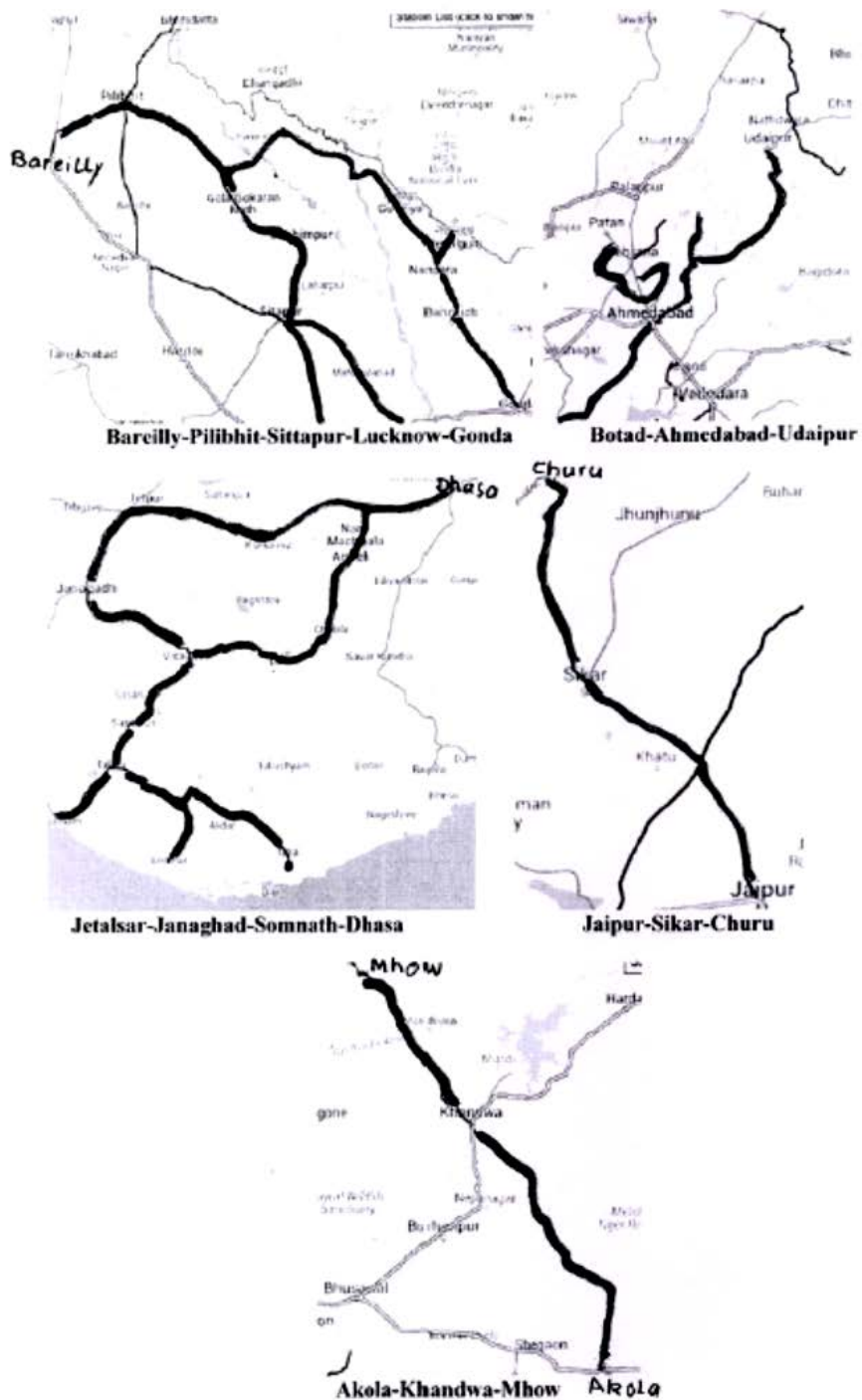
India (16,690 and 7,940 route km, respectively) remained separate until 1960, when the completion of the Khandwa - Hingoli section connected the two. This link went through Akot, Akola, and Basim, across the Tapti and Purna rivers and had 2 tunnels and 50 major bridges, and a spectacular spiral. This made possible the transit of freight from any MG station in India to any other (except, of course, the Nilgiri line, which was always an isolated MG section), which was important even though MG's share of freight was never very large (about 12% before the Unigauge project started). The last MG line to be built in India was probably the Himmanagar - Udaipur line.

For thinly populated areas, mountain railways and for other miscellaneous purposes two more Gauges with widths of 762 mm (2'6") and 610 mm (2') were chosen. Nowadays, most of the MG Lines had been converted to BG or are under Gauge Conversion. The MG Network is fast shrinking. In South India the last train on MG from Thiruvavarur to Pattukottai was running June 2012. Only the "Ooty" Hill Train of Southern Railway has been left on MG.

On 15th March 2015 the first BG Inspection Train reached Silchar coming from Lumding in Assam. The first passenger train from Silchar to Guwahati had been flagged off on 21st November 2015. The first Broad-Gauge train from Badarpur reached Agartala in Tripura on 13th January 2016.

Only few pocket MG networks in Gujarat: Jetalsar-Jhanaghat-Dhas, and of Northern Railway in the Bareilly-Sitapur- Lucknow-Gonda Region are left as well as the MG lines in Gujarat/Rajasthan: Botad-Ahmedabad-Udaipur, Jaipur-Sikar-Churu and Akola-Mhow.



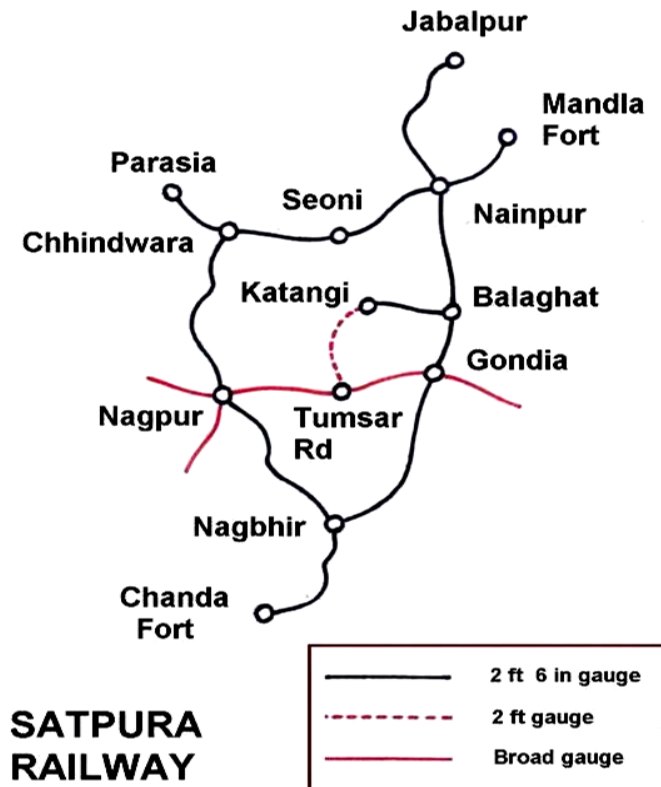


### Meter Gauge in Service left 2016

See: Indian Railways Living Atlas - India Rail Info;

<http://indiarailinfo.com/>

The scenic Heritage Railways on 2 ft. NG Neral - Matheran, 25 km; New Jalpaiguri – Darjeeling, 88 km; the 2 1/2 ft the 96 km Kalka-Shimla and the 164 km Joginder Nagar-Pathankot will remain. The 199 km 2 ft NG from Gwalior to Sheopur is already proposed for Gauge conversion. The balance left of the once largest 2 ½ ft. Network of the Satpura Lines of South Eastern Railway in the Nagpur region with once over 1000 km, which has diminished to around 300 km in the last decades, is already under Gauge conversion:



**The once 1005 km Satpura NG Network before Gauge Conversion**

From the once 359 km 2 ½ ft NG Network around Dabhoi in the Vadodara Region not much is any more left as NG.

**Dedicated High-Speed Lines** around the globe are built in 1435 mm standard gauge. Spain with its 1668 mm Iberian Broad Gauge had to switch for High-Speed to the international 1435 mm standard Gauge. And for High-Speed, India will need also dedicated new routes in 1435 mm Standard Gauge (SG), as the Japan International Cooperation Agency (ICA) recommended it for the Mumbai-Ahmedabad High Speed Project.



## B. The Gauge of Indian Metro Rail

The Gauge for Delhi Metro Rail had been a fierce debated issue. It ended up that Delhi Metro has two gauges, Indian broad gauge and international standard gauge:



**Delhi Metro Blue Line**

The Mumbai mid-day journalist Mr. Rajendra B. Aklekar reports about this battle for gauge in his book: *INDIA`S RAILWAY MAN*, Rupa Publications, New Delhi, 2017, ISBN: 978-81-291-4521-5:



**Elattuvalappil Sreedharan, born in Kerala 1932**

*When the Delhi Metro Rail was being built, the question of gauge for the line came up and Indian Railways, going by its strong belief in Indian broad gauge, ruled that it had to be 1667 mm Indian Broad Gauge and nothing else. There were differences in opinion. Elattuvalapil Sreedharan, the Managing Director of Delhi Metro from 1955 to end of 2011, while building the Delhi Metro, had selected standard gauge, 4 ft 8½ in, or simply 1435 mm, for the simple reason that most of the metro networks around the world used it, providing better speed, safety and maneuverability. In fact, not just metro systems, but approximately over 60 per cent of railway lines across the world use this gauge.*

*Recalling how the debate started, E. Sreedharan explained, 'The Indian Railways, represented by the Chairman of the Railway Board, insisted on broad gauge. Delhi Chief Minister Sheila Dixit wanted standard gauge, but the Ministry of Railways opposed it. Their argument was that the Indian Railways were following the unigauge policy. The railways said broad gauge meant more capacity and put forward some arguments. They wanted to thrust broad gauge on us. I proved to them that gauge had nothing to do with capacity.*

*The matter went up to the Cabinet and a meeting was held to discuss the issue. Lal Krishna Advani was the chairman of the committee and other members included the railway minister and the urban development minister. In the first meeting, all were convinced that the Delhi Metro should be standard gauge. But Railway Minister Mamata Banerjee was absent at the meeting. So Advani said it would not be correct to take a final decision in the absence of the Railway Minister against the decision of the Railway Ministry. So we postponed it to another day, when Banerjee would be available.*

*The second meeting, too, was going well and there were discussions about standard gauge. Then, a bombshell was dropped by the Chairman of the Railway Board, V. K. Agrawal. He said if we were going to have standard gauge, the Indian Railways would not be able to certify it because it had no experience with standard gauge. When Agrawal said this, the Urban Development Minister Jagmohan was the first to say that if that were the case we would have to go for broad gauge. According to the legal provisions in place, the Indian Railways are supposed to give safety certification to the Metro Railway. So everybody agreed to go for broad gauge. That is how broad gauge was decided.'*



## ***Change of Gauge***

*Explaining how Maharashtra politician Sharad Pawar played a key role in the change of gauge for Delhi Metro, Sreedharan recalls, 'Fortunately, sometime after this meeting, a Group of Ministers was appointed, Pawar became the chairman of the Group of Ministers. I kept fighting my battle and said, "Delhi Phase I is lost, but why should we continue broad gauge for the rest of the country?" I had a discussion with Pawar. He was fully convinced that standard gauge was best. This was after about a year from the meeting when the decision for broad gauge had been taken. Pawar then volunteered to call another meeting.' 'So, another meeting of the Group of Ministers was called, and it was Pawar who pioneered the decision that the Metro Rail should be standard gauge. Pawar had a vision. He said, "Why should the remaining cities suffer?"*

*He saved the day by putting across a clause that the gauge would be decided with the concurrence of the state governments building the Metro Railway, not by the Indian Railways. Then the Metro Act came in and things changed. The railways continue to create problems, but this decision by Pawar changed everything, and almost all the state governments went for standard gauge,' he says. This is the reason the Delhi Metro has two gauges.*

India had provided until 2010 its Metro Lines in Kolkata and Delhi (Phase I) with INR Broad Gauge following the Uni-Gauge Strategy until in Delhi the fifth Line, the Green Line, had been build with the internationally favored 1435 mm Standard Gauge. Sharad Pawar, the chairman of the group of ministers, played the key role in the change of gauge for Indian metros:



**Sharad Govindrao Pawar**

He pioneered the decision that Metro Rail of the rest of the country should be standard gauge (and not any more broad gauge), that Calcutta Tram Company is using since 1902. Almost all the State Governments followed him.

From today's perspective of interoperability of Metro Rail and Main-Line Railways the question is, if it had been a wise idea of Sharad Pavar to opt for standard gauge for all Metros in India. With the decision for standard gauge for Metro Rail in all Indian cities, the interchangeability of trains within the two sets of different gauges of Metro Lines (standard gauge) and Indian Railways Lines (broad gauge) as so-called "Metro Trains" for an intermodal service with Metro-Train Rolling Stocks, that would run intermodal on Metro Network as well on Indian Railway's Tracks, has become a hindrance, that had been overseen that time.

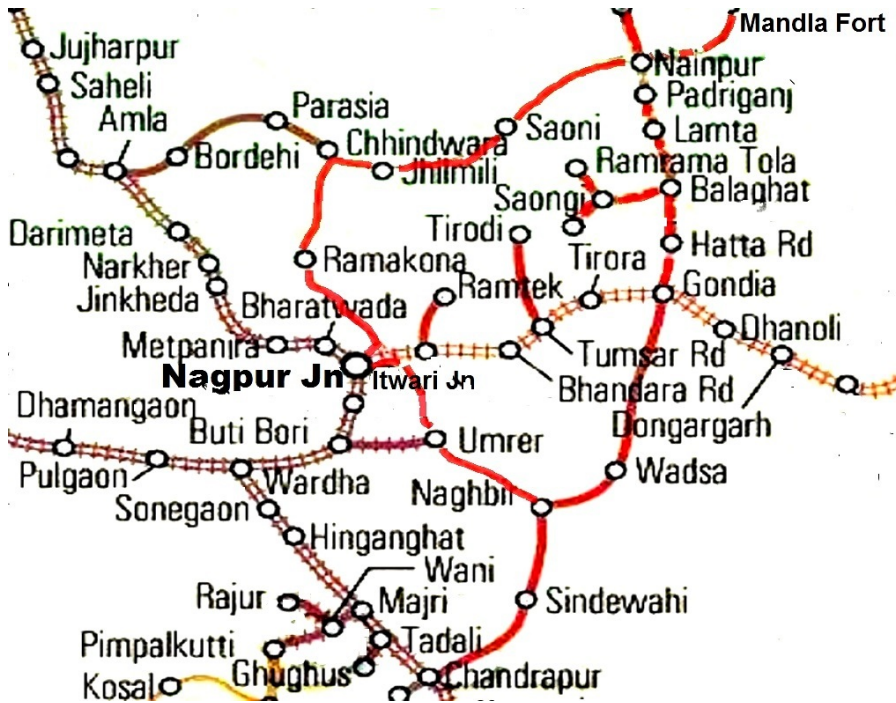
## **V. Cases for Metro-Railway Train Services in India**

### **A. Nagpur Region – a Case for a combined Broad Gauge Metro-Railway-Train Service**

Nagpur is the third largest Indian city and the winter capital of the Indian state of Maharashtra. It has been proposed as one of the Smart Cities in Maharashtra and is one of the top ten cities in India in the Smart City Project execution. According to a survey by ABP News-Ipsos, Nagpur was identified as the best city in India topping in livability, greenery, public transport, and health care indices in 2013. The city was adjudged the 20th cleanest city in India and the top mover in the western zone as per Swachh Sarvekshan 2016.

Nagpur has been the main centre of commerce in the region of Vidarbha since its early days and is an important trading location. Nagpur is embedded in a dense Railway Network connecting the town with adjacent commercial centers like Narkher, Ramtek, Wardha Bhandara, Saoner and Umrer:





One of the most ambitious projects proposed by Maha Metro is a combined Broad Gauge Metro and Railway Project with a combination of Metro Rail with Commuter-Rail, which would change the transportation pattern in Nagpur and surroundings by bringing the travelers seamless right from one city center to the next utilising the existing infrastructure of Indian Railways by providing air-conditioned, 120 kmph fast, reliable and comfortable services between Nagpur and the satellite towns mentioned above. Once implemented, Metro-Train Rolling Stocks would run intermodal on a broad gauge Metro Network as well on Indian Railways' Tracks. This will be the first-ever such Metro-Rail Railway-Train service to be introduced in India. The Spanish Cadiz broad gauge Metro-Rail/Railway-Train project had been the forerunner:



**Artist`s Concept for a 120 kmph intermodal Maha Metro-Rail/Railway-Train**

## B. Dehradun-Rishikesh-Haridwar Region – a Case for a combined Metro cum Regional Rapid Transit Train Service



**Google Map for Dheradun, Rishikesh and Haridwar in Uttarakhand**

The Uttarakhand Metro Rail Corporation has submitted to the Uttarakhand State Government a detailed project report to provide connectivity between the religious places of Dheradun, Rishikesh and Hardwar with a combined Metro cum Regional Rapid Transit Train service. This would allow traveling on the axis from the center of Dehradun via Rishikesh to Haridwar center seamless without changing the transport mode in a combined **Metro/Regional Rapid Transit Train**. The first 33 km are planned to get realized in 2024. The realization of such a project will allow commuting faster from one city center to the next than currently by bus or INR.

