METRO RAIL IN INDIA

a Success Story in Pictures

Three Tire Crossing of Delhi Metro Pink Line and Airport Express at Sadar Patel Marg

By Dr. F.A. Wingler, Germany, July 2020

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By Dr. F.A. Wingler, Germany, July 2020

PREFACE:

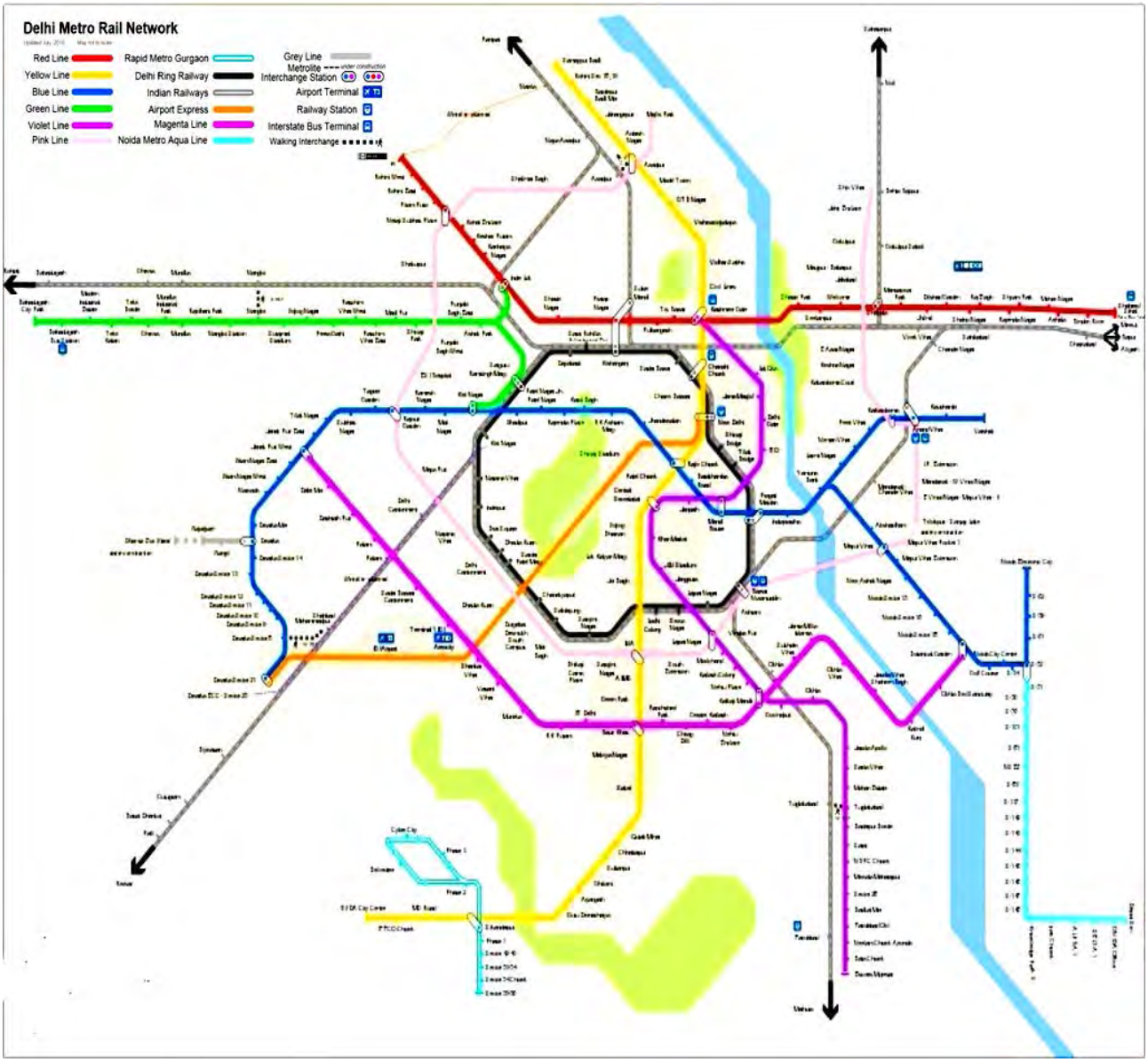
Worldwide India is raking second behind China in regard of the pace in installing and expanding in its cities **Metro Rail**. The operational total length as April 2020 has reached 692.65 km. Further 968 km are at present under construction or extension in varies cities. See **Tab. 1, 2 and 3**.

The fast paced implementation of **METRO RAIL** in several mega cities has become a main constituent within the Governmental Transport and Traffic Policy for urban development. **METRO RAIL** has become in several cities the main backbone or "lifeline" for **URBAN MOBILITY IN INDIA** as a Service boosting socio-economic development. The rapid success with Metro Rail is owed also to the fact, that India has imported the technology from abroad.

METRO RAIL IN INDIA, meeting the demand for Urban Mobility, is a success story for its fast paced legislation, planning, financing, construction and operation; and in the last 18 years has significantly improved **URBAN MOBILITY** and changed the public transport in several Indian cities; see also survey in http://sundarmukherjee.blogspot.com and Metro Newsletter 47 in Portfolio 3 in http://www.drwingler.com.

The **Kolkata** Metro was for 18 years the only Underground Metro Rail in India, opening for commercial services from 1984. It celebrates now its 35th anniversary.

Only after 18 years, **Delhi** was the second city to get Metro Rail. The construction started in 1998, and the first elevated section (Shahdara – Tis Hazari) on the Red Line opened on 24th December 2002, while the first underground section (Vishwa Vidyalaya – Kashmere Gate) of Yellow Line opened on 20th December 2004. Within only 18 years the network expanded to 692 km serving over 250 stations. The system has a mix of underground, at-grade, and elevated stations using both broad-gauge and standard-gauge. Delhi Metro operates with 8 lines (9 lines inclusive Airport Express Line) over 2,700 trips daily. All Delhi lines use electric overhead catenary feeding with 25 kV 50 Hz single phase current:



Delhi Metro Rail Network

Updated July, 2018 Map not to scale

Red Line
Yellow Line
Blue Line
Green Line
Violet Line
Pink Line

Rapid Metro Gurgaon
Delhi Ring Railway
Indian Railways
Airport Express
Magenta Line
Noida Metro Aqua Line

Grey Line
Metrolite *under construction*
Interchange Station
Airport Terminal T3
Railway Station
Interstate Bus Terminal
Walking Interchange

The prototypes of the BOMBARDIER ***MOVIA®*** Cars with ***MITRAC*** ® traction and build in Germany for Delhi Metro arrived on February 26th 2009 at Delhi Airport coming from Berlin on board of a Russian Antonov transport plane:

BOMBARDIER MOVIA Metro-Set for Delhi Metro arrives in India on 26th February 2009 on Board of Russian Antonov Transport Plane

Delhi Metro is a Pioneer in METRO RAIL EXPANSION and a Symbol of the Progress, that India has made in the last two decades. The leading eminent personality behind this success story is Mr. E. Sreedharan:

Elattuvalapil Sreedharan – called India`s *"Metro Man"*

See: Rajendra B. Aklekar: ***INDIA`S RAILWAY MAN - A BIOGRAPHY OF E. SREEDHARAN***, 2017, Rups Publication India Pvt., New Delhi, ISBN: 978-81-291-XXXX-X.

The Mumbai Metro is now proposed to become a 14 Corridor Network of about 337.10 km being built at the Cost of 1,40,814 Crores with an expected daily Ridership of 142.90 Lakh by 2031. As per date, only Line 1 with 11.4 km is operating; ***see Mumbai Metro: Here's all you need to know about the entire City Network*** ; updated: Sep. 13th, 2019, by Ranjedra B. Aklekar, mid-day.

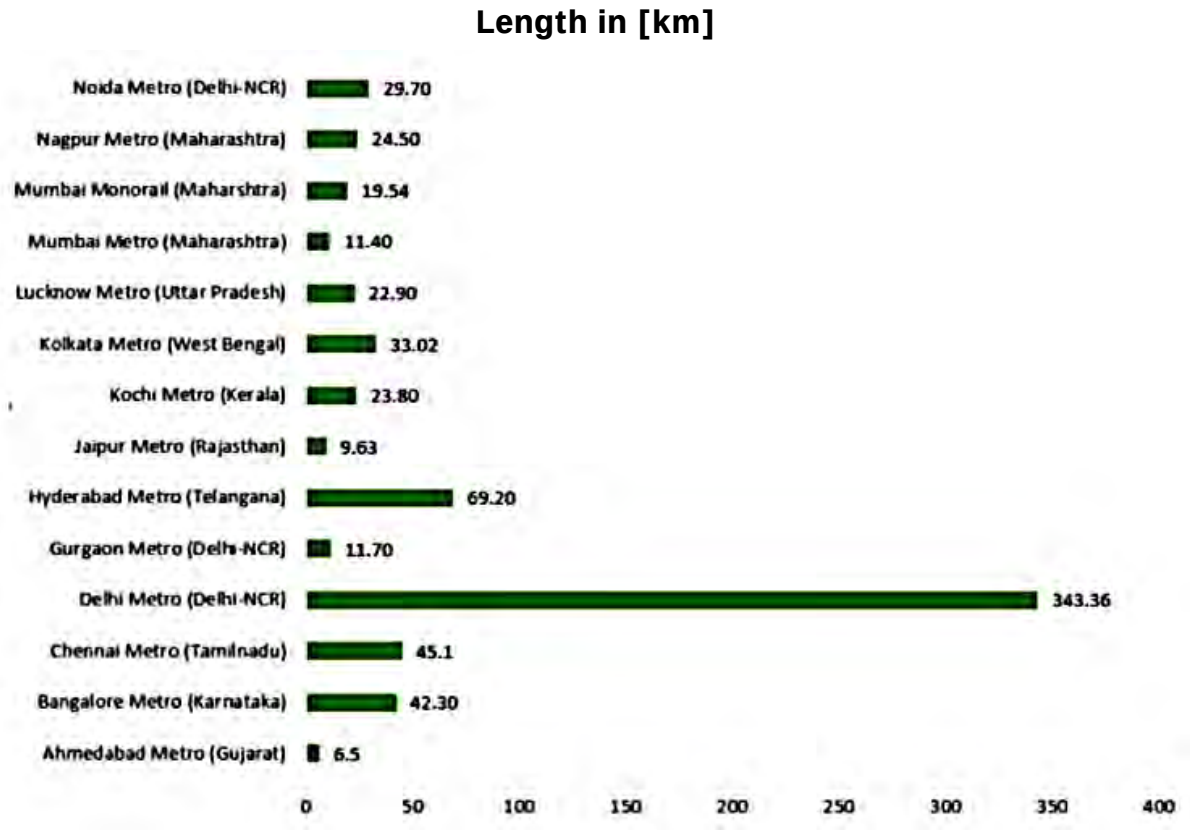
The implementation of Data based and driven tools (Sensor-, Monitoring Technologies, Building Information Modelling, Internet of Things, Artificial Intelligence, Digital Twins, Data Analytics and Communication Technologies) have already entered the **WORLD OF METRO RAIL IN INDIA.**

Maharashtra Metro Rail Corporation Ltd. (Maha Metro) India, deployed for Nagpur and Pune Metro a **Digital Project Management System**, developed through Bentley's OpenRail Connected Data Environment (CDE), which covers planning to performance stages of the project over the whole life cycle and bringing all participants in close communication.

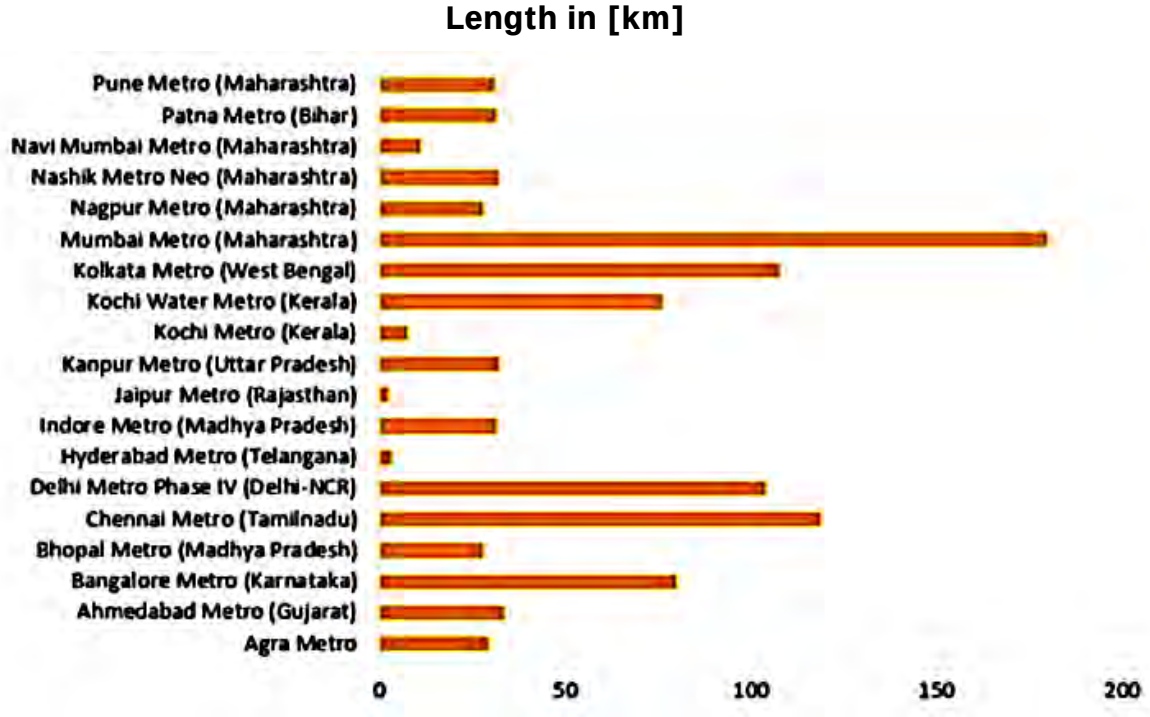
Several Metros in India are ready for Driver-less autonomous Operation, ATO. International operating suppliers have their foot in the doorstep: Siemens, Thales, Alstom Anasaldo. With ATO, platform screen doors are becoming a necessity:

Screen Platform Door at Delhi Kalkaji Purple Metro Station; pict. by Vishwa Tyagi

Tab. 1: OPERATIONAL METRO RAIL;
total Length: 692.65 km (source: Metro Rail News)**:**



Tab. 2: METRO RAIL UNDER CONSTRUCTION (new Lines and Expansions of existing Lines); total Length: 968.52 km (source: Metro Rail News)**:**



Tab. 3: **QUICK SNAPSHOT of operational Metro Rail in India** – Updated:

May 2020; from The Metro Rail Guy

Commencement Date of Metro Operations along with current operational Length:

- Kolkata: 24. October 1984 – 33.4 km
- Delhi: 24. December 2002 – 347 km
- Bangalore: 20. October 2011 – 42.3 km
- Gurgaon: 14. November 2013 – 12.1 km
- Mumbai: 8. June 2014 – 11.4 km
- Jaipur: 3. June 2015 – 9.6 km
- Chennai: 29. June 2015 – 45.1 km
- Kochi: 19. June 2017 – 23.8 km
- Lucknow: 6. September 2017 – 22.9 km
- Hyderabad: 29. November 2017 – 67 km
- Noida-Gr. Noida: 25. January 2019 – 29.7 km
- Ahmedabad: 6. March 2019 – 6 km
- Nagpur: 8. March 2019 – 22.9 km

"*MAKE IN INDIA*" of Metro Cars – another Success Story

When the first line of Delhi Metro was inaugurated in 2002, the coaches were imported as CBUs (Completely Built Units) from Germany and South Korea. 16 years later, 90% of the coaches running on the 8 lines of the over 300 km network of the country's largest and the world's 9th longest Metro network in Delhi is made in India. This indigenisation of Metro coaches was facilitated by the contract conditions of DMRC, which mandated a cap on the upper limit of 25 % for production abroad with the balance to be manufactured in India. This in turn brought in global manufacturers like Bombardier, Alstom, Hyundai Rotem (with BEML) and Titagarh Firema to form their subsidiaries and joint ventures in India.

In 2019 Titagarh Firema has been awarded a contract by Maharashtra Metro Rail Corporation (Maha Metro) to supply 102 aluminum-bodied metro cars for the first phase of the metro network in Pune

Alstom India rolled out out the 100th ***'Make-in-India'*** metro train-set today from its state-of-the-art rolling stock manufacturing facility in Sricity, Andhra Pradesh. The delivery of the centurion trainset to Kochi Metro Rail Corporation Limited (KMRCL) also marks completion of the Kochi Metro order for 25 trainsets by Alstom. Kochi operates a 100% ***'Make in India'*** metro fleet entirely custom-built at the flagship manufacturing facility at Sricity. The facility was set up in 2013 as Alstom's first global manufacturing centre for rolling stock in the Asia-Pacific region.

This plant commenced operations in November 2013 and delivered its first metro train-set to Chennai Metro Rail Corporation (CMRL) in February 2014. The facility currently employs more than 600 employees and has a production capacity of 240 cars per year. The factory is currently scaling up to double production capacity and also introducing latest industrial technologies.

Till date, Alstom's Sricity facility has made on-time deliveries of more than 420 metro cars for its Indian and international customers. This includes delivering completely indigenous train-sets to metro rail corporations of Chennai, Lucknow, Kochi and Sydney (its first international order).; see newsletter METRO 103, page 20 in **PDF Portfolio METRO 9**, http://www.drwingler.com.

In December 2018 Alstom achieved a significant milestone by completing the export of the last of the 22 Metropolis trains for Sydney Metro, Austria, delivered from its 2013 set up Sricity facility. Alstom India has begun from early 2019 to work on its second export order for the light Metro project in Montreal.

ALSTOM Driver-less *METROPOLIS* Metro Train build in India for Sydney, Australia

In 2002, BEML forayed into the manufacturing of state-of-the-art Metro Coaches. Since then, more than 1600 metro coaches have been supplied to various metro rail corporations in India such as Delhi, Bangalore, Jaipur, Kolkata and Mumbai. BEML holds over 48 percent market share in Metro coach segment in India against stiff competition.

To cater for burgeoning metro orders, BEML recently set up an additional assembly line, and currently the Company has the capacity in its units to produce over 700 rail coaches per year

and 300 metro cars per year. Further expansion plans would be based on market demand to augment the annual production capacity by 360 metro cars.

With the experience gained in manufacture, integration and testing of Metro cars, BEML expanded its role in Metro Business and is commanding a good market share in India; see exclusive Interview with Dr. Deepak Kumar Hota, Chairman & Managing Director, BEML, in METRO RAIL NEWS, Edition May 2020, page 24, ISSN 2582-2330 / Vol. IV / Issue 41; Symbroj Media Publication, India.

BEML build Metro Train for Bangalore Metro

Metro Rail Trainset Manufacturing Units in India; source UITP India 2014

The capital costs of Metro coaches in India are substantially lower than the rest of the world. The capital cost of a coach is around INR 89.4 million (US $ 1.35 million) in India, the cost in Vancouver is INR 160.8 million (US $ 2.5 million) and in San Francisco is INR 151.3 million (US $ 2.30 million). Three Metro coach manufacturing units have already been established in India:

Name of the Company	Facility at	Year of Establishment
Bombardier Transportation	Savli near Vododara (Gujarat)	2008
Bharat Earth Movers Limited (BEML)	Bengaluru (Karnataka)	2015
Alstom Transport	Sricity near Chennai (Tamil Nadu)	2010
Titagarh Firema India Ltd.	Mahametro Coach Facility Nagpur	1998

China Railway Rolling Stock Corp (CRRC) is planning to setup its manufacturing unit in the Multi-modal International Cargo Hub and Airport at Nagpur (MIHAN).

Metro Coach Market

The existing numbers of coaches supplied or ordered for various metro project is as follows:

Metro Rail Project	Rolling Stock Suppliers	Coaches
Delhi Metro (Broad Gauge)	Consortium of Hyundai, Mitsubishi & MELCO / Bombardier / BEML	1232
Delhi Metro (Standard Gauge)	BEML	164
Bangalore Metro	BEML-led Consortium with Mitsubishi & Hyundai	150
Mumbai Metro	CSR Nanjing (China)	64
Jaipur Metro	BEML	40
Kolkata Metro	CNR Dalian (a subsidiary of CRRC)	112
Chennai Metro	Alstom	168
Gurgaon Metro	CSR Zhuzhou (a subsidiary of CRRC)	36
Hyderabad Metro	Hyundai -Rotem	171
Lucknow Metro	Alstom Transport	80
Kochi Metro	Alstom Transport	75
Nagpur Metro	CRRC	69
Navi Mumbai Metro	CSR Zhuzhou (a subsidiary of CRRC)	12
Noida Metro	CRRC	76
Pune Metro	Titagarh Firema Wagons Ltd. India (a subsidiary of Titagarh Firema Italy)	102

THE SUCCESS STORY IN PICTURES

Left: **Ahmedabad Metro** or ***MEGA*** operating on Standard Gauge with 750 kV DC third rail electric feeding is being built by Gujarat Metro Rail Corporation for Gandhinagar and Ahmedabad - a company, established in 2010. A 6.5 km section of the east–west Blue Line was was opened to the public on 6th March 2019.

Phase 2 with a length of 28 km was approved by India's Central Government February 2019. Construction work is expected to begin by 2021. A total of 33 km new routes and extensions are under construction.

Right: Artist`s Concept for **Ahmedabad/Gandhinagar** ***MEGA*** Metro Train-Set.

Left: Prime Minister Narendra Modi inaugurated on 6th March 2019 a 6.5 km stretch of phase I, East West Blue Line, of Ahmedabad Metro.

After inaugurating the 6.5 km stretch, connecting Vastral to Apparel park area here, Modi took a ride on the Metro.

The Train-sets are provided by Hyundai Rotem, South Korea.

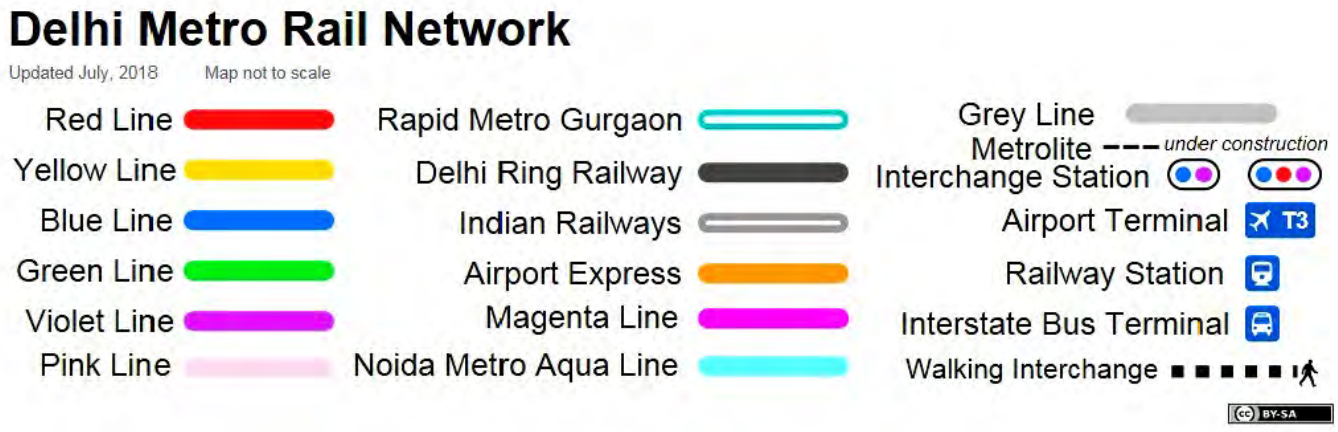
Left: **Bangalore Metro** also known as ***Namma*** Metro, is the fourth longest operational metro network in India after the Delhi Metro, Hyderabad Metro and Chennai Metro. The network consists of two colour-coded lines, Purple and Green, with a total length of 42.3 km on Standard Gauge and with 750 V DC third rail electric feeding. By 2023, the system is expected to complete its phase 2 network and provide connectivity to the city's important technical hubs of Electronic City and Whitefield. Namma Metro was the second Metro Rail in India to use 750 V DC third rail traction, the first being the Kolkata Metro.

Right: The first 6.7 km of the **Purple Line** between Baiyappanahalli and Mahatma Gandhi Road opened on 20th October 2011. The second 6.4 km stretch between Mysore Road and Magadi Road opened on 16th November 2015. The first underground 4.8 km section, a 4.8 km from Cubbon Park to Bengaluru City (KSR) Railway Station opened on 29th April 2016. This completed the 18.22 km Purple Line. The Rolling Stocks have been designed by Hyundai Rotem, Soth Korea, and manufactured by BEML in India.

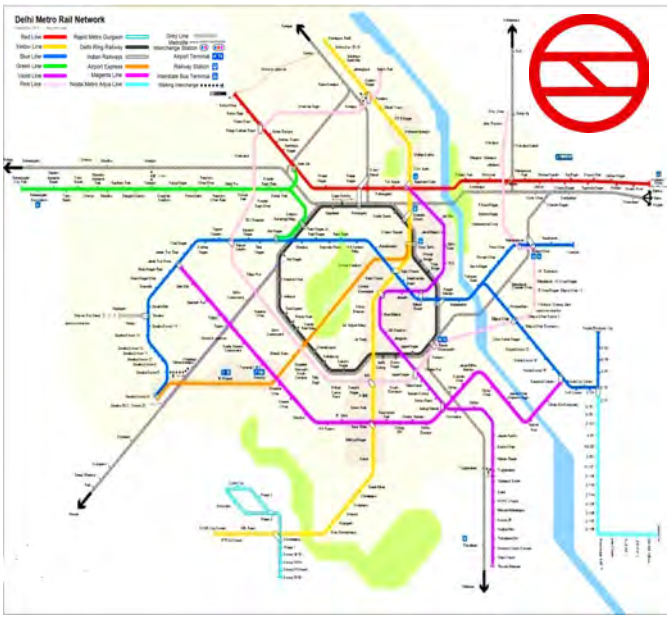
Left: The **Green Line** began operation on March 01. 2014 and connects Nagasandra in the north to Yelachenahalli in the south, covering a distance of 24.2 km. It is partly elevated and partly underground. The southern section of the line, beyond Majestic was thrown open to the public for commercial operations on 18th June 2017, thereby completing the entire Phase 1. Plans for Phase III have been proposed on 10th April 2019. The plan proposes five new lines covering a total of 83.02 km.

Left: **Chennai Metro** is the third largest Metro in India after Delhi and Hyderabad Metro. The system commenced service in 2015 after partially opening the first phase of the project. The network consists of two colour-coded lines, Green and Blue Line, total covering 45.1 km. It operates with 25 kV, 50 Hz Catenary-Feeding on Standard Gauge.Tunnels were drilled using Tunnel Boring Machines (TBMs); the first batch brought from Russia and China. A total of 12 TBMs were deployed from July 2012, 8 from Germany, 2 from China, and 1 each from the United States and Japan.The Rolling Stocks are from ALSTOM. The first nine trains were imported from Brazil and the remaining were manufactured at the new facility set up at Sricity in Tamilnadu, India.

Right: The **Green Line** or Line 2 commenced operation 29th June 2015. The line stretches 22 km from Chennai Central to St. Thomas Mount. Out of the 17 stations, 9 stations are underground and 8 are elevated. The **Blue Line** stretches 23 km from Chennai International Airport to Washermanpet with further extension to Wimco Nagar. It started operating on 21th September 2016.



Delhi Metro is by far the largest and busiest Metro in India, and second oldest after the Kolkata Metro. The network consists of 11 colour-coded regular lines serving 285 stations with a total length of 389 km. The system has a mix of underground, at-grade, and elevated stations using both broad-gauge and standard-gauge with 25 KV, 50 Hz Catenary feeding. Delhi Metro operates over 2,700 trips daily, starting at around 05:00 and ending at 23:30.



Left: Construction of **Delhi Metro** started in 1998, and the first elevated section (Shahdara to Tis Hazari) on the **Red Line** opened in 2002. The first underground section (Vishwa Vidyalaya – Kashmere Gate) on the **Yellow Line** opened in 2004. The development of the network was divided into phases. Phase I with 3 lines was completed by 2006, and Phase II in 2011. As of March 2020, Phase III is in the finishing stage and scheduled to be mostly complete by the end of the year. Construction on Phase IV was formally started on 30th December 2019. Delhi Metro also interchanges with the Rapid Metro Gurgaon and Noida Rapid Metro. October 2019, the DMRC took over the operations of the financially troubled Rapid Metro Gurgaon.

Right: The **Delhi Metro Red Line** had been the first Line at Delhi, which started operating on 24th December 2002. The 9.5 km eastward extension opened 08th March 2019. The total operational length is 34 km. The red Line runs on Broad Gauge with 25 kV, 50 Hz AC catenary electric feeding. The first coaches had been imported from Germany (Bombardier ***MOVIA*** platform with ***MITRAC*** traction technology) and South Korea. Under the Phase IV of the Delhi Metro the most heavy used Red Line will extended towards Narela by 21.73 km. For emergency evacuation in tunnels front and rear have detrainment doors.

Left: **Delhi Metro Yellow Line** is the second build line and runs from Samaypur Badli to Huda City, Gurgaon, on 49 km Broad Gauge with 25 kV, 50 Hz, AC electric catenary feeding. It started operating on 20th December 2004. The prototype Bombadier Movia trainsets with Mitrac propulsion technology had been build in Germany and transported to India by air. The other coaches have been build by Bombardier in its Savli manufacturing plant in Gujarat, that had delivered up to now 776 Metro Coaches for India. Its Chawri Bazar Station, the second deepest station of the Delhi Metro, is situated 30 m below ground level having 18 escalators.

Left: East-West **Delhi Metro Blue Line** (Line 3 and 4) runs from Dwarkar Section 21 to Noida Electronic City, 57 km, with a Branch line from Vaishall to Yammuna Bank, 8.7 km, and on a Broaf Gauge track with 25 V, 50Hz, AC catenary feeding. The first section opened 31th Dec. 2009. The train-sets are of Bombardier ***Movia*** platform with Mitrac propulsion technology. The Dwarka-Barakhamba Road section opened to the public on 31th Dec. 2005. It is the longest line (including branch line) currently running on the Delhi Metro network.

Right: The **Delhi Metro Green Line** (Line 5) is the fifth Metro network and the first line with standard gauge, as opposed to previous Indian broad gauge. The 30 km Line is fully operational since 24th June 2018. It runs between Inderlok and Brigadier Hoshiyar Singh with a branch line connecting the line's Ashok Park Main station with Kirti Nagar station on the Blue Line. Since it operates fully elevated, there are no front detrainment emergency doors. The first batch of Mitsubishi Hyundai Rotem racks came from Soth Korea, the later batches have been manufactured by BEML, India. The extension to Rohtak City Centre is planned.

The **Delhi Violet Metro** connects Kashmir Gate with Raja Nahar Singh via Faridabad on Standart Gauge and 25 kV, 50 Hz, AC. with a total length of 43 km. It opened October 03. 2010. The Central Secretariat - Sarita Vihar section was opened October 03. 2010 and was extended to Badarpur on 14th January 2011. On its full length it is operational since 19th November 2018. The Violet Line was originally planned to open in March 2010. On 12th July 2009, a portion of a bridge under construction collapsed when its cantilever pier collapsed on load of launching girder at Zamrudpur, near East of Kailash, on the Central Secretariat – Badarpur corridor. Six people were killed and 15 others injured. The day after, on 13th July 2009, a crane, that was removing the debris, collapsed, and with a bowling pin effect collapsed two other nearby cranes, injuring six. The rolling stocks are manufactured by the Hyundai Rotem BEML consortium.

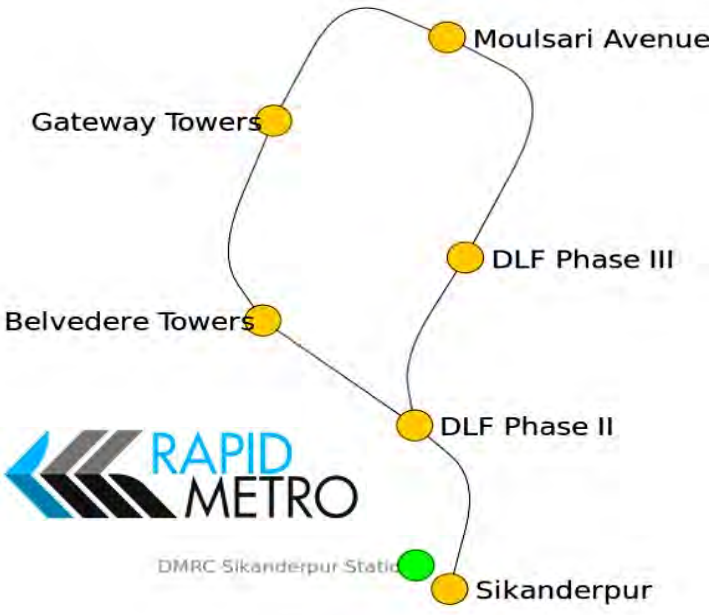
Left: July 12th, 2009: Portion of an under construction bridge collapsed when its launching girder lost balance as it was being erected at Zamroodpur for the **Violet Line,** near East of Kailash, on the Central Secretariat-Badarpur corridor slated to be opened September 2010. Five people were killed and 15 others injured.

Right: The **Delhi Metro Pink** Line from Majis Park to Shiv Vihar is with 59 km the longet Line, beginning to operate section wise from 14th March 2018 until 31th December 2018. It runs on Standard Gauge with 25 kV, 50 Hz, AC and catenary feeding. The trainsets have been build by the Hyundai Rotem-BEML consortium. In future, the line will be extended to Maujpur-Babarpur, creating one of the world's longest ring lines. The Pict. shows the Pink Metro crossing at Sadar Marg. the Delhi Metro Express, **Orange Line.**

Left: The **Delhi Metro Grey** Line connects Dwarkar with Njafgarh on Standard Gauge with 25 kV, 50 Hz, AC catenary feeding and is only 4.3 km long. The line was opened to the public on 4th October 2019. A further extension to Dhansa Bus Stand is scheduled to open in December 2020. But due to the Covid-19 crisi it may open later. The line uses the same Hyundai Rotem/BEML consortium rolling stock used on Delhi **Pink** and **Magenta** lines.

Left: **Delhi Airport Express, Orange Line,** connects New Delhi Raiway Station over the Airport with Dwarkar Sector 21 over 23 km. It opened 23th February 2011. Service was suspended from 7th July 2012 to 22th January 2013 due to technical problems with cracking Railfastening SKL clamps and defects in the elevated concrete structure. Delhi Metro Corporation took over the line from Reliance on July 01. 2013. It runs on standard gauge with rolling stocks from CAF, Spain, fit to run 135 kmph.

Right: The **Delhi Metro Margenta** Line 8 is thefirst metro in India, that can run Driver-less. Since 29th May 2018 it is full operable on 38 km standard gauge. It connects Janakpuri West with Botnical Garden by rolling stocks procured from the Hyundai-Rotem BEML consortium and with 25 kV, 50 Hz, AC catenary feeding. The trains are fit to run 110 kmph. For autonomous Train Operation, ATO, the platforms are secured with screen doors. Unlike the Airport Metro Express, it directly serves Terminal 1 of the Indira Gandhi International Airport. A stretch of 8.7 km from Botanical Garden-Kalkaji Mandir was opened on 25th December 2017. The remaining portion of line opened on 28th May 2018.



Left: The **Rapid Metro Gurgaon** on 12 km standard gauge with third rail 750V DC feeding had been fully private financed. It opened 14th November 2013 and operated on its full length on 31th March 2017. The train-sets had been build by a CRRC Zhuzhou-Siemens Consortium with Aluminium body. The Metro connects the commercial areas of Gurgaon and acts as a feeder link to the Delhi Metro Yellow Line. Built and operated by Rapid Metro Gurgaon Limited (RMGL), the system was the world's first fully privately financed modern metro.

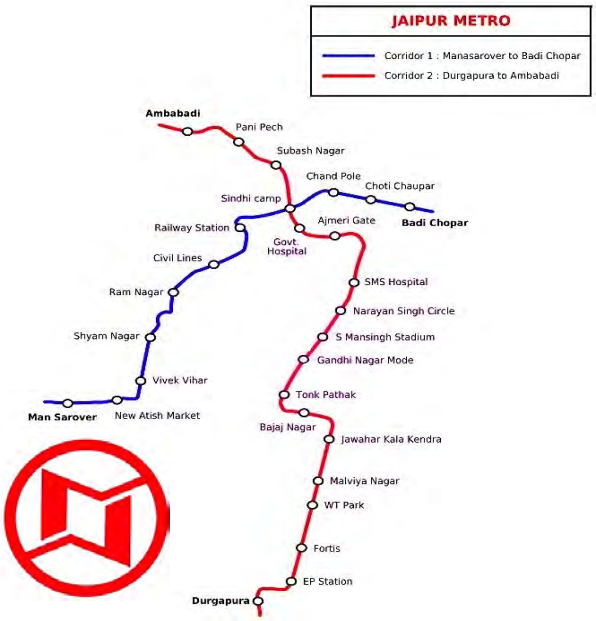
Left: Standard Gauge **Rapid Transit Gurgaon** operates with 750 DC and third rail electric feeding in the commercial area of Gurgaon. In September 2019, IL&FS announced that it does not have the resources to continue running the Metro due to financial issues with the company and is looking for another entity for to fund and takeover operations. After a short dispute with the Haryana Government and a court ruling from the Punjab and Haryana High Court the Delhi Metro Rail Corporation tookover the operation of the line from Infrastructure Leasing & Financial Services Limited, IL&FS.

Right: The **Noida Aqua Line** is operational between Sector 51 to Depot metro Station in Greater Noida, inaugurated 25th Jan. 2019. It operates on 30 km of standard gauge and 25 kV, 50 Hz. catenary electric feeding. The Communication based Train Control, CBTC, is supplied by Anasaldo STS. The line has an interchange station S 51 with the Delhi Metro at Noida Sector. All stations are equipped with platform screen doors. The Government of Uttar Pradesh approved the construction of Noida Metro and selected Delhi Metro Rail Corporation (DMRC) as the turnkey consultant for the project in October 2014. Construction began in mid-2015 and was completed by the end of 2017, while trial runs commenced in July 2018.

Left: **Noida Metro** runs a fleet of 19 light-weight trains provided by CRRC Nanjing Puzhen, China. Each train consists of two motor train units and two trailers units and can accommodate 1,034 passengers. The stainless steel train sets are approximately 23 m long and 2.9 m wide. Each cab of the train features double doors and has an axle load capac of 16 t. The trains are designed to run at a scheduled speed of 35 kmph and maximum speed of 95 kmph.

Left: The operational **Hyderabad Metro** Network is the second longest after Delhi, with 67 km and standard gauge, 25 kV, 50 HZ AC catenary feeding encompassing 3 Lines: **Red**, **Blue** and **Green**. It is being funded by a Public Private Partnership (PPP), with the State Government holding a minority equity stake. A special purpose vehicle company, L&T Metro Rail Hyderabad Ltd. (L&TMRHL) was established by the construction company Larsen & Toubro to develop Hyderabad metro rail project under Public Private Partnership (PPP). The first section of the **Red Line**, 29 km, opened 24th November 2017.

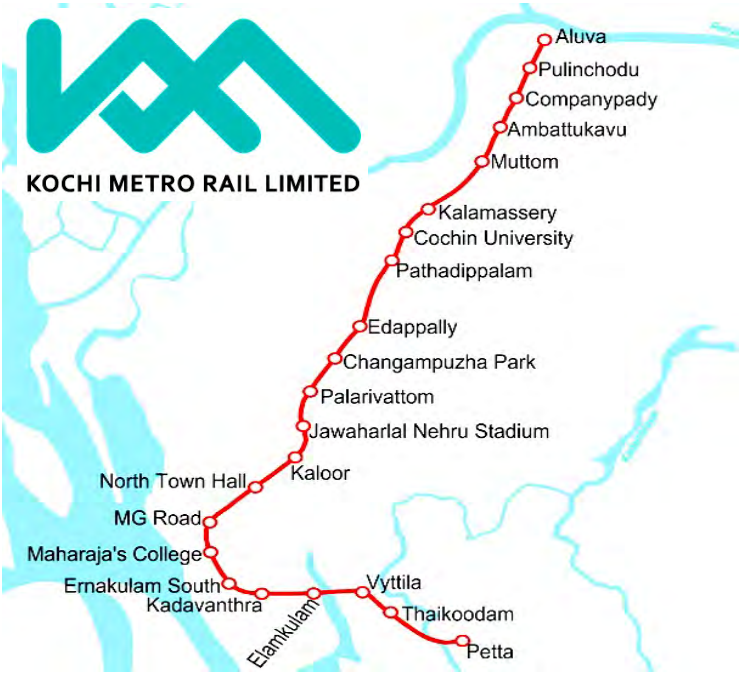
Right: The **Blue Line** running on 23 km from Rayadurgam to L.B. Nagar opened on 29th November 2017; the **Green Line**, 11 km, from Jubilee Bus Stand to Falaknuma, opened 07th Februar 2020. As of October 2019, the daily ridership is about 400,000. The rolling stocks had been delivered from Hyundai Rotem Factory Changwon in South Korea. The Phase II expansion plan is for about 62 km, which includes providing a link to Shamshabad RGI Airport.



Left: Construction on the mostly elevated part of the first line of **Jaipur Metro** , called Phase 1A, (on the map left lined in blue) comprising 12 km from Mansarovar to Chandpole Bazaar, started on 13th November 2010 and was completed in 2014. Operation started June 3. 2015. It operates on standard gauge with 25 kV, 50 Hz, AC and catenary feeding. The construction for Phase 1B from Ambadi to Durgapura (on the left map lined in red) was scheduled to be ready in 2020, but the Covid-19 pandemic will cause a delay. Jaipur Metro is famous for its fast pace construction. Jaipur Metro is the first metro in India to run on triple-storey elevated road and metro track.

Left: The **Pink Line** trains-sets are manufactured in Bangalore manufactoring plant of BEML as a consortium with Hyundai Rotem, South Korea, as the same type as for Delhi Green and **Violet** Line. The **Pink Line** has planned interchange with the Orange Line /under construction) of the **Jaipur Metro.** it also connects Mansarovar, the Largest Colony of Asia, with the Jaipur Junction of the Indian Railways and Sindhi Camp Bus Stand

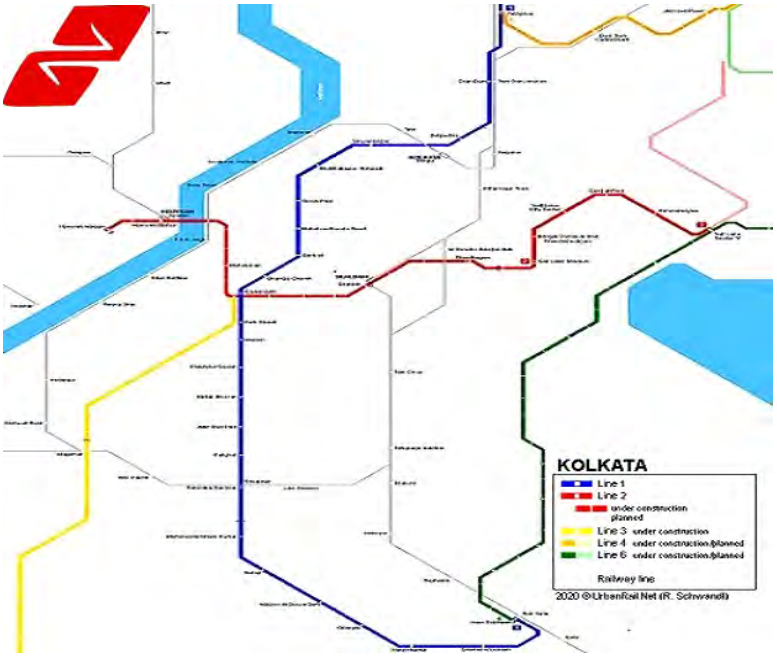
Right: **Kochi Metro** is operational since 17th June 2017 on 24 km standard gauge and 750 V DC third rail electric feeding with a headway of 8 Minutes from Aluva to Thaikoodam. On October 2017, **Kochi Metro** was named the Best Urban Mobility Project in India by the Urban Development Ministry. The third phase of the metro includes plans to extend the line from Aluva up to the Cochin International Airport. KMRL has built skywalks connecting metro stations and nearby landmarks. At present there are two skywalks: One connecting Edapally Station and LuLu Mall and the other connecting MG Road Station and Chennai Silks.



Left: Artist`s View of *"Green"* Kochi Metro. Kochi Metro was lauded for its decision to employ Kudumbashree workers and also members of the transgender community. It is the world's first rapid transit, whose entire management operations are handled by women. The system is also involved in sustainable initiatives with the introduction of non-motorized transport corridors, installation of solar panels for power and vertical garden on every sixth metro pillar.

Left: The rolling stocks have been deliverd by Altom. **Kochi Metro,** operating with Communication Based Train Control, CBTC, also includes the technology for Driver-less Autonomous Train Operation, ATO, and is hoping to implement this in the near future.

Right: The **Kochi Metro** project is the first metro in the country, which connects rail, road and **Water Metro** transport facilities. In February 2017, the Kerala Government announced a plan for Kochi Water Metro service spanning 16 routes in Kochi.



Left: **Kolkata Metro**, the first Metro Rail in India, started operation on 24th October 1984. It currently has two operational lines, a 27.22 km broad gauge line 1 from Noapara to Kavi Subhash and a 5.8 km standard gauge line 2 from Salt Lake Sector V to Salt Lake Stadium, for a total of 33.02 km. A section of the Line 2 on the East–West Corridor opened 13th February 2020. The East-West Corridor Line 2 will go in a tunnel under the Hoogly River. The ***"underwater"*** tunnel is ready. Four other lines are in various phases of construction. It operates with 750 V DC third rail electric feeding.

Left: Result of the ambiguous Project to carve a Metro Tunnel with a Tunnel Boring Machine, TBM, through a soft alluvian strata with water pockets only 14 m under the Bow Bazar Area at Kolkata for the East-West Corridor in September 2019.

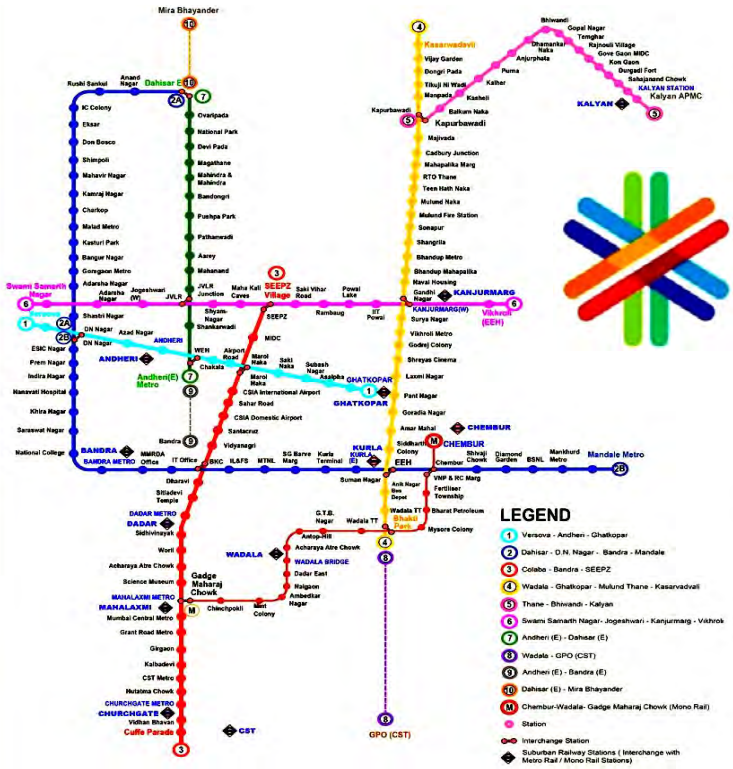
Right: The rolling stock of Line 1 uses Indian broad gauge track and had been manufactured by Integral Coach Factory, Chennai (ICF), and the electrical components had been manufactured by NGEF, Bangalore.

Left: **Kolkata Metro** will get 40 new air-conditioned broad gauge rakes for Line 1, the first of which has been delivered to the public carrier in July 2017.

Left: 14 new rakes had been ordered to arrive in the periode 2018-2020 manufactured by CRRC Dalian of China.

Right: **Lucknow Metro** started with one Line operation on 05th September 2017 on standard gauge with 25 kV, 50 Hz, DC catenary feed. The **Red** North-South Line is on 23 km fully operable since 08th March 2019 from Munshi Pulia Metro Station to International Airport. It is touted as the "***fastest Metro Project***" implementation in the country'. Once completed, Lucknow will have 2 Lines (1A & 1B), the longer Red North-South line and the **Blue East-West Line** (on the map right lined in magenta), running from Charbagh Railway Station to Vasant Kunj. Charbagh Railway Station will serve as the junction station between the two lines.

Left: The **Lucknow Red Line** rolling stocks are build on the Alstom ***METROPOLIS*** platform in its Sricity manufacturing plant in India. As of 2019, as many as 60,000 people are using this metro service on a daily basis. The 2013 report published by the Department of Housing and Urban Planning proposed the construction of an elevated Bus Rapid Transit System (BRTS) as a feeder service to the metro and as a more cost effective transport mode.



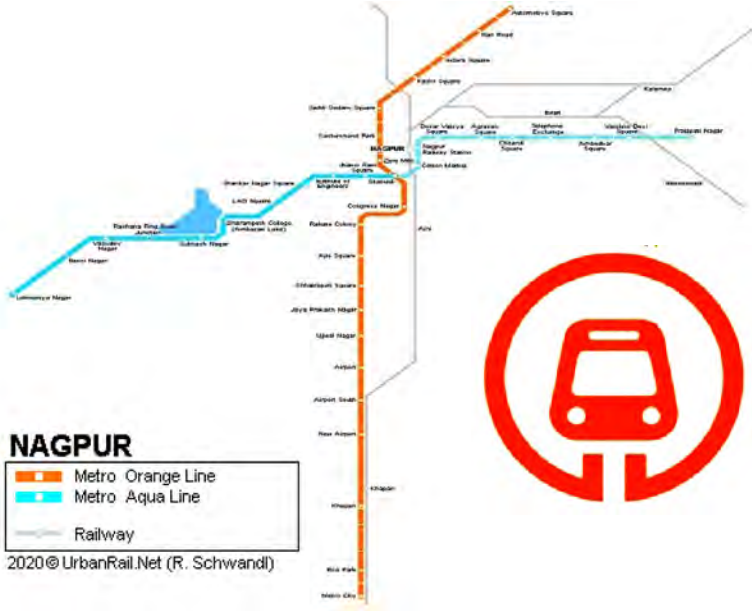
Left:The **Mumbai Metro** is proposed to become 14 Corridors of about 337.10 km being built at the Cost of 1,40,814 Crores with an expected daily Ridership of 142.90 Lakh by 2031. The Metro will run underground and on elevated structure. As per date, only Line 1 on elevated plinth trajectory is operating. This first 11.40 km Versova-Andheri-Ghatkopar Metro corridor has been opened on 08th June, 2014. The headway is 3 Minutes during peak hours and 8 Minutes during off-peak hours; see Mumbai Metro: "***Here's all you need to know about the entire City Network***"; Sep. 13th, 2019, by Rajendra B. Aklekar; mid-day. The gauge is standard gauge and the electric feeding is with a 25 kV, 50 Hz AC catenary. The train-sets for Line 1 have beed delivered by CSR Puzhem, China.

Right: A notable bridge on Line 1 is the 175 m long extradosed cable-stayed bridge over the Andheri Flyover on the Western Express Highway. The Andheri flyover is 13 m above ground level, and the metro line travels 6.5 m above it. The bridge is 39 m above the ground at its highest point. Construction on the bridge started in mid-2009 and was completed on 24th August 2012. The bridge was built by MMOPL, with Switzerland-based VSL International Limited as its partners.

Left: In early August 2019, joined workers from the Hindustan Construction Company (HCC) – Moscow Metrostroy (MMS) Joint Venture celebrated the breakthrough of a 6.68 m diameter ***TERRATEC*** hard rock Tunnel Boring Machine (TBM), named 'Vaitarna I,' on Mumbai Metro Rail Corporation Ltd's (MMRCL) Line 3 project in Mumbai. The major milestone saw the completition of the 3.82 km southbound running tunnel between Chhatrapati Shivaji Terminal (CST) and Mumbai Central Station.

Left: Line 1 contains another notable bridge, the 1284 m steel girder bridge crossing the Western Railway Line at Andheri. Construction of the bridge by Braithwaite Burn & Jessop Construction Company (BBJ), Kolkata, which is supported by 3 pillars, started in early 2012 and completed on 23th December 2012. The steel girders were pre-fabricated at BBJ's Heavy Plant Yard in Kolkata and was then disassembled and transported over the course in a week to the site.

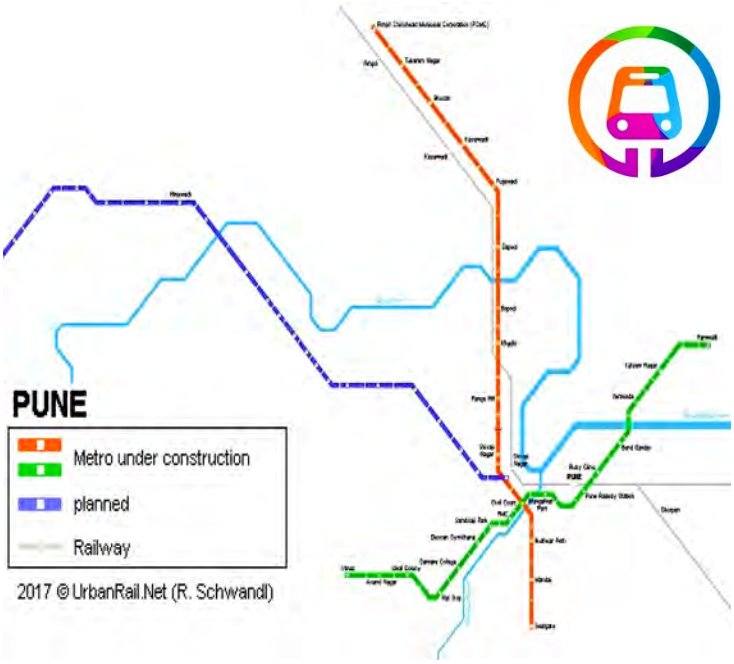
Right: **Nagpur Metro** with two lines becomes the 13th Metro in India to become operational. It is also being touted as the greenest Metro Rail in India. It operates on standard gauge with 25 kV, 50 Hz catenary feeding. The **Orange North-South Line** from Sitabuldi to Kapri started to operate at a length of 13.5 km on 08th March 2019. Nagpur is famous for the Nagpur Orange and is known as the "Orange City" for being a major trade centre of oranges cultivated in the region. Line 1 is coded accordingly as "***ORANGE LINE.***"



Left: BIM and Digital Twin Model of **Nagpur** Ujwal Metro Station. Maharashtra Metro Rail Corporation Ltd. implemented for Nagpur and Pune Metro a Data based and driven Project Management System utilising Building Information and Digital Twin tools, which covers planning to performance stages of the project over the whole life cycle.

Left: The rolling stocks with front emergency detrainment doors are coming from CRC Dalian, China. The entire 22.3 km length of Line 1 corridor is proposed as elevated except in 4.6 km at grade after Airport Station and in Mihan area near Khapri Railway Station.

Right: The entire length of the **Aqua Line 2** (19.4 km) is elevated, partly as double deck viaduct. This line has started operation partially between Sitabuldi to Lokmanya Nagar since 28th January 2020. The Aqua Line runs on the east-west corridor and passes over the huge lakes and water bodies of Ambazari Lake, Gandhi Sagar and Nag River giving the Line 2 its name "***Aqua".***



Left: **Pune Metro** should become by July 2020 the fourteenth operationable Metro in India. However the Covid-19 pandemic crisis in India has thwarted this plan. Now it is supposed for Line 1 (on map lined in red) to become operational in 2021/22. As of December 2019, the network comprises 3 lines with a total length of 54.6 km. The 16.6 km Line 1 PCMC Bhavan – Swargate is between PCMC Bhavan to Range Hills, from where it will run underground. Line 2 (green) will run from Vanaz to Ramwadi covering a distance of 14.7 km elevated. The planned 23 km elevated Line 3 (blue) will run from the Rajiv Gandhi Infotech Park in Hinjawadi via Balewadi to Civil Court.

Left: Assembling the pre-cast concrete segments for **Pune Metro** elevated viaduct structure.

Right: Presentation of train-set for **Pune Metro Line 1** in January 2020. A consortium formed by Kolkata-based wagon manufacturer Titagarh Wagons with its wholly-owned subsidiary Titagarh Firema SPA, Italy, recently won the international bid to supply 102 aluminium coaches for the Pune Metro Project. Pune Metro will run on standard gauge with 25 kV, 50 Hz catenary feeding.

Left: **Kanpur, Indore and Agra Metro** will become the next operationable Metro Rail in India envisaged for 2024/26. In Kanpur construction work is going in full swing. Construction of station near IIT has also started dated 5th March 2020. The animation shows a Design Study for new **BOMBARDIER *MOVIA*** Metro Train-Sets for **Agra and Kanpur Metro**

ANNEXURE I: Picture Gallery

Indian Metros in Operation cum Logos - Date of Opening Sequence

1. Kolkata Metro
October 24th, 1984
33.4 km

2. Delhi Metro
December 24th, 2002
347 km

3. Namma Metro Bangalore
October 20th, 2011
42.30 km

4. Rapid Metro Gurgaon
November 14th, 2013
12.1 km

5. Mumbai Metro
June 8th, 2014
11.40 km

6. Jaipur Metro
June 3rd, 2015
9.63 km

7. Chennai Metro
June 29th, 2015
45.10 km

8. Lucknow Metro
September 06th, 2017
23 km

9. Kochi Metro
October 03rd, 2017
27.80 km

10. Hyderabad Metro
November 29th, 2017
56.50 km

11. Noida Metro
January 25th, 2019
29.70 km

12. Nagpur Metro
March 07th, 2019
13.50 km

13. Ahmedabad Metro
March 14th, 2019
6.5 km

14. Pune Metro
scheduled opening 2021/2022, 7 km (under Construction: 31 km)

ANNEXURE II: LOGOS OF INDIAN METRO RAIL IN OPERATION

1. Kolkata Metro

2. Delhi Metro

3. Namma Metro Bangalore

4. Rapid Metro Gurgaon

5. Mumbai Metro

6. Jaipur Metro

7. Chennai Metro

8. Lucknow Metro

9. Kochi Metro

10. Hyderabad Metro

11. Noida Metro

12. Nagpur Metro

13. Ahmedabad Metro