

Review article

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## Railways of India. Time to update and upgrade

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**ABSTRACT** By the second decade of the XXI century, the railway transport of India came up with an important result – the Program announced on April 1, 1992, called Unigauge for the transfer of the railway network to a single gauge of 1676 mm was basically completed. In 2022, the operational length of wide-gauge roads on the Indian railway network was 65,094 km, or 95.7 % of its entire length. This opened up the possibility of creating a modern unified railway transport system and organizing its optimal interaction with other modes of transport.

The management of the railway transport of India, represented by the Ministry of Railways, has focused efforts on the modernization of all components of the large railway economy – strengthening track structures, upgrading bridge facilities, introducing modern means of ensuring train traffic and transportation safety, updating rolling stock. The basis for improving the work of railway transport is the electrification of railways, the completion of which is planned in the next decade.

All decisions taken to modernize railways are aimed at reducing operating costs, improving efficiency, environmental cleanliness, comfort and speed of passenger travel, reducing the delivery time of goods, as well as improving the safety of transportation by rail.

**KEYWORDS:** Indian Railways; history of transport; modernisation; electrification; increased economy and environmental friendliness of the transport; increased speed of freight and passenger delivery

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Обзорная статья

## Железные дороги Индии: время обновления и модернизации

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**АННОТАЦИЯ** Ко второму десятилетию XXI столетия железнодорожный транспорт Индии подошел с важным результатом – в основном завершена объявленная 1 апреля 1992 г. Программа, получившей название Unigauge по переводу железнодорожной сети на единую колею 1676 мм. В 2022 г. на железнодорожной сети Индии эксплуатационная длина дорог широкой колеи составляла 65 094 км или 95,7 % всей ее протяженности. Это открыло возможность для создания современной единой транспортной системы железных дорог и организации ее оптимального взаимодействия с другими видами транспорта.

Министерства железных дорог Индии сосредоточило усилия на модернизации всех компонентов большого железнодорожного хозяйства – усилении конструкций пути, модернизации мостового хозяйства, внедрения современных средств

обеспечения движения поездов и безопасности перевозок, обновления подвижного состава. В основу совершенствования работы железнодорожного транспорта положена электрификация железных дорог, завершение которой планируется в ближайшем десятилетии.

Все принимаемые решения по модернизации железных дорог направлены на снижение эксплуатационных расходов, повышение эффективности, экологической чистоты, комфорта и скорости проезда пассажиров, сокращение сроков доставки грузов, а также повышение безопасности перевозок по железным дорогам.

**КЛЮЧЕВЫЕ СЛОВА:** железные дороги Индии; история транспорта; модернизация; электрификация; повышение экономичности и экологической чистоты перевозок; увеличение скорости доставки грузов и пассажиров

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## CURRENT STATE OF INDIA'S RAILWAY TRANSPORT AND PROSPECTS FOR ITS DEVELOPMENT

As noted earlier, India's state railways rank fourth in the world in terms of track length (68,193 km). Today, the Indian railway network is almost entirely on the 1676 mm wide gauge (95.7 per cent of the operational length). In terms of railway density – the number of kilometres of operational length per 1,000 km<sup>2</sup> of territory – India, compared to other countries, is in the middle of the list – 20.4 km/1,000 km<sup>2</sup>, ahead of China (11.4) and four times higher than Russia (5.0). However, such an important indicator as the operational length of lines with two or more main tracks – 41.2 % of the total – needs to be improved. The relative indicator of the number of personnel engaged in railway operation is high; according to the given indicator per 1,000 km of operational length, it is 17.8 thousand persons (Table 1).

Indian Railways lags behind the other three largest railways in the world in terms of length: the US, China and Russia in terms of such an important indicator characterising transport output per unit length of the railway network as freight work per kilometre of operating length (freight load). The record holder in this indicator — Russian railways — has this value equal to 29.7 million tkm/km of operating length, while in China – 21.9; in the USA – 14.13; in India – 10.41 (Table 1).

The number of passengers carried in the first “Covid” year (2020) on Indian railways is 8086 million — is the highest in the world (in 2022, the number of passengers carried on Indian railways fell to 3,519 million), but if we look at it in comparison to the number

of population, it is not that much. India has 17 times the population of Germany, but Indian railways carried only twice as many passengers as German railways in 2022.

However, the passenger intensity (passenger load factor) of Indian railways is high. With 8080 million passengers carried per year and 1 050 738 passenger kilometres travelled, it is 15.4 million passenger kilometres/km of operational length. In Japan, the figure is 9.7; in China, 8.62; in Germany, 1.38; in Russia, 0.8.

The British colonisers left an unenviable legacy to India in terms of technical equipment of railways. The main problem, as noted above, was the mainline railway network, which consisted of sections with different gauges. In 1955, out of 54,500 km of operational length, 25,17,000 km (or 46.1 per cent) were of 1676 mm gauge; 24,15,000 km (44.3 per cent) were of metre gauge and 5,200 km (9.85 per cent) were of narrow gauge (762 mm and 610 mm gauge lines)<sup>1</sup> [8]. A large amount of financial and material resources have been channelled by the Ministry of Railways of India over the past decades to unify the Indian railway network on the basis of 1676 mm wide gauge. By now, the objective has been practically achieved: of the 68,193 kilometres of operational length, 95.7 per cent are 1676 mm wide gauge railways.

In 1955, 8 years after the country's independence, the wide-gauge steel rails with the weight of 44.6–49.6 kg/run. m were laid on the main tracks, which made up 46.1 per cent of the operational length. The length of the laid track was small: from 9.14 to 12.8 m, which resulted in a large number of joints, required manual labour for maintenance, and did not allow to provide the necessary comfortable and safe movement of trains at a speed of more than 100 km/h according

<sup>1</sup> Data from the 1955 compilation of World Railways [9]; data published in 2023 by the Indian Ministry of Railways differ slightly from the above, but within 1–2 per cent. Project Unigauge.

URL: [https://en.wikipedia.org/wiki/Project\\_Unigauge](https://en.wikipedia.org/wiki/Project_Unigauge);

What is project unigauge. URL: <https://www.railnewscenter.com/what-is-project-unigauge/railway-employee/>

Table 1

## Basic information on the railways of a number of technologically leading countries and BRICS countries

| Country                     | Area, thousand km <sup>2</sup> | Population, million persons | Population density, persons/km <sup>2</sup> | Operating length, km             | Of those with two or more tracks / % of total | Of those electrified / %   | Average headcount of personnel, thousand persons | Number of personnel per 1000 km of track length | Density of operational railway length / 1000 km <sup>2</sup> | Passenger transport                   |  | Freight transport                 |                                       | Residents per 1 km of track | Length of high-speed length <sup>1</sup> , km |                    |                  |
|-----------------------------|--------------------------------|-----------------------------|---|----------------------------------|---|----------------------------|--|---|--|---------------------------------------|--|-----------------------------------|---------------------------------------|-----------------------------|---|--------------------|------------------|
|                             |                                |                             |   |                                  |   |                            |  |   |  | Number of passengers, million persons | Passenger operations, million passenger-km | Cargo transported, million tonnes | Freight operations, million tonnes-km |                             | In operation                                  | Under construction | To be planned    |
| India <sup>2</sup>          | 3287                           | 1425                        | 420   | 67 956<br>68 043<br>68 193*      | 25 034/36,8<br>28 053/41,2                    | 39 329/57,9<br>50 395/74,1 | 1253,6<br>1212,9                                 | 18 462<br>17 834                                | 20,6<br>20,7   | 8086,0<br>3519,0                      | 1 050 738<br>590 217                       | 1208,4<br>1415,9                  | 707 665<br>871 816                    | 20 969<br>21 400            | –   | 508                | 7479             |
| Brazil <sup>3</sup><br>2019 | 8516**                         | 213**                       | 66**  | 29 817<br>(2008)                 | No data                                       | Suburban only              | No data  | No data   | 3,3  | 867,7**                               | 16 459**                                   | No data                           | No data                               | 7143**                      | –   | –                  | Approx.**<br>500 |
| China                       | 9563                           | 1411                        | 148   | 109 767<br>112 072               | 77 114/70,2<br>79 464/70,9                    | 88 417/80,5<br>91 004/81,2 | 1557,5<br>1548,6                                 | 14 197<br>13 830                                | 11,4<br>11,7   | 2992,8<br>1895,3                      | 946 499<br>651 837                         | 2749,6<br>2795,2                  | 2 404 180<br>2 571 665                | 12 800                      | 40 474  | 13 063             | 11 238           |
| France                      | 549                            | 67                          | 123   | 27 213<br>26 944                 | 11 200/41,1<br>16 628/61,8                    | 16 013/58,8<br>16 122/59,9 | 1244<br>1272                                     | 4573<br>5075                                    | 45,5<br>44,5   | 879,6<br>1131,8                       | 75 058<br>100 814                          | 32,92<br>31,0                     | 15 870<br>15 869                      | 2462                        | 2735  |                    | 1725             |
| Germany                     | 358                            | 83                          | 233   | 33 399<br>33 468                 | 18 556/55,70<br>18 634/55,79                  | 20 540/61,6<br>20 655/61,8 | 323,6<br>324,4                                   | 9688<br>9701                                    | 93,2   | 1202,0<br>1737,1                      | 46 169<br>76 475                           | 226<br>222,3                      | 84 850<br>84 468                      | 2485                        | 1571  | 147                | 291              |
| Italy                       | 301                            | 59                          | 197   | 17 305<br>17 302                 | 7739/44,7<br>7738/44,7                        | 12 208/70,5<br>12 232/70,7 | 85,8<br>83,3                                     | 4959<br>4815                                    | 57,4   | 865,1<br>498,3                        | 34 169<br>34 612                           | No data                           | 21 800<br>21 971                      | 3409                        | 921   | 327                |                  |
| Japan <sup>4</sup>          | 378                            | 126                         | 333   | 15 621<br>19 123                 | 5720/36,6                                     | 9689/62,1                  | 111,4  | 7141  | 41,3   | 6610,9                                | 151 711                                    | No data                           | 19 369                                | 9218                        | 3081  | 402                | 194              |
| Russia                      | 17 098                         | 144                         | 8   | 85 555                           | 38 611/45,5                                   | 44 255/51,7                | 690,32   | 8073  | 5,0  | 872,0<br>1135,0                       | 76 135<br>122 762                          | 1366,4<br>1355                    | 2 544 828<br>2 636 555                | 1683                        | 659   |                    | 670              |
| South Africa                | 1219                           | 58                          | 47  | 20 953                           | 12 955/61,1                                   | 7998/58,2                  | 26,05<br>Partial data                            | 1243  |  | No data                               |  |                                   |                                       | –                           | –   | –                  | –                |
| Spain                       | 506                            | 47                          | 94  | 15 963<br>16 150<br>Partial data | 6212/39,0<br>6265/38,9                        | 10 345/65,0<br>10 435/64,8 | 28,58<br>Partial data                            | 1367  | 31,5   | 403,8<br>437,4                        | 16 821<br>24 270                           | 15,88<br>14,6                     | 5676<br>5493                          | 2946                        | 3661  | 1055               | 863              |
| UK                          | 244                            | 67,2                        | 276   | 16 351<br>15 732                 | 10 101/61,9<br>11 786/75,0                    | 6162/73,8<br>642/38,4      | 43,69<br>42,0                                    | 2680<br>2670                                    | 67,0   | 25,3<br>3,3 <sup>5</sup>              | 8051 <sup>5</sup>                          | 33,2 <sup>6</sup>                 | 13 485 <sup>6</sup>                   | 4109                        | 113   | 225                | 341              |
| USA                         | 9832                           | 332                         | 34  | 148 750<br>148 553               | 147 694/99,3<br>148 553/100                   | 0<br>0                     | 137,91   | 931   | 15,1   | 10,1<br>24,4                          | 3593 <sup>7</sup><br>8232                  | 1260,1 <sup>8</sup><br>1333,7     | 2 102 084 <sup>8</sup><br>2 239 400,7 | 2231                        | 735   | 274                | 3784             |

Note: *italics show UIC statistical data for 2022* [3, 4]; <sup>1</sup> – see [2]; <sup>2</sup> – in addition to UIC data [3, 4]; \* – the operational length from Indian source [5] is given; [2], <sup>3</sup> – in the UIC statistical report [3, 4] the data marked with \*\* are given. The rest of the data are from source [6]. After the mass privatisation of railways in Brazil between 1996 and 1999, intercity passenger traffic virtually ceased and is now carried by air transport and buses. Suburban railway traffic in the regions of Rio de Janeiro and São Paulo has been preserved; <sup>4</sup> – data for 2020 [3, 4]. Only the five largest railway companies within the Japan Railways Group (JRG) are reported, with no statistics for the smaller, mostly suburban, private companies. Information on track lengths of the West Japan Railway Company is not given. Data for the WJR Company's Sanyo Shinkansen line is taken from source [7]. JR Freight Company (JRF) does not have its own railway tracks, uses tracks of other companies and is not included in the statistics. In addition to UIC data, operating lengths are from a Japanese source [8]; <sup>5</sup> – data summarised for EUROSTAR INTL (2017) [3] and TRANS LINK (2018) [3, 4]; <sup>6</sup> – data for EUROSTAR INTL (2017) [3, 4]; <sup>7</sup> – data for Amtrak [3, 4]; <sup>8</sup> – data for Association of American Railroads [3, 4].

to the ideas of that time. The track was laid mainly on wooden sleepers, rarely on metal ones. On a number of narrow-gauge lines single cast-iron supports instead of sleepers were used [9, p. 359].

With such track structure maximum speeds on the wide track rarely reached 96 km/h, on the metre track — 72 km/h, on the narrow track 762 mm — 48 km/h and 610 mm — 29 km/h. On the electrified section of the wide-gauge passenger trains on several sections developed speed up to 104 km/h [9, p. 359].

At present, high-strength thermally compacted rails with the weight of 52–60 kg/run. m, welded into long lengths and laid on reinforced concrete sleepers with the help of elastic rail fasteners, are laid throughout the entire wide gauge railway network of India [10].

In 1955, the main means of communication in the movement of trains on especially important single-track sections was the electrical tablet system. The telegraph method of communication and such systems of train traffic organisation (mostly on metre and narrow-gauge lines, but also on some wide-gauge sections) as “movement by one locomotive”, “movement with one tablet”, “movement by written messages” were also used.

Autoblocking was used on some double-track lines and dispatch control of train traffic was introduced on a number of lines [9].

Single-wing semaphores were mainly used as signalling devices, signalling “track clear” by lowering the wing, as it is customary on the British railways. Traffic lights were used on autoblocked sections (about 100 km), as well as at a few large stations such as Bombay (Mumbai), Kolkata, and Madras, equipped with electrical centralisation systems for switches and signals. The Naihati sorting station is equipped with wagon retarders [8]. The Second Development Plan of Indian Railways (1956–1960) envisaged significant work to improve signalling, centralisation and interlocking (SCI) systems and to improve the safety of train traffic, however, until today the state of SCI and communication devices lags behind the general pace of development of the country's railways.

As of the beginning of 2020, only 3.5 thousand kilometres of the operational length of railways have automatic interlocking of train traffic [10]. The rest of the length is mainly manually controlled by switches and signalling by signallers, mostly with the use of traffic lights. The development of signalling and communication systems with automatic devices, including the latest microprocessor-based ones, is the most important task of modernisation of Indian railways against the backdrop of one of the highest accident rates on Indian railways in the world today.

## SWITCHING TO NEW TYPES OF TRACTION

In 1955 the main means of traction were steam locomotives, the total number of which was: 5,360 wide gauge, 2,789 metre gauge, 405 narrow gauge. There were 35 wide gauge diesel locomotives, 66 electric locomotives, two battery cars, 7 diesel locomotives of wide gauge, 46 of metre gauge, 151 of narrow gauge. On suburban electrified wide gauge sections 151 passenger motor cars were used, on electrified sections of metre gauge — 24 motor cars [9].

The total fleet of passenger cars was 8211 units (wide gauge), 6908 units (metre gauge), 1111 units (narrow gauge). The fleet of freight wagons included 157 thousand units (wide gauge), 59 thousand (metre gauge), 5.4 thousand (narrow gauge). Wide-gauge cars and partially metre gauge wagons were almost completely equipped with vacuum brakes, all narrow-gauge cars — with hand brakes [9].

Nowadays steam traction is used only for the movement of special excursion retro trains both on wide gauge and other railways. All passenger and freight work on the railway network is carried out using diesel locomotive and electric traction, which will be discussed in more detail below. New supplies of locomotives are made by Indian factories.

The freight wagon fleet is dominated by four-axle wagons for various purposes, the need for which will be met by Indian factories.

Indian railways are intensively renewing the passenger wagon fleet. Newly delivered passenger rolling stock of various purposes and comfort levels is mainly equipped with air conditioning systems, which is important for a country with a hot and humid climate.

The era of steam locomotives is considered to have ended on the Indian mainline railways on December 6, 1985, when a steam locomotive of the WL-15005 series (*Fig. 1*) ran the last train on the gauge line from Ferozepur to Jalandhar, about 118 km. The production of steam locomotives in the country was completed even earlier. The last steam locomotive of the WG series was built at Chittaranjan Locomotive Works in June 1970 and was aptly named Antim Sitara — “The Last Star” in Hindi.

The first experiments with the use of diesel traction on Indian railways date back to the 1930s, when several small diesel locomotives with a capacity of about 300–1000 hp were operated on the North Western Railway on a trial basis — mainly for shunting work [11].

The first mainline diesel locomotives were put into operation on the Indian Railways after the country gained independence. These were diesel locomotives of the WDM-1 series<sup>2</sup> (*Fig. 2*), manufactured by the Ameri-

<sup>2</sup> Acronym WDM-1 from Wide Gauge (W); Diesel powered (D); Mixed load (M), the first model. One of these cars is preserved in the National Railway Museum in New Delhi.





**Fig. 1.** Steam locomotive series WL-15005 on the Rewari Steam Centre steam locomotive storage base<sup>3</sup>



**Fig. 2.** WDM-1 diesel locomotive No. 17000 at the National Railway Museum in New Delhi. 2020.  
Photo by Dmitry A. Shchukin<sup>4</sup>



**Fig. 3.** Diesel locomotive WDG-5. 2013.  
Photo by Chandra Vimlesh<sup>5</sup>



**Fig. 4.** Diesel locomotive WDG-6. 2020<sup>6</sup>

can Loco. Co. (ALCo) in 1957–1959 (the so-called “World Series of ALCo locomotives”). It was an electrically powered locomotive, having two bogies, each with three driving winding axles (UIC classification — axle formula C0–C0). Rated power of the 12-cylinder four-stroke diesel engine was 1,950 hp (1,450 kW), design speed was 104 km/h. The diesel locomotive had one control cabin (it was a section of “A” type) and could be operated as a combination of two sections coupled by the body ends without driver’s cabins, with control by the system of many units to increase the power in train operation. A total of 100 such diesel locomotives were purchased.

At present, the Indian industry produces diesel locomotives for various purposes for operation on wide gauge and shunting mainline railways, as well as metre gauge and narrow-gauge diesel locomotives.

In the last decade two models of powerful diesel locomotives with electric transmission for freight work WDG-5 and WDG-6 have been produced in India. The WDG-5 diesel locomotive (Fig. 3), built by Banaras Locomotive Works (BLW) in Varanasi in collaboration with Electro-Motive Diesel (the diesel locomotive and electric locomotive division of Caterpillar Inc.), has a hood type body, C0 to C0 axle arrangement. Nominal diesel power is 5,500 hp (4,045 kW). In 2012–2018, 7 WDG-5 locomotives were manufactured.

The WDG-6 electric diesel locomotive (Fig. 4) also, like the one mentioned earlier, has a bonnet type body and the same C0 to C0 axial formula. The first two vehicles were produced at the former GE Rai, now Wabtec plant of Westinghouse Air Brake Technologies Corporation and MotivePower Industries’ Westinghouse Air Brake Technologies Corporation in the US and delivered to India in 2019. Production of these diesel locomotives was then organised at General Electric India’s plant in Marhaura, Bihar.

The WDG-6 freight diesel locomotive with a design speed of 100 km/h is designed based on the GE Evolution Series platform and is powered by a four-stroke 16-cylinder supercharged four-cylinder diesel engine with a rated power of 6,000 hp (4,416 kW). With an axle load of 23 tonnes, this diesel locomotive is one of the most powerful in the relatively lightweight category in the world.

## ELECTRIFICATION OF THE INDIAN RAILWAYS

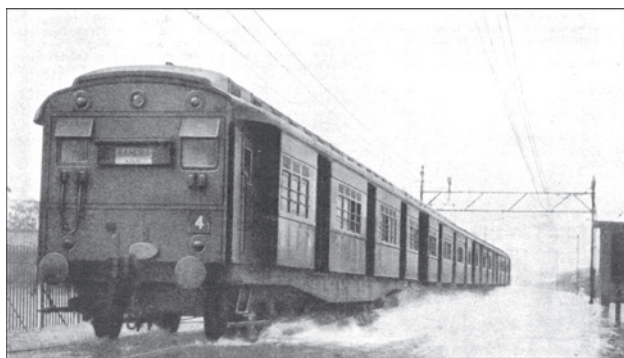
Electrification is the most important area of railway infrastructure improvement in India, in addition

<sup>3</sup> Development of Steam Locomotive Designs in Railways in India // URL: <https://artsandculture.google.com/story/2AVhj-uITVuVKA>

<sup>4</sup> URL: <https://railgallery.ru/photo/41545/?vid=102920>

<sup>5</sup> URL: <https://www.flickr.com/photos/67259157@N06/9333137336>

<sup>6</sup> URL: <https://d.indiarailinfo.com/loco/26100>



**Fig. 5.** An electric train on the Victoria Terminus line in Bombay (today Chhatrapati Shivaji Terminus and Bandra station on the outskirts of Bombay (Mumbai). The train is travelling on tracks flooded by monsoon rains. Mid-1920s<sup>7</sup>

to bringing the entire railway network to a single track. The first proposals for the use of electric traction were presented in India in 1925 and the budget for the initial work was set at the same time [12]. As in many countries, railway electrification in India started with small suburban sections. On March 3, 1925, a 1.5 kV DC electrified (with power from the overhead catenary) section between Victoria Terminus in Bombay (now Chhatrapati Shivaji Terminus in Mumbai) and Bandra suburban station on the Arabian Sea coast (now called Harbour Line) was put into operation.

The electrification was based on technical solutions well proven on the Newport-Shildon, England line, which were among the most advanced at the time. Electric trains were supplied by Kamele Laird (England) and Uerdingenwagonfabrics (Germany) [12, 13]. The electrical components for these trains (Fig. 5) were supplied by BTH/AEI and English Electric from England, Siemens-Schuckert from Germany, and Ansaldo from Italy.

Electrification on the main lines using 1.5 kV direct current began with the modernisation in 1929–1930 of the high gradient sections in the Western Ghats on the busy Great Indian Peninsula Railways (GIP) freight and passenger main line. Here the operation of the powerful EF/1 series of electric freight locomotives began, the

first of which arrived at the port of Bombay in August 1927.

These articulated locomotives were typically German-Swiss in design and appearance and had coupled wheels with drawbar gearing, resembling that of a steam locomotive, from two mono-electric motors mounted on the frames of the two end bogies. The electric motors were placed on the frame of the locomotive, as in the famous Swiss articulated electric locomotive Ve 6/8 series, nicknamed “Crocodile” for its characteristic profile resembling a toothy reptile. This locomotive proved itself in train work on the Gotthard Pass in the Alps. In India, these electric locomotives with a power of 1940 kW and a design speed of 80 km/h also came to be called “Crocodile”. Later, the Indian Railways changed their EF/1 series name to WCG-1<sup>8</sup> (Fig. 6).

Following the British tradition of naming locomotives like ships after prominent figures, the first of the EF/1 (WCG-1) locomotives to arrive was named Sir Leslie Wilson<sup>9</sup>.

On 1 June 1930, the Deccan Queen high-speed passenger train was put into service<sup>10</sup>, which established itself as one of the most luxurious trains of its time, not only in India but also in the world (Fig. 7). The train



**Fig. 6.** WCG-1 series electric locomotive commissioned in 1930 and decommissioned in 2020 at the National Railway Museum, New Delhi. 2020<sup>11</sup>

<sup>7</sup> Electrification overseas. Development of Power Schemes in the Dominions. URL: <http://mikes.railhistory.railfan.net/r099.html>

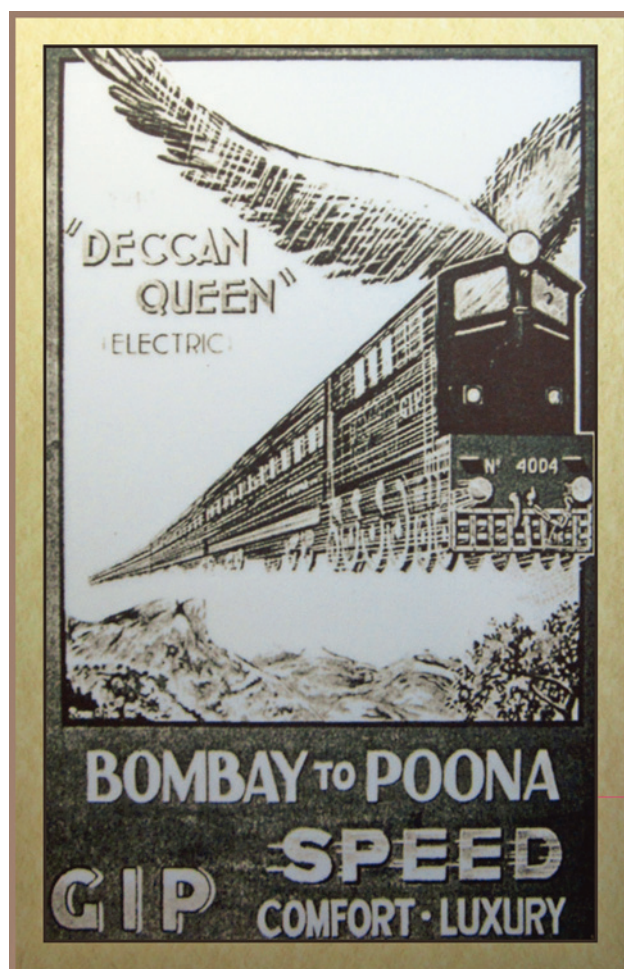
<sup>8</sup> WCG-1 – acronym for wide gauge (W); direct current (C) – this is how direct current was agreed to be labelled, as opposed to Alternating Current (A); Goods traffic (G). Two of these locomotives have been preserved to this day.

<sup>9</sup> Sir Leslie Orme Wilson (1876–1955) is a participant of the Second Anglo-Boer War, captain of the Royal Marines, participant of the First World War with the rank of colonel, prominent British politician, member of the British Parliament, from 1923 Governor of Bombay, supported and promoted the idea of electrification of the Indian railways, from 1832 to 1946 (the longest in this position) – Governor of Queensland in Australia.

<sup>10</sup> The name of the train is derived from the vernacular respectful name of the city of Pune “दख्खन ची राणी” Deccan Queen, the cultural capital of the region. The city is located in the historical and socio-political region known as Deccan, occupying a mountain plateau of the same name, stretching a little south of Mumbai from the coast of the Arabian Sea to the Bay of Bengal.

<sup>11</sup> URL: [https://www.tripadvisor.com/LocationPhotoDirectLink-g304554-d19799017-i443857282-Heritage\\_Gully-Mumbai\\_Maharashtra.html](https://www.tripadvisor.com/LocationPhotoDirectLink-g304554-d19799017-i443857282-Heritage_Gully-Mumbai_Maharashtra.html)





**Fig. 7.** An advertising poster from the early 1930s of the Deccan Queen, a posh Indian express train of its time. Chhatrapati Shivaji Terminus Museum, Mumbai. Photo by the authors. 2016

was designed for wealthy passengers travelling from Bombay (Mumbai) to the city of Pune<sup>11</sup> (Poona) [14], where horse races were held at the nationally famous hippodrome, attracting the socialite public. The train was initially timetabled on weekends, but later became a daily service. This very popular express train was a first in India: the long-distance train was served by electric locomotives, and for the first time in India its carriages were connected by enclosed crossing platforms<sup>12</sup> (so-called {vestibuled trains}), for the first time special carriages for women and a dining carriage were included in the composition of the train.

The train covered a distance of 192 kilometres between end points in 4 hours (today — 3 hours 10–15 minutes) with a route speed of 50 km/h, reaching speeds of 80 km/h in some sections (up to 105 km/h today).

The services provided to passengers en route, the comfort and convenience of the train carriages, and, most importantly, the speed of the journey, have brought the train the love of wealthy passengers over the ninety years of its operation. The Deccan Queen train's birthday is celebrated every year on June 1 as a celebration of the Deccan region.

The Deccan Queen trains were served by India's first passenger high-speed electric locomotives, the EA/2, later renamed WCP-2, a 1.5 kV DC 1,562 kW locomotive with a design speed of 137 kilometres per hour. This Swiss Locomotive and Machine Works (SLM) designed electric locomotive was one of the most successful high-speed locomotives of its time. The first car was named Sir Roger Lumley<sup>13</sup> (Fig. 8).

Before India's independence in 1925–1947, only 388 km of railways were electrified [14]. Under the 1951–1956 plan, another 141 km were electrified.

In 1958, electrification was carried out in the Howrah – Bardhaman section of the Eastern Railway in the form of an experiment using DC of higher voltage — 3kV.



**Fig. 8.** The Sir Roger Lumley electric locomotive, commissioned in 1930, was the first passenger electric locomotive of the Indian Railways. A 1.5 kV DC, type 1-2-2 machine, originally given the serial name EA/2, later renamed WCP-2, preserved in the National Railway Museum, New Delhi. It is believed that this particular electric locomotive was part of the first Deccan Queen train to enter the route on June 1, 1930<sup>14</sup>

<sup>12</sup> Prior to this, all passenger coaches in India had open inter-carriage platforms, which were uncomfortable and dangerous to use when travelling from carriage to carriage. The introduction of enclosed vestibule platforms between carriages by the American company Pullman in 1887 for the first time united the carriages of a passenger train into a single comfortable space and gave rise to the creation of Pullman luxury trains — “palaces on wheels”. In 1930, the first such train appeared in India.

<sup>13</sup> Lawrence Roger Lumley, 11th Earl of Scarbrough (1896–1969) — politician, General of the British Army, member of the House of Commons of the British Parliament, Governor of Bombay, Chancellor of Durham University.

<sup>14</sup> URL: <https://www.irfca.org/gallery/Heritage/img113.jpg.html>

In 1957 the leadership of the country and the railways made an important decision on further electrification of the railways only on the system of alternating current of 50 Hz industrial frequency with voltage of 25 kV. In 1960, the first pilot section of the South Eastern Railway Raj Kharswan – Dongoaposi was electrified. Since then, electrification in India has been carried out only using 50 Hz industrial frequency alternating current [10, 11].

In 1961, India started its own production of WCM-5 electric locomotives. Before that, all electric locomotives were delivered from abroad in a fully assembled form. The creation of its own electric locomotive manufacturing was a great achievement of the country in the process of gaining technological sovereignty. The first WCM-5 was a DC electric locomotive with DC traction collector motors with a total power of 2721 kW and a design speed of 105 kilometres per hour. The first electric locomotive was given No. 20083 and the name Lokmanya<sup>15</sup> (Fig. 9). The locomotive was assembled on October 14, 1961 at the Chittaranjan Locomotive Works, a locomotive and steel works established in 1950. India's first Prime Minister Jawaharlal Nehru attended the launching ceremony of the locomotive. It is believed that this locomotive later drove the famous Deccan Queen express train.

At present, the Indian industry produces modern electric locomotives for various purposes, including freight traffic. One of the most powerful in the world two-section eight-axle freight locomotive of WAG-12B series was created by Indian specialists at Electric Locomotive Factory, with the support of French concern Alstom. The AC locomotive with asynchronous three-phase motors with a total power of 8820 kW and a design speed of 120 km/h is designed for use on freight lines to drive trains weighing more than 6000 tonnes. The electric locomotive is equipped with four Alstom-designed traction converters on GTO and IGBT semiconductor elements.

The first WAG-12B electric locomotive was ceremonially released from the plant on 10 April 2018 with the participation of Indian Prime Minister Narendra Damodardas Modi (Fig. 10). On April 3, 2023, the 300th locomotive of this series was handed over to Indian Railways for service.

Among the expected new additions to Indian Railways' high-speed rail passenger electric rolling stock



Fig. 9. WCM-5 series electric locomotive No.20103, kept at the National Railway Museum in New Delhi. Photo by Basu Avishek<sup>16</sup>



Fig. 9. WCM-5 electric locomotive No. 20083 Lokmanya leads the Deccan Queen express. July 1980. Photo by Vaedhal Harsh<sup>17</sup>



Fig. 10. Electric locomotive WAG-12B with goods train 2020<sup>18</sup>

<sup>15</sup> Lokmanya Bal Gangadhar Tilak (1856–1920), marāṭhī, Indian politician, nationalist, conservative, advocate of orthodox Hinduism and fighter for Indian independence, the first leader of the Indian independence movement, nicknamed “Lokmanya” by the people, meaning “accepted by the people as a leader”, persecuted by the British colonial authorities, imprisoned for several years. Mahatma Gandhi called him “the creator of modern India”.

<sup>16</sup> URL: <https://24coaches.com/the-electric-locomotive-roster-dc-acdc-electrics/>

<sup>17</sup> URL: [https://www.irfca.org/gallery/Locos/Electric/wcm1\\_to\\_6/img097.jpg.html?g2\\_imageViewsIndex=1](https://www.irfca.org/gallery/Locos/Electric/wcm1_to_6/img097.jpg.html?g2_imageViewsIndex=1)

<sup>18</sup> URL: <https://www.rushlane.com/indias-most-powerful-train-engine-first-official-video-12362674.html>



are the Vande Bharat electric trains, which were previously available in the seating version. According to media reports, an agreement has been signed in New Delhi to set up a new company, Kinet Railway Solutions, which will supply 16 long-distance coach trains with sleeper seats to Indian railways. The joint venture with the participation of JSC Transmashholding (TMH, 75 per cent share) and the Indian company Rail Vikas Nigam (25 per cent) will build Vande Bharat trains and provide their service. It will manufacture 120 long-distance electric trains based on the results of a tender organised by Indian Railways, the results of which were announced on March 1, 2023 [16].

## CHANGE IN THE STRUCTURE OF THE TRACTION ROLLING STOCK FLEET

Back in the 1990s, several thousand steam locomotives were in operation in the country; today about three dozen steam locomotives are used only for driving tourist vintage trains. Initially, the fleet of diesel locomotives increased rapidly with the beginning of work on replacing steam traction with progressive — diesel and electric traction. In 1990–1991, the number of diesel locomotives exceeded the number of electric locomotives, but in the 2000s, as electrification rates increased, the growth of diesel locomotives slowed down and stopped by 2010. At present, the number of electric locomotives in train operations is one and a half times that of diesel locomotives. Electric locomotives carry about two-thirds of freight traffic in India. Approximately 60 % of passenger trains run on electrified IR lines, and they account for 38 % of the total

Table 2

Change in the structure of the locomotive fleet

| Years     | Number of locomotives, units |                    |                      |        |
|-----------|------------------------------|--------------------|----------------------|--------|
|           | Locomotives                  | Diesel locomotives | Electric locomotives | Total  |
| 1950/1951 | 8,120                        | 17                 | 72                   | 8,209  |
| 1960/1961 | 10,312                       | 181                | 131                  | 10,624 |
| 1970/1971 | 9,387                        | 1,169              | 602                  | 11,158 |
| 1980/1981 | 7,469                        | 2,403              | 1,036                | 10,908 |
| 1990/1991 | 2,915                        | 3,759              | 1,743                | 8,417  |
| 2000/2001 | 54                           | 4,702              | 2,810                | 7,566  |
| 2010/2011 | 43                           | 5,137              | 4,033                | 9,213  |
| 2020/2021 | 39                           | 5,108              | 7,587                | 12,734 |

Table 3

Share of different types of traction in the volume of train operations, %

| Years     | Passenger traffic |                    |                      |                | Freight traffic |                    |                      |
|-----------|-------------------|--------------------|----------------------|----------------|-----------------|--------------------|----------------------|
|           | Locomotives       | Diesel locomotives | Electric locomotives | Electric train | Locomotives     | Diesel locomotives | Electric locomotives |
| 1950/1951 | 93.0              | –                  | 2.0                  | 5.0            | 99.0            | –                  | 1.0                  |
| 1960/1961 | 91.0              | –                  | 2.0                  | 7.0            | 94.0            | 5.0                | 1.0                  |
| 1970/1971 | 77.0              | 7.0                | 7.0                  | 9.0            | 46.0            | 39.0               | 15.0                 |
| 1980/1981 | 49.0              | 25.0               | 14.0                 | 12.0           | 18.0            | 62.0               | 20.0                 |
| 1990/1991 | 21.8              | 42.4               | 22.6                 | 13.2           | 3.0             | 60.6               | 34.4                 |
| 2000/2001 | –                 | 56.2               | 31.2                 | 12.7           | –               | 43.5               | 56.5                 |
| 2010/2011 | –                 | 49.4               | 36.6                 | 13.9           | –               | 37.5               | 62.7                 |
| 2020/2021 | –                 | 18.8               | 63.7                 | 17.4           | –               | 27.0               | 73.0                 |

Table 4

Length of electrified tracks

|      |        |
|------|--------|
| 1951 | 388    |
| 1961 | 748    |
| 1971 | 3,706  |
| 1981 | 5,345  |
| 1991 | 9,968  |
| 2001 | 14,856 |
| 2011 | 19,607 |
| 2021 | 44,802 |
| 2022 | 52,508 |

electricity expenditure on traction [17]. Table 2 shows how the composition of the locomotive fleet of Indian railways has changed (based on data up to 31 March 2021), Table 3 shows the change in the share of different types of traction in the volume of train operations in passenger and freight traffic [17].

As of the end of 2022, 52,500 km of railways in India have been electrified, accounting for 77.1 % of the total operational length (Table 4) [15]. In FY 2021, India has achieved the longest electrification in all the years of such work — 6015 km. In the last seven years

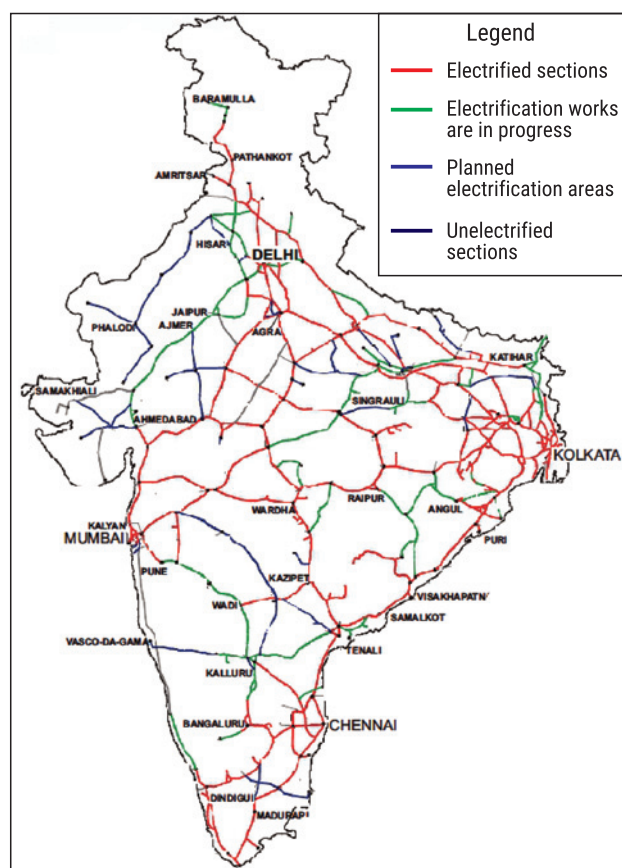


Fig. 11. Prospective scheme for electrification of India's railways. 2015<sup>19</sup>

(2014–2021), the electrification rate has increased more than 5 times compared to 2007–2014 (Fig. 11). It is planned that by 2024, Indian railways will be almost completely converted to electric traction [5].

## PROSPECTS FOR THE DEVELOPMENT OF THE INDIAN RAILWAYS

Over the years, a forward-looking railway development plan has been evolving with the participation of various organisations in the country under the leadership of the Ministry of Railways of India. On March 21 2022, the Ministry of Railways published the National Railway Plan of India (NRP), which aims to create a future-ready railway system by “2030” [18]. India's National Rail Plan 2030 aims to create a greener and cheaper to operate network of accessible and efficient railways.

The plan aims to reduce freight delivery time by increasing the average speed of goods trains to 50 km/h. The new plan aims to reform and make the railways

more sustainable, efficient and modern, while providing cheaper safe passenger and freight transport.

In a written reply to an enquiry by the Rajya Sabha Constitutional Council of States, India's Minister of Railways, Communications, Electronic & Information Technology Ashwini Vaishnaw said {Minister of Railways, Communications and Electronic & Information Technology Ashwini Vaishnaw}: “The objective of the Plan is to build capacity ahead of demand, which in turn will also contribute to future demand growth up to 2050 and also increase the share of railways in freight transport to 45 %. To achieve this goal, all possible financial models are being considered, including public-private partnerships (PPPs)” [19].

Other important objectives of the NRP include identifying new high-speed rail corridors and new dedicated freight corridors, estimating rolling stock requirements for passenger traffic, and freight wagon and locomotive requirements to meet the goals of 100 % electrification and increased freight share.

In addition, the new plan aims to ensure sustainable private sector participation in various areas such as freight and passenger terminal development, rolling stock operation and ownership, and track infrastructure development and operation.

Under the Vision 2024 NRP, measures have been taken to accelerate some critical projects including construction of second and third tracks on congested routes and 100 % electrification [18, 19].

The priorities for 2030 include: updating the technical policy and regulatory framework of Indian Railways; introducing effective means to improve the efficiency and safety of Indian Railways; a strategy to attract private capital to the railways; and infrastructure development [18].

## CONCLUSION

Over the last two decades, after solving the urgent task of uniting the country's railway network on the basis of reconstruction of the most important transport directions with a single 1676 mm gauge, the Indian railway transport has started technical re-equipment of the industry on the basis of introduction of electric traction. The initial stage of replacing steam traction with diesel locomotive traction, which was carried out in the 1970s and 1980s, was replaced in the 1990s by the active introduction of electric traction against the background of the unprecedented electrification of the country. Indian railwaymen took as an example the model of railway development in the USSR-Russia and China, rejecting the Ameri-

<sup>19</sup> Indian railways green energy initiatives. URL: [http://www.irgreenri.gov.in/tile\\_elect.html](http://www.irgreenri.gov.in/tile_elect.html)



can way of railway development — the use of diesel traction as environmentally harmful and dead-end for the country, which needs huge volumes of liquid hydrocarbon fuel, which has to be imported from abroad.

The Indian railways are faced with the challenge of improving control systems and train safety to make full use of the upgraded track facilities, the benefits of electric traction in increasing the speed of transport and the safety of rail transport.

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