Unifying Tracks, Evaluating the Standardization of Railway Gauge for Enhanced International Connectivity and Forward Looking Recommendations

Gul Hassan[1]

Dr. Muqeem-ul-Islam [2]

KJPP

Citation:
Hassan, G. (2023). Unifying tracks: Evaluating the standardization of railway gauge for enhanced international connectivity and forward-looking recommendations. Khyber Journal of Public Policy*, 3(2), Spring.*

Article Info:
Received: 10/02/2024
Revised: 22/02/2024
Accepted: 12/03/2024
Published:31/03/2024

Abstract:

Railways are a crucial mode of transportation for both freight and passengers, with a longstanding historical presence in industrialized nations. Pakistan Railways, the second largest institution in the country, has historically used Broad Gauge (BG) tracks, which have significant strategic and operational importance. This paper examines the feasibility of converting Pakistan Railways' BG network to Standard Gauge (SG) and finds it impractical due to prohibitive costs and operational disruptions. The analysis reveals that while SG offers advantages in terms of spare parts and market access, the high cost and operational challenges of converting existing BG tracks outweigh the benefits. The paper concludes that SG should only be introduced in isolated new networks or cross-border areas where gauge breaks are unavoidable. Recommendations include maintaining the current BG system, constructing new SG lines in strategic locations, and enhancing local production capabilities to reduce dependency on international markets.

Key words:

Railways, Broad Gauge, Standard Gauge, Pakistan Railways, Track Conversion

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1 Divisional Mechanical Engineer/KDA, Mechanical Engineering Department, Ministry of Railways
2 Faculty Advisor

Introduction

Railways function as the principal mode of transportation for both freight and passengers. Railways emerge as the most efficient, quickest, and cheapest mode for transporting people and goods worldwide. All industrialized and developed nations have established railway networks throughout their territories. The most notable progress in railways has been witnessed during the last two decades in our neighboring country, China. Pakistan Railways stands as the second largest institution after the armed forces. Pakistan Railways has played a pivotal role in conveying goods and people across the country and is also recognized as a means of transportation for the common people. Pakistan Railways is also significant in wartime, aiding the armed forces in the efficient and safe transportation of troops, ammunition, and equipment. Pakistan Railways plays a vital role in positioning Pakistan as a central global hub for international transportation and trade due to the geographical location of Pakistan.

The internal distance between two running rails of track is referred to as track gauge. The track is a major component in railways, and the selection of track gauge has always remained a complex issue throughout the history of railways. There are various types of gauges used worldwide. The principal gauges include the Standard Gauge (4′-8.5″ or 1435 mm), the Broad Gauge Russian BG (4′-11 27/32″ or 1520 mm) and Indian BG (5′-6″ or 1676 mm) also used in Pakistan, Meter Gauge (MG) (3′-3 3/8″ or 1000 mm), and Narrow Gauge (NG), the gauge below 1000 mm but mostly 2′-6″. Every gauge has its own significance and is adopted in different countries considering strategic, financial, or operational reasons. Nowadays, most countries in the world have adopted the Standard Gauge (1435 mm). Countries that have adopted SG for their railroad networks not only possess an advantage in the procurement of spares but also have access to a large market for purchasing track machinery, locomotives, and carriages. Therefore, it seems that shifting from the BG system to Standard Gauge would be advantageous in the future for countries that have not yet adopted it, such as Pakistan, where manufacturing facilities are not available. The national track gauge of Pakistan is Broad Gauge, which is the only operational gauge in the Pakistan Railways network. Historically, the first Broad Gauge (BG) railway line in Pakistan was inaugurated on May 13, 1861, for public traffic between Karachi city and Kotri, a distance of 169 km. The tracks in most sections of PR were laid for strategic purposes to safeguard the British Empire in the Subcontinent. At present, only BG track is operational in PR. The total route length of the PR network is 7791 km, while the total length is 11881 km as of June 30, 2020. The length of BG track is 7479 route km and 11492 track km. The length of Meter Gauge track is 312 route km and 389 track km, existing in PR but non-operational (Ministry of

Railways, 2020).

Statement of the Problem

Pakistan Railways inherited a variety of rail widths, including Broad Gauge (BG), Meter Gauge (MG), and Narrow Gauge (NG), which were laid by the British primarily for strategic purposes. Presently, only the BG track remains operational in Pakistan. Despite the widespread acceptance of Standard Gauge in most countries, such as those in Europe, America, and China, PR has persisted in constructing new tracks using the BG gauge. Pakistan Railways relies entirely on Europe and other nations for the importation of locomotives and rolling stock due to the absence of local manufacturing facilities and technology. Consequently, manufacturers must tailor their products to meet the requirements of Pakistan Railways for the broad gauge track, incurring significant costs and time. Given these constraints, there is an urgent need for Pakistan Railways to contemplate adopting the Standard Gauge. However, the feasibility of introducing SG on the existing PR network or international borders poses considerable technical, operational, and financial challenges that must be precisely evaluated.

Significance and Scope of Research

Considering the realities of elevated expenses and the shortage of BG rolling stock and locomotives, the importance of the Standard Gauge system rises. The objective of the study is to examine all the strategic, technical, operational, and financial dimensions of implementing Standard Gauge in Pakistan Railways. The investigation will concentrate on determining the extent to which SG should be implemented either across the entire PR network or in segments thereof. A detailed examination of the pros and cons of introducing SG in PR will be conducted.

Literature review

Examination of literature such as the Battle of Gauges in India, Standardization of Railway Track Gauge, Railroad Gauges and Spatial Interaction, and the Gauge Committee Report proved invaluable in comprehending the historical context and comparative analysis of various gauges. The literature review on railway track gauges underscores that Standard Gauge earned its name for unifying the diverse gauges prevalent in Great Britain during the 19th century. Other nations adopted this gauge due to Great Britain's influential status and the availability of SG locomotive technology at that time (Puffert, 2001). Additionally, historical accounts suggest that the BG track was considered superior to SG upon its introduction in India in 1853 (Murthi, 1953). Moreover, Broad Gauge emerged victorious over Standard Gauge in 1845 trials conducted to determine the optimal gauge for the United Kingdom (Siddall, 1969). While no direct research specifically addresses the need to introduce SG in Pakistan Railways, pertinent data from the Chief Engineer Survey & Construction PR HQ records of feasibility studies, Railway CPEC ML-1 data, and CAREC Railway Strategy 2017-30 (CAREC Secretariat, 2017) have proven instrumental in analyzing the situation. Considering Pakistan's strategic and geographical location, the question arises whether Standard Gauge adaptation in PR or adherence to existing BG tracks is preferable.

Methodology

Both quantitative and qualitative methodological approaches are considered to analyze diverse datasets and information. The research methodology for this paper relies on data acquired from various branches of Pakistan Railways concerning the existing information on the Broad-Gauge system, data from electronic sources, and Railway CPEC data of the ML-1 project. Quantitative data concerning the prevalence of SG globally and rough estimations of conversion costs from existing BG tracks of PR to SG tracks will be juxtaposed to derive conclusions. Similarly, strategic factors pertaining to cross-border rail connectivity with Iran, Afghanistan, India, and China will be scrutinized. Through this analysis, conclusions will be drawn, and recommendations will be provided to ascertain the optimal gauge choice for the PR network, considering future prospects.

Organization of the Paper

The research paper is divided into two sections to facilitate simplicity, comprehension, and logical flow. The first section focuses on the comparative analysis of Standard Gauge and Broad Gauge. It delves into the historical background of both gauges and discusses their technical, financial, and operational aspects. The second section explores the determinants of introducing SG to Pakistan Railways and the associated challenges. This section examines three different scenarios for the introduction of SG in PR: on ML-1 alone, across the entire PR network, or on border tracks with India, China, Afghanistan, and Iran. Drawing on the analyses from both sections, conclusions will be drawn, and recommendations will be provided accordingly.

Comparative Analysis of Broad and Standard Track Gauges

History of Standard and Broad Gauges

The Standard Gauge, measuring 4 feet 8.5 inches (1435 mm), originated with George Stephenson's pioneering Liverpool & Manchester line in 1830 in

England (Puffert, 2001). Also referred to as the Stephenson gauge or sometimes the international gauge, it was exported from Britain to Europe and the United States alongside British locomotives built to fit it. However, no study has conclusively established whether the Standard Gauge is technically or economically superior or inferior. Its initial adoption by Stephenson was little tested, and its widespread adoption resulted from the expansion of rail transport to this gauge. Stephenson's adoption of the gauge was not due to any inherent technical superiority; rather, he followed the precedent of the 4′-8″ gauge prevalent since 1825 on the Stockton and Darlington Railways in Great Britain, merely adding half an inch to allow more space between rails and wheel flanges. As Stephenson's son Robert later testified to a parliamentary commission, his father did not "propose" the gauge but rather "adopted" what was already in use in his home region. The British standard gauge was later adopted by Europe and America with the export of British locomotives built on the standard gauge. Another reason for its widespread adoption, particularly in Europe, was the interconnectivity of all European countries, aimed at increasing trade and facilitating travel for people across different nations (Puffert, 2001).

In 1845, a Gauge Commission was established to determine the best gauge for the UK. Trials were conducted on Broad Gauge and Standard Gauge locomotives, with the Broad Gauge winning. However, the Commission recommended the adoption of the 4 ft 8½ inch track gauge for the United Kingdom, primarily because the Standard Gauge track was much more prevalent in the UK at that time than the Broad Gauge track (Siddall, 1969). This gauge was declared the Standard Gauge for the United Kingdom.

The Broad Gauge was first introduced in India in 1853. The British East India Company dispatched Mr. F. W. Sims to India to report on the feasibility of introducing railways there. Lord Dalhousie had proposed permitting the introduction of two gauges in the United Kingdom: the Standard Gauge in England and a suitable broader gauge in India. The Broad Gauge (5′-6″) seems to have been the brainchild of Mr. F. W. Sims, a consulting engineer. At that time, the Standard Gauge was prevalent in Britain and America, but a gauge wider than the standard gauge (4′-8.5″) was proposed by Sims due to the storms and violent winds in India. However, this proved to be incorrect in later years, as no incidents of engines toppling over due to violent winds were reported on smaller gauges like meter-gauge. Nonetheless, the Broad Gauge found its footing during that period (Murthi, 1953).

Prevalent Track Gauges in Different Countries

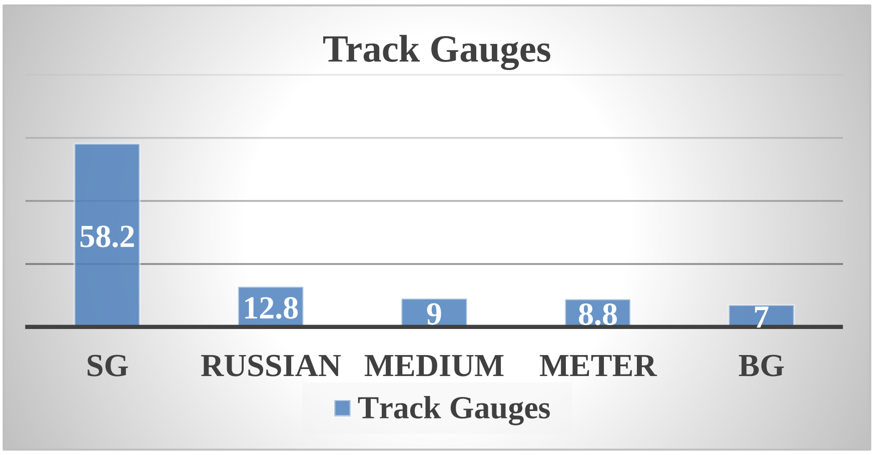
Various types of gauges exist worldwide, including Broad Gauge (5′-6″) measuring 1676 mm, Standard Gauge (4′-8.5″) measuring 1435 mm, Meter Gauge, and various Narrow Gauges such as 2′-6″ and the Russian Gauge (1520 mm). Broad Gauge is utilized in countries like Pakistan, India, Bangladesh, Sri Lanka, Argentina, and Chile. On the other hand, Standard Gauge is prevalent in Europe, Canada, the USA, the Middle East, China, Japan, North Africa, Australia, Argentina, and Chile. The percentage of Standard Gauge usage is increasing annually, particularly due to railway expansions led by China, which involve the construction of new routes featuring Standard Gauge tracks. A comparison of the prevalent principal gauges as of the year 2000 is presented in the table below.

Table 1: Percentage of Principal Track Gauges in the World (Year 2000)

S.N.	Gauge Type	Gauge (ft in)	Gauge (mm)	% age	Countries
1	Standard Gauge	4'-8.5"	1435	58.2	USA, China, EU, Australia, Canada, Japan, Middle East
2	Broad Gauge	5'-6"	1676	7	Pakistan, India, Sri Lanka, Bangladesh
3	Meter Gauge	3.28'	1000	8.8	India, Pakistan, Brazil, Chile, Spain
4	Medium Gauge	3'-6"	1067	9	Australia, Japan, New Zeeland
5	Russian Gauge	4'-11 27/32"	1520 and 1524	12.8	Russia, Central Asia
6	Other Gauges	2'-6", 3', 5'-3"	762, 914, 1600	4.2	China, India, Australia, Ireland

Source: The Standardization of Railway Track Guage, Douglas J. Puffert, 2001 https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.200.6291&rep=rep1&type=pdf

Figure 1: Chart showing Percentage of Principal Track Gauges in the World in Year 2000



Source: The Standardization of Railway Track Gauge, Douglas J. Puffert, 2001
https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.200.6291&rep=rep1&type=pdf

Inter-connectivity of SG and BG Tracks

Interchange arrangements for goods and passenger transit between Broad Gauge and Standard Gauge are essential at junction stations. This involves the dual arrangement of rolling stock. In instances where a railroad network incorporates two gauge systems, such as Broad Gauge and Standard Gauge, it leads to a 'break of gauge,' hindering interconnectivity and necessitating the exchange of rolling stock for the transshipment of goods and passengers. This results in increased time consumption to reach the destination and entails additional costs for operating trains and maintaining track machinery handling two types of rolling stock.
Nevertheless, transshipment in the event of a break of gauge is less daunting today due to the availability of state-of-the-art cranes and machinery. These cranes efficiently transfer containers from one freight train to another within a short duration. However, the break of gauge remains undesirable.

Availability of Locomotives & Rolling Stock for SG and BG

Locomotives and rolling stock for SG tracks are generally available at comparatively lower prices. When it comes to Broad Gauge, there is a common perception that clients need to place special orders with suppliers for BG-based rolling stock. Conversely, with SG, purchasing off-the-shelf from international markets is feasible, although specifications often necessitate custom products. While this holds true to some extent, locomotives and rolling stock are not readily available in the market. These items are manufactured upon special orders, depending on each country's specific custom-based design requirements and dimensions, including the gauges prevalent in that particular railroad network, even for SG. Hence, the cost difference is not significant when comparing the two gauges. Therefore, this criterion alone is insufficient to decide on the introduction of Standard Gauge on the existing network of Pakistan Railways, as conversion costs are not manageable for an economically stressed country like Pakistan (Basharat Waheed, 2022).

Comparative Research and Technology Advancement of SG & BG

Research on Broad Gauge has been conducted extensively in India due to its vast size. However, Pakistan does not benefit similarly due to ongoing tensions between the two nations. Conversely, the majority of advanced technology and research are directed toward Standard Gauge, primarily undertaken in Europe, the USA, and China, where Standard Gauge is prevalent. Furthermore, most countries worldwide have Standard Gauge tracks.

Comparative Design Parameters of SG and BG

Infrastructural Parameters

Broad Gauge rolling stock exerts less pressure on the sub-grade below and spreads over a wider area in transverse and longitudinal directions due to its wider gauge width compared to Standard Gauge, where the load dispersion is greater. However, the difference in stress induced underneath is not significant when compared with the stress induced in the case of BG for the same axle load.

In the case of Broad Gauge, longer curves are provided, whereas sharper curves can be accommodated with Standard Gauge, thus requiring less land (M Ravindra, 2012). Additionally, 2750 mm length sleepers are laid on BG under the rails, compared to 2600 mm long sleepers in SG track (MD Sleeper Factory, 2022). The shorter length of sleepers is due to the narrower axle width in SG rolling stock, thereby reducing the per kilometer cost of track for SG, especially in hilly or densely populated areas.

Rolling Stock Design Parameters

The utilization of a wider gauge enables the use of wider coaches and wagons, providing increased lateral stability on BG. Conversely, SG requires narrower coaches, which will likely cost less than BG coaches. However, it is important to note that the passenger-carrying capacity of narrower SG coaches will also be reduced. Consequently, more coaches will be required for the same number of passengers. Therefore, when comparing the cost of coaches in both scenarios, it is evident that the cost difference for converting BG track to SG will play a negligible role.

Relative Speed Design Parameter

High-speed trains primarily operate on SG tracks, with a maximum speed of 350 km/h already operational in China on an electrified track between Beijing and Shanghai. After the completion of the ML-1 Track project, a maximum speed of 160 km/h on BG (5'-6") track will be observed on PR. Since BG tracks are predominantly present in Pakistan and India, the technology gap for high-speed trains will be more pronounced if introduced on BG (5'-6") tracks. Speeds on curves on SG tracks in hilly areas or densely populated urban areas will be slightly higher than those on BG tracks, with a nominal difference (M Ravindra, 2012).

Comparative Initial Cost of Construction of SG and BG

The initial expenses for constructing Broad gauge are higher due to the wider rolling stock and infrastructure. Conversely, converting existing Broad-gauge tracks into SG entails significantly higher costs. Generally, it is believed that the construction cost of standard gauge is lower due to its narrower width compared to broad gauge. This aspect of Standard gauge provides an economic advantage over broad gauge when building new lines. It is understood that standard gauge will necessitate less land acquisition, reduced formation width, and shorter length of sleepers. These gauge features imply lower construction costs compared to broad gauge. However, the impact of construction costs is not substantial when compared with converting BG tracks to SG, so this factor is not compelling for adopting standard gauge on existing lines of the PR network.

Introduction of Standard Gauge in PR and Challenges

Comparative Initial Cost of Construction of SG and BG

The initial expenses for constructing Broad Gauge are higher due to the wider rolling stock and infrastructure. Conversely, converting existing Broad-Gauge tracks into SG entails significantly higher costs. Generally, it is believed that the construction cost of Standard Gauge is lower due to its narrower width compared to Broad Gauge. This aspect of Standard Gauge provides an economic advantage over Broad Gauge when building new lines. Standard Gauge requires less land acquisition, reduced formation width, and shorter length of sleepers. These gauge features imply lower construction costs compared to Broad Gauge. However, the impact of construction costs is not substantial when compared with converting BG tracks to SG, so this factor alone is not compelling for adopting Standard Gauge on existing lines of the PR network.

Introduction of Standard Gauge on ML-1 and Challenges

The ML-1 (Main Line-1 Kemari-Karachi to Peshawar) project of Pakistan Railways is a large project financed by China, where the Broad-Gauge track will be enhanced for a speed of 160 km/h. The PC-1 of Rs. 6.806 billion dollars was sanctioned in August 2020 for the enhancement of 1681 km from Kemari to Peshawar with BG (5′-6″) track (Infrastructure Specialist CPEC, 2022). The project has been postponed to date for some undisclosed reasons. Despite the project being approved for BG track after a feasibility study and with input from Chinese and Pakistani railway experts, there are murmurs within PR and sometimes in the media questioning why the ML-1 BG track is not converted to SG.

In this context, the Railway CPEC Ex. Team Leader and Infrastructure Specialist were interviewed. Considering the introduction of Standard Gauge only on ML-1 while other branch lines, ML-2 and ML-3, remain on BG, numerous issues and challenges will be encountered, and minimal advantage will be gained. These are discussed as follows. In the event of converting ML-1 Broad Gauge track to SG from Karachi to Peshawar, transshipment arrangements will need to be provided at all the junction stations on the route. The operational junction stations requiring this facility are listed below.

Table 2: List of Junction Stations on ML-1 Route

S.No.	Junction Station	Branch Line Route
1	Kotri	Kotri -Dadu - Habibkot
2	Hyderabad	Hyderabad – Mirpurkhas, Hyderabad - Badin
3	Rohri	Rohri - Sukkur - Quetta
4	Sammasatta	Sammasatta - Bahawalnagar
5	Lodhran	Lodhran – Pakpattan, Lodhran – Khanewal via Chord
6	Sher Shah	Sher Shah – Kot Addu
7	Khanewal	Khanewal - Shorkot
8	Raiwind	Raiwind - Pakpattan
9	Lahore	Lahore - Wagah
10	Shahdara	Shahdara – Sheikhupura Shahdara – Narowal - Sialkot
11	Wazirabad	Wazirabad – Sangla Hill, Wazirabad – Sialkot - Narowal
12	Lala Musa	Lala Musa – Sargodha
13	Golra Sharif	Golra Sharif – Basal - Kundian
14	Taxila	Taxila - Hevellian
15	Attok City	Attok City - Jund

Source: Chief Operating Superintendent, PR HQ, Official Time Table, 2022

The aforementioned 15 junction stations will necessitate transshipment arrangements, implying dual provision of locomotives and rolling stock, dual gauge setups, and machinery for cargo transshipment handling, which will require substantial finances. Furthermore, all operations will result in significant delays, which are highly undesirable for railway customers as well as all stakeholders. The implementation of the complete ML-1 Project will consume considerable time and will be conducted in various phases to transition the existing BG track to SG. During construction, train operations cannot continue as there will be no provision of dual gauge at stations to facilitate the movement of BG trains. The track at stations will initially be converted to SG, followed by the adjoining block section. The existing BG rolling stock will need to operate on this segment even though the track will have been converted to SG. Even if SG rolling stock is arranged, there will still be portions of BG track that will not accommodate SG rolling stock. The same scenario will be encountered at all work sites. Furthermore, all rolling stock needed for SG track will have to be procured, which will again entail substantial costs. From the foregoing discussion, it is evident that the conversion of the BG ML-1 route to SG track is not financially or operationally feasible.

Introduction of SG Over Entire Railway Network and Challenges

The implementation of Standard Gauge across the entire railway network spanning 11,492 km, including ML-1, ML-2, ML-3, and all other branch lines, will entail substantial costs. This can be assessed using an approximation method when compared to the already approved PC-1 of the ML-1 Project in August 2020. The estimated cost of the approved ML-1 Project is 6,806 million dollars for a length of 1,681 km of double-line track to be upgraded in 8.5 years (Infrastructure Specialist CPEC, 2022). The cost per km comes to 4.049 million dollars per km. The approximate cost of introducing Standard Gauge on the entire PR network of 11,492 km can be roughly calculated, as shown in Table 2.

Table 3: Rough Cost Estimation of SG on entire PR network

Railway Line	Length (km)	Per km cost Double Line (Million Dollar)	Per km cost Single Line (Million Dollar)	Total Cost (Million Dollar)	Remarks
ML-1	1681 x 2 = 3362	4.049	2.025	6806	8.5 Year time
l PR lines	11492	-	2.025	**23271**	**5 years' time**

Source: Infrastructure Specialist, Railway CPEC Approved PC-1, 2022

Accordingly, the conversion of the entire PR railway network spanning 11,492 km in length will require approximately 23.3 billion dollars, with a timeframe of about 25 years. This cost only covers track conversion; additional expenses for replacing rolling stock and locomotives will also be incurred. Furthermore, all railway workshops and sleeper factory infrastructure will require structural changes. Pakistan is not in a financial position to even contemplate such a massive investment in railways solely for replacing its track gauge from BG to SG. Therefore, the option of converting the entire broad-gauge network to standard gauge is not technically, operationally, or financially feasible.

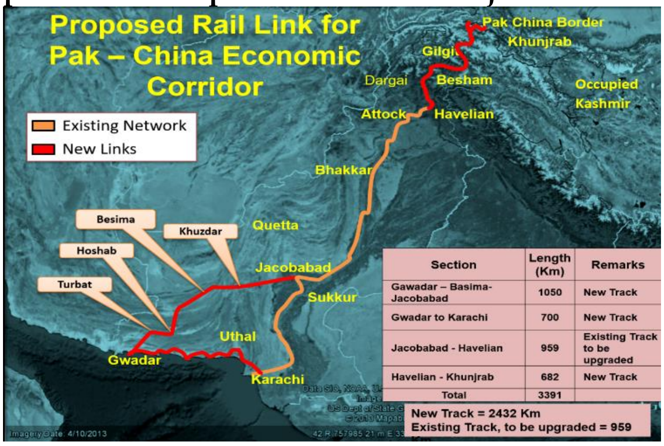
Introduction of SG on Interconnections with Neighboring Countries

Rail transport is deemed cost-effective and an efficient means of transporting large cargo over extended distances. Numerous countries have bolstered railway connectivity, making it an integral component of economic corridors within their regions. South Asia, often regarded as one of the least integrated regions globally, has lagged behind other regions in terms of railway connectivity. The geography of Pakistan presents a uniquely advantageous position, with Gwadar Port, Karachi Port, and Port Qasim situated on the Arabian Sea in the south, India to the east, China emerging as a global superpower to the north, Iran to the southwest, and Afghanistan to the northwest. Afghanistan, a landlocked country, is further linked with Central Asian landlocked states abundant in natural resources. This confluence renders Pakistan a pivotal country in the region, as distances can be shortened through railway connections with China and Afghanistan, extending up to Central Asia and Russia. Through these interconnections, Pakistan has the potential to emerge as a hub of international trade and transportation.

Interconnection with China

Pakistan currently lacks a rail link with China. Pakistan Railways' track in the north is operational up to Havellian, which is connected 55 km away with ML-1 at Taxila Junction on the Karachi-Peshawar line. A new track spanning about 682 km is set to be constructed from Havellian to Khunjerab. This track will traverse through challenging mountainous terrain, necessitating the construction of numerous tunnels, curves, and bridges. Meanwhile, China has a standard gauge track up to Kashgar on its side. Consequently, the track from Havellian to Khunjerab is proposed to be constructed as SG, given its isolated nature with minimal impact on the BG network of PR and considering the lower construction costs involved for SG curves, tunnels, and bridges to be built by Pakistan. Moreover, the primary traffic beyond Havellian will be related to China, making SG the most suitable option, as China plans to construct about 350 km of track on its side from Khunjerab to Kashgar as SG track. Transshipment facilities need to be developed at Havellian since Pakistan has a Broad Gauge track up to Havellian. A dry port is proposed at Havellian in the Railway CPEC framework with transshipment arrangements (Basharat Waheed, 2022).

Figure 2: Proposed route map of Havellian-Khunjrab new railway track



Source: PR, Chief Engineer S&C HQ office, Lahore, 2015

Since the track from Havellian to Khunjerab is to be newly laid and isolated from the rest of the country, it will encounter fewer issues regarding transshipment due to China's advanced machinery and equipment at the dry port. As China has SG on its side, the break of gauge is inevitable in this case; thus, the introduction of Standard Gauge from Havellian to Khunjerab is feasible. Dual gauge and transshipment facilities are to be provided at the Havellian dry port. Figure 1 above illustrates the proposed new track alignment of the Gwadar–Jacobabad and Havellian–Khunjerab route, which will further extend up to Kashgar in the Xinjiang province of China.

Interconnection with India

Pakistan has railway connections with India at Wagah and Zero Point station near Khokhrapar. Broad Gauge track exists on both sides of the border at Wagah-Atari and Khokhrapar-Zero Point-Monabao sections. Pakistan had operational goods and passenger trains on these sections until August 2019, when services were suspended in protest after the Indian Government revoked Articles 370 and 35A related to Kashmir. However, these services may need to be restored in the future. Additionally, Sikh special trains operated in 2022 on the section, coming from India to facilitate Indian Sikh yatris visiting Nankana Sahib and Hassan Abdal. Indian Railways adopted a uni-gauge policy in 1990, opting for Broad Gauge for its entire network (M Ravindra, 2012). Consequently, all railway lines that were on other gauges are being gradually converted to Broad Gauge by Indian Railways.

No country has changed its prevailing gauge to Standard Gauge in recent years due to the high financial costs involved. Thus, introducing SG on cross-border tracks with India is not viable, as transshipment of goods and passengers would be required for a short distance of 24 km from Wagah to Lahore, and Zero Point Marvi station is 200 km from Hyderabad. Given the significant financial implications and India's broad gauge policy, introducing SG on cross-border tracks with India is not recommended.

Interconnection with Iran

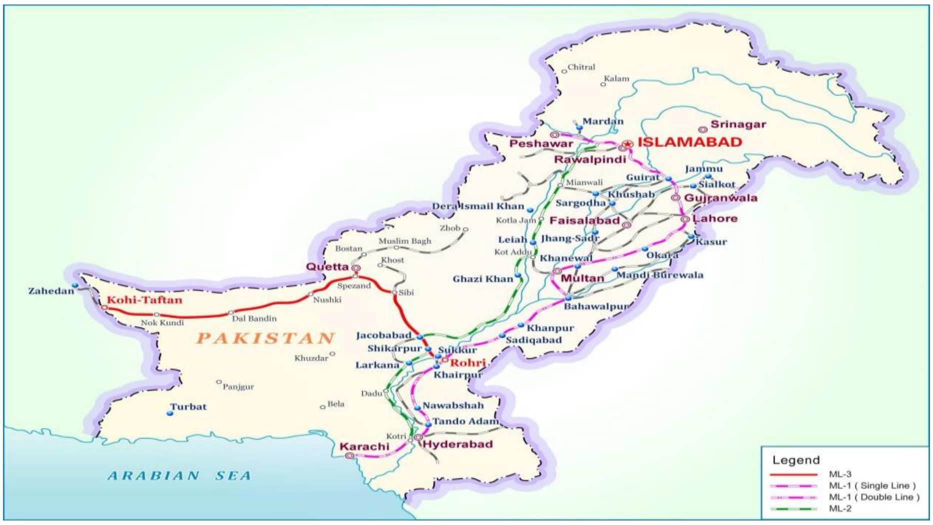
Pakistan has a Broad Gauge track at the interconnection station of Kohe-Taftan on the Iran border. The track from Kohe-e-Taftan to Zahedan, which is 95 km long and within Iranian territory, is laid in Broad Gauge. This arrangement resulted from an agreement between Pakistan Railways and Iranian Railways in 1959. The Broad Gauge track from Taftan to Zahedan is jointly maintained by Pakistan Railways and the Iranian side. Maintenance labor is provided by Iran, but the BG track material is supplied by Pakistan Railways because Iran only has Standard Gauge facilities, and any rolling stock, material, or machinery related to BG is provided by Pakistan Railways. Dual Gauge arrangements are available at Zahedan, accommodating both BG and SG (Kashif, 2022).

The Islamabad-Tehran-Istanbul (ITI) train runs to this border, where transshipment occurs to shift to SG track on the Iranian side at Zahedan. The ITI Cargo Train can cover a distance of 1,990 km in Pakistan, 2,600 km in Iran, and 1,950 km in Turkey in 14 days. In Turkey, the railway tracks are Standard Gauge. Turkish Railways send its rolling stock (carriages and wagons) to Zahedan, which then picks up the cargo from the arriving rolling stock of Pakistan Railways.

The rehabilitation/upgrading of the existing Quetta-Taftan section for higher speeds and axle loads has become necessary to make this section commercially viable and competitive with road transport. It is also essential for serving as a viable passenger and freight line and for providing access to

Europe via Iran and Turkey. Pakistan Railways conducted a feasibility study for the upgrading of this section, carried out by the Chinese firm Siyuan in 2019. The final technical recommendation of the feasibility report is to upgrade this section as a single-line Broad Gauge (1676 mm) track with a 25-ton axle load and a maximum speed of 120 km/h, except from Glangur to Nushki, where a speed of 80 km/h is recommended (Chief Engineer S&C, PR, 2019).

Figure 3: Map of Pakistan Railway ML-3 Rohri-Taftan Section



Source: PR HQ Chief Engineer S&C, Feasibility study of Quetta Taftan 2019

Introducing Standard Gauge on this section on the Iranian border side up to Zahedan and on the Pakistan side is not advisable solely for the ITI train, as this would shift the break of gauge to Quetta or Spezand due to Broad Gauge tracks extending all the way to Islamabad. Consequently, Pakistan Railways would need to implement dual gauge, dual stock, and transshipment arrangements, which are unavoidable due to the different gauges prevalent in both countries.

Interconnection with Afghanistan

Currently, there is no railway link between Pakistan and Afghanistan. However, Pakistan could potentially establish connections with Afghanistan from two sides: the Quetta-Chaman route up to Kandahar and the Peshawar route up to Jalalabad-Kabul. This would facilitate the linkage of Central Asian states and Russia to warm waters through Gwadar, fulfilling a longstanding regional aspiration if realized.

The 11 member countries of the Central Asian Regional Economic Cooperation (CAREC) recognize the importance of railways in completing this multimodal corridor network. Pakistan also endorsed "The Railway Strategy for CAREC, 2017-30" at the CAREC ministerial conference held in Islamabad on October 26, 2016 (CAREC Secretariat, 2017). The vision behind the CAREC railway strategy is to make rail transport the preferred mode for trade: quick, efficient, and easy to use throughout the region. The development of effective rail infrastructure aims to address gaps and missing links along designated rail corridors (DRCs), most of which pass through Afghanistan and then Pakistan to reach the warm waters of the Arabian Sea, as depicted in Figure 4 below

Figure 4: CAREC Designated Rail Corridors

Source: CAREC Railway Strategy 2017-30, CAREC Secretariat [*www.carecprogram.org*](http://www.carecprogram.org)

Considering the above, the significance of the railway link between Pakistan and Afghanistan is evident. However, the decision regarding the gauge on the Jalalabad and Kandahar sides is complex, as Afghanistan has not clarified its national gauge due to the intricate situation surrounding rail gauges. Afghanistan uses the Russian gauge (1520 mm) for its connections to Central Asian neighbors, namely Turkmenistan, Uzbekistan, and Tajikistan. The gauge on the China and Iran sides is SG, while Broad Gauge is used in Pakistan. Given this situation, it is essential for Afghanistan to address gauge breaks, whether it opts for the Russian Gauge, SG, or BG. The decision regarding the gauge on the two interconnections with Pakistan will depend on the gauge chosen by Afghanistan, considering the designated rail corridors (DRCs) of CAREC. However, it can be stated that Afghanistan cannot avoid the break of gauge, so Pakistan may propose BG for both routes up to its borders: the Peshawar-Jalalabad route (145 km) and the Chaman-Kandahar route (107 km). Transshipment arrangements should then be organized near the Afghanistan borders.

Conclusion

Considering the above comparative analysis, issues, and challenges discussed in Sections 1 and 2, it is concluded that converting the entire existing network of Broad Gauge (5′-6″) track to Standard Gauge is not a viable option for Pakistan Railways, either now or in the future, as it involves prohibitive financial costs and train operations would cease during the construction period. Although the break of gauge is undesirable, it is unavoidable for regional connectivity with neighboring countries that use different gauges. Standard gauge can only be introduced on isolated networks or newly constructed alignments, especially in hilly terrain or cross-border track areas where the break of gauge is unavoidable. The cost of converting existing BG to SG track is indeed very high, but for new lines, particularly in hilly terrain, the cost of SG track is lower. However, this difference is not significant enough to justify opting for multi-gauge within the country based solely on cost. Standard Gauge is named as such, but this does not imply that BG (5'-6"), Meter gauge, or Russian Gauge is non-standard. Each gauge has its own significance and has been historically adopted in different countries for strategic, financial, or various other reasons. Therefore, Pakistan Railways must adhere to Broad Gauge as the national gauge.

Recommendations

Based on the aforementioned research, several recommendations are proposed for Pakistan Railways and the Government, outlined as follows:

The current BG track of Pakistan Railways should not be converted to SG, even in the future.

It is recommended to build a new railway line from Havellian to Khunjerab in challenging hilly terrain as a Standard Gauge track. This choice is prompted by the inevitable gauge break at the border with China, given that China operates SG track on its Kashgar line.

The proposed new track connections with Afghanistan should be constructed on BG on the Pakistan side, along the Peshawar–Jalalabad route and the Quetta–Chaman–Kandahar route. This recommendation stems from the unclear future gauge policy of Afghanistan, due to the complex situation of different gauges on its borders. Nevertheless, following the determination of Afghanistan's national gauge, this recommendation should be reassessed accordingly.

It is proposed to upgrade the track from Quetta to Taftan on the existing BG track, considering the unavoidable gauge difference with Iran. Hence, relocating transshipment to Pakistan or adopting multi-gauge on the Pakistani side is operationally and economically undesirable.

It is strongly advised that Pakistan Railways establish its own workshops for the local production of rolling stock and locomotives. Prioritizing technology transfer in future international procurements is crucial to prevent dependency on the international market and conserve significant foreign exchange.

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