UIC narrow-gauge (September 2025)

Current status and analysis of narrow-gauge rail networks worldwide

INTERNATIONAL UNION OF RAILWAYS

ISBN 978-2-7461-3524-6

<table>
<tr><td colspan="4">DOCUMENT DATA SHEET</td></tr>
<tr><td colspan="2">Designation
UIC</td><td colspan="2">This version
September 2025</td></tr>
<tr><td colspan="2">Title of document
Current status and analysis of narrow-gauge rail networks worldwide</td><td colspan="2">Languages
Original: Fr ☐ D ☐ En ☒
Translation: Fr ☐ De ☐ En ☐</td></tr>
<tr><td colspan="2">Author(s)
Adrian Corrales. Universidad Politécnica de Madrid (UPM)</td><td colspan="2">Pages: **60** Figures: **20** Tables: **10**
(Excluding annexes)</td></tr>
<tr><td colspan="4">Project</td></tr>
<tr><td colspan="2">Contractor
International Union of Railways (UIC)
Asset Management, Infrastructure and TTI Unity
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F – 75015 PARIS</td><td colspan="2">Customer</td></tr>
<tr><td colspan="2">Contractor Project No.</td><td colspan="2">Customer Project No.</td></tr>
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Abstract

Narrow-gauge railways are types of infrastructure with a smaller distance between the rails than the standard gauge (1435 mm), usually with a gauge of 1000 mm, commonly known as the metre gauge, or with a gauge of 1067 mm.

The use of this type of rail configuration is widespread in countries in Africa, the Asia-Pacific region and Latin America, forming large rail networks that connect and link different regions of the countries. The objective of this document is to review the current status of narrow-gauge networks around the world, as well as any projects and studies carried out, as well as technologies developed on narrow-gauges in order to collect the most important data and characteristics.

Subsequently a working group will be created within the International Union of Railways (UIC), made up of railway experts from countries with extensive narrow-gauge networks, with the aim of providing solutions to the problems that these networks present.

With the aim of obtaining reliable data, a questionnaire was shared by UIC with various railway sector professionals and experts from countries with narrow-gauge networks.

Keywords

Narrow-gauge network, railway, rail infrastructure, railway gauge.

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Amendments

Amendment number	Amendment made by (in CAPITALS)	Date made (YYYY-MM-DD)

Members

At the time of compiling the present report, the Working Group was composed as follows:

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Preface

This document has been developed within the framework of a collaboration agreement between UIC and the Civil Engineering School of the UPM.

The advisors of the work were Clara Zamorano (UPM), Carlos Romero (UPM), Rosa Casquero (UIC) and Jesús Palma (UIC).

1. Introduction

1.1. Defining gauges: Narrow-gauge, standard gauge, and broad gauge

Railway infrastructure has a multitude of characteristics and parameters that define, characterise and differentiate them from one another. One of the primary characteristics that distinguishes one track from another is its gauge. This is defined as the distance between the inner edges of the rails, measured 14 mm below the running surface in a straight line (ADIF, 2023). In other words, the gauge is an intrinsic characteristic of any infrastructure, and rolling stock is adapted to the existing gauge to run on the tracks.

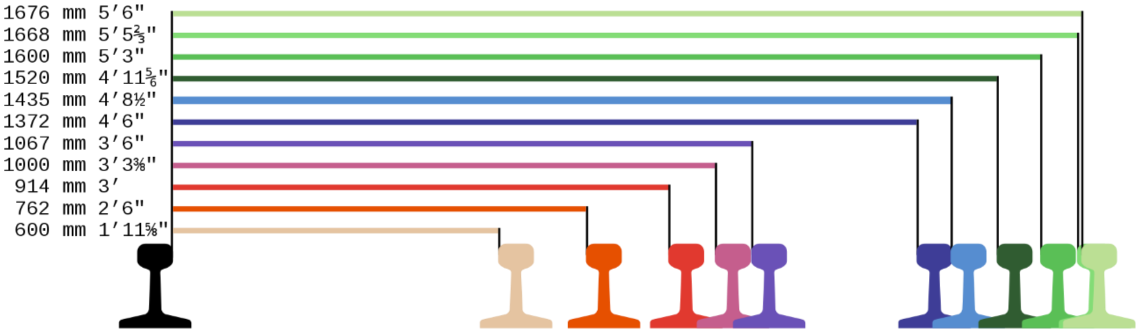

Figure 1: Track gauges.
Source: Geotren

There is a wide range of railway gauges in use worldwide, ranging from 600 mm to 1676 mm. However, as a rule, they are divided into three groups: narrow-gauge, international or standard gauge (with the latter more commonly used), and broad gauge.

Narrow-gauge encompasses all lines with a rail spacing shorter than the standard gauge (900, 914, 950, 1000, and 1067 mm), which this document specifically addresses.

The standard gauge, with a rail spacing of 1435 mm, is the most common rail gauge in the world and has the most kilometres of track built. All gauges longer than 1435 mm, including the Spanish and Portuguese Iberian gauge (1668 mm), are classified as broad gauge.

1.2. Lines with different gauges

Generally, a railway line has the same gauge from beginning to end, to facilitate operations and maintenance work, but there may be cases where there is a change of gauge at some point along the line.

1.2.1. Track gauge changers

To solve this problem, the two most used options are either using "gauge changers", or requiring the passenger to change trains when a different gauge on which the vehicle cannot run is reached. While the second option is simpler in terms of maintenance, it is less convenient for passengers, affecting their comfort and increasing travel times.

Figure 2: Gauge changers in Spain.
Source: ADIF

On the other hand, variable gauge systems allow rolling stock to operate interchangeably on different track gauges. However, this requires specific rolling stock that is compatible with the gauge-changing mechanism to be acquired, while also engendering increased maintenance costs for the variable gauge equipment, given its unique and crucial role in the operation of the line.

Some of the existing technologies for gauge changes, as described in document UIC B 190/RP 1, are listed below.

1.2.1.1. Talgo Technology

This is technology used by the Spanish infrastructure manager Red Nacional de Ferrocarriles Españoles (RENFE), and has been used continuously since 1969, making it the most seasoned in the world. This gauge change technology is used for metre, standard, Russian (1520 mm), and Iberian gauges.

In Spain, ADIF-developed dual gauge switches are currently used, which combine Talgo and CAF technology and are adaptable to narrow-gauges (https://www.adif.es/cambiador-ancho-dual).

1.2.1.2. RAFIL/DB System AG

This system only allows gauge changes for empty or loaded freight wagons and is used for standard, Russian, and Iberian gauge configurations.

1.2.1.3. SUW System 2000/PKP

This technology was developed by the Polish State Railways (PKP) and was used on the international Warsaw-Vilnius (2000 - 2005) and Krakow-Kiev (2000 - 2006) corridors. It has also been used on the Wroclaw/Krakow-Lviv line since 2009. The system works for 1435/1520 mm and 1435/1668 mm configurations.

1.2.1.4. BRAVA Technology (CAF)

Created in 2000, this is also Spanish technology used to switch between the standard and Iberian gauge. This system is used on high-speed trains in Spain (with speeds of 250 km/h). BRAVA technology has been proven to be safe, reliable, and applicable to single or multiple traction and diesel or electric systems.

1.2.1.5. Gauge change train (GCT)/Japanese system

The Japanese railway network consists mainly of two types of gauge, the standard and 1067 mm, meaning that the Shinkansen (high-speed) and conventional trains cannot run on the same line. This technology has been designed using an electric multiple-unit (EMU) train, which performs the gauge change autonomously and without having to stop. Since 2001, several prototype trains have been tested between 1067 mm and standard gauges in Japan.

1.2.1.6. Gauge changing bogie - EV 09/Swiss System.

Implemented on the Montreux-Oberland Bernois (MOB) line, with trains passing from the metre to standard gauge without stopping. This technology was developed by PROSE, an independent private company specialising in railway rolling stock engineering solutions, established in Europe. This system, however, is not currently available for commercial sale.

1.2.1.7. Bulgarian system

This technology was designed, manufactured, and tested in Bulgaria between 1985 and 1995. It was built by the Bulgarian State Railways and was intended to be used for freight wagons. The system works between the standard and Russian gauge.

Figure 3: Gauge change manoeuvre in Switzerland.
Source: Railway Gazette International (2019)

1.2.2. Multiple or double gauge

There is also a type of rail gauge known as the mixed or double gauge, where there are three rails present on the track instead of two. Here, trains with one of the two gauges run on one track, without issue or interference from the other gauge. This type of solution for different rail gauges is common in Vietnam, a country with more than 200 kilometres of mixed metre and standard gauges (CIA The World Factbook, 2014). Another example is Spain, with approximately 272 kilometres of mixed gauge lines, with the majority of them located on the country's Mediterranean coast (Observatorio del transporte y la logística en España, 2022).

Some of the double rail configuration’s main features are (as provided by Vietnam Railways):

- Mixed gauge specifications: Combining the more restrictive characteristics of narrow-gauge with the less demanding specifications of standard or other gauges, can result in unmet standard gauge requirements (for example, the curve radius, track bed gauge, etc.). This limits the train speeds and causes difficulties for maintenance work.
- Operational complexity: Running both freight and passenger trains on both gauges within the same station is more complicated than on a single gauge track. This requires stricter working procedures and safety measures.

- Cant alignment issues: The cant of the narrow-gauge track is typically aligned with the cant of the other track gauge, which can affect the quality of transport on the narrow-gauge track.
- Uneven rail wear: The rails are unevenly worn (the shared rail experiences more wear in straight sections).
- Switch types: There are two types of turnouts, with a shared lane either on the left or the right. Their structure is also more complicated than normal.

Experience shows that this mixed gauge mode increases maintenance, especially on the shared rail of the two gauges, since it carries twice as much traffic as the other two, meaning that it needs to be replaced more frequently. Switches, which are sensitive and conflictive points on railway lines, become critical elements in a superstructure with three rails instead of two.

Additionally, the construction of new mixed gauge lines will significantly increase costs due to the need for special sleepers that can accommodate three simultaneous rails.

However, compared to the investment required to build separate infrastructure for each gauge, upgrading the existing infrastructure to double gauge represents a substantial cost saving.

Figure 4: Mixed gauge on the Barcelona-Valencia line.

Source: International Railway Journal

2. Characteristics, advantages, and disadvantages of narrow-gauge networks

2.1. Main characteristics of the narrow-gauge

The principal and most important difference between a narrow-gauge line and others lies in the rail spacing, which is smaller than the standard 1435 mm. This variation has significant technical and constructional implications, especially in terms of its ability to adapt to difficult terrain.

Narrow-gauge lines can handle steeper gradients and tighter curves than standard gauge or broad gauge lines, mainly due to the smaller size and therefore lighter mass of the rolling stock. As a result, the construction of a narrow-gauge line is often more economical, as its flexible design avoids having to build costly structures such as tunnels, viaducts, or bridges to bypass geographical obstacles (Railsystem.net). This has an additional benefit in lower structure maintenance costs.

Additionally, tighter curves require lower expropriation costs to build the track.

2.2. Advantages of narrow-gauge networks

The main and most notable advantage associated with the development of a narrow-gauge network has already been mentioned in the previous section: lower construction and maintenance costs. Railway infrastructure is inherently rigid in terms of layout, as maintaining wheel-rail adhesion requires controlling maximum and minimum gradients. Being able to handle steeper gradients, as already mentioned, coupled with improved acceleration and braking capabilities, increases the layout flexibility in both plan and profile, thus reducing construction costs.

Additionally, given their lower maintenance costs, narrow-gauge networks are particularly suitable for developing countries, where infrastructure managers do not have the financial solvency to build and maintain a rail network with a multitude of tunnels and viaducts or bridges in difficult terrain.

In recent years, rail transport has proven to drive social and economic development, while also having environmental benefits (Blumenfeld et al., 2019), with entities such as the African Union promoting the strategic development of the continent’s railway network (African Union, 2019) through the creation of the African Continental Free Trade Area (AfCFTA).

2.3. Disadvantages of narrow-gauge networks

This document will attempt to analyse and respond to one of the main disadvantages of narrow-gauge networks: the lack of harmonisation between regulations and communication on best practices. These would help countries with increasingly fewer and degraded narrow-gauge networks to focus on development or maintenance to solve certain problems, thus creating freight and passenger transport lines capable of competing with other modes of transport, such as road and air.

One of the main drawbacks of narrow-gauge tracks is the pressure that the rolling stock exerts on the rails, which influences its load capacity, as well as the maximum track operating speed, which in turn limits the line's capacity due to slower train traffic (Saputro et al., 2020).

The most notable disadvantages of narrow-gauge tracks are:

- Limited availability of spare parts and special equipment, such as track equipment
- The machinery for superstructure and infrastructure construction must be adapted to the specific characteristics of the narrow-gauge
- A lack of standardisation in the design and construction of dual-track platforms (Gailienė et al., 2018)

In many African countries, railway networks and lines constructed during the imperialist era by colonising nations have deteriorated significantly, although there are exceptions, such as Eswatini (formerly known as Swaziland).

3. Historical context

3.1. Origin of narrow-gauge networks

In mines, where working space was minimal and the galleries had a horizontal geometry with sharp curves and numerous nooks and crannies, a means of transporting the loads adapted to these conditions was required, allowing for the efficient movement of large quantities of material with minimal effort. This is how narrow-gauge networks were conceived, as the mining hoppers were small, fitting to the geometry of the mining tunnels. The close arrangement of rails also enabled tight turns, which also reduced construction costs (Johnson, 2013).

This adaptation to difficult geometries and terrain, with steep slopes and abrupt changes in alignment, led to the extension of narrow-gauge use to terrain with complicated topology, where a standard or other type of gauge would have entailed a higher construction cost.

3.2. Development of narrow-gauge networks between the end of the 19th century and the beginning of the 20th century

The period from the late 19th century to the mid-20th century is known as the colonial era. Driven by the global industrial revolution, countries such as Spain, France, Portugal, England, Germany, Italy, the Netherlands, and Japan established colonies in various parts of the world, primarily on the African continent and in the Asia-Pacific region (Briones-Quiroz & Medel-Toro, 2010).

Most of the railway lines built during this period were narrow-gauge networks, due to the economic savings involved.

3.3. Historical context in Africa

The resources on the African continent spurred its colonisation by European countries, leading to a nearly complete occupation of Africa during this period. The large majority of continent was divided among Spain, France, Portugal, Italy, Germany, Belgium, Holland and Great Britain. The formal colonisation of Africa can be established as lasting from 1885 to 1957 (Wabgou, 2012), but the occupation ended up later on some of the countries.

Figure 5: Map of African colonies.
Source: El País

From a railway perspective, colonisation played a key role in the choice of gauge used for construction. Comparing Figure 5 with Figure 6, territories under French control opted for the metre gauge for their railway network development, while countries under British influence chose the 1067 mm gauge. This is evident in the current railway networks of Sierra Leone, Ivory Coast, or Nigeria.

In the British colonies, the South African leader Cecil Rhodes, Prime Minister of the Cape Colony from 1890 to 1896, played a crucial role (Ferro, 2000). Rhodes' vision was to create a railway line spanning the continent from South Africa to Egypt, both under British influence. Although, the line was never completed, its construction from South Africa northward influenced the choice of gauge in the countries through which the line ran (Institution of Civil Engineers, ICE). At the other end, Egypt also began construction of its 1067 mm line, connecting the cities of Luxor and Aswan, but due to the work being halted, the line was later converted to standard gauge (sinfín.net).

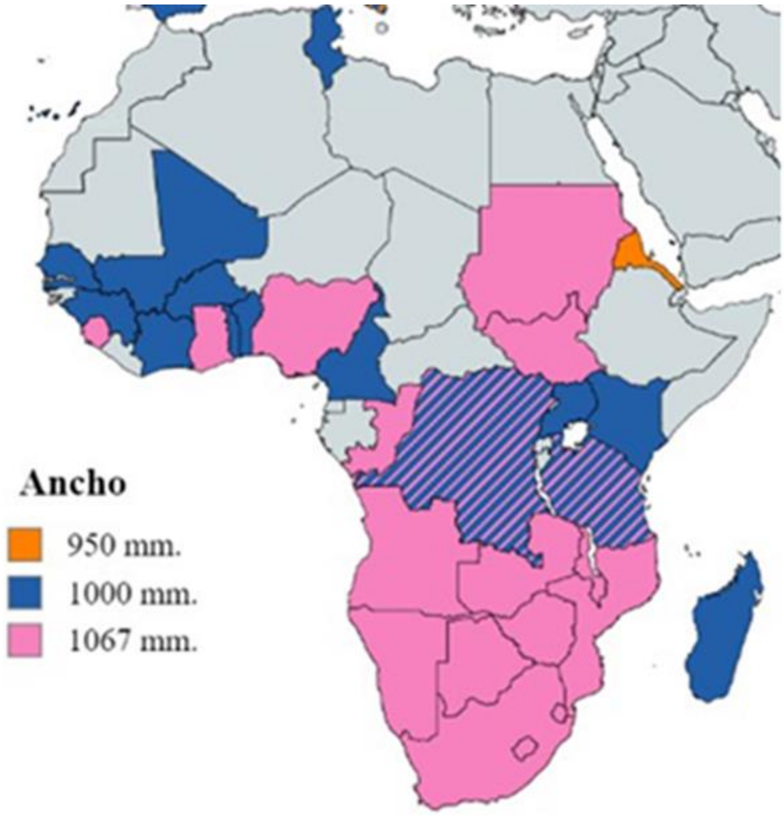

Figure 6: Map of narrow-gauge networks in Africa today.
Source: Own elaboration

Also noteworthy is the choice of gauge during railway construction in Ethiopia and present-day Eritrea. Being under Italian colonial control, they opted for the 950 mm gauge which was used for the Mediterranean country’s narrow-gauge network.

Table 1 below shows the construction dates of the narrow-gauge rail networks for the different African countries.

Country	1st date of construction & operation
Angola	1889
Benin	1906
Botswana	1896
Burkina Faso	1934
Cameroon	1902
Congo Republic	1934
Cote d'Ivore	1903
Democratic Republic of the congo	1910
Eritrea	1888
Ghana	1903
Guinea	1902
Lesotho	1905
Madagascar	1909
Malawi	1904
Mali	1923
Mozambique	1894
Namibia	1895
Nigeria	1898
Senegal	1885
Sierra Leone	1896
South Africa	1856
South Sudan	1961
Sudan	1875
Tanzania	1893
Togo	1905
Tunisia	1874
Uganda	1898
Zambia	1905
Zimbabwe	1897

Table 1 - Date of initial construction and operation of the railway network in each country. Source: Data from Bouraima et al. (2023), own elaboration

3.4. Historical context in the Asia-Pacific Region

Similar to the African continent, South Asia and the Pacific islands were also influenced by colonialism in their choice of rail gauge during the initial construction of their railway networks. Here, the greatest colonial presence also came from Great Britain, France, Portugal, Holland and Spain, among others (see Figure 7) (Wabgou, 2012).

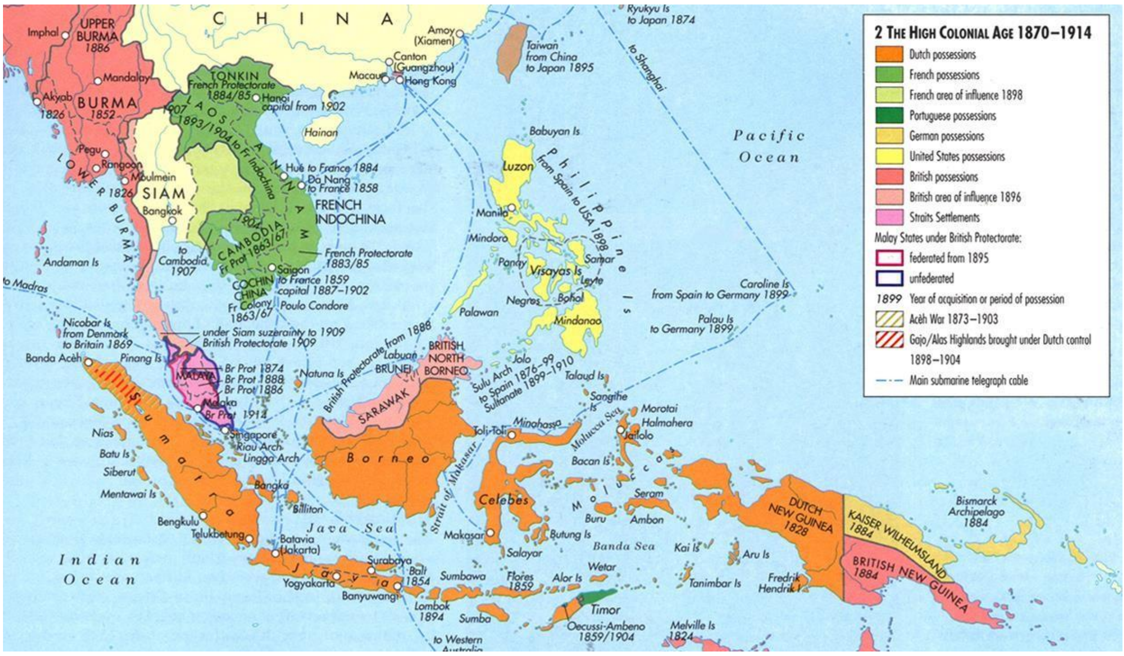

Figure 7: Map of Asian colonies.
Source: Princeton University

Figure 8 illustrates the countries that currently have a metre gauge or 1067 mm gauge network. Although territories such as present-day India, Bangladesh, and Myanmar were under the dominion of the British Empire, the metre gauge here was chosen, and not the 1067 mm gauge as in the case of the African colonies. In Vietnam, Cambodia, and Laos, who were under French control, the same gauge as in the French African colonies was used.

India presents a unique case. Despite having more than 15,000 kilometres of metre gauge network in 2000 (approximately 25% of its total network (Hearsch, 2000)), subsequent gauge conversions have effectively reduced the narrow-gauge network to zero. In 2014, according to the CIA World Factbook, only 1604 kilometres of the metre gauge network remained.

In Japan, although never being under British control or influence, the first railway line in the country, opened in 1872, was built by British engineers between the cities of Tokyo and Yokohama, which explains why Japan's current conventional network is built with a 1067-mm gauge (Britannica, 2014). Subsequently, during the Meiji Era restoration process, railway construction in Japan was expedited to enhance the nation's prosperity and military power (Kim, 2021).

Figure 8: Map of current narrow-gauge networks in the Asia-Pacific region.
Source: Own elaboration

During the Second World War, the Japanese invasion of certain areas of present-day Thailand and Myanmar led to the partial destruction of their railway networks. During that period, Japan undertook the reconstruction and rehabilitation of the affected network for military purposes. Additionally, an international line connecting the two countries was built using forced labour, resulting in the loss of many workers' lives (Thailand-Burma Railway Centre, 2022).

In Indonesia, its railway infrastructure was initially standard gauge, but, under Dutch control, this was changed to 1067 mm for economic reasons. During the Japanese occupation in World War II, much of the railway network across the islands was damaged by bombing, although some of it was later rebuilt by the Japanese (Al-Rasyid & Lubis, 2007).

Similar to other countries, in the Philippines, the 1067 mm gauge was chosen for economic reasons. Here, the development of the railway network was for improved sugar cane transport.

Australia offers one of the best examples of narrow-gauge network success today. From 1850 to 1901, Australia was divided into six separate colonial governments (New South

Wales, Tasmania, Western Australia, South Australia, Victoria, and Queensland), with each colony having a separate railway authority. Nowadays, the states with extensive narrow-gauge in Australia are Queensland, Tasmania and Western Australia and rest of Australia is extensive standard gauge and broad gauge.

3.5. Historical context at South America

Unlike Africa and Asia, South America did not experience a colonial period in the late 19th and early 20th centuries. The last Spanish territory in the Americas, present-day Cuba, gained independence in 1898. Consequently, the choice of gauge for railway infrastructure construction was not influenced by a colonial power, with each country with a narrow-gauge network today being independent when construction began. Here again, cost was the principal factor for choosing the narrow-gauge, although the topography of the individual Latin American countries was also of vital importance. For instance, Chile or Argentina have predominantly mountainous areas where the use of narrow-gauge was imperative to overcome steep slopes and gradients.

Consequently, railways in Latin America can be said to have reached maturity in the mid to late 19th century. However, the specific circumstances of each country make it difficult to establish a definitive time range. (Ficker, 2015).

In Central America and certain northern South American countries, railway networks were directly constructed with narrow-gauge tracks, while the gauge landscape is more mixed with the other South American countries. Nevertheless, most of the gauges initially chosen here were close to the Spanish Iberian gauge, which allowed the use of second-hand rolling stock from Spain (sinfín.net).

In countries like Colombia, the initial construction of the railway network was influenced by the individual states, these being sovereign over their own land. This led to the design of the lines without considering the technical specifications of the other states, until the narrow-gauge was established as a common construction policy throughout the country (Barón-Mora, 2014).

3.6. Historical context at Europe

On the European continent, the metre gauge networks of Spain, Switzerland, and Italy stand out, each with a different historical development and different reasons for choosing this type of gauge.

In the case of Spain, the narrow-gauge network is located in the north of the country, where the topography made the use of the narrow-gauge imperative, since using the Iberian gauge would have incurred prohibitive costs.

The Metre Gauge Network (RAM) line was built from the mid-19th century until the beginning of the 20th century. The main reason for its development was the economic activity in the area, which made it necessary to move large quantities of goods (coal, ore, wood, etc.) along the entire Cantabrian coast (Muñoz-Rubio et al., 2005). At first, the line's construction and administration were managed by private companies, with its management and operation later passing to the Spanish state.

In the Italian peninsula, the gauge chosen for the narrow-gauge network in the southern regions of the country was 950 mm, thereby becoming formally known as Italian gauge. It was also used in the African territories (Ethiopia and Eritrea) under Italian influence in the late 19th and early 20th centuries.

The Calabria region had the first such network in the country. Between 1910 and 1926, the Italian state entrusted the Società Italiana per le Strade Ferrate del Mediterraneo, a Milanese joint-stock company, with the concession for the construction and operation of the narrow-gauge railways of Basilicata and Calabria, to meet the local transport demand. In 1956, the network counted more than 760 kilometres in operation. Major railway accidents caused the concession to be revoked, and the lines were taken over by the reginal public administration (Ferrovie della Calabria).

The situation in Switzerland was similar to that of Spain and Italy. Due to the very mountainous landscape, railway construction was very expensive, leading to the construction and management of Swiss railway lines initially being entrusted to private companies. More than 400 million francs (approximately 453 million euros) were spent on this endeavour, and by 1863 Switzerland already had 1,300 kilometres of standard-gauge network. The metre gauge network was then used to complement the standard gauge network, particularly in areas with steep gradients (Suisse Romande).

4. Current situation

The extensive narrow-gauge networks across numerous countries, combined with their unique cultural contexts, current economic and political situations, and so on, result in a diverse array of narrow-gauge networks today. The primary use of narrow-gauge railways varies by continent, as follows:

- In Africa, railways focus on freight transport, with passenger transport less common. However, in countries with extensive networks, such as South Africa, railways are used for both freight and passenger transport.
- In the Asia-Pacific region, railways are more focused on passenger transport, although, some countries, like Vietnam, utilise their networks for both passenger and freight transport.
- In Europe and Latin America, rail is used for both passenger and freight transport.

Figure 9 shows a map of the countries that currently have narrow-gauge lines:

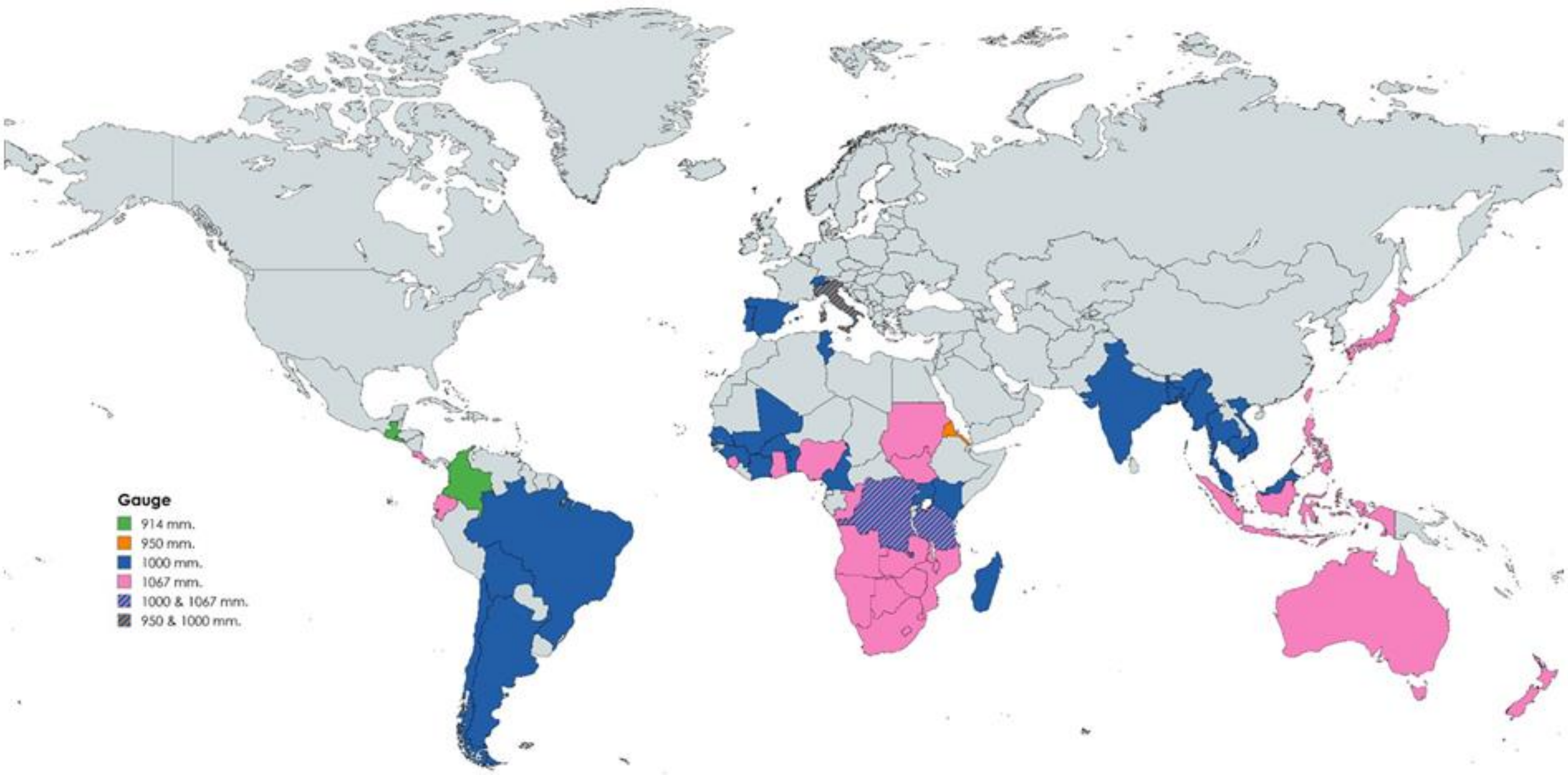

Figure 9: Countries with narrow-gauge networks.

Source: Own elaboration

4.1. Current state of narrow-gauge lines in Africa

The situation in Africa is very complex, with approximately 69,000 kilometres of narrow-gauge lines throughout the continent (CIA World Factbook). Table 2 shows the distribution of narrow-gauge line kilometres:

COUNTRY	GAUGE USED (mm)	LENGTH (km)	KILOMETERS ELECTRIFIED (km)	DATA FROM (Year)
Angola	1067	2638	0	2022
Benin	1000	438	0	2014
Botswana	1067	888	0	2014
Burkina Faso	1000	622	0	2014
Cameroon	1000	987	0	2014
Democratic Republic of Congo	1067//1000	3882//125	858//0	2014
Eritrea	950	306	0	2018
Eswatini/Swaziland	1067	301	0	2014
Ghana	1067	947	0	2022
Guinea	1000	807	0	2017
Cote d'Ivoire	1000	660	0	2008
Kenya	1000	3334	0	2018
Madagascar	1000	836	0	2018
Malawi	1067	767	0	2014
Mali	1067	593	0	2014
Mozambique	1067	4787	0	2014
Namibia	1067	2628	0	2014
Nigeria	1067	3505	0	2014
Republic of Congo	1067	510	0	2014

COUNTRY	GAUGE USED (mm)	LENGTH (km)	KILOMETERS ELECTRIFIED (km)	DATA FROM (Year)
Senegal	1000	906 (713)	0	2017
Sierra Leone	1067	458 (0)	0	2015
South Africa	1067	19756	8271	2014
South Sudan	1067	248 (0)	0	2018
Sudan	1067	5581	0	2014
Tanzania	1067//1000	969//2707	0//0	2022
Togo	1000	568	0	2014
Tunisia	1000//1435+1000	1694//8	65//0	2014
Uganda	1000	1244	0	2014
Zambia	1067	3126	0	2014
Zimbabwe	1067	3427	313	2014

Table 2 - Kilometres of narrow-gauge lines by country in the Africa region. Source: CIA World Factbook. Own elaboration

South Africa, with almost 20,000 kilometres of 1067 mm wide lines, has the largest network, with, because of this, some literature using the term "Cape Gauge" to refer to the 1067 mm gauge.

The state railway line maintenance varies significantly from country to country. In some cases, such as Eswatini, the network is well-maintained and capable of handling considerable volumes of freight traffic. The country's geographical location makes it a transit point, connecting the ports of Durban and Richards Bay, in South Africa, with the ports of Maputo and Matola, in Mozambique. Therefore, optimal infrastructure and safety conditions are essential for efficient freight rail operations. (Logistics Cluster, 2022).

In other countries, a lack of maintenance, coupled with high network renewal costs, have led to the complete closure or dismantling of the network, as in the case in Sierra Leone or South Sudan.

The operation and management of narrow-gauge railway lines in Africa are typically public and managed by individual countries, particularly regarding infrastructure. However, some lines linking two countries are operated by joint state authorities, such as the line connecting the port of Dar Es Salaam in Tanzania with the city of Kapiri Mposhi in Zambia. It is operated by the Tanzania-Zambia Railway Authority (TAZARA), making it a bi-national railway line.

There are also instances of private management and operation, such as the Nacala Logistic Corridor. This rail freight corridor connects the northern regions of Mozambique with the coastal gateway of the Nacala-à-Velha Port, and extends onward to Zambia.

In general, the state of maintenance of railway lines is poor, due to a lack of resources to maintain the infrastructure, leading vandalism security and security issues that hinder the operation of the line. To address this, countries such as Tunisia or Mali have conducted studies to efficiently manage their network maintenance, in order to reduce costs and avoid switching to a different gauge, such as the standard gauge.

There are international projects aiming to rehabilitate disused lines or sections, with one of the most notable being the Dakar-Bamako line rehabilitation project, carried out by the TYPSA company, which links the capitals of Senegal and Mali. This line was previously managed by the TRANSRAIL company, whose concession was revoked in 2016 due to poor management (The World Bank, 2019).

4.2. Current state of narrow-gauge lines in the Asia-Pacific region

In the Asia-Pacific region there are approximately 66,000 kilometres (CIA World Factbook) of narrow-gauge networks, with Table 2 providing further details by country.

COUNTRY	GAUGE USED (mm)	LENGTH (km)	KILOMETRES ELECTRIFIED (km)	DATA FROM (Year)
Australia	1067	18007	3448	2022
Bangladesh	1000	1801	0	2014
Cambodia	1000	642	0	2014
India	1000	1604	0	2014
Indonesia	1067	8159 (4816)	565	2014

COUNTRY	GAUGE USED (mm)	LENGTH (km)	KILOMETRES ELECTRIFIED (km)	DATA FROM (Year)
Japan	1067//1435+1067	22207//132	15430//132	2015
Malaysia	1000	1792	339	2014
Myanmar	1000	5031	0	2008
New Zealand	1067	4128	506	2018
Philippines	1067	745 (466)	0	2021
Taiwan	1067	1118	793	2018
Thailand	1000	4043	0	2017
Vietnam	1000//1435+1000	2169//253	0//0	2014

Table 3 - Kilometres of narrow-gauge lines by country in the Asia-Pacific region. Source: CIA World Factbook. Own elaboration

As the table shows, over 50% of the narrow-gauge kilometres in the Asia-Pacific region are located in Australia and Japan. These two countries not only have the most extensive networks but also boast the best-maintained narrow-gauge infrastructure globally, largely due to the amount of resources available to them.

The Asia-Pacific region is in a similar position to that of Africa, with lines closed due to poor maintenance, although this is generally better than on the African continent. Additionally, the topographic conditions of the area are unfavourable, with countries such as Bangladesh having a large number of rivers complicating railway line construction. This, coupled with extreme weather conditions at various times of the year (typhoons, tropical storms, etc.), means that these narrow-gauge networks may be rendered in-operational due to damage.

There is currently an ambitious international project underway related to narrow-gauge networks called ASEAN-RAILWAY, which includes Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Thailand and Vietnam. The goal of this project is to standardise and harmonise connectivity and interoperability between countries, with the aim of creating a common railway infrastructure among the participating countries and China. This initiative is expected to boost production and goods transport and could also facilitate the creation of "code-sharing" tickets for passengers.

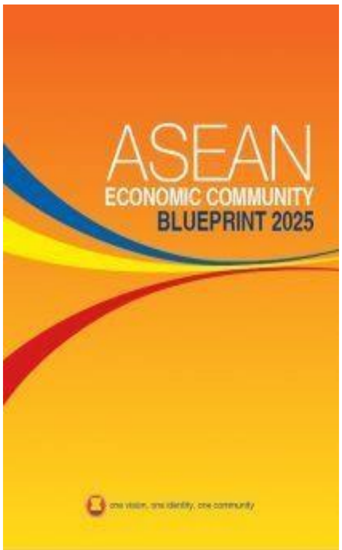

Figure 10: ASEAN Economic Blueprint, 2025

Another existing project is called UNIGAUGE, which aims to standardise the existing gauges in India. There are currently 4 of these, ranging between 610 mm, 762 mm, the metre gauge and 1,676 mm. Through the UNIGAUGE project, all metre gauge lines are being converted to 1676 mm gauge to facilitate maintenance work on the entire network.

The UNIGAUGE project was launched in 1992. The key statistics in India from 1970-2013 are as follows (Indian Railways Key Statistics (1970-2013)):

- 35,109 kilometres of lines with a gauge of 1,676 mm
- 23,238 kilometres of metre gauge
- 4,066 kilometres of 610 and 762 mm-wide lines

In 2022, with the gauge conversion project still in operation, the statistics showed that there were (Indian Railways Yearbook 2021-2022):

- 64,403 kilometres of lines with a 1,676 mm gauge
- 2,112 kilometres of metre gauge lines
- 1,588 kilometres of 610 mm and 762 mm wide lines

As seen above, the reduction in the number of existing metre gauge kilometres is significant, falling to just 10% of the kilometres recorded in 1971. Below is a graph depicting the annual decrease in kilometres from 1971 to 2022.

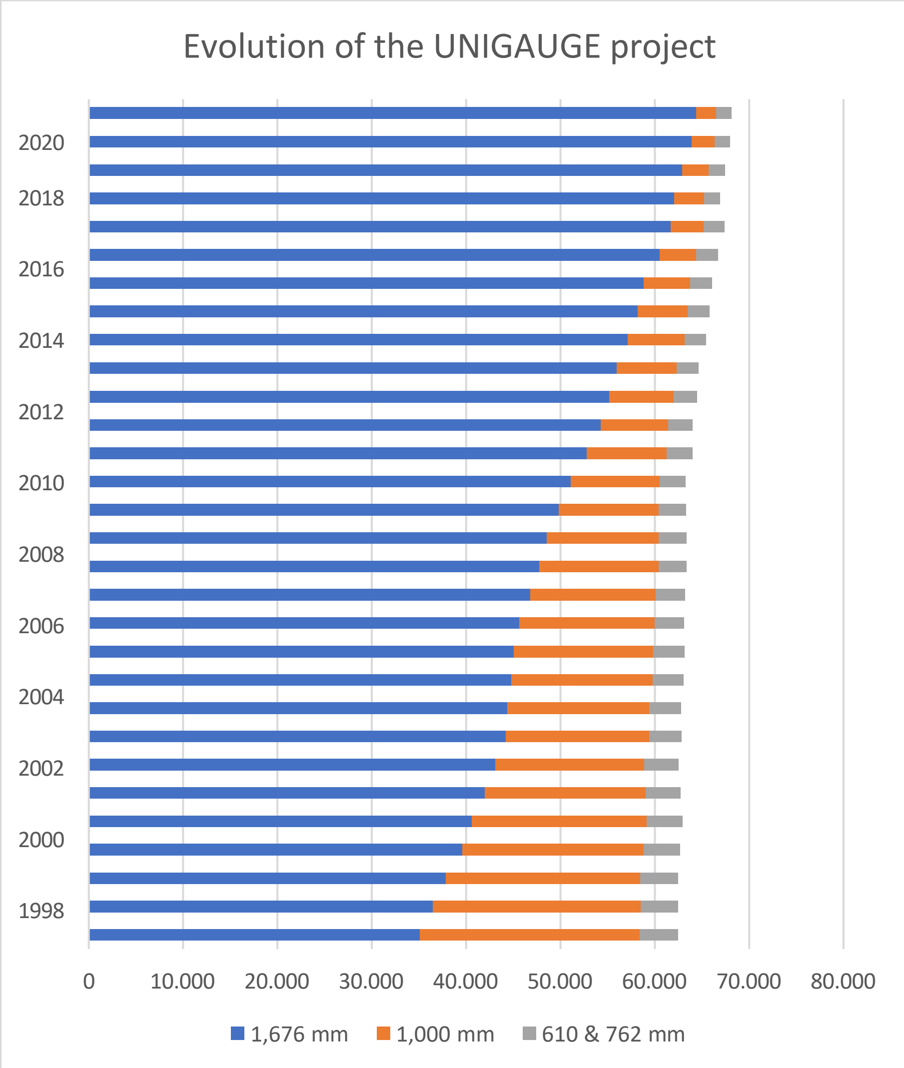

Figure 11: Progress of the UNIGAUGE project.

Source: Own elaboration

4.3. Current state of narrow-gauge lines in South America

There are approximately 40,000 kilometres (CIA World Factbook) of narrow-gauge networks in South America, with Table 4 providing further details by country.

COUNTRY	GAUGE USED (mm)	LENGTH (km)	KILOMETRES ELECTRIFIED (km)	DATA FROM (Year)
Argentina	1000	10800 (4800)	0	2019
Bolivia	1000	3960	0	2019
Brazil	1000//BROAD+1000	23341//492	24//0	2014
Chile	1000	3853	0	2014
Colombia	914	1991	0	2019
Costa Rica	1067	278	0	2014
Ecuador	1067	965	0	2022
Honduras	1067/914	279/420	0	2014

Table 4 - Kilometres of narrow-gauge lines by country in the South American region. Source: CIA World Factbook. Own elaboration

As the table shows, the majority of narrow-gauge kilometres are in Brazil. Moreover, its metre gauge network is not only the most extensive in the region, but also accounts for nearly 60% of the existing narrow-gauge kilometres on the continent.

In Argentina, the entire metre gauge network is known as the Ferrocarril General Belgrano (FCGB). It is the most extensive network in the country, connecting a significant portion of the northern and central regions. However, only 4,800 kilometres out of 10,800 km are operational (ADIFSE).

There are numerous projects aiming to comprehensively renovate the Belgrano line infrastructure in Argentina, especially in the urban area of Buenos Aires.

Colombia and Honduras use a gauge other than the metre and 1067 mm for their railway network, and is unique to South America. In Guatemala, this track gauge was also used for its railway network. Unfortunately, due to neglect and vandalism, rail traffic was interrupted in 2005 and the narrow-gauge network does not exist today (Logistics Cluster).

Narrow-gauge networks in South America are either managed and operated by public companies in some countries (ADIFSE in Argentina, ANTF in Brazil, MTOP in Ecuador, Ferrocarril Nacional de Honduras, etc.) or by private companies in other cases (Ferroviaria Andina and Ferroviaria Oriental in Bolivia).

In the case of Ecuador, the MTOP liquidated the public railway company (Ferrocarriles del Ecuador) in 2020 (La Hora, 2021), due to low profitability and accumulated losses. Today there is still no concessionaire for the railway network.

4.4. Current state of narrow-gauge lines in Europe

In Europe, in contrast to the rest of the regions analysed in this document, there are very few kilometres of narrow-gauge lines, with only 3 countries having developed networks, totalling approximately 4,000 kilometres (CIA World Factbook).

COUNTRY	GAUGE USED (mm)	LENGTH (km)	KILOMETRES ELECTRIFIED (km)	DATA FROM (Year)
Italy	950	1289	151	2020
Spain	1000	1193,4	374,6	2022
Switzerland	1000	1312	1312	2011

Table 5 - Kilometres of narrow-gauge lines by country in Europe region. Source: CIA World Factbook. Own elaboration

Of these three countries, only in Spain is the narrow-gauge network administered by the national administrative body, while in the case of Switzerland and Italy, the regional administrations are in charge of the respective narrow-gauge networks. No private companies are involved in these endeavours.

The Spanish metre gauge network is located mainly in the north of the country, given the region's difficult topography. The infrastructure manager is the Administrador de Infraestructuras Ferroviarias (ADIF), and the network is operated by the Spanish National Railway Network (RENFE). It currently serves both freight and passenger transport, although its principal focus is passengers.

In Italy, the 950 mm narrow-gauge network is located in the southern regions of the country and on the island of Sardinia, and its main function is to connect the standard gauge network to improve access for the entire population. It is managed and operated by different regional companies, such as Ferrovie della Calabria, in the southern region of Calabria, and Ferrovie della Sardegna, on the island of Sardinia.

Switzerland's metre gauge network is very similar to Italy's, where it serves to complement the almost 4000 kilometre standard-gauge network, and to allow greater railway access. Much of Switzerland's metre gauge network is in the eastern part of the country, but lines can be found throughout. As in Italy, there are several regional public undertakings responsible for managing and operating the metre gauge lines, the largest of which is Rhätische Bahn (RhB).

Since narrow-gauge use is limited to these three countries in Europe, and all new lines are built using other gauges (such as the standard gauge), European regulations do not include the narrow-gauge in their legislative scope (for further details see 6.4 “Examples of normative documents”).

5. Questionnaire for countries with narrow-gauge networks and lines

As part of this study, and to obtain information related to the narrow-gauge networks in different countries, a questionnaire was shared asking about certain aspects related to the main characteristics that define the railway infrastructure. The questionnaire took approximately 15 minutes and consisted of a total of 22 questions.

Once the relevant questions were defined, the questionnaire was sent through the UIC communication channels to all countries with narrow-gauge networks. As of 25 June 2024, a total of 12 responses had been received. By UIC region, the responses were:

- Five in the Africa region
  - Angola, Sudan, Burkina Faso, Tunisia and South Africa
- Four in the Asia-Pacific region
  - The Philippines, Vietnam, Malaysia and India
- Two from the Latin America region
  - Argentina and Chile
- One from the Europe region
  - Portugal

This section provides an analysis of the questions which were considered most representative, as well as the responses obtained in each case.

Note: Certain questions allowed more than one answer per country, such as the actions carried out in the last and next 10 years, so the aggregate number of responses may be greater than the number of countries that responded to the questionnaire.

5.1. Actions carried out in the last ten years on the narrow-gauge network

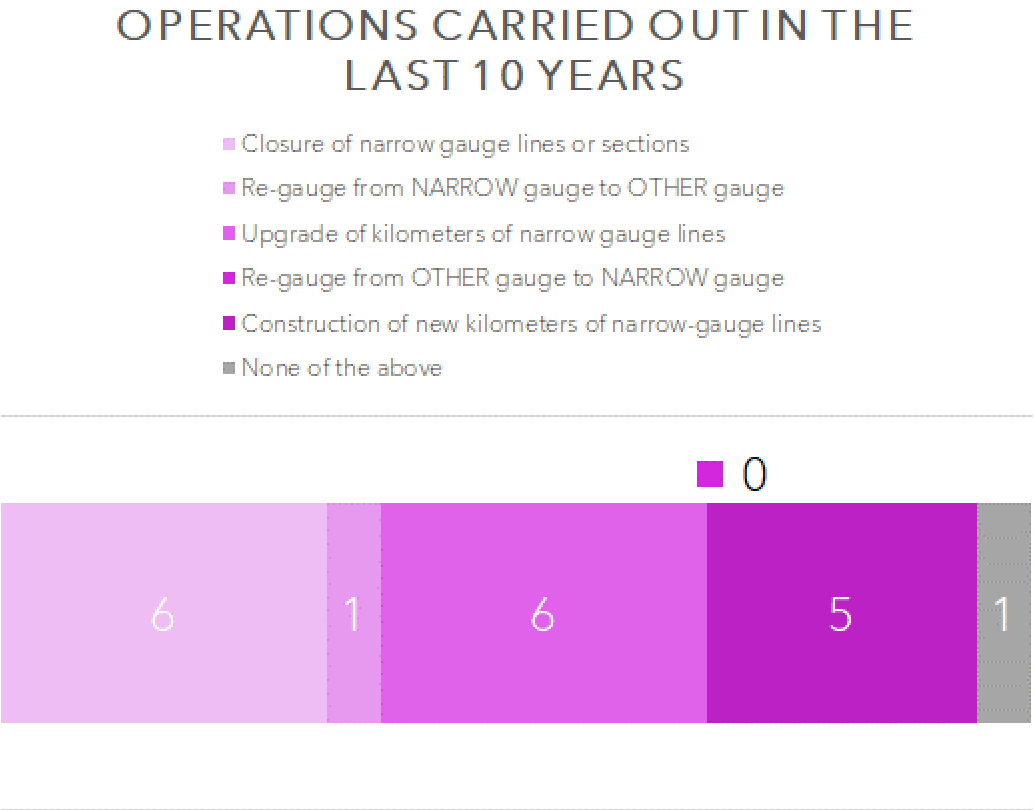

Figure 12: Operations carried out in the last 10 years.

Source: Own elaboration

The answers obtained on the actions carried out in the last 10 years on the narrow-gauge network of the respective country are shown in Figure 12. It can be seen that these mainly consist of renovating existing narrow-gauge lines and adding kilometres, with 13 actions of this type being recorded.

On the other hand, six actions consisted of closing narrow-gauge lines, with a single action to change the gauge from narrow to a different type. This was carried out in India as part of the UNIGAUGE project (see 4.2), which seeks to standardise the rail gauge throughout the country.

5.2. Actions planned over the next ten years on the narrow-gauge network

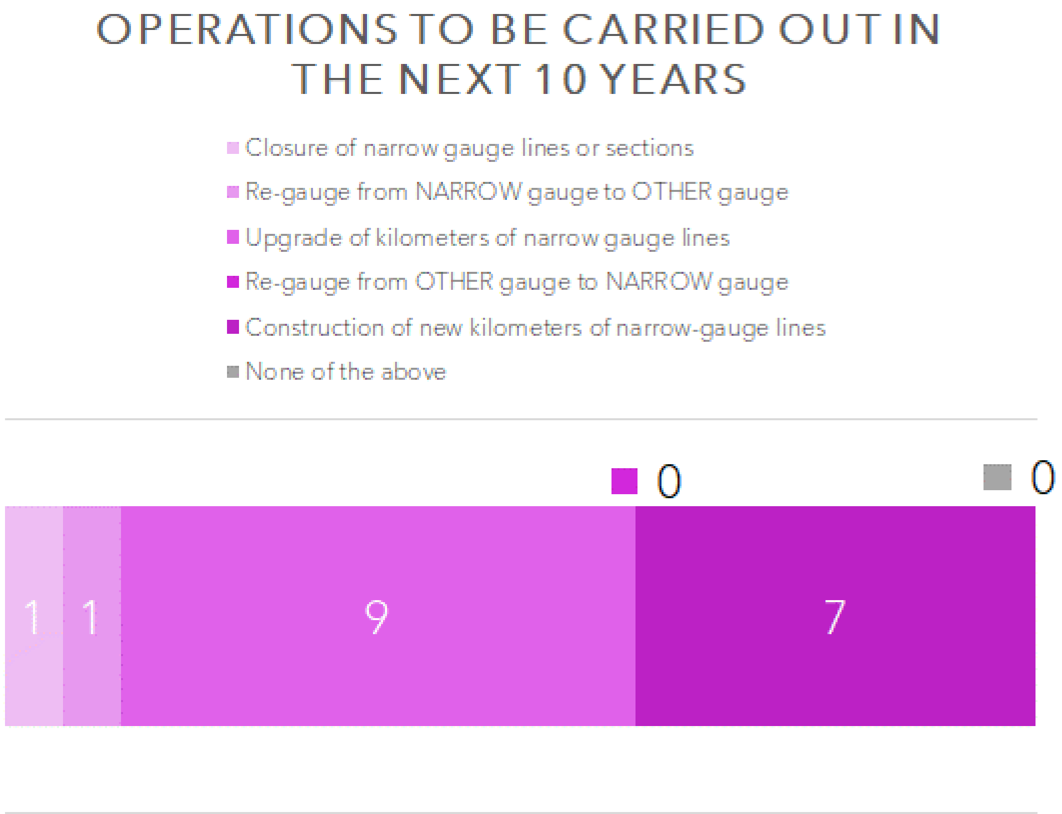

Figure 13: Operations to be carried out in the next 10 years.

Source: Own elaboration

Once again, when asked about the actions planned over the next ten years, most of the plans involved improving the existing kilometres and building new narrow-gauge sections, with a total of 16 planned actions. In contrast, there were only two involving line closures, taking place in Argentina, and one to change from a narrow-gauge to another type, again in line with the UNIGAUGE project in India.

From the two figures analysed, it should be noted that none of the cases consider it feasible to transition from a different track gauge to the narrow-gauge.

5.3. Origin of the standards used in the narrow-network

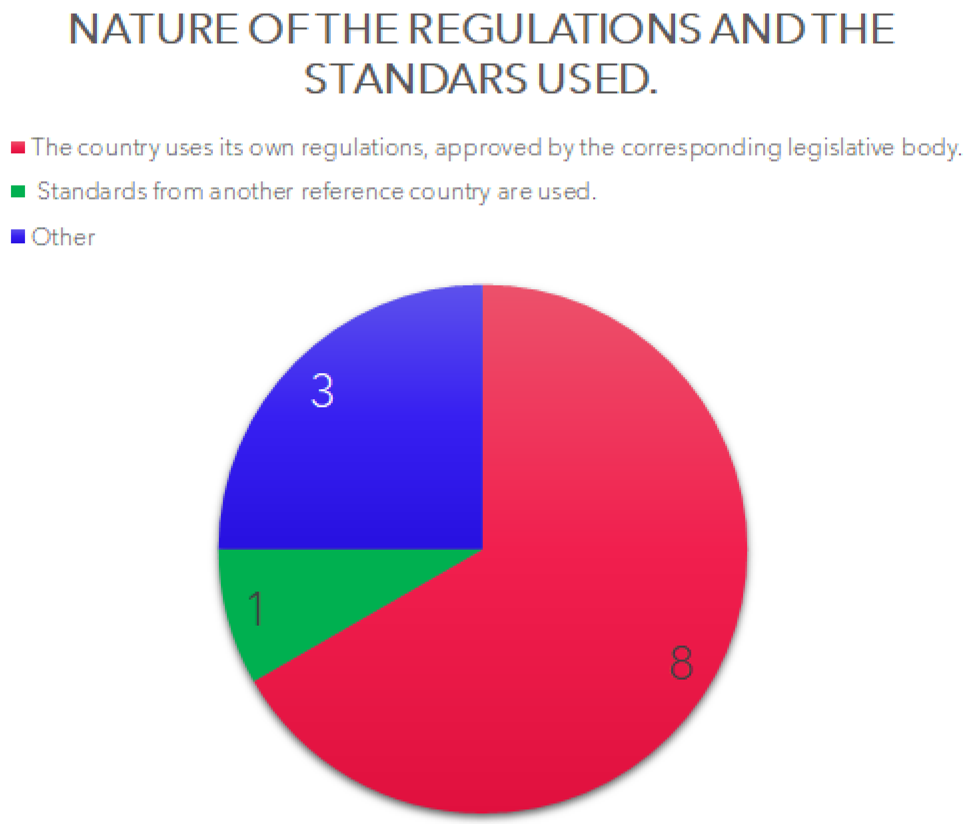

Figure 14: Nature of the regulations and the standards used.

Source: Own elaboration

One of the narrow-gauge's main problems is the lack of standardised regulations for construction, maintenance, renewal, and so on.

This question reflects the nature of the regulations used by the participating countries. As can be seen, nearly 75% of the countries use their own regulations, which have been approved and drafted by the corresponding legislative body. Only one country, Angola, uses Portuguese regulations to maintain and build its narrow-gauge lines.

The countries that responded "Other" use different method to regulate the construction, maintenance, etc. of their narrow-gauge networks. The regulatory section of this document provides detailed analysis of this question (see 6.2), giving a more specific overview of the responses received.

5.4. Maintenance of the narrow-gauge network

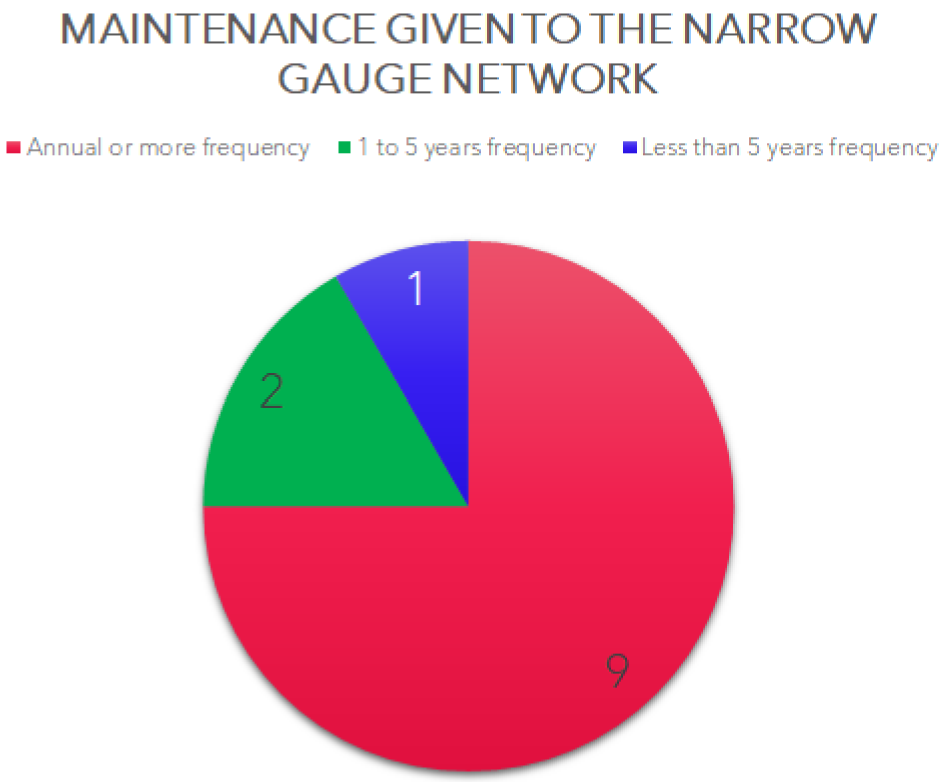

Figure 15: Maintenance of the narrow-gauge network.

Source: Own elaboration

The maintenance[1] status of the network and the maintenance frequency are crucial for providing an idea of the condition of the infrastructure. The higher the maintenance frequency, the sooner a problem can be detected and corrected with simple operations. If the maintenance frequency is low, simple problems can evolve into critical failures that lead to major rail traffic disruptions.

When asked this question, 75% of the countries responded that they perform maintenance on their narrow-gauge network with an annual frequency or more, while three countries perform maintenance with a frequency of less than one year, and only one of the countries was recorded performing network maintenance with a frequency of less than 5 years.

[1] Maintenance is understood as any action of auscultation/inspection/measurement of the track or any of its parameters, being subsequently carried out the necessary interventions/operations to fix or avoid any flaws or deflects.

5.5. Most commonly used material for sleepers

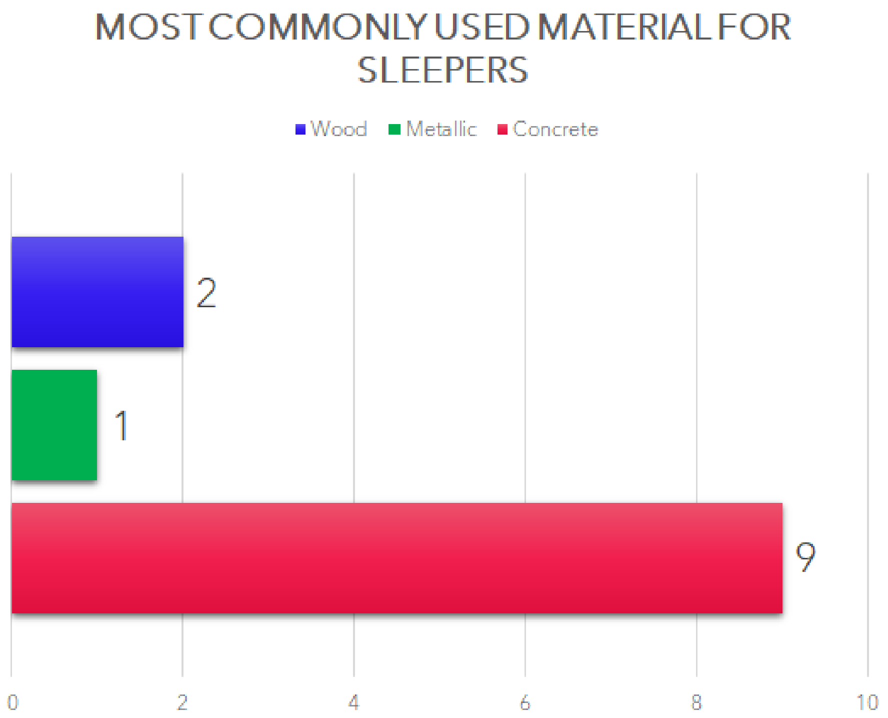

Figure 16: Most commonly used material for sleepers.

Source: Own elaboration

Sleepers are defined as the wooden, concrete or metal support elements on which the rails are bedded, linking the rails and ballast. It has two functions: to maintain the rail spacing (i.e., the track gauge) and to transmit the stresses it receives to the underlying ballast.

The sleeper material plays a critical role on the maintenance, as well as service life of the sleeper. Concrete sleepers are more expensive than wooden sleepers, but have a higher performance, as well as requiring considerably less maintenance. Metal sleepers are currently the least used sleepers.

In the questionnaire, of the twelve countries that responded, nine of them primarily use concrete sleepers in their narrow-gauge networks, while two of them mainly use wooden sleepers, with only one using metal.

5.6. Most commonly used signalling systema

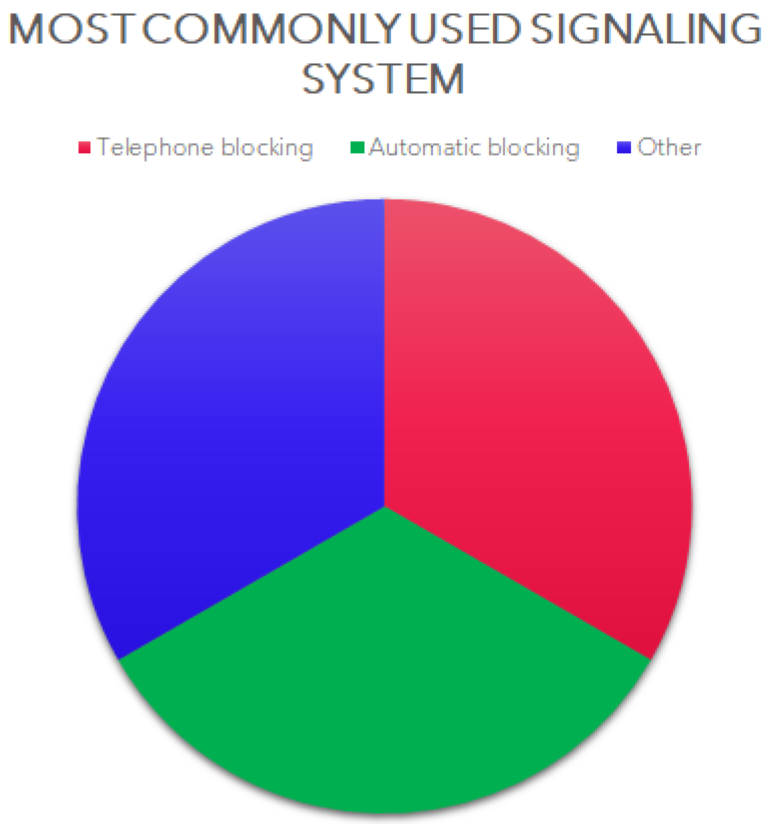

Figure 17: Most commonly used signalling system.

Source: Own elaboration

Finally, the questionnaire asked about the most commonly used signalling system on a country's narrow-gauge network. The responses were equally divided between the two main signalling systems, telephone blocking and automatic blocking, as well as "other". There were therefore four responses from countries that use other types of signalling systems, such as the fixed block system used in the Philippines, or track warrant control, similar to direct traffic control, which is used in Chile.

6. Regulations

6.1. Introduction

The purpose of this section is to provide an overview of the regulations governing the construction and maintenance of narrow-gauge network infrastructure worldwide.

As a rule, except in certain countries in Africa (such as South Africa, Mozambique, and Eswatini), Asia (such as Cambodia, Vietnam, and Malaysia) and Latin America (including Argentina, Brazil, Chile), narrow-gauge networks are isolated, with no connection to adjacent countries. This is especially the case in Europe for Spain, Switzerland, and Italy. It can therefore be concluded that narrow-gauge networks are not interoperable between countries.

For this reason, these networks also tend to be less well maintained, and have lower admissible loads and lower maximum speeds than standard or other gauge lines. This, in addition to the age of the infrastructure (especially in European countries where it is rare to construct new narrow-gauge lines), means that less research is carried out, which prevents the development of new techniques and technologies applicable to narrow-gauge, and leads to the regulations being less solid and advanced.

6.2. Detailed analysis of the questionnaire's regulatory question

One of the questions in the survey concerned the nature and origin of the narrow-gauge regulations in the participating countries, with eight having their own narrow-gauge regulations, drafted and approved by the respective legislative and technical bodies. These countries are Burkina Faso, South Africa, Tunisia, Sudan, Vietnam, India, Argentina, and Portugal.

On the other hand, only Angola uses regulations not drafted by its own agencies, thus making use of a foreign country's consolidated regulations. There are also three countries, Chile, the Philippines and Malaysia, which use other means to regulate the construction, maintenance, and so on of their narrow-gauge networks.

This question was followed by the request to summarise the main characteristics and situations dealt with in the infrastructure and superstructure regulations. In general, the answers were similar among all the countries, with a few special cases.

The option was then provided to list regulatory aspects or characteristics that are not included in each country. As this was an optional question, not all countries responded. The most notable responses were those of Burkina Faso, whose regulations do not include aspects of interoperability; Tunisia, where the regulations do not include intruder detection in the infrastructure, or the measurement of rail temperatures; and Portugal, where the regulations do not reflect the possible interferences or incidents that the catenary may have with the rolling stock.

6.3. General structure of a regulatory body

Generally speaking, for a narrow-gauge regulatory body to be considered complete, its documents must cover the following fields, at a minimum:

- **Components:** All components that make up the infrastructure and superstructure of the line must be standardised and compatible with each other. Compatibility studies should be carried out between the different components. Table 9 shows an example of the sleepers standardised in Spain and their compatibility with the different types of UIC-standardised rails.
- **Section and gauge:** The type of section for different track configurations, whether single track, double track or other types of track configuration, should be standard. Measurements, such as the distance between track centres (if there is more than one), the distance from the track centre to enclosure, the slope gradient, the thickness of the ballast and sub-ballast layers, among others, should be taken into account. A standard section is closely related to the gauge of a line, which must be defined so that rolling stock can always operate in safe conditions, leaving sufficient margins.
- **Track alignment:** Standards should be followed for a track alignment design that meets safety and comfort criteria, in the case of passenger lines. Proposed reference values can be taken from relevant studies performed, as well as from old standards that have demonstrated sufficient effectiveness with their design parameters. Examples of design values for metre gauge lines in Spain are shown in Table 6 & Table 8.
- **Construction:** Although the construction method for a new line may vary from one area to another, depending especially on the resources, both mechanical and human, that are available, studies should be carried out that to the greatest possible extent standardise certain construction techniques, such as the conditions under which ballast can be concreted or spread, and so on.

- **Maintenance criteria:** Maintenance plays a vital role in railway lines, since a proper monitoring and maintenance process can help prevent problems and failures. There are different maintenance methods, including cyclic methods, by indicator, etc., that vary when establishing minimum tolerances. Maintenance plans should always be meticulously studied to be as effective as possible.
- **Geometric qualities of the infrastructure:** This is related to maintenance. They should always be above the minimum tolerances established in the maintenance plans of the lines. In the event that the geometric tolerances are below those established in the maintenance plans, the necessary action, ordinary or extraordinary, must be taken to return the line to a sufficient state of operation.

6.4. Examples of normative documents

This section provides specific examples of European regulations, drafted and approved by the European Railway Agency (ERA), as well as the Spanish and Japanese metre gauge network regulations.

6.4.1. ERA and TSIs

ERA is a European body in charge of integrating the rail networks of all European countries. Since 2006, it has been in charge of working together with the railway sector, national authorities, institutions, and so on, in order to develop technical standards and safety measures, and define targets. As part of its functions, ERA is the body responsible for drafting the Technical Specifications for Interoperability (TSI), which are mandatory standards for railway systems in all member countries of the European Union.

Nevertheless, given the particularities of the narrow-gauge network, exceptions are provided for. For example, in the Infrastructure and Energy TSIs, the scope of application of the respective standards state:

"The TSI shall apply to networks with the following nominal track gauges: 1 435 mm, 1 520 mm, 1 524 mm, 1 600 mm and 1 668 mm.

“6. ***Metre gauge is excluded from the technical scope of this TSI. [...]"***

In other words, none of the normative documents proposed by ERA apply to the metre gauge or any narrower-than-standard gauge. This is due to the location of the narrow-gauge networks in Europe, which, as previously stated, are isolated with no international connections (except for Italy and Switzerland, where there is a single section of metre-gauge line connecting the two countries). It is therefore up to the countries with narrow-gauge networks to draw up their own regulatory documents.

6.4.2. Spain

In Spain, the Administrador de Infraestructuras Ferroviarias (ADIF) has its own regulations, which are published on its website for public consultation (https://www.adif.es/empresas-contratacion/normativa-tecnica). However, it does not exempt it from complying with the requirements established both by the competent Ministry and the European TSIs, which are transposed into Spanish legislation.

Three different rail gauges are currently in use in Spain (metre, Iberian and standard). The metre-gauge network is located in the north of the country and is mainly focused on passenger transport. As there are three different gauges, there are particularities, which are provided for in most of the regulations. For example, specific values are given for standard and Iberian gauges, and these are entirely different from the values proposed for metre gauge lines.

The main explanation for this is the origin of the metre gauge network in Spain. Until 2012, it was operated and managed by Ferrocarriles Españoles de Vía Estrecha (FEVE) which carried out the same functions for the metre gauge network as RENFE did for the others.

In 2012, when the line's administration and operation were separated, ADIF began to manage the entire railway infrastructure, and RENFE began to manage freight and passenger transport on the entire metre gauge network previously operated by FEVE, which had closed that same year.

When the values and characteristics of the three very different gauges had to be grouped into a common standard, those included in the FEVE standards were incorporated by ADIF. This means that certain FEVE regulations from the year 2000 are still in force.

Below are several examples of ADIF regulations where specific values for the metre gauge are shown, which are different to those proposed for the Iberian and standard gauges.

6.4.2.1. Acceleration

Acceleration due to superelevation deficiency (m2/s)					
Speed (km/h)			Minimum	Normal	Exceptional
	v <	230	0,65	1,00	1,00
230	< v <	300	0,52	0,85	1,00
300	< v <	350	0,39	0,52	0,65

NAP 1-2-1.0

Table 6 - Acceleration due to superelevation deficiency for Iberian and UIC gauge (m²/s). NAP 1-2-1.0

Acceleration due to superelevation deficiency for metric gauge (m2/s)		
Minimum	Normal	Exceptional
0,65	0,85	1,00

NAP 1-2-1.0

Table 7 - Acceleration due to superelevation deficiency for metre gauge (m²/s). NAP 1-2-1.0

As can be seen, the metre gauge values are independent of the line operating speed, while the values proposed for the standard and Iberian gauges do depend on this. These values are given in policy document NAP 1-2-1.0.

NAP 1-2-1.0	Maximum vertical acceleration in vertical curves (m2/s)			
	Reference	Normal	Exceptional	
			Convex	Concave
V < 220 km/h	0,22	0,31	0,51	0,59
V ≥ 220 km/h		0,44		

Table 8 - Maximum vertical acceleration in vertical curves for the Iberian and UIC gauges (m²/s). NAP 1-2- 1.0

Máximum vertical acceleration in vertical curves for metric gauge (m2/s)			
Reference	Normal	Exceptional	
		Convex	Concave
0,22	0,3	0,35	0,40

NAP 1-2-1.0

Table 9 - Maximum vertical acceleration in vertical curves for the metre gauge (m²/s). NAP 1-2-1.0

6.4.2.2. Types of sleepers

As in 6.4.2.1, the values proposed for the metre gauge do not depend on speed, while those proposed for the Iberian and standard gauges are different for speeds greater or less than 220 km/h. These values are also found in the NAP 1-2-1.0 standard.

ET 03.360.571.8

Type of sleeper	Gauge	Type of rail
MR	1.668	54E1/60E1
PR	1.435 ó 1.668	54E1/60E1
AI	1.435	60E1
AE	1.435	60E1
AM	1.435 y 1.668	54E1/60E1
SR	1.435 y 1.668	54E1/60E1
SI	1.435 y 1.668	54E1/60E1
MM	1.000	45E3 /54E1
RP	1.435 ó 1.668	54E1/60E1
RM	1.000	45E3/54E1
MA	1.000, 1.435 y 1.668	
TR	1.435 ó 1.668	54E1/60E1
TM	1.435 y 1.668	54E1/60E1

Table 10 - Types of sleepers.
ET 03.360.571.8

Table 10 shows all of the currently standardised sleepers in Spain. As can be seen, there are specific sleepers for the metre gauge, such as the MM and RM, and there is a type of sleeper, the MA, which in turn allows a mixed gauge of metre with standard and Iberian.

6.4.2.3. Size of the ballast

For ballast sizing in Spain, there is the Order FOM/1631/2015 standard. Within the scope of application of this document, the following is established:

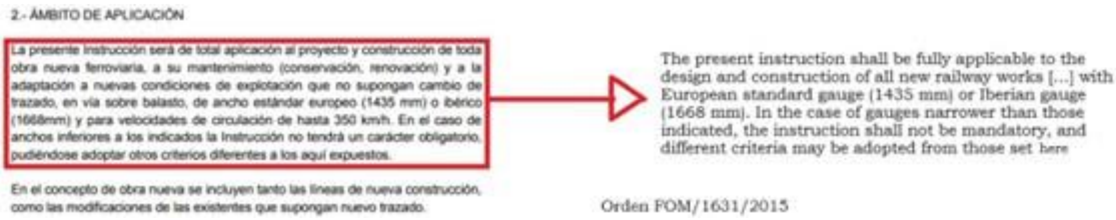

Figure 18: Scope of application from FOM/1631/2015

In other words, as is the case with the TSIs, this standard is not mandatory for the ballast of metre gauge lines, and other types may be used, with criteria and sizing parameters different from those given in Order FOM/1631/2015. Here, for the ballast and sub-ballast of a metre gauge line in Spain, the NFI Track 002 standard, drafted in 1999 by FEVE, would be used.

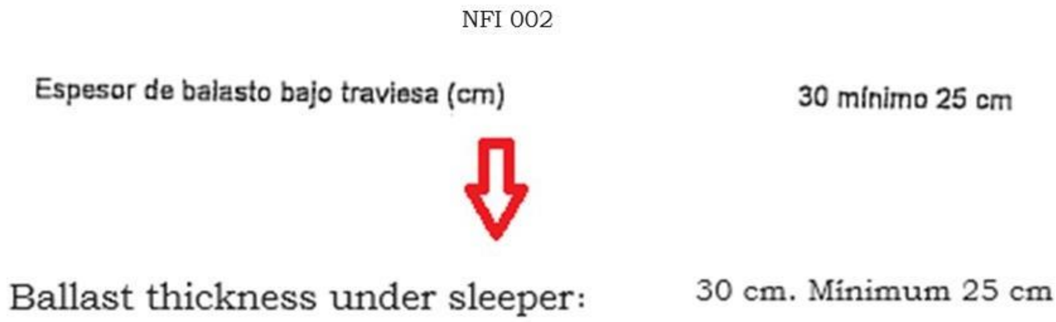

Figure 19: Ballast thickness under sleeper.
NFI 002

6.4.3. Japan

Japan's conventional rail network consists entirely of 1067 mm gauge lines, forming an extensive network of more than 22,000 kilometres long that extends throughout the country, connecting the entire territory (CIA World Factbook, 2015).

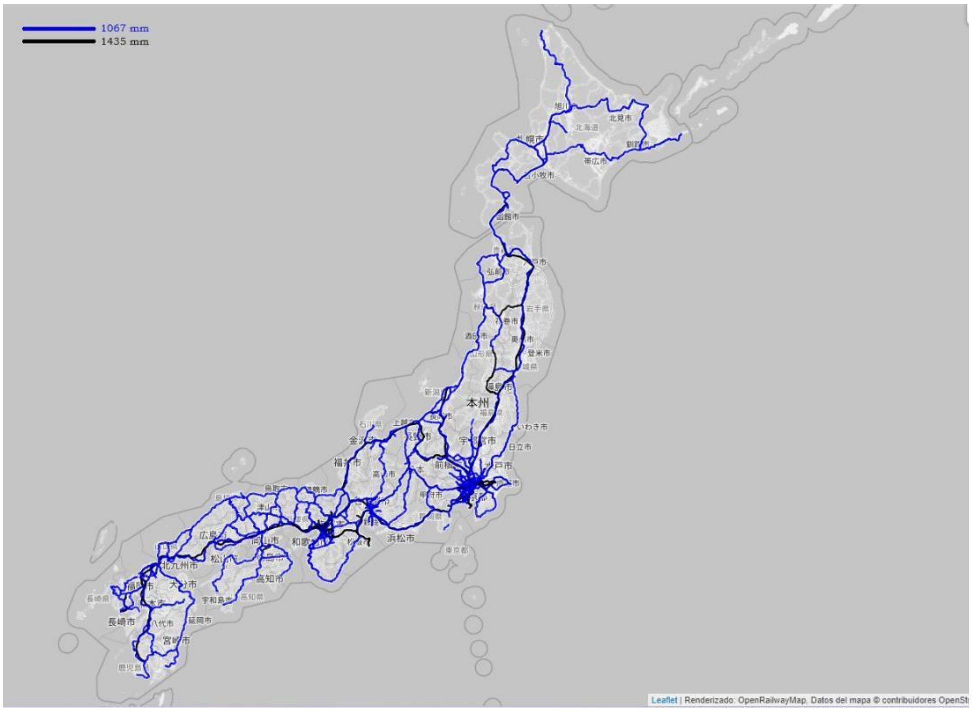

Figure 20: Japan railway network.
Source: OpenRailwayMap

Japan's railway lines are privately operated, with a large part of the narrow-gauge network being managed by the Japan Railways (JR) Group, a product of the privatisation of the public company Japan National Railway (JNR). The JR Group is divided into several areas operated by companies belonging to the JR Group. On the main island of the Japanese archipelago, JR East, JR Central and JR West operate. In addition, on the islands of Hokkaido, Shikoku, and Kyushu, the companies JR Hokkaido, JR Shikoku, and JR Kyushu operate.

In the area around Tokyo, JR East manages most of the former JNR tracks, with the exception of the Tōkaidō Shinkansen operated by JR Central, and the freight-only tracks operated by JR Freight (JRF, which also has operating rights to some JR East lines).

JR East's narrow-gauge commuter lines use track infrastructure that closely resembles that of the Shinkansen, with 50 kg or 60 kg of rails with 200 m long sections continuously welded together. This configuration helps minimise noise and infrastructure maintenance, and increases reliability and passenger comfort ("JR East Takes Measures to Create Better Environment along Railway Lines," 2008).

The infrastructure is mostly ballast with concrete sleepers, although wooden sleepers can be found on some parts of the network. Operating speeds can reach up to 130 km/h depending on the line and the rolling stock used.

To reduce maintenance, in 1997, JR developed a type of low-maintenance ballasted infrastructure called the "TC Type Low-Maintenance Track", which uses 400 mm wide concrete sleepers on 750 mm centres instead of the 240 mm sleepers previously used. The spacing between sleepers is 350 mm. This improves the load distribution as well as sleeper and rail support, reducing the need for rail realignment and maintenance due to wear and tear (Murao & Aihara, 2005).

In 2002, JR began to implement new electronically controlled switching devices (ES-type point machines) with remote monitoring capability. They subsequently developed an improved version (ESII-type) with enhanced water and lightning resistance, adapted for AC-powered lines. These devices replaced the older "NS-type" relay-controlled switching devices (Obata et al., 2010).

JR also introduced next-generation 2000-type switches with an improved design to more accurately hold the needles, reducing the likelihood of foreign objects clogging them and reducing the need for lubrication and adjustment (Izumi et al., 2009).

Near Tokyo, the majority of rails are double track, with some double lines being used for local and express trains. The separation between tracks varies from 3.5 to 4 meters between the centrelines.

7. Identifying problems, proposed solutions, and conclusions

7.1. Main problems arising from having a narrow-gauge

At an online UIC meeting held on 30 April 2024, with railway experts from different UIC member countries attending, a variety of problems related to narrow-gauge were discussed. While many of the challenges affect narrow-gauge networks, they are not inherently caused by the track gauge itself. Instead, they stem from other factors unrelated to gauge. The most significant of these issues are outlined and explained below.

7.1.1. Lack of maintenance and resources

The main problem identified at this meeting was the lack of maintenance and human, material, and financial resources. This is especially the case for the countries in the Africa region. Although it's true that specialized maintenance machines for narrow-gauge railways are less common – due to the relatively limited global extent of narrow-gauge networks – human labour and financial resources required for maintenance are not inherently dependent on the track gauge.

Given the insufficient economic resources for proper maintenance of the railway networks in many African countries, transitioning to standard gauge is currently unfeasible. The main problem, therefore, is the lack of resources and manpower, and should therefore be the primary focus of development efforts in these regions.

Stemming from the broader issue of inadequate maintenance, the question of when, how and what to maintain naturally arises, due to the lack of clear regulations governing the maintenance practices of narrow-gauge railway networks.

In certain countries, studies have been carried out to decide whether it is worthwhile to switch from the narrow to standard gauge, with it being concluded that maintaining the current infrastructure is the priority, and that resources must be secured to keep the current networks in the best possible condition.

7.1.2. Maintaining rolling stock

Although rolling stock operates with a degree of independence from rail infrastructure, it is inherently constrained by the rail gauge, which determines the types of vehicles that can run on a given network. Since most of the world's rail tracks are built according to standard gauge, both rolling stock and maintenance facilities are commonly found.

In contrast, narrow-gauge railways, having less lines, often lack the same level of infrastructure and resources for maintaining rolling stock. This leads to rolling stock deterioration and eventually resulting in significant mechanical failures, requiring the vehicle to be immobilised until it is properly repaired. Here, these challenges are not due to any technical limitations of the narrow-gauge itself, as the issue stems more from the economic resources available.

7.1.3. Cost of acquisition

This problem occurs due to both infrastructure and rolling stock maintenance issues. Infrastructure maintenance is complicated, as the lack of specific machinery for maintenance drives up acquisition costs.

Therefore, a key objective should be to lower the costs associated with acquiring spare parts, infrastructure components, and the specialised machinery required for maintenance to ensure the reliable operation of the railway network.

7.1.4. Research and technological development capacity

Research is a fundamental driver of technological advancement in any field, in this case narrow-gauge railways. The greater the research and development capacity, the better the chances are of technological innovations emerging, leading to more efficient and sustainable railway services.

However, in the case of narrow-gauge networks, especially in African countries, the research and development of technology is constrained by limited financial and technical resources. Therefore, almost all available resources are directed towards maintaining the railway networks to prevent service disruptions.

On the other hand, in countries like Japan, where sufficient economic and human resources are available, technologies and techniques for maintenance and construction are being developed and researched to make the networks more efficient and sustainable.

Collaboration in research, both academic and technological, between countries with economic resources, along with the subsequent dissemination of findings to amplify the impact of the developed techniques, may be the solution to supporting the technological development capacity of countries lacking sufficient resources. Therefore, sharing studies and research on narrow-gauge construction and maintenance techniques to improve networks should be a priority.

7.1.5. Interoperability

Just as the main problem facing railway networks in African countries is maintenance and the lack of resources to carry out the necessary work, the biggest challenge for networks in the Asia-Pacific region is interoperability between the different narrow-gauge networks. As mentioned earlier in this document, there are initiatives such as the ASEAN Railway project, whose aim to harmonise all of the necessary mechanisms to make the countries' networks interoperable.

7.1.6. Vandalism and theft

Vandalism and theft of railway material, especially in the Latin American or African networks, have a severely negative impact on the proper functioning of the rail systems, sometimes leading to accidents caused by the removal of critical components.

Once again, this issue is not inherently related to the use of metre gauge; the type of gauge has no technical bearing on the problem.

In the case of freight transport, especially in Africa where high-value commodities such as coal and metals are frequently moved, piracy and theft pose significant risks. These threats can discourage private rail operators from using the railway system, as the potential loss of goods may outweigh the benefits of rail transport.

To remedy these incidents, it is essential to implement adequate infrastructure security measures, as well as systems to detect the presence of unauthorized individuals and deterrent mechanisms to prevent theft.

7.2. Solutions

It is difficult to provide specific solutions for all of challenges faced by narrow-gauge networks, as each country has its own unique circumstances. Moreover, it is not the objective of this document to provide tailored solutions for every country. In general, the establishment of a UIC working group, focused exclusively on improving narrow-gauge networks, would be a crucial first step toward developing effective solutions. All of the countries with narrow-gauge networks should participate in this working group to pursue shared objectives.

Standardising existing regulations is also essential for achieving interoperable and efficient networks, as well as reducing costs of acquiring and manufacturing railway components such as signalling and blocking systems.

Additionally, the publication of information on the about the challenges faced by individual countries and the solutions adopted to address these can be of vital importance for others encountering similar issues in their narrow-gauge networks. The scientific dissemination of research and technological developments is also a key part of this information sharing process. Furthermore, cooperation and collaboration are vital and play a central role in overcoming common challenges.

7.3. Conclusions and future lines of research

Although less widespread than the standard gauge, narrow-gauge railways remain an important type of infrastructure in most countries across Africa, Latin America, the Asia-Pacific region, and, to a lesser extent, Europe. These networks emerged during the second half of the 19th and early 20th centuries, and continue to play a vital role in many regions, serving as economic drivers and helping to connect national regions by providing populations with access to rail transport.

While operating speeds are generally lower, the narrow-gauge does not have technical limitations that place it at a disadvantage compared to other types of gauges, such as the standard gauge. Therefore, the maintenance and renewal of current infrastructures should be prioritised, without necessarily converting to a different gauge, allowing for the preservation of financial resources that can instead be invested in improving the current networks.

Looking ahead, countries with mature and technologically advanced networks, such as Japan, Switzerland, and Spain, should take the lead in forming working groups aimed at addressing the challenges faced by countries with more limited economic resources. These efforts should also promote the standardisation of existing narrow-gauge regulations, and encourage the sharing of best practices and potential solutions.

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