3. Justification for Inscription

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Albula line > The steep climb between Bergün/Bravuogn and Preda called for a complicated alignment with numerous engineering structures. A Rhaetian Railway passenger train crossing the Albula Viaduct III.
Foto Geiger

3.a Criteria under which inscription is proposed (and justification for inscription under these criteria)

The property is nominated according to Criteria i, ii and iv pursuant to Article 77 of the *Operational Guidelines for the Implementation of the World Heritage Convention* on the following grounds:

Criterion i

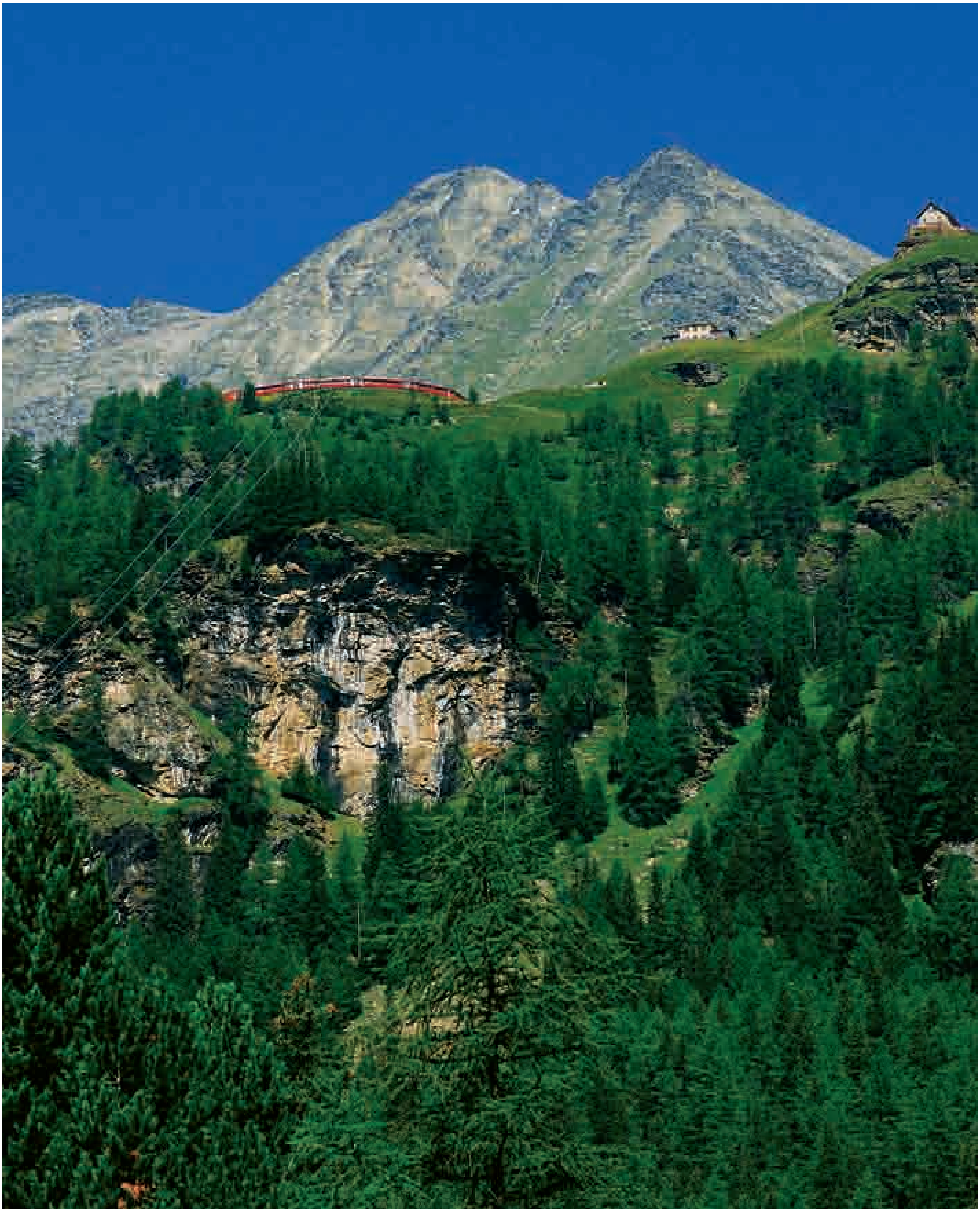
The "Rhaetian Railway in the Albula/Bernina Cultural Landscape" is an exceptional masterpiece of creative genius generated by the interaction of aesthetic standards, engineering acumen, technical innovation and perfect craftsmanship in a *Gesamtkunstwerk*. It is the outcome of the outstanding cooperation of wide skills with a highly innovative approach and handling of difficulties.

Criterion ii

The "Rhaetian Railway in the Albula/Bernina Cultural Landscape" is a pioneering work of modern engineering and architectural structures that exhibits the important interchange of human values on innovative technical developments in the early 20th century. It is an excellent example of a harmonious relationship between human interaction and natural beauty, exemplary of the perception of the Alps as a sublime experience of the relationship between nature, culture and technology.

Criterion iv

The "Rhaetian Railway in the Albula/Bernina Cultural Landscape" is an outstanding example of a technological ensemble which illustrates the zenith of the golden age of mountain railways. It has also exerted a powerful influence on how the Alps have been perceived over the years.



Bernina line > The daring alignment at Alp Grüm ensures an unimpeded view of the landscape.
C. Gilli /Rhaetian Railway

3.b Proposed Statement of Outstanding Universal Value

In exceptional fashion, the "Rhaetian Railway in the Albula/Bernina Cultural Landscape" is an example as unique as it is typical of a mountain railway integrated into an Alpine landscape. The Albula line, with its spectacular alignment and original engineering structures that represent a most impressive technical achievement, is an outstanding 'product' of the golden age of high altitude railways. From the outset, it was recognised as a transport route most harmoniously embedded in the landscape. The Bernina railway, as an electric surface railway at exceptionally high altitude and with extreme upgrades, is a unique example of the application of a technology that was highly innovative about 1900, but would soon become widespread. What is more, the development of its alignment was planned with a view to the best possible integration into the surrounding landscape. The Albula/Bernina line, as a railway that traverses an entire mountain range, links three distinct linguistic and cultural regions. To this day, it remains in full service, transporting both passengers and goods.

The combination of two different kinds of mountain railway – on the one hand with crest tunnels (and the equally technically demanding spiral tunnels) and on the other a surface electric railway crossing a high altitude mountain pass in the open – make the Albula/Bernina line simultaneously unique and typical, an outstanding example of a railway in the mountains. Its major role in the history of railway construction and the quality of the achievement established the basis for the worldwide recognition it has enjoyed ever since it was first brought into service. It is essentially different from the mountain railways already figuring on the World Heritage List: the Albula line, as a masterpiece, constructed with lavish planning and excellent craftsmanship, represents the archetype of the mountain railway from the golden age of rail. With its many stone viaducts of varying heights and lengths, the complex, sometimes overlaid structures of the helical tunnels and the long crest tunnel, the meticulous and architecturally valuable design of the elevated structures, and finally the actual operation itself, it displays all the characteristics of a main-line railway, even though it was constructed with a narrow gauge. The Bernina line, on the other hand, an electric surface railway at a high altitude and with the extreme gradient of 70‰, opened up new technical territory and introduced a new type of railway which would soon become widespread. The Albula/Bernina section represents a special type of "high-altitude mountain railway": over a distance of some 130 km and with a maximum difference in altitude (1,550 to 1,700 m) it crosses a mountain range, from one side to the other. While the "Semmeringbahn" UNESCO World Heritage Site marks the beginning of accessing mountainous areas by rail, the Albula/Bernina line represents the golden age of mountain railway construction: it was only with the development of mechanical tunnelling machines in the second half of the 19th century that long tunnel constructions and special types of tunnel (such as spiral tunnels) could be erected within acceptable time and cost constraints. The construction of alpine mountain railways came to an end with the First World War. Since then, no new trans-alpine railways have been completed, while spiral tunnels no longer feature in contemporary rail construction.

The construction of the Albula/Bernina line was rendered possible by an exceptionally creative exploitation of technical, economic and socio-cultural influences. An important goal which was promoted by the construction of the railway, was to preserve the diverse cultural and linguistic areas within the canton of Graubünden. In view of the topography, the Albula line was laid out as a narrow-gauge railway, but its design and operation followed the pattern of a mainline (standard gauge) railway. The aim was to facilitate access to the Engadin, in both summer and winter. Thus the railway contributed to the development of a new branch of the economy, namely winter (sports) tourism. Indeed tourism was to become the main industry in the region. The railway line was integrated subtly into the diversified cultural landscape and continues to enrich it today. The Bernina line was a product of the hydroelectric projects, built on Italian initiative, to generate power for the Lombard metropolis of Milan, and exploited the capital released by these projects. Moreover, the concerns of tourism were taken into account by aligning the track to ensure an exceptional 'mountain experience' from the comfort of the train. To satisfy these special conditions, the latest technology was used to construct the high Alpine railway as an electrical surface operation. The "Rhaetian Railway in the Albula/Bernina Cultural Landscape" is an exceptional example of a masterpiece created by a unique and diversified interplay between economics, politics, engineering, culture and nature.

Even at the time the railway was built, the outstanding quality of the landscape to be traversed was recognised and deemed worthy of preservation. Emphasis was put on harmonious integration of the railway infrastructure, while at the same time the alignment – particularly in the case of the Bernina line – was planned, as far as possible, to present the landscape to the traveller in all its magnificence as a landscape experience. The structurally created measures to enhance perception of the landscape during a rail journey together with the railway landscaping realised during construction are unique in the early 20th century. The experience of the exceptional views is an inherent element of the quality of the property. The "Rhaetian Railway in the Albula/Bernina Cultural Landscape" displays emblematically this synthesis of nature, culture and technology which has exerted a powerful influence on how the Alps have been perceived over the years: a vignette of cultural history.

Bernina line > The train crosses the 2,253 m Bernina Pass in the open giving passengers an uninterrupted view of the mountain panorama.
P. Donatsch / Rhaetian Railway

3.c Comparative analysis (including state of conservation of similar properties)

3.c.1 Identifying comparable railways

The aim of the comparative analysis is to show that the potential UNESCO World Heritage Site of the "Rhaetian Railway in the Albula/Bernina Cultural Landscape" is of an exceptional and universal value that transcends specific countries, periods and cultures. Both its particular and shared features, i.e. its unique and typical aspects, will be highlighted with reference to comparable railways.

The comparison will be made systematically and on the basis of transparent criteria. The first object is to select a number of railways for a detailed comparison i.e. the development of a method for the selection of comparative railways throughout the world. Secondly, the relation between those railways and their environs will also be compared.

The views from the railway and on to it (landscape perception) as well as other functional points of contact with the surrounding landscape enhance the intrinsic value of the Albula-Bernina railway: they have been incorporated in the buffer zone and duly protected (cf. 1, 2 and 5). The aim to integrate the engineering structures of the railway line in the cultural landscape contributes to the quality of the property as well and will be compared with the circumstances surrounding the comparative railways. It is therefore appropriate to consider the various functions of the environs of comparable properties in this respect. Consequently, the comparative properties were also analysed from the aspect of "Railway lines within their surrounding landscape".

Type definition

A group of international experts was set up to identify the comparative railways. It comprised Prof. Robert Lee (Sydney, Australia), Mag. Günter Dinhobl (Vienna, Austria), historian of technology, Dr. sc. techn./dipl. Arch. ETH Hans-Peter Bärtschi (Wintherthur, Switzerland), historian of industry, and Gion Caprez (Chur, Switzerland), specialist in the history of the Rhaetian Railway. The Director of the Institute for Railway Studies & Transport History, Prof. Colin Divall, (York, UK), agreed to produce an expert opinion and act as external consultant to the study.

In a first step, the world was subdivided into six regions for separate examination:

> Oceania, East and South Asia
> South and West Asia
> Africa
> South America
> North and Central America
> Europe

The railways comparable with the Albula/Bernina line were selected on the basis of the categories proposed on the occasion of the *1st World Railway Heritage Conference* held on March 16, 1998 (cf. the ICOMOS study *Railways as World Heritage Sites*, 1998). The proposal made at that time was to subdivide the railway lines into:

> Main lines
> Colonial lines
> Mountain railways, and
> Narrow-gauge railways.

This categorisation was used at the Conference to evaluate the subsequent UNESCO World Heritage Site of the "Semmeringbahn" in Austria both as a main line and a mountain railway. The two Indian railways of "Darjeeling" and "Nilgiri" were also inscribed in the UNESCO World Heritage List: they were categorised as colonial railways but at the same time as mountain railways and narrow-gauge railways. The Albula/Bernina railway can also be assigned to three different classes on the basis of these criteria: it is a narrow-gauge railway, a mountain railway and – in its section between Thusis and St. Moritz (Albula route) – structurally also a main line railway (whose route parameters and structural design are adapted to mainline standards, cf. 2.a.3). This composition – a narrow-gauge main line located in a mountain region – was decisive for selecting the international comparative railways. These were consequently – with two deliberate exceptions – restricted to those railways that satisfied these criteria.

The special case of mountain railways

In the mountain-railway category, a distinction must be noted that has become established in the German-speaking area: that between a “Gebirgsbahn” and a “Bergbahn”.

Mountain railways of the “Bergbahn” type

These railways are used to open up mountain regions to economic activity, either to tourism, to agricultural use or for mining. Some of them were built in isolation, i.e. with no connections to railways linked to the major network. When used for tourism, they are usually operated only on a seasonal basis. So mountain railways of the “Bergbahn” type are not comparable with the Albula/Bernina line and are therefore outside the scope of the present analysis.

Selection of high-altitude mountain railways of the “Bergbahn” type

Country	Connection	Gauge	Culmination point [1] [m]
USA/Colorado	Manitou Springs – Pike’s Peak (Manitou & Pike’s Peak)	Normal, Z	4302, Pike’s Peak
USA/Colorado	Silver Plume – Mt. McClellan	914 mm †	4159, Mt. McClellan
Switzerland	Kleine Scheidegg – Jungfraujoch (Jungfrau Railway)	Metre, Z	3454, Jungfraujoch
Switzerland	Zermatt – Gornergrat (Gornergrat Railway)	Metre, Z	3088, Gornergrat
Germany	Garmisch-Partenkirchen –Zugspitze (Bavarian Zugspitze Railway)	Metre, Z	2650, Schneeferner
Switzerland	Brienz – Rothorn	800 mm, Z	2349, Rothornkulm
Switzerland	Alpnachstad – Pilatus-Kulm (Pilatus Railway)	800 mm, Z	2070, Pilatus
Switzerland	Lauterbunnen – Grindelwald (Wengernalp Railway)	800 mm, Z	2061, Kleine Scheidegg
Australia	Perisher Blue (underground Skitube 1986)	Metre, Z	2054, Perisher Blue
Switzerland	Glion – Rochers-de-Naye	800 mm, Z	1973, Rocher de Naye
Switzerland	Wilderswil – Schynige-Platte	800 mm, Z	1967, Schynige Platte
Spain	Ribas-Caralps – Nuria	Metre, Z	1964, Nuria
USA/NH	(Bretton Woods) – Mount Washington	Normal, Z	1918, Mount Washington
France	Chamonix – Montenvers	Metre, Z	1913, Montenvers
Austria	Puchberg – Hochschneeberg	Metre, Z	1798, Hochschneeberg
Switzerland	Arth – Rigi	Normal, Z	1750, Rigi-Kulm
Austria	Brannenburg – Wendelstein	Metre, Z	1723, Wendelstein
Switzerland	Capolago – Monte Generoso	800 mm, Z	1620, Monte Generoso
Switzerland	Aigle – Leysin	Metre, Z	1453, Leysin
Great Britain	Llanberis – Snowdon Mountain	800 mm, Z	1064, Snowdon
Japan	Yokogawa – Usui Toge	1067 mm*, Z †	940, Usui Toge

Z = cog system

[1] various figures are quoted for highest stations or culmination points

* 3.5 feet, also known as Cape gauge

† closed down

Mountain railways of the “Gebirgsbahn” type

The term “Gebirgsbahn” has become accepted in the German-speaking area for a railway that traverses a mountain massif or range in its entirety. For a long time, mountains represented an obstacle to human movement and acted as barriers for the regions on either side. As a result – despite quite short physical distances in some cases – these became the scene of various cultural developments manifested in the diverse characteristics of the individual cultural landscapes. Consequently, a mountain railway of the “Gebirgsbahn” type often has particular importance from a cultural or cultural-landscape viewpoint, as it represents the technological connecting infrastructure between cultural areas separated from each other by the local topography. In the Alps, for instance, the southern cultural area has a Romance character, whereas the northern one is Alemannic.

Railways of this type are usually integrated into larger super-regional railway networks (e.g. railways in low-lying and hilly country).

In his railway encyclopaedia *Enzyklopädie des Bahnwesens* (Railway Encyclopaedia), a standard work published in 1912, Victor Röll characterises mountain railways of the “Gebirgsbahn” type as possessing the following features:

> Prolonged steep gradients
> Numerous curves
> A complex layout on steep slopes high above the valley floor
> Reach a significant height
> Extensive safety measures protecting against snowdrifts, avalanches, rockfalls and mudslides
> Sometimes traverse major deep-cut valleys and waterways that have to be diverted to prevent flooding of the railway track.

Fürst’s lexicon *Der Verkehr auf dem Land* (Vol. II) (Transport on land) from 1924 lists the elements along the route of “Gebirgsbahn” railways that allow major differences in altitude to be overcome:

> Setting-back tracks
> Circumventing the mountain
> Tunnelling under it
> Loops in tributary valleys
> Helical and spiral tunnels

Taking all these factors into account, the Albula/Bernina must be classified as a ‘Gebirgsbahn’.

Comparative railways >

1	Yunnan Railway	Vietnam / China
2	Darjeeling Railway	India
3	Nilgiri Railway	India
4	Eritrea Railway	Eritrea
5	Guayaquil&Quito Railway	Ecuador
6	Denver&Rio Grande Railroad	USA
7	Train Jaune	France
8	Semmering Railway	Austria
9	Gotthard Railway	Switzerland

Selection

A list of all existing mountain railways of this type would exceed a thousand. Ascanio Schneider mentions 170 railway lines in his hitherto unique overview *Gebirgsbahnen Europas* (Europe's mountain railways), first published in 1967, for Europe alone. Further delimitation short-listed only those mountain railways with culminating points above 1,000 m or 3.230 feet. This delimitation is also used in British publications, such as the *Guinness Book of Rail Facts* of 1979. Even then, that left more than 100 technically comparable routes for selection, although some routes, like a number of those opened in China since 1960 with culminating points above 1,000 m, were excluded due to a lack of specific data. In cooperation with the staff of *Fahrplan-center-News*, a journal that reports on the latest developments in railways outside Europe, the railways best suited for comparison with the Albula/Bernina line were selected for further evaluation from the lists for each world region according to the above criteria. These remaining 46 railways were examined in depth in a transparent way on the basis of the following detailed comparison criteria and subsequently evaluated:

> **Construction period:** (a) early high-altitude railways up to and including the Gotthard Railway (1882); (b) railway structures built up to the First World War (before 1915) or (c) more recent railways built after 1915.

> **Difficulty and attractiveness** of embedding the route in the local topography.

> **Alignment:** (a) largely original; (b) slightly changed; (c) greatly changed.

> **Density of engineering structures** (tunnels, bridges, cuttings, embankments): (a) very high; (b) high; (c) low.

> **Equipment:** (a) with rare/early/innovative power supply; (b) with largely original or significantly changed superstructures; (c) with rolling stock from the period of construction or electrification.

After consultation in the expert group, the selection for the detailed comparison was restricted to one railway for each world region. In view of the exceptional importance of Europe both for the development of the railways in the 19th and early 20th centuries as well as for modern tourism, three railways were selected for this region.
The railways already listed in the UNESCO World Heritage List were also used as comparison railways. This explains the inclusion of the Semmering Railway, whose culmination point is below 1,000 m.

The following railways were selected for a detailed comparison:

> **Oceania, East and South-East Asia:** *Yunnan Railway*, Vietnam/China

> **South and West Asia:** *Darjeeling and Nilgiri Railway*, India

> **Africa:** *Eritrea Railway*, Eritrea

> **South America:** *Guayaquil&Quito Railway*, Ecuador

> **North America:** *Denver&Rio Grande Railroad* (especially *Cumbres & Toltec Scenic Railway*), USA

> **Europe:** *"Train Jaune"*, France

> **Europe:** *Semmering Railway*, Austria

> **Europe:** *Gotthard Railway*, Switzerland.

Making the comparisons

The comparative analysis of the railway line was performed on the basis of its significance in terms of its technological and economic history. The visual and functional relationships to the buffer zones of the comparative railways will be analysed in a second part. This data, initially divided up into regions, will finally be combined in a third step to produce an overall view of the *unique* and *typical* features of the Albula/Bernina railway corridor.

Comparison of railways (core zone)

The first part of the analysis compares the selected railway routes, whereby each section is preceded by an overview of the railways in the respective world region. Here attention is drawn explicitly to the pioneer character of the work, particularly with respect to the tabular breakdown. This is followed by a detailed study, performed on the basis of a standardised grid, of the selected railway lines covering the following points: “construction history”; “line layout and railway structures” and “operation and equipment”. A comparison with the Albula/Bernina line is made at the end of each chapter.

Comparison of the surrounding countryside (buffer zone)

The second section of the comparison focuses on the countrysides that surround the railway lines or in which the latter are embedded. In this section as well, the comparison is made systematically on the basis of a standardised survey grid comprising four sectors: “agriculture”; “structures”; “transport routes” and “perception”. As in the railway comparison, this section also concludes with a comparison with the Albula/Bernina.

3.c.2 Comparison of railways

Oceania, East and South-East Asia

Railways came rather late to densely populated East Asia and the sparsely populated "fifth continent" of Australia. The most outstanding achievements in railway construction were realised in Japan and China.

From 1872 onwards a rail network in Cape gauge (1,067 mm) was introduced on all four of the main Japanese islands. In Honshu, there are several cross connections with a pronounced mountain railway character. The Shinkansen (New Trunk Route) standard-gauge network, which opened in 1964 and was intended for high-speed transport, without a doubt, marked the most important milestone in railway traffic after the Second World War. This line incorporated not only two of the longest tunnels in the world, but also the world's densest succession of earthquake-proof civil engineering works.

After the Second World War, China restored the colonial railway network from the second half of the 19th century. With the exception of the Yunnan Railway, the mountain railways providing access to the interior were all opened after 1950. The latest Chinese mountain railway – first brought into use in 2006 – connects the Chinese heartland with Tibet and crosses over a 5,000 meter high mountain pass; no other railway in the world travels at such high altitudes. The current Chinese railway network also includes the Manchurian segment of the Trans-Siberian Railway, built between 1891 and 1903, and its bypass route, the Amur Railway, built by Russia after the Russo-Japanese War (1904/05). Due to the construction difficulties, the Amur Railway could not be brought into operation until 1916. The Transiberian is the oldest East Asian mainline railway in continuous operation. It runs on the segment between Chita and Ulan Ude at over 1,000 m.

With the exception of the so-called "Great Zig Zag" – the oldest mountain railway line in this part of the world (opened in 1868) and the best known railway monument in Australia – the majority of the mountain railways in Australia and New Zealand have their highest points at below 1,000 m. The Great Zig Zag travels over the Great Dividing Range of the Blue Mountains, with its highest point at an altitude of 1,114 m in the Lithgow Valley. The original route was replaced by a direct railway line in 1910; today a museum railway is operated on the older route which, however, does not have the original standard gauge; the rail line was reconstructed in the narrower Cape gauge (1,067 mm).

The South-East Asia railway network is characterised by the colonialist efforts to build an uninterrupted meter-gauge connection from India to China. The unfinished segment of this route, between Thailand and Myanmar (Burma), was built during the Second World War by Japan, which occupied large areas of South-East Asia at that time. Parts of this South-East Asian meter-gauge network can be classed as mountain railways.

The railway network in Indonesia dates back to the period of Dutch colonial rule – this was the first and originally also the densest in the whole of Asia. Several of its lines it have mountain railway features. Worthy of mention is the cog railway to the collieries in West Sumatra, as it travels from the sea port to an altitude of 1,154 m.

Mountain railways in Oceania, East and South-East Asia (a selection for China) with highest points over 1,000 m

Country	Connection	Gauge	Highest Point in m [1]	Opened [2]
China	Qinghai/Xining – Lhasa (Tibet Railway)	Normal	5072, Tangula	2006
China	Wuwei – Shibalipu (Silk Road)	Normal	2400, Shibalipu	1962
China	Urumqi – Kasachstan (Silk Road)	Normal	2400, Tunnel Wushaoling	2006
China	Lanzhou – Xiling	Normal	2300, Xiling	1960
China	Chendu – Kunming	Normal	2300, Samala	1970
Vietnam, China	Haiphong – Kunming (Yunnan Railway)	Metre	2026, at Yiliang	1910
China	Nanning – Kunming	Normal	2000, Kunming	1998
China	Peking – Suiyuan	Normal	1585, Suiyuan	1970
China	Baotou – Lanzhou	Normal	1560, Lanzhou	1958
China	Xian – Lanzhou	Normal	1560, Lanzhou	1952
China	Zhongwei – Baoji – Lanzhou	Normal	1560, Lanzhou	1960
Vietnam	Thap Cham – Da Lat	Metre, Z	1463, Da Lat	1933
Japan	East Koumi – Nobeyama (JR East Koumi Line)	1067 mm*	1345, Nobeyama	1919
Myanmar	Mandaly – Myitkyina (Burma Railways)	Metre	1405, Kalaw	1921
Indonesia	Padang – Kota Baru (West-Sumatra Coal Mine)	1067 mm*, Z	1154, Kota Baru	1891
Australia	Lithgow Valley – Clarence Tunnel (Great Zig Zag)	Normal, 1067 mm*	1114, Blue Mountains	1868
Russia	Ulan Ude – Chita	1524 mm	1040, Jablonovyi	1900

1) various figures quoted for highest stations or culmination points
2) various figures quoted for part or generally continuous opening
* 3.5 feet, also called Cape gauge
Z cog system

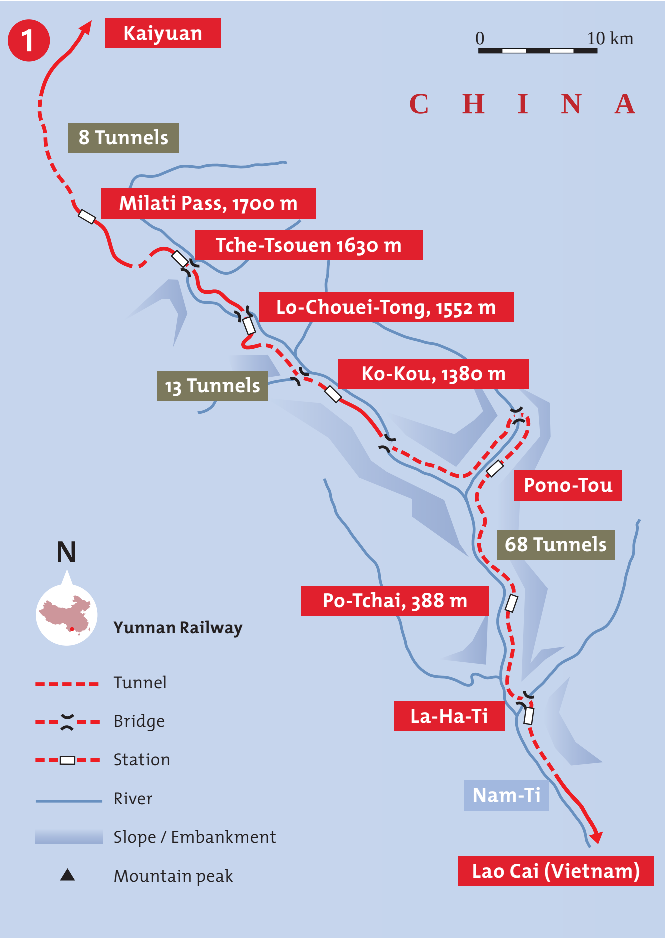
Yunnan-Bahn, Vietnam/China

The choice of the Yunnan Railway for comparison with the Albula/Bernina line was based on the following criteria:

> Construction period comparable with the Albula/Bernina line
> Narrow gauge
> Outstanding contemporary construction work and engineering achievements
> Overcoming of large differences in altitude (several vegetation zones)
> Still in operation

Construction history

The Yunnan Railway connects the Vietnamese seaport of Haiphong with Kunming (formerly Yunnan Fou), the capital of the Chinese Province Yunnan and located on a high plateau at and altitude of 1,900 m, between the rivers Yangtse and Yuan Jiang. Kunming, an ancient trading centre, acquired a strategic importance with the French colonisation of Indo-China and the English expansion in East India in the last quarter of the 19th century. Both of these colonial powers pushed on towards Yunnan with railway constructions. In the 1880s Britain built a mountain railway from Rangoon to Lashio, in the heart of Myanmar. From there the route progressed on the road (Burma Road) high above the canyons of the Salween and the Mekong to Dali and then on to Kunming. A rail connection between Xiaguan, near Dali, and Kunming was opened in the middle of



Yunnan Railway > Mountainous section.
H.P. Bärtschi

Yunnan Railway > Bridge at km 83 with works train. Photograph 1906.
Edition Si-An

Yunnan Railway > Haiphong station, built 1903. Photograph 2003.
H.P. Bärtschi

Yunnan Railway > Bridge on the delta of the Red River. Photograph 2003.
H.P. Bärtschi

the 1990s. France, for its part, built the Yunnan Railway. The origins of the project date back to the year 1897, when Paul Doumer, in his function as the French Governor General of the Annam colony (Vietnam, Laos, Cambodia), drafted a meter gauge network to open up the colonial empire. The core element was the *Ligne impériale de l'Indochine*, between Phnom Penh and Yunnan. From 1898 to 1899 the *Société de Construction des Chemins de Fer Indochinois* carried out survey work for the line routing of the Yunnan Railway. Under the engineer Guillemot, the accredited surveyors proposed a line routing from the port railway in Haiphong over Hanoi and along the Red River to Lao Cai (today Vietnam). A dispute arose on how best to overcome the sharp gradient that starts there; this led to adjustments of the originally planned alignment during the construction work. Eventually a deviation from the main valley was made which allowed the track to follow the contours of several side valleys. In the most difficult segment, between Lao Cai and Mengzi, 149 tunnels, mostly short, were planned. In 1901, even before the start of construction work, the financing had to be reorganised with the *Compagnie Française de Construction des Chemins de Fer de l'Indochine et du Yunnan*. The realisation of the 861 km rail line began in the river delta, and the segment between Haiphong and Hanoi was completed in 1903. In 1906 Lao Cai was reached. The completion of the demanding mountain segment would not have been possible without several additional subsidies. Around 60,000 local workers were reckoned to have been involved in the realisation of this ambitious project, for which the construction site managers were mainly recruited in Italy. In addition, 8,000 horses and mules were used as beasts of burden. The construction work was eventually completed in 1910.

Feeder lines

Work began on the construction of a 160 km long Y-shaped network, in 600 mm gauge, in 1915. The line, which began at Mengzi, was built to provide access to the coal mining areas in the southern Chinese provinces of Gejiu and Baoxiu . Further connecting rail lines, tangent to the Yunnan Railway, led to the Sa Pa mountain health resort near Lao Cai and to the "Petrified Forest" at Shiling near Kunming. Around 1970, China completed the standard-gauge high mountain segment from Kunming to the northerly Chengdu, as well as a railtrack along the coastline, from Nanning to Hanoi, and in 1997 a similar standard-gauge railway connection was opened between Nanning and Kunming.

In the late 1990s a revival in rail transportat led what is currently the last new construction, namely from the Vietnamese side. To improve access to Hanoi, the Vietnamese State Railway began with the construction of a secondary rail route lying to the north of the Yunnan Railway, as well as a second rail and road bridge over the Red River.

Track layout and railway structures

Despite repeated destruction due both to natural disasters and as a consequence of the various hostile disputes in the region, the single track rail route has survived over long stretches in its original condition.

In Haiphong, the harbour buildings and the – still usable – harbour tracks built in 1903 are still in existence; the neoclassical entrance halls and, to a large extent, the workshops (smithy, steam hammer) and the mechanical equipment are also retained in their original form. The railway line runs to Hanoi mainly on embankments above rice paddies and irrigation canals. The trusses of the three major bridges, Som-Tam-

Bac (90 m span), Song-Lai-Vu (120 m) and Thai-Ninh (380 m), are to a large extent original, although the pillars and abutments have for the most part been replaced. The line leaves the river delta by the bridge over the river Claire (295 m). From there, a branch line leads to the main station of Hanoi, which has been largely reconstructed. In contrast, the nearby depot still retains its concrete skeleton constructions dating from 1903. The bridge over the Red River, repeatedly bombed during the Vietnam War and originally a cantilever metal construction, was reconstructed with surviving truss components supported by eleven old and twenty-six new pillars – its length today totals 1,513 m. The next segment of the route, extending as far as Lao Cai, where the railway runs alongside the Red River, does not have any large engineering structures. Between Lao Cai and Lahadi, the line climbs at gradient of 10 ‰, and subsequently at 25 ‰. On the 82 km route up to the Milati Pass at 1,700 m, the train passes through a total of 81 tunnels. The route then dips downhill to Kaiyuan at 1,059 m, before climbing up to the highest point in Yiliang (Kuangyuan) culminating at 2,026 m. The difference in altitude on the few remaining kilometres to Kunming (1,900 m) is relatively modest. The total route boasts 172 tunnels, as well as 107 bridge structures. The most spectacular construction is the triple arched bridge over the Nam Ti canyon with a height of 100 metres. Bridges were also constructed in stone and in the typical American trestlework design. On the mountain section, small railway stations in the French style, the majority of which have been preserved, were erected at regular intervals. These were not provided as shelter for travellers, but to protect linesmen and the operational safety facilities. In the urban areas of Kunming the railway installations have been relocated, and the original buildings have mostly disappeared.

Both the base structure and superstructure of the Yunnan Railway today show evidence of improvised maintenance procedures. Many track sections reveal ferro-concrete sleepers which, however, have frequently been poorly serviced.

Operation and Equipment

The Yunnan Railway probably reached its peak frequencies in freight transport during the two World Wars and in the Vietnam War. The sections in the border regions remained closed from 1979 to 1994. After expensive repairs to these segments the railway was later brought back into operation along its entire length. However, flooding caused extensive damage in 2002. In the meantime, the mountainous segment of the railway has been repaired yet again, and two tandem trains per week have been running between Kunming and Hanoi since 2005. In addition, the line in the commuter belts around Kunming and Hanoi is still used widely for local transport.

China is currently planning the construction of a Trans-Asia railway line from Kunming to Singapore, which would give Kunming a standard-gauge connection with the Red River valley. The narrow-gauge line for transport between Kunming and Hanoi is nonetheless to be retained as declared by the Chinese Railways Ministry at the end of 2004.

Around the year 2000, wagons and steam locomotives from the French colonial period and their Chinese-Vietnamese duplicates (141 N°101– 115 SACM 1953 ff., N° 121 – 122 Vietnam 1961 ff., N° 151…216 Tangshan; N° 231–301 SACM 1932) could still be seen in Haiphong and Hanoi. In 1988, Japanese steam locomotives from the Second World War (131 “C12” Nr. 96–97 and 140

"KD55" N°. 501…576 Kawasaki 1913– 1926) were parked in China and also in Vietnam. These days, Bo'Bo'diesel locomotives from the 1970s and 1980s, as well as converted and newly constructed passenger carriages are deployed on the Yunnan Railway.

Comparison

The Yunnan Railway was built in the same period as the Albula/Bernina route and also boasts spectacular route planning, overcoming differences in altitude by loops sweeping into side valleys. However, no costly spiral tunnels or prolonged crest tunnels were needed on the Yunnan line, as was the case, on the Albula. And in a similar manner to the Bernina line, the Yunnan Railway also traverses a pass in the open, which, with an altitude of 2,026 m, is at approximately the same elevation as the Bernina Pass (2,253 m). Here, the alignment on the steep slopes high above the valley floor also proved to be complicated. As with the Albula/Bernina line, the layout of the route on the Yunnan Railway remains to a large extent the original; the railway buildings have, however, been replaced in part, especially in urban areas, and route segments affected by storm damage have frequently simply been patched up. Whilst the Albula/Bernina route has operated a full passenger and freight service since its construction, cross-border operations on the Yunnan between Vietnam and China were discontinued in the 1970s, recommencing in the 1990s, albeit with only modest train traffic. And while the Albula route was completely electrified in 1919, the Bernina route operated electrically from the outset. The Yunnan Railway switch to diesel locomotives took place in the 1970s. Whereas the Albula/Bernina route is today an important element in the public transport system, the continuation of the Yunnan Railway was long in the balance – until 2004 when Chinese Railways Ministry declared its intent to retain and expand the line. Like the Albula/Bernina railway, the Yunnan Railway also has an inventory of historical rolling stock.

South and West Asia

In 1848, the British colonial power began the construction of a railway network on the Indian sub-continent with a wide gauge of 1,676 mm. On its completion the network covered a total length of 30,000 km. The pioneer route from Bombay to Thane was opened in 1853 as the first railway line in Asia. From 1870, in addition to the wide-gauge network, a total of 26,000 km of metre-gauge railway lines was built. In India, over the past several decades these were either for the most part broadened to wide gauge or they were closed down. Nonetheless, as in Pakistan and Bangladesh, both gauges are still in use there today. In Sri Lanka, on the other hand, only the wide gauge is still operated. In this part of the world railways with gauges of 762 mm and 610 mm were also common; these covered a total length of over 5,000 km.

In India, in particular the surmounting of the Deccan Plateau presented serious challenges to the railway builders; however, none of the routes built there exceeded 1,000 m. Altitudes of well over 2,000 m are indeed reached by three other mountain railways in India: – the Darjeeling Railway in the hinterland of Calcutta, the Nilgiri Railway in the region of Madras and the Kalka–Simla Railway to the north of Delhi. Each of these lines leads from a valley into the mountains, but none of them crosses a mountain range. Furthermore, all of these railways have a connection to a main-line service at their starting points.

The wide-gauge network in very mountainous Sri Lanka reaches its highest point at 1,898 m. The Pakistani Quetta–Zhob (Fort Sandman) line – a part of the 762 mm gauge railway network already mentioned – reaches an altitude of 2,222 m. All of the various projects launched by the British colonial powers to build a railway connection between India and Iran failed due to British conflicts with the highland peoples of Afghanistan and Beluchistan. The railway connection from Karachi over Quetta, Kandahar and Herat to Turkmenistan, begun in 1876, also remained incomplete on Afghan territory. The dual-track section between Sibi and Chaman, built between 1880 and 1891 under Field Marshal Lord Roberts of Kandahar, reaches its highest point of 1,950 m on the Bolan Pass. The second mountain railway from Pakistan to Afghanistan also rises to an altitude of over 1,000 m. The line winds up through the Khyber Pass using setting back tracks. The Trans-Iran Railway, completed in 1941, which leads into the Iranian highlands and crosses the foothills of the Elbrus Mountains to Turkmenistan, reaches heights of over 1,000 m. Mountain railways were also built in Turkey to overcome the mountain chains between the Mediterranean and the Black Sea, leading over the Taurus and the Pontin mountain ranges. The Hedjaz Railway and its feeder lines over the Lebanon and Anti-Lebanon mountains also reach heights of over 1,000 m at three points.

Many railway pioneers of the 19th century shared a vision of linking up all the existing railways to create an uninterrupted network stretching from Europe to South-East Asia. From the West, standard-gauge railway lines ran through Turkey and Iran. However, the strategic railway project from the Mediterranean ports to Mecca, dating back to the last year of the Ottoman Empire (1922), remained uncompleted. Under German influence the first segments of the Baghdad Railway (Instanbul – Baghdad) were opened before the First World War, whereas the entire stretch could not start operating until 1940.

Mountain railways in South and West Asia with highest points over 1,000 m

Country	Connection	Gauge	Highest Point in m [1]	Opened [2]
India	Shiliguri – Darjeeling (Darjeeling Railway)	610 mm	2258, Ghoom Pass	1889
Turkey	Sivas – Kars	Normal	2256, Asit	1917
Pakistan	Zhob – Quetta	762 mm †	2222, Kan Mehtarzai	1918
Iran	Ahvaz – Tehran (Trans-Iran South Section)	Normal	2217, Nurabad	1930
India	Mettuppalaiyam – Udagmandalam (Nilgiri Railway)	Metre, Z	2203, Udagamandalam	1899/1908
Iran	Tehran – Gorgan (Trans-Iran Elbrus)	Normal	2112, Gaduk	1938
India	Kalka – Simla	610 mm	2094, Simla	1903
Pakistan	Quetta – Chaman	1676 mm	1950, Shelabagh	1891
Sri Lanka	Kandy – Badulla	1676 mm	1898, Pattipola	1894
Syria	Damaskus – Zebdãni	1050 mm	1794, Zebdãni	1895
Pakistan	Sukkur – Quetta	1676 mm	1791, Kolpur	1887
Turkey	Adana – Taurus	Normal	1494, Taurus	1920
Lebanon	Beirut – Zebdãni (Libanon Railway)	1050 mm †	1487, Zhale	1895
Jordan	Amman – Maan (Hedjaz Railway)	1050 mm	1128, Maan	1904
Pakistan	Peshawar – Landi Kotal	1676 mm	1068, Khyber Pass	1926

1) various figures quoted for highest stations or culmination points
2) various figures quoted for part or generally continuous opening
† closed down
Z cog system

Darjeeling and Nilgiri Railways, India

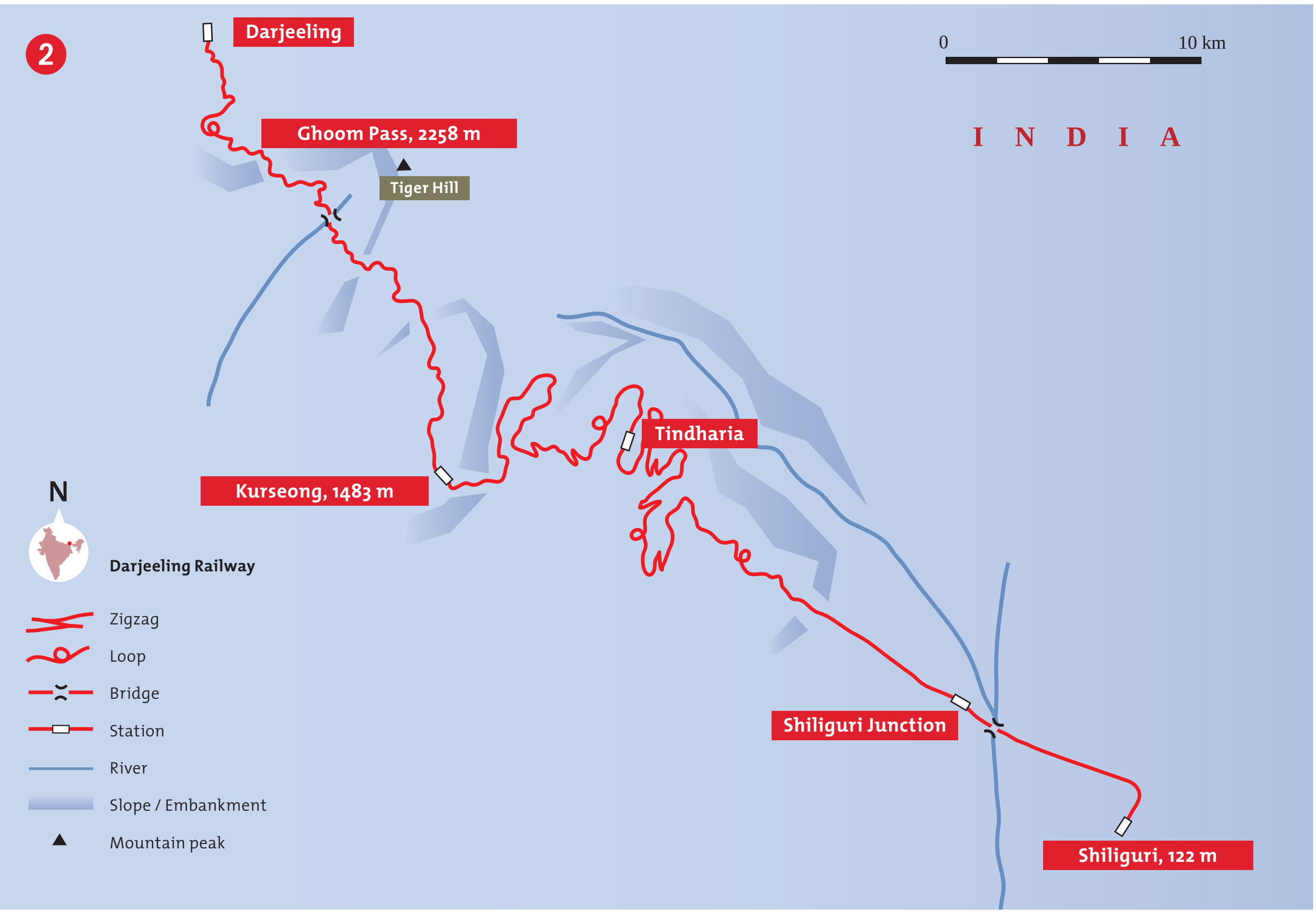
The choice of the Darjeeling and the Nilgiri Railways for comparison with the Albula/Bernina Line was based on the following criteria:

> Narrow gauge
> Innovative solutions to problems (Darjeeling: light railway, in part with joint use of the road; Nilgiri: cog railway)
> Surmounts significant differences in altitude
> Still in operation
> UNESCO World Heritage locations (Darjeeling since 1999, Nilgiri since 2005)

Darjeeling Railway

Construction history

The Darjeeling Railway from Shiliguri to Darjeeling was built in two stages. In 1880 the section as far as Kurseong (1483 m) was completed, and in 1889 the remaining track to Darjeeling (2,076 m). The valley station already had a main-line connection when the line was built. The Darjeeling Railway is licensed as the ‘Steam Tramway Company’, whose main objective was to improve the development of Darjeeling. From 1838 onwards, Darjeeling village was expanded into a mountain health resort or hill station. There were also tea plantations in the region, and by the 1870s the tea industry there was already very prominent. The cost-effective transport of agricultural goods from the mountains down to the valley promised high profits, and for precisely this reason a railway was planned that could be constructed with the lowest possible expenditure. By English standards, the Darjeeling Railway was a ‘light



Darjeeling Railway > The entire section.
H.P. Bärtschi

Darjeeling Railway > In Shiliguri there are tracks in three different gauges (610 mm, broad and narrow gauge). Photograph 1992.
H.P. Bärtschi

Darjeeling Railway > Layout as road-railway in Ghum. Photograph 1992.
H.P. Bärtschi

railway' and by German standards it had "Feldbahn in Hochgebirge" status, that is a 'light railway in high altitude, mountainous terrain'.

Rail track alignment and railway structures

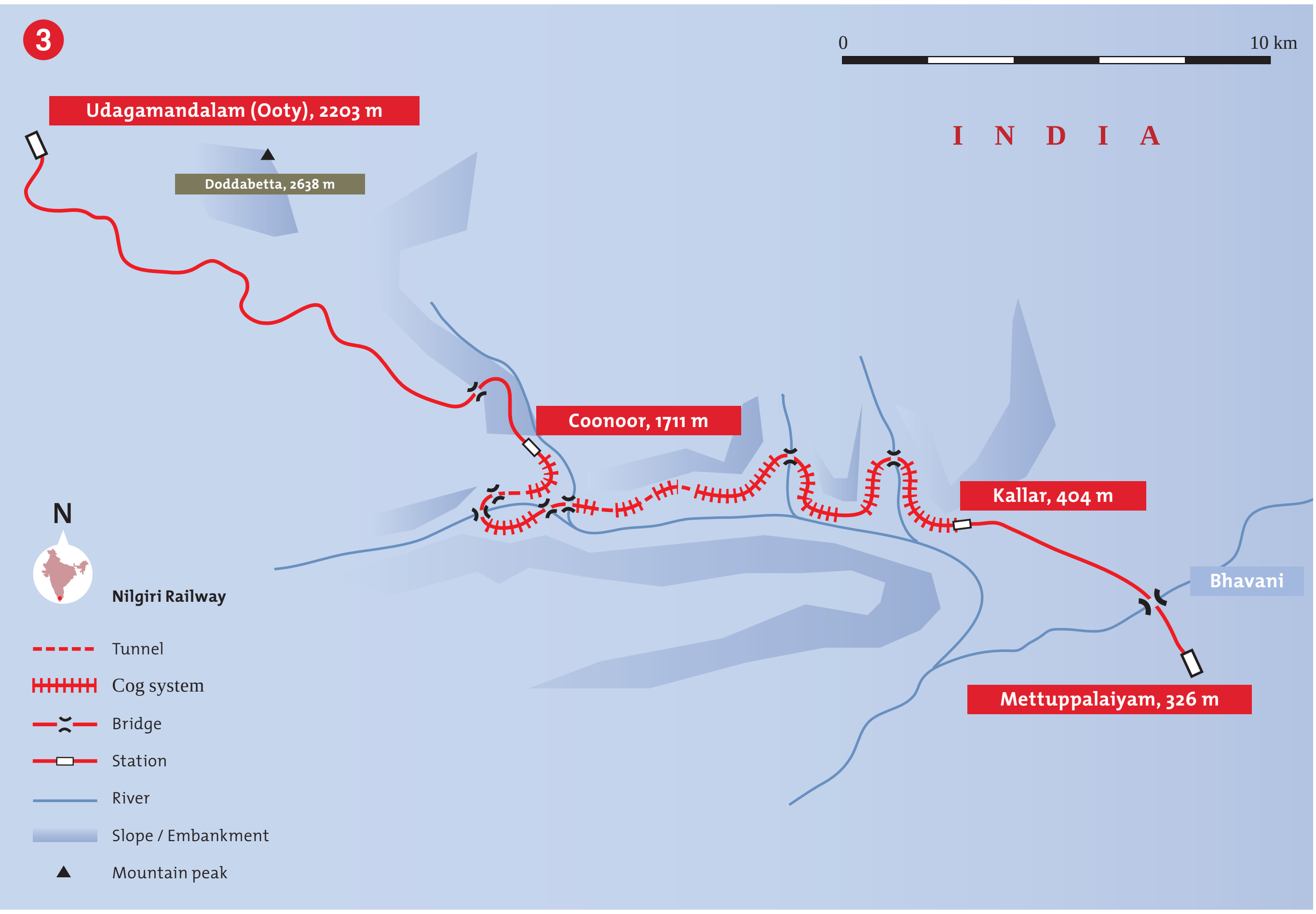
The main challenge on the Darjeeling Railway was to build a railway that surmounted a difference in altitude of 1,954 metres over a straight-line distance of 40 km. The alignment of the single track route, running for long distances alongside the trunk road, remains to a large extent the original – only in zones exposed to landslides and in areas with very steep gradients have modifications been necessary. Prolonged steep inclines, numerous curves and the routing along precipitous slopes high over the Brahma Putra plain are still as impressive today as they were in the past. Some reverse curves have a radius of a mere 18 metres; including three spiral reverse curves and the double 'Batasia Loop'; in addition, the line also features setting back tracks. The railway runs completely in the open. There are no tunnels and among the bridges – mostly small streams crossed by road and railway – there is only one substantial construction, namely the 700 metre long iron bridge over the Mahanadi near Shiliguri. The line has only a limited number of safety constructions to protect against flash floods and landslides. There are stations, workshops and depot facilities, in part with very old equipment, in New Jalpaiguri, Thindaria Ghum and Darjeeling.

Operation and Equipment

The narrow 610 mm gauge and the modest foundation permit the operation of only light rolling stock. On this line the burden of three to four loaded wagons should not exceed the weight of a standard-gauge double-axle goods wagon of 27 tons. The typical steam locomotives on the Darjeeling Railway feature two coupled axles and a saddle tank on the boiler. To help prevent wheel-spin a sander, perched on a seat to the fore of the smoke box, scatters sand onto the rails by hand. The wagon stock has been modernised since the 1980s, and generally only one or two of the remaining 20 steam locomotives from 1889 to 1925, are in daily operation to haul the school train on the Kurseong–Darjeeling segment. The train pairs that travel the entire route – with one train running in each direction – connect to the fast line to and from Calcutta and are each pulled by a diesel locomotive. Since India gained its independence in 1947, the journey time has extended from 5¼ to 8 hours. After the monsoon rains the route is sometimes interrupted for considerable periods.

Comparison

The Darjeeling Railway, which leads from lowlands to an altitude of over 2,000 metres, was constructed as a 'light railway', with a layout designed as simply as possible to run alongside roads, using open loops to gain height and thereby reducing the number of engineering structures to an absolute minimum. With its concept of minimum capital investment, the Darjeeling Railway represents a completely novel response to the needs of the 1880s. The Albula/Bernina route, constructed some 20 years later, is diametrically opposed to the Darjeeling philosophy in that, in the case of the Albula line, the parameters of a main-line railway were adopted for a narrow-gauge route and, in the case of the Bernina Railway, the risks of electrical operation through high, snow-covered mountains were recognised and accepted. Further, the Albula/Bernina line is a unique testimonial to the development of narrow-gauge railways.



Nilgiri Railway > The entire stretch.
H.P. Bärtschi

Nilgiri Railway > Transition from cog wheel to adhesion railway at Coonoor. Photograph 1988.
H.P. Bärtschi

Nilgiri Railway > Bridge at Wellington. Photograph 1988.
H.P. Bärtschi

As with the Albula/Bernina line, the Darjeeling Railway also has historical rolling stock; the modernisation of railway operations with the acquisition of new passenger carriages began in the 1990s and, in addition, four diesel locomotives have also been in service since the year 2000.

Nilgiri Railway
Construction history

The Nilgiri Railway, named after the mountain range, travels from Mettuppalaiyam over Coonoor to Udagamandalam (Ooty) at 2,203 m. Mettuppalaiyam was developed by the Indian Railway network in 1872, ten years after the nearby town of Coimbatore. As a result, a region very rich in natural and cultural attractions became more easily accessible. At that time, in Udagamandalam there were already scattered residences that representatives of the British colonial powers had had built, so they could escape the torrid, subtropical heat of the valley in summer. In 1876, Niklaus Riggenbach, a Swiss engineer and owner of a firm that manufactured cog-wheel locomotives, drafted an initial project for a cog railway into the Nilgiri Mountains but the project was not adopted. Eventually – under new sponsorship – a more economical variation using a combined adhesion and cog-wheel system (cog-wheel operation on the Abt principle) was adopted. Nevertheless, the railway construction company was forced to declare bankruptcy in 1894, while the construction work was in progress. In 1899, however, the Mettuppalaiyam – Coonoor segment was opened at last by a successor company. Completion of the route to Udagamandalam was not possible until after nationalisation of the railways in 1908.

Rail track alignment and railway structures

The construction of the metre-gauge mountain railway proved to be extraordinarily difficult, as the route led through a jungle region and had to surmount a difference in altitude of 1,800 metres over a relatively short distance. In the section between Kallar and Coonoor the railway line has a gradient of 80 ‰ and progresses along the valley slopes in sweeping rounded loops. While the construction of costly helical and spiral tunnels could be dispensed with thanks to its cog railway design, sixteen tunnel constructions with lengths of up to 300 metres and numerous rock cuttings and excavations were nevertheless unavoidable. Building measures to protect against rockfall and mudflows were adopted analogous to German and Swiss examples – the Harzquerbahn at Blankenburg in Germany was also visited for study purposes.

Near Mettuppalaiyam, the Nilgiri Railway crosses the river Bhavani by a large bridge. The Adderley viaduct with stone-arch foresections and three plate girders are located here, in the middle of the jungle. There are numerous smaller bridges along the entire route. The railway is attractively embedded in the steep slopes of the jungle and the hilly regions where the upper segment of the line runs. The Abt-system cogged sections end in Coonoor, and the 40 ‰ gradient in the upper segment is traversed using the adhesion principle. The single track layout of the Nilgiri Railway is still in the original form throughout. In the upper segment many slope stabilisation supports and some bridges have been renewed at considerable cost.

Equipment and Operation

Today, the Nilgiri Railway is primarily used as a tourist railway, while goods are transported on the roads. The rolling stock comprises a second generation cog wheel steam locomotive (Winterthur, Switzerland 1914), eleven other steam locomotives (the majority built in Winterthur, Switzerland between 1920 and 1952) and individual carriages from the founding period. The majority of the rolling stock used on a daily basis has new bodywork. Adhesion diesel locomotives are in operation on the Coonoor–Udagamandalam segment, and depending on the season, two to four tandem trains per day work there. A steam powered tandem train is in daily use (in 2005) on the cogwheel segment.

Comparison

The Nilgiri Railway, opened at almost the same time as the Albula/Bernina line, which runs from the valley floor to an altitude of 2,203 m can be divided into two segments, one with a cog wheel and the other with adhesion. In the late 1870s, this mixed operation presented an innovative method for meeting the challenge of surmounting large differences in altitude over short distances using steam locomotives. Furthermore, this mixed technology made it possible to keep the number of engineering structures to a minimum. In contrast to the Albula/Bernina Railway, the building of roads led to a shift of goods and passenger transport away from the Nilgiri route, with the result that today the Nilgiri Railway is above all a tourist railway. The railway still has historic rolling stock and carriages and locomotives from the 1920s, while the laborious steam locomotives in the adhesion segments have been replaced by diesel locomotives.

In comparison to the Albula/Bernina Railway, it should be stressed that whilst the conventional technology of steam locomotive operation was used on the Albula line, the Bernina Railway stole the limelight with its electrical operation – at the time a radically new technology. This made construction on much steeper gradients possible. The Bernina Railway created, as it were, the next level of technological development after the (steam-driven) cogged railway approach, as represented on the Nilgiri Railway. Electrical operation was introduced on the Albula route after the First World War, albeit with other technical parameters – direct current instead of alternating current. Today, with electrical railway operation having replaced steam locomotion worldwide, the Bernina Railway remains an outstanding testimonial from the early days of electrically powered railways.

Africa

The first railway line in Africa ran between Alexandria and Cairo and was brought into operation in 1856. However, due to the complicated political relationships both during and after the colonial period which prevented links being established between the large railway networks of South Africa and East Africa, the Maghreb, Egypt and the Sudan, the dream of a full railway connection between Egypt's capital city and Cape Town remained unfulfilled.

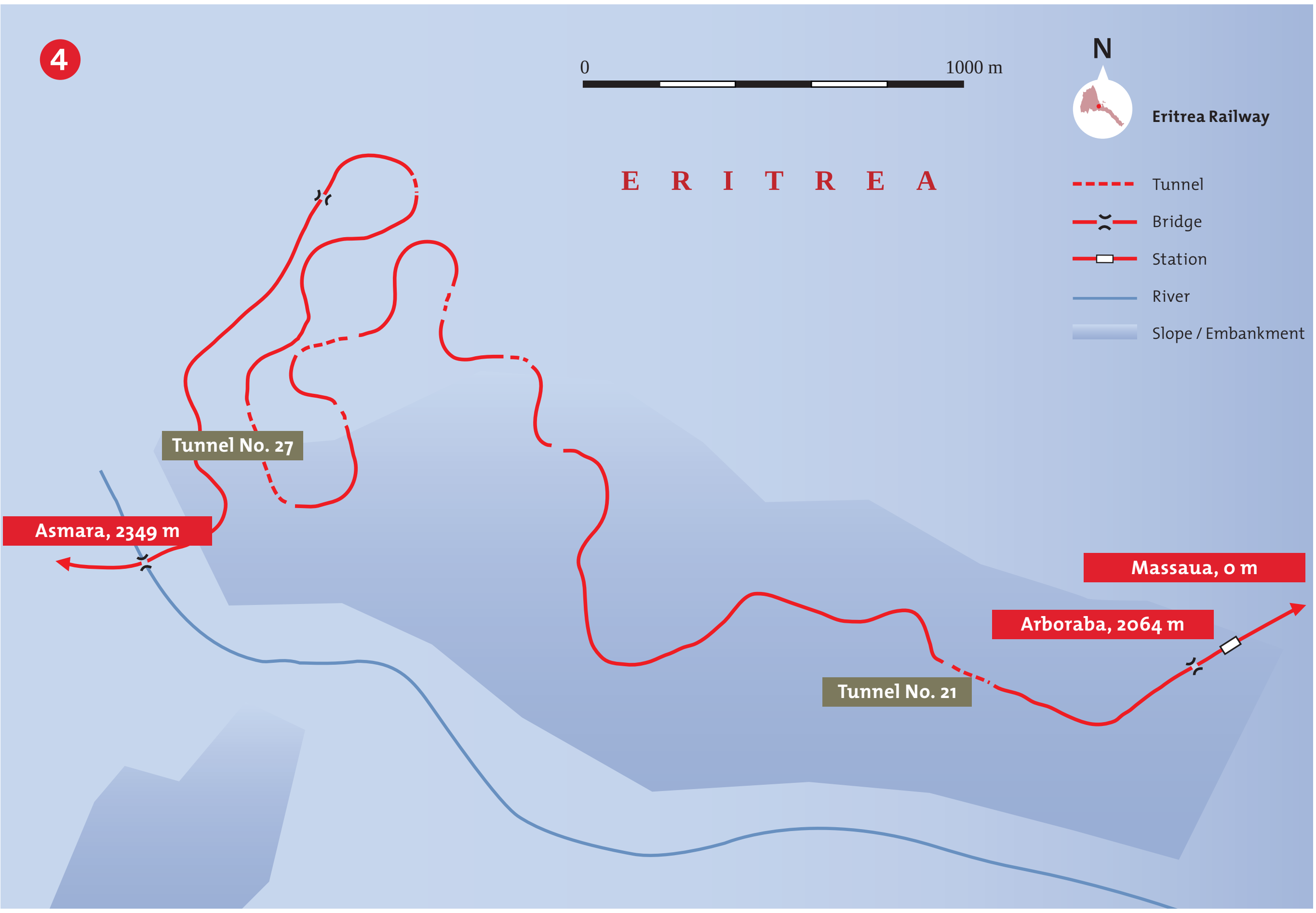
The standard track gauges in the north of the continent are normal and metre gauge, whilst the railway network constructed by the British colonial power in the South was built to the 'Cape gauge' (1,067 mm, or 3.5 feet).

During the 1890s, Britain and Germany constructed railway lines in East Africa from the ports of Mombasa, Tanga and Dar Es Salaam inland towards the west. In terms of topography, Britain had the greatest difficulties to overcome. At the time, the two countries were in a race to build a railway line up to the foot of Mount Kilimanjaro (5,892 m); in 1900, Britain completed a mountain railway which began in Mombasa and culminated at an altitude of almost 2,400 m. The section of this line close to the port, is part of the 2,000 km long Uganda Railway linking Uganda with the Indian Ocean. This was completed as far as Nairobi in 1901. The culmination point of this section of the line is at 2,658 m; its continuation in to Uganda was only completed in 1930. East of Lake Victoria, the Uganda Railway rises to 2,783 m – the highest point accessed by any railway line in Africa.

Significant heights are also reached by lines in the 'Cape gauge' networks of South Africa and the former Rhodesia Railways. The lines that have the particular characteristics of a mountain railway are those crossing the mountain massifs in the south-eastern part of South Africa. The Nigeria Railway was also built to the Cape gauge. This line runs from the northern interior of the country in two branches towards the ports of Lagos and Port Harcourt, and reaches its highest point in Mekiri at 1,370 m.

In Western Africa, only isolated colonial railway lines were built. The sole exception to this is the Benguela Railway – the trans-continental railway line running from the Atlantic port of Lobito in Angola towards Benguela and then on to the Shaba mountain area in the south of the Congo and to Zambia's copper belt. This line has a branch leading to the port of Beira (Mozambique) on the Indian Ocean, and provides a link between the coastal region and the interior of the country – an area rich in raw materials. The coastal areas of the belts of land around the Sahara have also been opened up by railway lines; in Algeria the line crosses the foothills of the Atlas Mountains where it reaches an altitude of well over 1,000 m. The Trans-Sahara Railway – which was discussed for years – was never built.

The Horn of Africa lines have a special significance. The strategic value of the region around Ethiopia rose substantially when the Suez Canal was constructed and the area fell under the domination of the three colonial powers, Britain, France and Italy. France, with the aid of the Swiss Alfred Ilg, built the Franco-Ethiopian Railway, which connects what was then the French military base of Djibouti with Addis Ababa, the capital city of Ethiopia. Its highest point is 2,470 m. By 1875, Britain had been able to extend its area of influence from Egypt as far as the Eritrean port of Massawa and into Ethiopia. Later, Italy succeeded in establishing military bases in Massawa and Mogadishu, and the Italian colonial authorities planned to construct



Eritrea Railway > An important section of the line.
H.P. Bärtschi

Eritrea Railway > Four steps above one another: railway 'acrobatics' at Arboraba. Photograph 2004.
H.P. Bärtschi

Eritrea Railway > Alignment at Embatalla. Photograph 2004.
H.P. Bärtschi

a section of 950 mm gauge railway line from Massawa to Asmara and on across the Ethiopian highland to Addis Ababa and Mogadishu. There were also plans to add a second line connecting with the British-built Sudanese railway network, through the Blue Nile region and on across the Ethiopian highland towards Somalia. In the end, the only parts built were the sections around Mogadishu and the two mountain railway lines between Massawa and Asmara, and between Asmara and Biscia.

Mountain railways in Africa with highest points over 1,000 m

Country	Connection	Gauge	Highest Point in m [1)]	Opened [2)]
Kenya	Nairobi – Kampala	Metre	2783, Timboroa	1930
Kenya	Mombasa – Nairobi	Metre	2658, Mau Summit	1901
Ethiopia	Dschibuti – Addis Abbeba	Metre	2470, bei Addis Abbeba	1917
Eritrea	Massaua – Asmara (Eritrea Railway)	950 mm	2412, Summit	1911
Kenya	Nairobi – Fort Hall	Metre	2395, Kikuyu	1900
Eritrea	Asmara – Sudanes. Border	Metre	2349, Asmara	1920
South Africa	Pretoria – Magaliesberg	1067 mm*	2095, Nederhorst	1902
South Africa	Kaapmuiden – Belfast	1067 mm*	1970, Belfast	1894
South Africa	Durban – Johannesburg	1067 mm*	1748, Johannesburg	1890
Rhodesia	Beira – Harare	1067 mm*	1688, Marandellas	1899
Madagascar	Tamatave – Tananarive	Metre	1687, Tananarive	1909
Nigeria	Ebutte Meta – Minna (Nigeria Railway)	1067 mm*	1370, Mekiri	1900
Algeria	El Kroub – Tuggert (Sahara – Altas)	Normal	1313, Batna	1882

[1)] various figures quoted for highest stations or culmination points
[2)] various figures quoted for part or generally continuous opening
* 3.5 feet, also called Cape gauge

Eritrean Railway, Eritrea

The choice of the Eritrean Railway for comparison with the Albula/Bernina line was made based on the following criteria:

> Construction at about the same time as the Albula/Bernina line
> Narrow gauge
> The line had to overcome great differences in altitude
> The ‘Darjeeling of Africa’ (cf. 3.c.3)
> Still in operation

Construction history

In 1890, Italy declared Eritrea an Italian colony. The relocation of the colonial administration from Massawa to Asmara (which lies at 2,349 m) led to the construction of the Eritrean Railway. The railway was built to a track gauge of 950 mm, which, at the time, was the standard gauge for railway lines in southern Italy. The first 69 km of track was completed in 1904 and reached as far as the foot of the Abyssinian highland. The Italian engineer, De Corné, was responsible for the layout of the mountain section of the line beyond Ghinda. The German railway engineer, Schupfer, was responsible for preparing the construction drawings; these were completed in 1905 and financing of the railway was secured in 1908. The first construction section was completed within about two years, and the line as a whole was inaugurated at the end of 1911.

Feeder lines

Work on extending the Eritrean Railway continued without delay, taking it from the plateau towards the west and the border with Sudan. By 1928, the section had been extended as far as Akordat and by 1932 as far as Biscia. Here again the reason for this was the desire to link the Eritrean Railway and Sudan's Cape gauge network – a link which was never achieved. The Second World War brought the work to an end, leaving the Trans-Eritrean Railway with a total length of only 337 km.

During the Second World War the British tried, unsuccessfully, to close the gap by constructing a line from Malawiya in the Sudan into Eritrean territory.

Section alignment and railway structures

From the port of Massawa the line runs on embankments past ancillary railway facilities to the mainland. The following section, through the desert, also mainly runs on embankments. Just before Dogali the track crosses a river bed by means of a stone arch viaduct. The next section is in an area of mountain foothills. As the line crosses them the height of the embankment and the height of the stone arch viaducts increase. In Ghinda the track reaches a height of 888 m. Here, a depot with a turntable and a classic station building are the only remnants of the original facilities. The line now begins its ascent towards its maximum altitude of 2,412 m. The length of this section, as the crow flies, is only 20 km. The line then dips down again towards the railway station in Asmara (2,349 m). This part of the line contains most of the 30 tunnels and 530 bridges and galleries. The gradient of the single track line has a maximum of 35‰, and the curve radii are nowhere tighter than 72 m. In the section near Embatkalla the line has reverse loops and tunnels and actually passes above itself three times. At one point, at the 'railway circus' near Arobraba, the line can even be seen passing backwards and forwards over itself four times, at heights of 2,133, 2,200, 2,233 and 2,266 m. In Asmara, the railway station (1910), the characteristic engine house and the workshops dating from 1928 still containing some machine tools have all been preserved.

Operation and equipment

The Eritrean Railway was largely destroyed during the war of independence in the second half of the twentieth century, but was completely rebuilt between 1994 and 2003. Since 2004 services can again run along the whole of the section between Massawa and Asmara, which was designed and constructed between 1897 and 1911. Although some isolated sections were destroyed during the war, the connecting line to Biscia has largely kept its original alignment and many of the original stone bridges have survived. Today, a train service normally operated by steam locomotives runs from Massawa to Asmara on weekdays. This service is almost exclusively used by groups of tourists; photo stops are arranged when the train makes dummy approach runs. The line currently carries no freight traffic. Besides two-axle tender locomotives (seven of them have been preserved), in 1907 the Eritrean Railway acquired two Maffei B'B' Mallet locomotives; one of which still stands in Asmara today. From 1911, Ansoldo delivered 25 'R440' series Mallet locomotives; three copies of which were constructed in Asmara. Five of these locomotives are still in operable condition today and at least five others have been taken out of service. Only one of the nine Fiat 'Littorino' diesel railcars delivered from 1935 is still in use today. Many of the original rolling stock of 2 and 4-axle freight wagons have been preserved but are no longer in use. A number of these were originally used on the narrow gauge network in southern Italy before being shipped to Eritrea. The bodies of the passenger coaches, originally dating from the 1930s and still in usable condition today, have all been modernised.

Comparison

The Eritrean Railway, like the Albula/Bernina line, was opened in the decade before the First World War. The Eritrean Railway is comparable with the Albula/Bernina line both in terms of the level of engineering difficulty (complex alignment along steep slopes high above the valley floor) and in terms of the attractiveness of its integration into the local topography. The density of engineering structures – tunnels, bridges, cuttings, embankments – can be compared with that of the Bernina line. Bridges of a size similar to those which would have been necessary on the Albula line to cross valley cuttings are not found on the Eritrea line, neither did this line require the construction of costly spiral tunnels or even a crest tunnel.

As with the Albula/Bernina line, the original section alignment has been preserved. Following the civil war the track of the Eritrean railway was reconditioned and repaired during the 1990s, but it was not altered. Compared with the Albula/Bernina line, where almost all the original structures have been preserved, in the case of the Eritrean Railway this applies only in part. Both railways possess historic rolling stock, and today the Eritrean Railway operates using rolling stock dating from the years between 1907 and 1957. In contrast to the Albula/Bernina line, at present the Eritrean railway only carries passenger traffic; freight traffic has shifted to the roads.

South America

Up till the 1980's, South America could claim a railway network of more than 100,000 km of track, spread across 12 countries, with altogether one hundred different companies involved in its operation. Some 40 % of the railway lines were located in Argentina, and another 30 % in Brazil. However, from the 1950s the privatisation of the railways and the increased level of motorisation led to rail services being discontinued in many places. The track gauge differs from country to country, and there are few international connections. Thanks to its many waterways, the gigantic basin of the Amazon has good accessibility, with the result that the area only contains a few branch terminal lines. Patagonia and the island of Tierra del Fuego also only have branch terminal lines.

The Andes Mountains form the greatest natural barrier to trans-continental transport in South America. They extend along the whole of the western side of the continent, cover a width of up to 800 km and reach a height of 6,958 m. Railway lines were built in this mountain range quite early on. The Andes railways could claim the highest point of any line in the world (a record only beaten in 2006 with the opening of the Tibet railway). They also overcome the greatest differences in altitude.

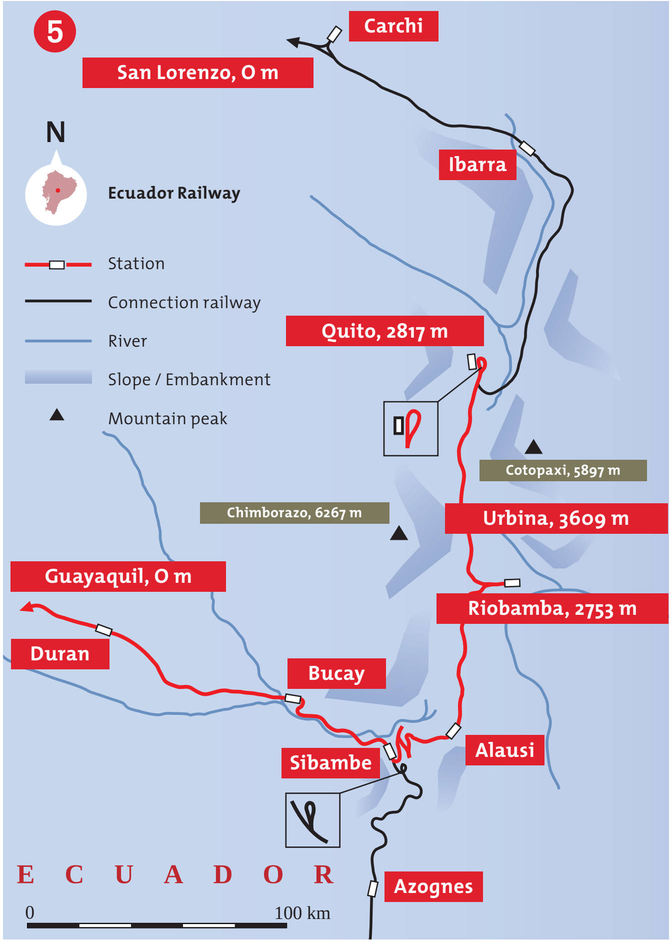
Almost all the Andes railways were designed by Europeans. Their primary purpose was to open up access to mining areas, and they had their starting point around the ports. Many were originally designed as trans-mountain links, although eventually they were not always realised as such. One of the earliest Andean railways was the line in southern Peru running from the seaport of Mollendo to Arequipa and Juliaca. One line leads off from Juliaca to Cuzco (opened in 1892) and a second towards Puno (3,850 m) on Lake Titicaca. By 1876, the line had been built as far as Crucero Alto – the culmination point of this section is at 4,474 m. In 1889, the narrow-gauge Chile-Bolivia Trans-Andean Railway began operations, linking the seaport of Antofgasta to the mining areas of Oruro; its highest point is at 3,959 m. The Collahuasi branch line (opened in 1908 and no longer in service) even reached a maximum altitude of 4,826 m. Other Andean railway lines with culmination points above 4,000 m were opened during the period from the beginning of the 20th century to the 1920s. Some – including the highest-altitude lines – were used as mine railways and have since been closed down. Others, like the Zapala railway between southern Chile and Patagonia, were never completed. Yet other lines suffered long periods when no services were operated or when sections were dismantled; for example the Argentinean railway from Mendoza to the Cumbre tunnel. Some of the sections of this line had rack and pinion traction and no longer exist today. However, the continuation of the line in Chile, running via Los Andes to Valparaiso, with no rack and pinion traction is still in operation.

South America contains several other railways besides those referred to above, for example the lines in Brazil, Colombia and Ecuador.

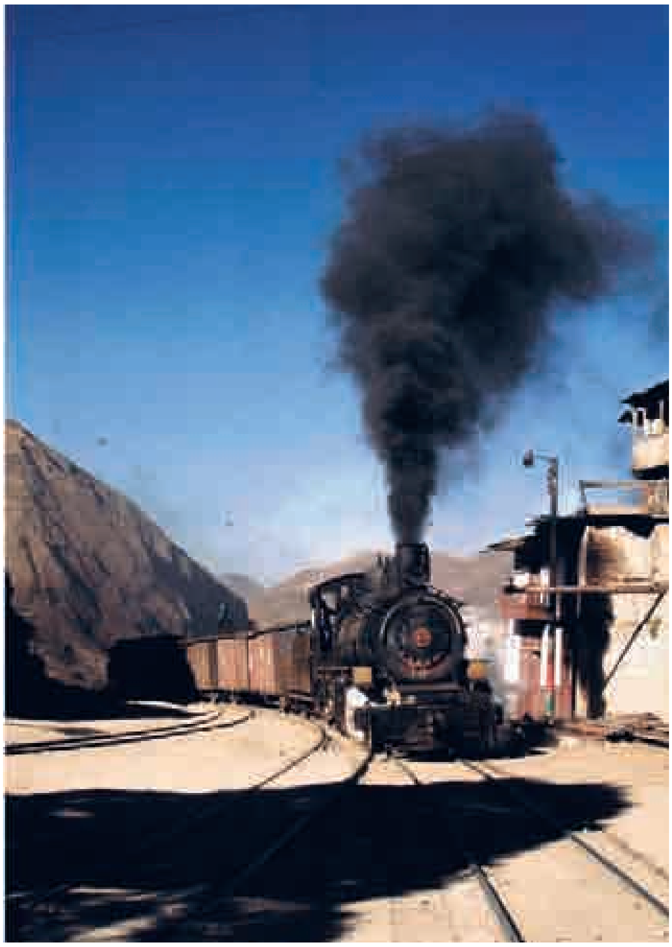
Mountain railways in South America with highest points over 1,000 m

Country	Connection	Gauge	Highest Point in m [1]	Opened [2]
Chile	Ollogue – Minas de Cobre (A&B)	Metre †	4826, Collahuasi	1908
Peru	Ticlo – Morococha (Peru Central)	Normal †	4818, La Cima	1908
Bolivia	Rio Mulato – Potosi	Metre	4787, Condor	1912
Peru	Callao – Huancayo (Peru Central)	Normal	4781, Galera	1892
Peru	Pachacayo – Chaucha	Normal †	4602, Caja Real	1904
Argentina	Salta – Socomba	Metre	4475, Chorrillos	1948
Peru	Mollendo – Juliaca	Normal, G	4474, Crucero Alto	1876
Bolivia, Chile	Antofagasta – Uyuni	Metre	4401, Yuma	1917
Peru	Cerro de Pasco – Goyllarisquisga	Normal	4385, Alcacocha	1900
Peru	Juliaca – Cusco	Normal	4314, La Raya	1892
Chile, Bolivia	Arica – La Paz	Metre	4257, General Lagos	1915
Peru	Oroya – Cerro de Pasco	Normal	4214, La Cima	1904
Bolivia	Cochabamba – Oruro	Metre	4137, Cuesta Color	1900
Bolivia	Guaqui – La Paz	Metre	4106, EI Alto	1903
Bolivia	Ollagua – Calama	Metre	4057, Ascotan	1925
Bolivia	Potosi – Sucre	Metre	4033, Potosi	1929
Chile, Argentina	Antofagasta – Salta	Metre †	4000, Munano (Soc.)	1948
Chile, Bolivia	Antofagasta – Ollague	Metre	3959, Ascotan	1889
Argentina	Ouquios – Tres Cruces	Metre †	3693, Tres Cruces	1907
Ecuador	Guayaquil – Quito	1067 mm*	3609, Urbina	1908
Argentina	Tucuman – La Quiaca	Metre	3559, Pumahuasi	1908
Bolivia	Villazon – Atocha	Metre	3447, Villazon	1924
Argentina	Mendoza – Cumbre	Metre, Z †	3191, Cumbre Tunnel	1910
Chile	Puente Alto – El Volcan (FC Militar)	600 mm †	3050, El Volcan	1910
Colombia	Medellin – Buenaventura (FC de Antioquia)	914 mm	1900, Quiebra	1914
Brazil	Campos do Jordão – Cacique	Metre	1715, Cacique	1912
Brazil	Paranagua – Curitiba	Metre	1010, Roca Nova	1885

[1] various figures quoted for highest stations or culmination points
[2] various figures quoted for part or generally continuous opening
† closed down
* 3.5 feet, also called Cape gauge
Z cog system
G freight only



Guayaquil&Quito Railway > Mountainous section.
H.P. Bärtschi



Guayaquil&Quito Railway >Arrival at Alausi with hand-braked wagons. Photograph 1990.
H.P. Bärtschi

Guayaquil&Quito Railway > Zigzag alignment at the Devil's Nose. Photograph 1990.
H.P. Bärtschi

Guayaquil&Quito Railway > Autoferro in Urbina at 3,609 m, before the Mount Chimborazo. Photograph 1990.
H.P. Bärtschi

Guayaquil&Quito Railway, Ecuador

The choice of the Guayaquil&Quito Railway as an object of comparison with the Albula/Bernina line was based on the following criteria:

> Commissioning of the whole section similar to that of the Albula/Bernina line
> Narrow gauge
> The need to overcome great differences in altitude
> Railway constructed to open up access to the country – linking the coastal region with the capital city
> The line passes through an attractive and varied cultural area
> Planned for passenger and freight traffic (in contrast to the mountain railways in the Andes)
> Extensive sections still in operation

Construction history

From the time it gained independence from the Spanish colonial power in the first half of the 19th century, one of Ecuador's principal objectives was the construction of a railway linking the coastal region with Quito, the capital (2,817 m). From 1871, government funds were used to push forward the construction of the line from the port of Guayaquil, initially with a track gauge of 914 mm. Progress with the construction work through the swamps and wetlands of the tropical lowland was very slow. From 1877, serious social unrest and the eruption of the Cotopaxi volcano further delayed work on the line. As a result, the government loan taken out in England had to be renewed and the capital increased. Initial plans proposed crossing the bay between Guayaquil and Duran (Eloy Alfaro) by ferry, but in the 1880s a rail track was set up there. By 1884, the work had reached Barraganeta and by 1888 the town of Bucay, 80 km into the interior of the country at the foot of the Andes where major workshops were erected. The construction work ground to a standstill in the humid tropic region. In 1897, a new contract was signed with a North American company. In view of discrepancies, this company decided to build the mountain section after Bucay in the British 'Cape gauge' (1,067 mm) giving the alignment a grade of 55 ‰, considerably steeper than the original project. When the line reached some 3,000 m the railway engineers found they had to struggle with some extremely difficult subgrade conditions: drift sand and volcanic ash. The whole of the line between the port of Guayaquil und Quito was finally opened in 1908, with the section in the lowland area originally built to a 914 mm track gauge, now rebuilt to the correct gauge.

Feeder lines

In 1957, a second connection was completed between Quito and the sea, terminating in the port of San Lorenzo close to the border with Colombia. Today, only parts of this line are in operation. From Ibarra onwards, 'Autoferro' railcars are used since part of the line to the port has been dismantled. Ecuador's third section of mountain railway, branching off from the Ecuador Railway towards Cuenca, completed between 1915 and 1965, has been closed down. Here again, considerable segments of the tracks have been removed. Several connecting lines were built to link up with the section between Guayaquil and Quito. These include lines to the Ingenio San Sarli sugar factory and to the Empresa de Carros Urbanos plantations.

Section alignment and railway structures

Between Guayaquil and Bucay the line runs through a flat but marshy region. The 90 km. long, mountain section begins in Bucay. Part of

the line has to overcome a difference in altitude of 3,000 m; the gradient used here is 55 ‰. A double setting back track was constructed at a height of 2,606 m; a low-cost method of gaining height artificially. The line rises up along a mountain formation known as the 'Devil's Nose', and reaches its highest point (3,609 m) in Urbina, below Mount Chimborazo (6,267 m). From there the railway runs through the north-south valley, past Octopi (5,897 m) and down to Quito, the capital.
The mountain section of the Guayaquil&Quito Railway has prolonged, steep gradients and many curves, with the line running along precipitous slopes high above the valley floor. Despite the great altitude of the line, there is no extensive protection against rockfalls and mud flows, nor have any larger bridge structures been built to cross valleys and waterways. Tunnels are also almost completely absent. The most significant civil engineering works are the cuttings and embankments.
Since its opening in 1908, maintenance of the railtrack and structures along this single-track corridor have been minimum; as a result they are largely unchanged, but in need of repair. There have been no additions worth mentioning. There is an almost complete lack of ballast on some, and the rails are frequently simply secured to the rough-hewn timber sleepers with wrought-iron nails, without any railway-chairs. The mountain section from Bucay to Riobamba (km 228) was rehabilitated during the 1990s; the section from Riobamba to Cotopaxi (km 386) in 2004/2005.
The structures and workshops are also still largely in their original form. In Duran, railway workshops with machinery dating from the 1880s can still be seen today. The Duran railway station has been listed as a national monument, but it is in a very poor structural condition. The workshops in Riobamba have been partly abandoned. However, in Quito the classic railway station and the depot workshops dating from when the line was constructed have all been preserved.

Operation and equipment

Violent storms have interrupted the section again and again leaving only sub-sections operable. Through services have not been run since the beginning of the 21st century. The tracks from Bucay to Milagro (km 34) have been tarred over. The central government has brought an action against the local municipalities on this and there are now plans for a bypass line. Several times since the 1980s the lack of protective structures in the mountain section has resulted in extensive damage to the line by landslides, entailing extensive repair work.
Two to three steam locomotives are used to run tourist trains in Bucay and along the Devil's Nose. Most of the passenger coaches and freight wagons dating from the time the line was constructed are now in poor condition. The trains which run on the flat sections haul five to six wagons, but only up to three on the ramp sections. Each wagon is braked by hand, even on the steep parts of the line. The section between Quito and Cotopaxi at the foot of the volcano is popular with tourists and runs a regular service at weekends, mostly using railcars. Combined passenger and freight trains run between Riobamba and Sibambe three times a week.
The original rolling stock has largely been preserved. Priority was given to modernising the locomotive fleet – a number of steam locomotives were purchased in 1927, and a further three series of diesel locomotives were delivered in 1957, 1970 and from 1991. None of the ten older ALCO

diesel locomotives (supplied in 1970) and the five Alstom BBB diesel locomotives purchased in 1957 are still in service. Only three or four of the 9 Alstom BBB diesel locomotives delivered between 1991 and 1993 are still in use. The fleet of locomotives also includes two Baldwin 1'C engines dating from 1901 and twelve Baldwin 1'D engines built between 1927 and 1953. A number of railcars and freight cars are also available; these are conversions of (or built from parts of) various road vehicles, including a new, air-conditioned Mercedes coach.

Comparison

The Guayaquil&Quito Railway was opened at the same time as the Albula/Bernina line, although the first sections had been constructed as early as the 1870s. The highest point on the Guayaquil&Quito Railway is at 3,609 m – considerably higher than the Bernina railway (2,253 m) – and the line even begins at sea level. and must therefore overcome a much greater difference in altitude. With respect to the technical-constructional challenge the Guayaquil&Quito Railway is certainly comparable with the Albula/Bernina line. As with the other comparative railways beyond Europe, the alignment of the Guayaquil&Quito Railway was designed to avoid the need for any complex engineering structures. Consequently there are no major bridges and few tunnels: there is neither a spiral nor a crest tunnel, section, altitude being gained through the use of setting back tracks, a solution which was common in the 1840s.

The Guayaquil&Quito Railway is also comparable with the Albula/Bernina line in terms of the attractiveness of its integration into the topography. The spectacular section of the line with its setting back tracks in the 'Devil's Nose' area is world-famous. In contrast to the Albula/Bernina line which still operates a full service today, parts of the Guayaquil&Quito Railway have already been closed down. Where the railway is still running, long stretches of the original alignment have been preserved. The density of historic monuments along the line is, however, much lower than that of the Albula and Bernina line. Those parts of the Guayaquil&Quito Railway which still exist today – a significant contrast to the Albula/Bernina line – now only carry a very low volume of passenger and freight traffic. However, demand has increased near the capital city of Quito and on the spectacular engineering section near the 'Devil's Nose', where special tourist trains operate. Both the Albula/Bernina line and the Guayaquil&Quito Railway now operate with modern rolling stock. However, both railways also have historic rolling stock and the Guayaquil&Quito Railway still has steam locomotives dating from the 1920s.

North and Central America

In 1930, the rail network of the USA was the largest in the world, stretching over some 460,000 kilometres of track. Begun in Baltimore in 1827, it is also one of the oldest in the world. The dense expansion of the network in the northeast and southeast, which were early industrialised, was followed in the 1860s by the opening up of the West. With the breakthrough of individual transport and competition from air travel, the US rail network, which is largely unsubsidised, has shrunk to little more than half of its peak size since the second half of the 20th century. Numerous mergers since the 1970s have also reduced the once large number of private railway companies. In 1995, for example, the *Burlington Northern Railroad* and the *Atchison, Topeka and Santa Fe Railway* merged to become the *Burlington Northern Santa Fe* BNSF with a total rail network of around 51,500 km. The merger discussions begun in 1999 between the *Burlington Northern Santa Fe* and the *Canadian National* CN were broken off a year later due to the objections of other rail companies and potential difficulties in implementing the fusion.

The Canadian network, which once extended over 74,000 km, was generated by the competition between private and state railway companies. The state subsidised rail construction, via the *Canadian National*, in order to fend off US investment interests.

In Central America, in the early 1840s, Cuba, then still under Spanish colonial rule, became the first country in this region to have a railway. This operated in the area around Havana. The building of the railways in Mexico, Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica was dominated by the USA. With the exception of Mexico (greatest extent of the rail network: 24,000 km), rail no longer played a significant role in these countries; operation of the existing lines has largely been terminated.

In Central and North America, as in South America, the Cordilleras which dominate the whole length of the west of this part of the world constitute the greatest challenge to rail construction. The Appalachians, in the eastern part of North America, seem harmless in comparison with this mighty mountain system, and were conquered by mountain railways as early as the 1840s. The North American Cordilleras comprise of several mountain ranges (Rocky Mountains, Coast Ranges, Cascade Range, Sierra Nevada, Sierra Madre) which are separated from each other by basins and plateaux. The highest elevation is Mount McKinley (6,187 m) in the Alaskan chain. Between the Coast Ranges, running parallel to the Pacific coast, near San Francisco and the 4,500 km long Rocky Mountains, the Cordilleras spread over a width of 1,500 km.

The first mountain railways were built in the Cordilleras of the USA, in connection with the settlement of the West following the discovery of gold. From the later 1860s, the rival rail companies *Union Pacific* and *Southern Pacific* both opened railways which crossed what were for those times extremely high passes. A large number of high altitude railway lines are concentrated around the mineral and coal-rich mountain region near Denver, where the Rocky Mountains reach their highest elevation with Mount Elbert, which soars to 4,402 m. Denver itself came into being in 1859 as a gold prospectors' camp.

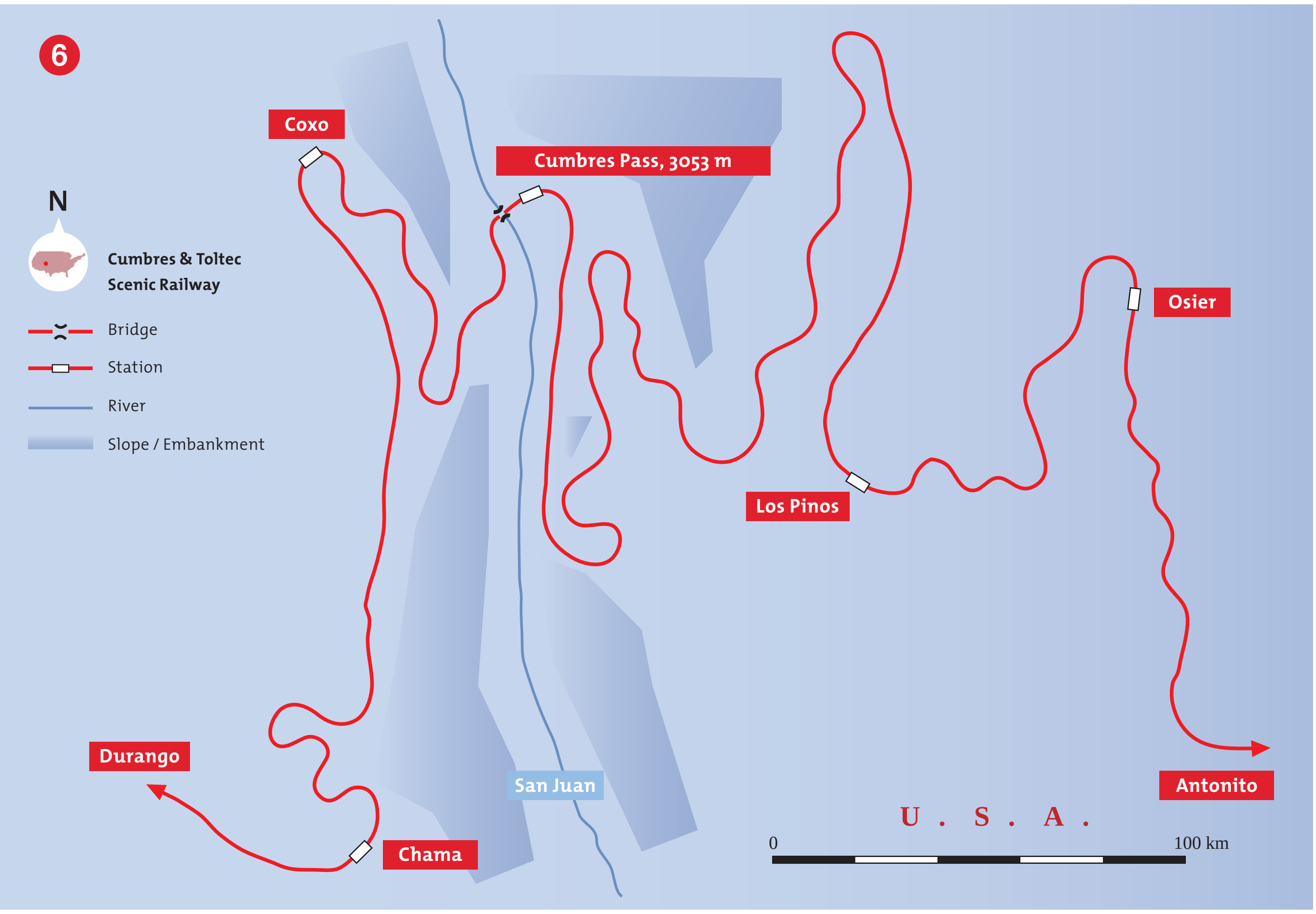
In Canada, the *Canadian Pacific* won the race for the first transcontinental through line. In 1885, the railway line from Winnipeg to Vancouver reached a high point of 1,625 m near

Great Divide at Kicking Horse Pass.
In Mexico, where rail construction was state subsidised, the first mountain railway was built in 1872. More were to follow. They served principally to open up the capital, Mexico City, situated at 2,240 m, but also the uplands to the north between the Madre Oriental and the Sierra Madre Occidental mountain ranges.

Mountain railways in Central and North America with highest points over 1,000 m

Country	Connection	Gauge	Highest Point in m [1]	Opened [2]
USA/Colorado	Denver – Kremmling	Normal	3560, Rollins Pass (1928: 2817 Moffat Tunnel)	1904
USA/Colorado	Colorado Springs – Leadville	Normal †	3515, Hagerman T. (1893: 3338 Ivanhoe Tunnel)	1887
USA/Colorado	Nathrop – Gunnison	914 mm †	3512, Alpine Tunnel	1882
USA/Colorado	Como – Breckenridge	914 mm †	3500, Boreas Pass	1890
USA/Colorado	Leadville – Dillon	914 mm †	3450, Fremont Pass	1882
USA/Colorado	Breckenridge – Leadville	914 mm †	3450, Fremont Pass	1884
USA/Colorado	Salida – Gunnison	914 mm †	3309, Marshall Pass	1881
USA/Colorado	Leadville – Red Cliff	914 mm †	3180, Tennessee Pass (1890: Tunnel, Normal)	1881
USA/Colorado	Durango – Ridgway	914 mm v	3124, Lizard Head Pass	1891
Mexico	La Cima – El Oro	Normal †	3054, La Cima	1882
USA/Colorado	Chama – Antonito	914 mm	3053, Cumbres Pass	1880
USA/Colorado	Webster – Como	914 mm †	3045, Kenosha Pass	1879
USA/Colorado	Walsenburg – Alamosa	914 mm †	2817, Veta Pass	1877
Mexico	Pueblo – Mexico City	Normal	2561, Nanacamilpa	1883
USA/Colorado	Bond – Steamboat Springs	Normal	2540, Toponas	1913
Mexico	Paso del Macho – Esperanza	Normal	2536, Maltratata	1872
Mexico	Chihuahua – Topolobampo	Normal	2460, Los Ojitos	1961
USA /Wyoming	Cheyenne – Ogden	Normal	2443, Sherman Hill	1868
USA/Colorado	Gunnison – Montrose	914 mm †	2429, Cerro Summit	1882
USA/Colorado	Trinidad – Albuquerque	Normal	2312, Raton Pass	1878
USA/Utah	Price – Provo	Normal	2268, Soldier Summit	1882
USA/Arizona	Albuquerque – Barstow	Normal	2212, Continental Divide	1883
USA/Calif./Nevada	Sacramento – Reno	Normal	2147, Donner Pass	1868
USA/Montana	Miles City – Avery	Normal †	1934, Pipestone Pass	1909
USA/Montana	Great Falls – Butte	Normal	1929, Butte	1888
USA/Utah/Nevada	Salt Lake City – Winnemucca	Normal	1799, Shafter	1906
USA/Montana	Billings – Spokane	Normal	1743, Bozeman Pass	1883
Canada	Calgary – Kamloops	Normal	1625, Kicking Horse Pass (Great Divide)	1885
USA/Montana	Shelby – Whitefish	Normal	1589, Marias Pass	1892
USA/Texas	San Antonio – El Paso	Normal	1547, Paisano	1882
Costa Rica	Puero Limon – Alajuela	1067 mm	1547, El Alto	1891
Guatemala	Puerto Barrios – Puerto Quetzal	914 mm	1497, Cd. Guatemala	1884
Canada	Lethbridge – Nelson	Normal	1359, Crowsnest Pass	1898
USA/California	Bakersfield – Mojave	Normal	1228, Tehachapi Summit	1876
Canada	Vancouver – Prince George	Normal	1208, Horse Lake	1918
Canada	Edmonton – Kamloops	Normal	1110, Yellowhead Pass	1913

1) various figures quoted for highest stations or culmination points
2) various figures quoted for part or generally continuous opening
† closed down



Cumbres & Toltec Scenic Railway>
Important section of the line.
H.P. Bärtschi

Cumbres & Toltec Scenic Railway >
Needleton station with Rio Grande water tower. Photograph 1974.
P. Gloor

Cumbres & Toltec Scenic Railway>
Section above Animas Canyon. Photograph 1974.
P. Gloor

In Guatemala, the Guatemala Railway (highest point 1,497 m) with its tremendous steel bridge constructions was inaugurated in 1884. In 1891, a mountain railway was also opened in Costa Rica.

Denver&Rio Grande Railroad (key focus: Cumbres & Toltec Scenic Railway), USA

The choice of the Denver&Rio Grande Railroad for comparison with the Albula/Bernina line was based on the following criteria:

> Extensive narrow-gauge network to access the region
> Mountain railway character overcoming great differences in altitude
> Attractiveness of the surrounding landscape (cf. 3.c.3)
> Presence of original substance (even if only still in operation on some sections)

Construction history

In 1870, the Kansas Pacific railtrack reached the city of Denver. At the same time, William Jackson Palmer (1836 – 1909) founded the *Denver&Rio Grande* D&RG rail company. His first objective was to establish a rail line to the coal regions around Canon City and Walsenburg in the eastern foothills of the Rocky Mountains as well as a connection to El Paso (Texas) on the Mexican border. To minimise construction and operating costs, Palmer chose a narrow-gauge design, although from the later 1880s onwards, the D&RG was, to build its track increasingly in standard gauge with a view to compatibility. Palmer himself was the founder of a coal mining company which branched out into the crude oil business, calling itself the *Colorado Fuel & Iron Company* (with a refinery in Alamosa). The discovery of silver near Marshall Pass (3,225 m) in 1877 and the silver rush that this caused allowed the D&RG to progress rapidly with rail construction in the mountains. The principal aim was now to access the Rocky Mountains in Colorado and the neighbouring states by establishing a network. In 1880, the narrow-gauge track of the D&RG led from Denver to Pueblo, and south-westwards from there via Walsenburg and Alamosa to Antonito and onwards over the Cumbres Pass in the San Juan Mountains to Chama. Another route branched off to the northwest towards Leadville, which lead through Canon City and Salida. There was also a connection between Pueblo and Santa Fe, situated to the south. In 1881, the route between Chama and Durango was opened, and one year later the silver mines to the north of Durango could be reached by rail from Silverton. Also brought into operation in 1882 was a line leading from Gunnison and Montrose to Salt Lake City and Odgen in the state of Utah. The D&RG narrow gauge network constructed in the Rocky Mountains since the 1870s eventually extended over 2,500 km. On the segment between Pueblo and Santa Fe, the D&RG had a three-rail track installed in the 1890s so that trains of the *Santa Fe* railway company, which were built for standard-gauge track could also reach the steel works in Pueblo. To the west of Leadville, also under the aegis of D&RG, the normal-gauge line from Denver via Dotsero and Grand Junction was extended to Salt Lake City and Ogden. The narrow-gauge line to Salt Lake City was then taken out of service. Another normal-gauge line from Denver to Antonito was opened in 1901.

In 1894, the D&RG took over the *Rio Grande Southern* railway company, and with it the track built in 1891 between Durango and Ridgway (near Silverton). After further mergers around 1900 with rail companies operating in the region, the main focus of the D&RG was the expansion of its normal-gauge network. The narrow-gauge network collapsed when the construction of the three-rail track on certain sections was abandoned. In 1921, the organisation renamed itself the *D&RG-Western* in reference to the Western Railway bought up in 1901. In 1947, the D&RGW took over the important mountain railway network of the *Denver & Salt Lake Railway*, and with it the Denver – Craig line, which as a standard-gauge mainline railway includes some spectacular mountain sections. The segment between Bond and Craig is today used almost exclusively by heavy coal trains. After 1947, the changes of gauge and closures accelerated. In 1984, the billionaire Philip Anschutz bought the D&RGW only to sell it on to the *Southern Pacific* in 1992; which has since been integrated into the *Union Pacific*.

Since the great wave of line closures in the 1960s, the great majority of the narrow-gauge network lines constructed by the D&RG is no longer in service. The some 112 km of the line from Antonito to Chama over the 3,053 m high Cumbres Pass was acquired by the US states Colorado and New Mexico, which brought it back into service in 1972, four years after the closure, exclusively for tourism purposes. Since then, a museum train operation has been run there during the spring and summer months under the name *Cumbres & Toltec Scenic Railway*. No buyer could be found for the section leading on to Durango and the track there has been dismantled. At present, the now isolated narrow-gauge segment between Durango and Silverton is also being operated as a museum railway.

Rail track routing and railway structures

The Cumbres & Toltec Scenic Railway line dates from between 1878 and 1880 but the entire original track has been preserved. The line climbs some 650 m in a spectacular ascent, including several S-bends, between Antonito (2,404 m) and the Cumbres Pass (3,053 m), before making its way – negotiating a similar difference in altitude – with a 40 ‰ gradient to Chama.

The route along the curving contours, at such an altitude was very complex. In order to keep the building outlay to a minimum, cuttings and the erection of major embankments and bridges were avoided wherever feasible. There are only a few substantial civil engineering structures on the section. Among these are the two suspension bridges over Wolf Creek near Lobeto (30 m high, 94 m long) and Cascade Creek near Osier (35 m high, 131 m long) and the two tunnels in the vicinity of Toltec (Toltec Tunnel 110 m long; Mud Tunnel 104 m long). Hardly any defences against avalanche and mudflow were built in spite of the considerable altitude of the passes to be crossed. On Cumbres Pass itself, there had been more than 20 snow protection galleries, up to 250 metres long which were built in the 1880s. Many of these were lost to fires, with the result that from the 1920s there was a shift to building snow trap fences at exposed points.

In Chama, the original substance of the station buildings, water towers and depot facilities has largely been retained, while the structures at the other end of the Cumbres & Toltec Scenic Railway in Antonito were, for the most part, reconstructed in the 1970s. There are also a few station buildings and water towers along the route which are preserved in their original condition, as well as some which were reconstructed in the 1980s and 1990s. The rigorous climatic conditions and the long suspension of operation during the winter months make continuous maintenance work on the predominantly wooden structures essential.

Operation and equipment

The Cumbres & Toltec Museum Railway is in operation every day from the end of May to the middle of October. As a rule, a steam-driven train leaves from each end of the section to make the seven-hour journey along the whole route and back. As well as this, additional special excursion trips are organised. Every two years the original 'Alco' steam snowplough from 1923 makes the trip for a "photo safari". There are several 2-8-2 wheel arrangement tender locomotives (Baldwin 1903 and 1925; D&RGW 1928-1930), six of which are operational. As well as reconstructed four-axle wooden box cars, a complete fleet of goods wagons has also been preserved. The outfitting with rolling stock reconstructed from the original 1920s plans is a special attraction of this museum railway.

Comparison

The route of the Cumbres & Toltec Scenic Railway was opened a quarter of a century before the Albula/Bernina line. In contrast, at least to the Albula railway, its construction was realised with minimum investment. The topographical circumstances were advantageous in this respect, not requiring the building of any high-cost engineering structures (such as spiral or crest tunnels, or larger bridges) or calling for new technical solutions (such as electrical operation) to be tried out. As a rule it was possible to conquer the differences in altitude by making loops in side valleys (as demonstrated by the Semmering Railway). The maximum gradient of 40 ‰ corresponds to the criteria for steam locomotive operation (Albula line 35 ‰).
The original track has been retained on both railways, but in the case of the Denver&Rio Grande Railroad only one section – between Antonito and Chama – is still in operation. After it was brought into service as a tourist railway in 1972, renovation work was carried out on the remaining structures. Since then it has been necessary to reconstruct some of the, for the most part, wooden buildings due to the poor state of the substance. In contrast, the Albula/Bernina civil engineering structures have largely been preserved in their original condition, or, where preservation was not possible, have been replaced with structures designed to blend in well. On the Cumbres & Toltec Scenic Railway each of the passenger cars, with their wooden superstructures, has been rebuilt on an original goods wagon chassis. The steam locomotives date from the 1920s and some are still operational. The Cumbres & Toltec Scenic Railway has acquired a special significance thanks to the attractiveness of the landscape it runs through, and particularly from the designation 'Scenic Line of the World', which is examined in more detail in 3.c.3.

Europe (without Switzerland)

Europe was a world leader in railways until well into the 20th century. In its heyday, the European rail network – including the lines in Switzerland and the part of Russia belonging to Europe – comprised some 410,000 km of track, only around 50,000 km less than that of the USA. In Western Europe, the massive expansion in the road network, which started in the 1960s, undermined railway frequencies. A similar pattern occurred in the eastern European states after the political upheavals at the end of the 1980s.

Railways, as we know them today, had their origin in England in the early 19th century. To create a link between the industrial centres in the northwest and those on the east coast, railways were built over the Pennines as early as the mid-840s. In France, the first railway line was built in the Massif Central, in the region of St. Etienne; it was still based on a mixed operation using both steam locomotives and horses. In the course of time, all the mountain ranges of Europe have had rails laid over them, or through them in tunnels. The first European railway to exceed the altitude of 1,000 m was the Neuchâtel line, in the Swiss Jura, built in 1860. The first mainline railway to exceed 1,000 m was the Spanish North Railway. This linked the cities of Madrid and Avila across the Castilian dividing range. Planned from as early as 1858, it was opened in 1863. The first transalpine line ran over the Semmering and was brought into service in 1854. The second alpine railway, the Brenner line, was opened 13 years later. In France, two mountain railways were constructed between 1868 and 1870. More were to follow. The longest rail tunnel of the time came into operation with the opening of the transalpine Mont Cenis line in 1871. In the Carpathian Mountains of Romania, the Bucharest – Brasov main line was completed in the 1870s, with its highest point at over 1,000 m. The economic crisis of the late 1870s virtually brought major European rail projects, such as the Gotthard (see below) and the Arlberg tunnels, to a halt for some time. Further mountain railways were eventually built at the end of the 19th century under Austrian influence, in Spain, France and in Italy, where several majestic railways cross the Apennines. By the beginning of the First World War, more than a dozen other new rail lines in Europe had maximum elevations of over 1,000 m – one example is the Bergen Railway in Norway. By 1976, the number of mountain railways was to double.

Train Jaune, France

The choice of the Train Jaune (Yellow Train) in France for comparison with the Albula/Bernina line was made based on the following criteria:

> Similar construction period
> Narrow gauge
> Overcoming large differences in altitude (several vegetation levels)
> Attractiveness of the landscape through which it runs (cf. 3.c.3)
> Still in operation
> Around 2001 the Train Jaune was considered for nomination as UNESCO World Heritage; extensive documentation was prepared in this context.

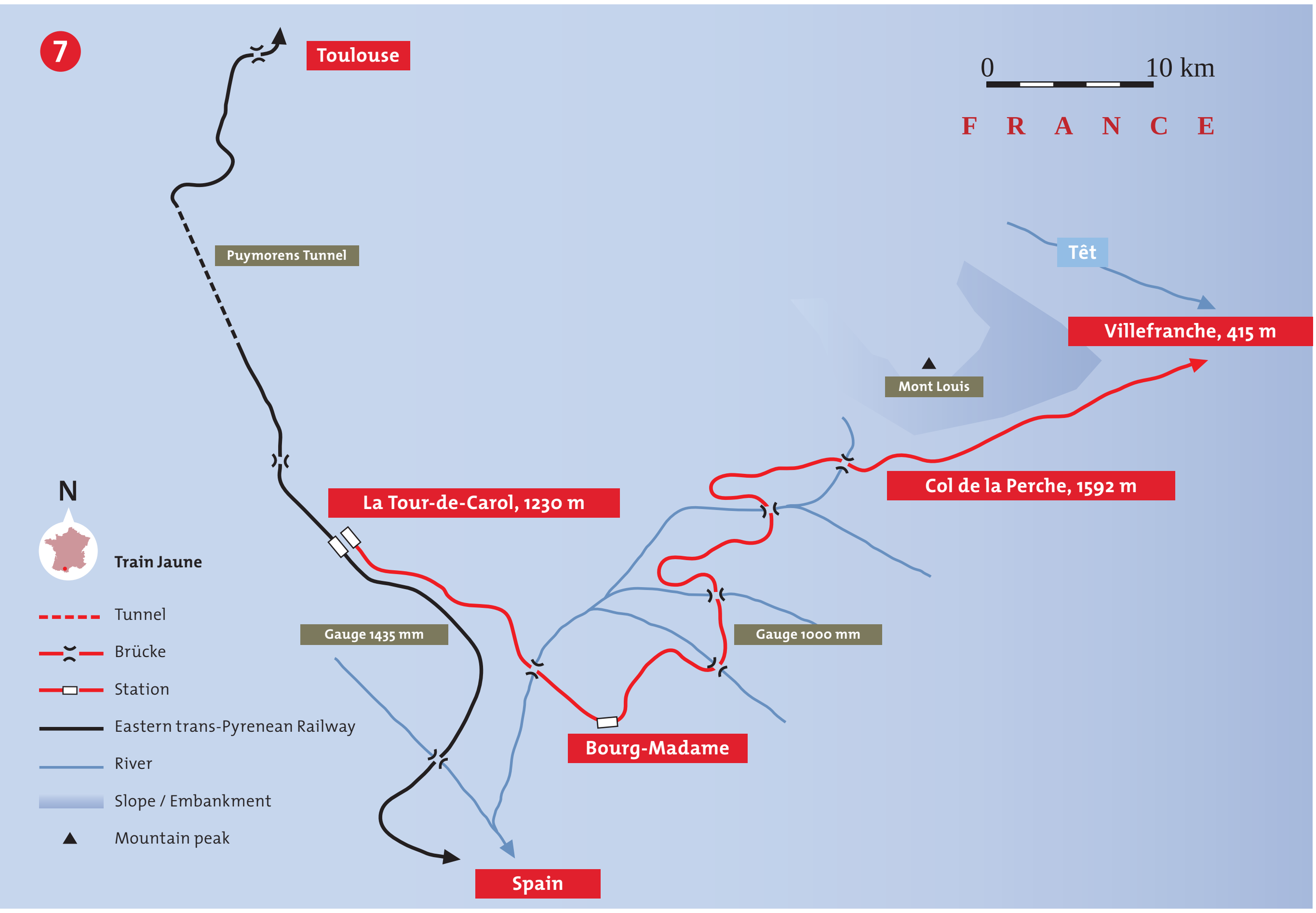
Construction history

Spain and France are separated by the Pyrenees, a chain of mountains stretching between the Atlantic Ocean (Bay of Biscay) and the Mediterranean (Gulf of Lyon). The building of trans-Pyrenean railways was considered from the late 1860s, but the actual planning for the construction of the easterly line from Toulouse

Mountain railways in Europe (without Switzerland) with highest points over 1,000 m

Country	Connection	Gauge	Highest Point in m [1]	Opened [2]
France	Villefranche – La Tour-de-Carol (Train Jaune)	Metre	1592, Col de la Perche	1911
France, Spain	Toulouse – Barcelona	Normal	1567, Porté Puymorens	1929
Italy	Dobbiaco – Calalco (Dolomites Railway)	950 mm †	1529, Cima bianche	1910
France	St-Gervais-le-Fayet – Vallorcine	Metre †	1386, Montets	1910
Austria	Innsbruck – Brènnero	Normal	1371, Brenner	1867
Spain	Madrid – Sierra de Ávila	1676 mm	1359, La Cañada	1863
Italy	Cosenza – San Giovanni	950 mm †	1340, Montescuro	1931
Austria	Feldkirch – Innsbruck	Normal	1311, Arlberg	1884
Italy	Torino – Modane	Normal	1306, Mont Cenis (1866: 2081, construction railway)	1871
Spain	Madrid – Burgos	1676 mm	1304, Somosierra	1968
Norway	Olso – Bergen	Normal	1301, Finse	1908
Spain	Madrid – Segovia	1676 mm	1296, Guadarrama	1888
Spain	Ujo – Pusdongo	1676 mm	1271, Perruca Túnel	1884
Italy	Sulmona – Isernia	Normal	1267, Rivisòndoli	1897
Bulgaria	Septemvri – Dobrini'ste (Rhodopen Railway)	760 mm	1267, Avromovo	1937
Austria	Schwarzach-St.Veit – Villach	Normal	1226, Tauern-Tunnel	1909
Spain	Sagunto – Zaragoza	1676 mm	1218, Escandón	1901
Italy	Fortezza – San Càndido (Pustertal Railway)	Normal	1210, Dobiacco	1871
Austria	Leoben –Hieflau (Erzberg Railway)	Normal	1206, Präbichl	1873
France	Livron – Briançon	Normal	1204, Col de Cabre	1876
France/Spain	Canfranc – Pau	Normal	1195, Canfranc	1928
Spain	Bilbao – León (La Robla Railway)	Metre	1192, Bercedo Pass	1894
Austria	Innsbruck – Scharnitz (Karwendel Railway)	Normal	1185, Seefeld im Tirol	1912
France	Grenoble – Marseille	Normal	1176, Col de la Croix	1877
France	Aurillac – Neussargues	Normal	1152, Lioran Tunnel	1868
Spain	Aranjuez – Valencia	1676 mm	1132, Palancares Tunel	1947
Spain	Almería – Linares-Baeza (Sierra Nevada-Linie)	1676 mm	1129, Huénejar-Dolar	1899
Austria	Scharnitz – Pfronten-Steinach (Ausserfern Railway)	Normal el.	1128, Lähn	1913
France	Le Puy – St. Germain	Normal	1089, Sembadel	about 1900
Spain	La Coruña – Zamora (Sierra de la Culebra)	1676 mm	1087, La Mezquita	1958
France	Bort – Neussargues	Normal	1081, Clarièrespass	about 1900
Spain	Torre – Brañuelas (La Granja)	1676 mm	1080, Divisoria Tunnel	1882
France	Le Puy – La Levade d'Ardèche	Normal †	1076, S. Cirgues	1936
Italy	Cùneo – Ventimiglia	Normal	1073, Tenda-Tunnel	1915
Romania	Bucarest – Brasov	Normal	1057, Predeal	1879
France	Neussargues – Béziers (Causses)	Normal	1056, Arcomie	1888
Romania	Brasov – Ploesti (Karphaten Railway)	Normal	1054, Predeal	about 1900
Poland	Kamienna Gora – Krzeszow	Normal	1052, Krzeszow	1899
Yugoslavia	Belgrad – Bar	Normal	1032, Kolasin	1976
France	Nîmes – Clermont-Ferrand (Cevennes)	Normal	1030, S. Laurent les B.	1870
Norway	Trondheim – Dombas (Dovre)	Normal	1025, Hierkinn	1921
France	Nice – Digne	Metre	1023, Thorame Haute	1894
France	Le Puy – Vichy	Normal	1021, Allègre	1902
Bosnia	Usice – Mostar (Bosnian Railways)	760 mm †	1000, c. Usice	1891

[1] various figures quoted for highest stations or culmination points
[2] various figures quoted for part or generally continuous opening
† closed down



Train Jaune > Mountainous section.
H.P. Bärtschi

Train Jaune > 'Le Viaduc Séjourné' at Fontpédrouse. Photograph 2002.
H.P. Bärtschi

Train Jaune > 'Pont suspendu Gislard' over the river Têt. Photograph 2002.
H.P. Bärtschi

via La Tour-de-Carol to Barcelona was not to begin until 1910. However, the route was not completed until 1929, just in time for the World Exhibition in Barcelona. The transnational rail line which led from the Mediterranean near Montpellier via Perpignan to Barcelona was built already in the 1860s. In 1880, the *Compagnie des Chemins de fer du Midi*, known as the Midi, was awarded a concession for the construction of a high-altitude mountain railway from Villefranche to La Tour-de-Carol over the plateau of the Cerdagne in the French part of the East Pyrenees. It was to connect with the transnational Mediterranean lowland route to Prades, in operation since the 1870s, which branched off to the west at Perpignan. By 1895, the Midi had extended this to reach Villefranche. The construction of the high-altitude section from Villefranche was originally intended – like the lowland railway – to be built in standard gauge. However, the laying of the track proved difficult, entailing lengthy delays in completion. The construction of the railway was of national significance: in the first place for military reasons, due to the border installations in the Cerdagne, and secondly with respect to securing the power supply. In the end, in order to achieve rapid completion of the construction, a franchise was awarded in 1903 for a metre-gauge railway with gradients of up to 60 ‰, that would reduce expenditure considerably. Immediately the concession had been granted for a new rail variant, the Midi began planning the section between Villefranche and Bourg-Madame on the Spanish border. Initially a steam railway with cogged sections was considered. However, as the state was at that time subsidising the construction of power stations and the electrification of the border region, it was decided to build an electrically operated railway. The 53 km metre-gauge high-altitude line began operating between Villefranche and La Cabanasse in 1910, and finally as far as Bourg-Madame in 1911, with an lateral rail being installed for the supply of electrical energy (850 volt direct current). In view of the opening of the already mentioned easterly trans-Pyrenean railway (Toulouse-Barcelona) the line was extended in 1927 to La Tour-de-Carol, increasing the length of the route known as the 'Train Jaune' to 63 km.

Feeder lines

The standard-gauge easterly trans-Pyrenean railway, which meets the Train Jaune in La Tour-de-Carol, with its highest point of 1,567 m and a spiral tunnel in France and one in Spain, together with the Train Jaune counts as one of the most spectacular mountain railways in the Pyrenean region. To the north of La Tour-de-Carol it crosses the foothills through the 5.4 km Puymorens Tunnel. Together with the transnational line along the Mediterranean and the Train Jaune it forms an H-shaped rail network along and across the principal ridge of the Pyrenees.

Rail track routing and railway structures

The individual sections of the Train Jaune, which was built in stages (1910, 1911 and 1927) – the highest continuous line in France – have all been preserved in their original condition with regard to track, power supply, and civil engineering structures and buildings. The route includes prolonged, steep gradients and an alignment with many curves, across steep slopes high above the valley floor. In the mountainous easterly section, there are many safety structures to protect against rainfall, rockfalls and mudflows. There is a total of 233 bridges, 177 of them built of stone.

The gradient begins immediately after the terminal at Villefranche, at 415 m. The route runs along the right bank of the river Têt. Before Thuès-les-Bains, it traverses several spurs of the mountains in tunnels. Tributary valley loops are provided with extensive protective structures and bridges. Between Thuès-entre-Vails and Fontpédrouse, the line crosses the main river on the great stone Séjourné viaduct. It then winds its way up the narrow gorge on the left bank. The large power station, which also delivers power to the railway is located at Fontpédrouse-Saint Thomas-les-Bains. The line has now already reached an altitude of 1,050 m. Further up, it crosses the gorge of the Têt on the unique 'Pont Gislard', a braced suspension bridge. The bridge is named after the railway commandant who suffered a fatal accident here in 1909 during the bridge trial run. The line makes another loop and passes through a short tunnel to reach the fortified town of Mont Louis-La Cabanasse, at 1,510 m. The route passes through 19 tunnels with lengths of up to 380 m on its way to its maximum altitude of 1,592 m at the Col de la Perche. It then makes its way down, with many curves, past the Spanish enclave of Llivia into the Cerdagne basin and then along the Spanish border to the station of La Tour-de-Carol.

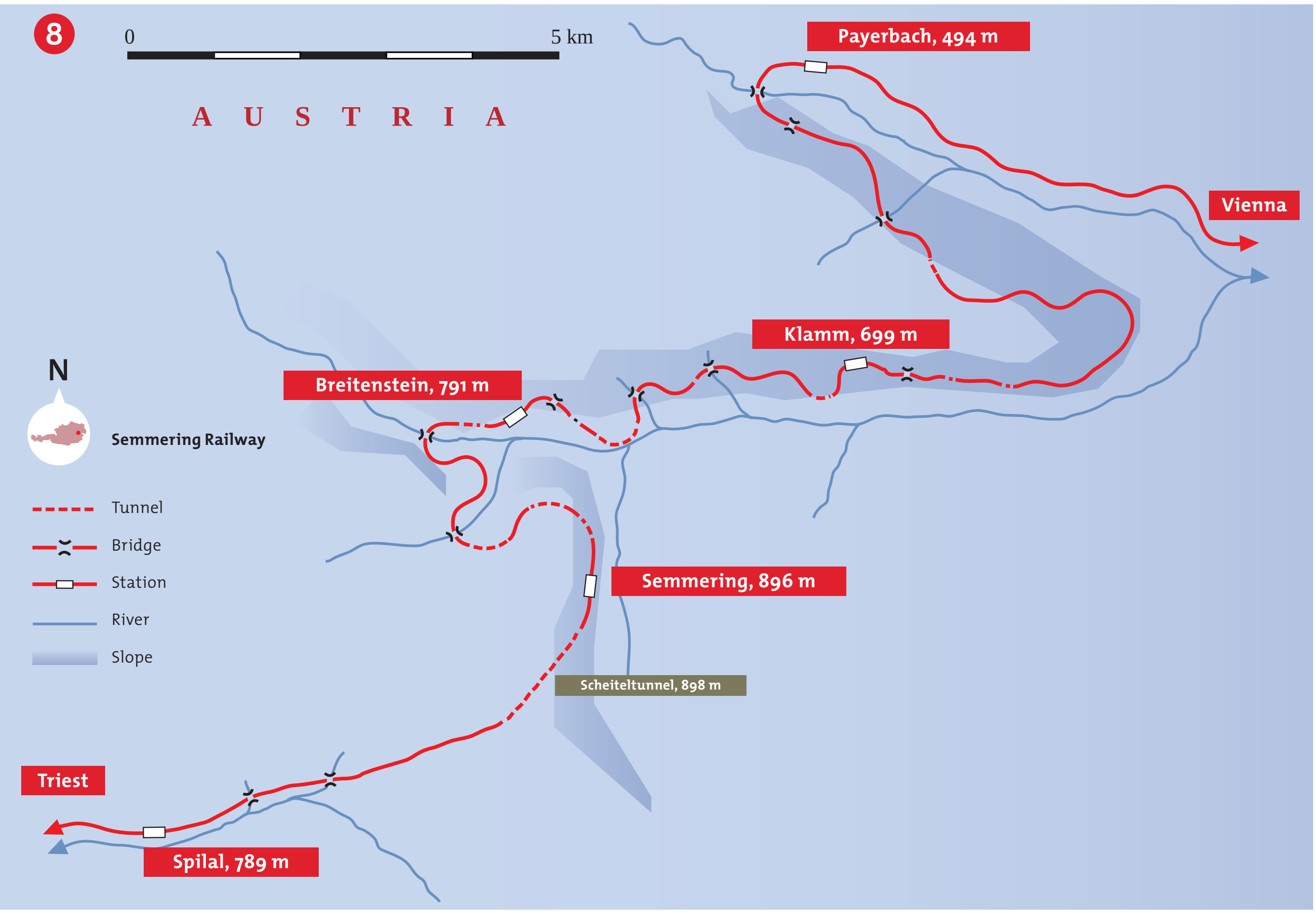
The railway installations in Villefranche are fascinating; with its standard-gauge station, platform roofs and depot, as well as the loading equipment of the metre-gauge rail at the sloping channel to the north. The station layout in La Tour-de-Carol, dating from 1927 – 1929, includes platforms in three gauges, because the metre-gauge of the Train Jaune, the standard gauge of the French national railway and the wide 1,676 mm gauge of the Spanish national railway all converge here.

Operation and equipment

Since the cessation of the generally low-level freight transport in 1974, the section between Villefranche and La Tour-de-Carol has been used only for a modest level of passenger, principally tourist, travel. Until 2002, the whole passenger operation – five to six pairs of trains per day – was run with the original rolling stock from the early days. The chassis, frames and lateral electricity take-up equipment still bear the Midi logo and the axle bushings are dated 1908. The carriage-work was renewed in the 1980s and new locomotives have been acquired since 2003.

Comparison

The Train Jaune, like the Albula/Bernina line, is one of the mountain railways which were completed in the decade before the First World War. The highest elevation of 1,592 m is significantly lower than that of the Albula/Bernina line. The topography demanded numerous complex constructions, including two large bridges. The number of tunnels is considerable, although it was not necessary to build any spiral tunnels. Overall, the degree of technical difficulty in the construction of the Train Jaune is less than that of the Albula railway. With regard to the mode of operation, the Train Jaune is identical to the Bernina railway, in that both are examples of the earliest electrical railways. The power supply by means of lateral rails used for the Train Jaune, however, did not establish itself as a means of supply in other surface railways. Nevertheless, both lines exemplify the need to consider the mode of operation in direct relation to the technically feasible route parameters, such as maximum gradient. With regard to the risk involved in building an electric railway in the mountains at the beginning of the 20th century, in view of the lack of experience, the boldness of design of the Bernina railway exceeds that of the Train Jaune, in spite of the latter's maximum gradient being 10‰ more and its highest elevation some 660 m higher. As with the Albula/Bernina line, the track and buildings – apart from the usual operationally necessary adaptations – have been retained in their original state. The rolling stock from the early 20th century has also been largely preserved, with respect to mechanical features, although since 2003 the locomotives have been replaced by new ones, now in modest daily use. In contrast, the Albula/Bernina railway operates a full service schedule daily using the new rolling stock throughout, while the historic cars and locomotives are used for museum purposes.



Semmering Railway > An important section of the line.
H.P. Bärtschi

Semmering Railway > Stone arch viaduct across the Kalte Rinne. Photograph 1979.
H.P. Bärtschi

Semmering Railway > East portal of the crest tunnel. Photograph 1979.
H.P. Bärtschi

Semmering Railway, Austria

The choice of the *standard-gauge* Semmering Railway in Austria for comparison with the Albula/Bernina line was based on the following criteria:

> UNESCO World Heritage Site
> World's first high altitude railway – character as prototype
> Overcomes great differences in altitude
> Attractiveness of the surrounding landscape (cf. 3.c.3)
> Still in operation

Construction history

The Semmering is one of the most easterly Alpine passes; it reaches an altitude of 984 m. In 1842, the government of the then Austrian Empire resolved to build a – standard gauge – railway from the capital in Vienna to the Adriatic port of Trieste. This meant that the Semmering region acquired new significance; comparative studies prepared before the construction of the line came to the conclusion that for a railway from Vienna to Trieste, the best route would be through the Semmering region. This assessment is remarkable because at that time there was no experience with railways in mountain ranges and massifs with deep valleys and great heights to draw on. At the end of the 1840s, the highest railways in the world reached a maximum of around 660 m. On the Semmering, a difference in altitude of almost 500 m, and a landscape cleft by deep valleys, had to be overcome within a linear distance of less than 10 km.

In 1842, the construction manager Carl Ghega travelled to England and North America to study the latest developments in railway technology as preparation for the definitive planning work for the construction of the Semmering Railway. At the same time, comparative studies were carried out to determine the best, that is, the technically and economically most advantageous type of track. Ghega, who was able to draw on 20 years of professional experience in high-altitude road construction, coupled this with the knowledge gained from his study trips in his planning and building of the Semmering Railway. The outcome was a serpentine layout between the towns of Gloggnitz and Mürzzuschlag sweeping into tributary valleys; this artificial lengthening of the route permitted a gradient which could be taken by steam locomotives (27 ‰ at its maximum). The planning was completed in 1844. However, it was not possible to start construction until the time of the revolution of 1848, coupled with the search for employment projects to occupy the dissatisfied population. As many as 20,000 men worked between 1848 and 1854 on the nearly 42 km route, without tunnel drilling machines or effective explosives. To overcome the topographical difficulties, 16 large viaducts (four of them two-storey) and 15 tunnels had to be constructed. In both cases new ground was being broken, and both viaducts and tunnels were laid out in tight turns, which meant special challenges with regard to the surveying (tunnels) as well as to the stress of the heavy trains (viaducts).

After only six years of construction, the Semmering Railway was successfully brought into operation, and the contemporary press reported ecstatically that there was now no mountain over which a railway could not be led, and no river over which a bridge could not be built (Lloyd Triestino, July 2nd 1854).

Feeder lines

The Semmering Railway is thus part of the Vienna – Trieste rail connection. At Gloggnitz, its northerly end point, it connects to the lowland railway leading to Vienna and the Vienna catchment area, and again at Mürzzuschlag; at the southern end the route continues on the valley floor through the Mürztal and the Murtal. In 1879, a standard-gauge auxiliary line was built through a side valley from Mürzzuschlag to Neuberg, and from 1922 an electric narrow-gauge railway led from the station at Payerbach-Reichenau as a transport line for the paper industry based in Hirschwang. From 1926, with the introduction of passenger travel, this also functioned as a feeder for the Rax cable railway up to the high mountains. The auxiliary line mentioned is now (2006) no longer functional, while the narrow-gauge line operates only a nostalgia service.

Layout and railway structures

The Semmering Railway starts in Gloggnitz in lower Austria at an altitude of 439 m and gains height by means of a wide loop into the Reichenau valley. At Eichberg station – only 2 km from Gloggnitz as the crow flies – the track is already 170 m higher. Further loops into the Adlitzgräben valley, where the famous viaduct over the 'Kalte Rinne' (182 m long, 46 m high and situated on a 180 m curve) is located, also serve to artificially lengthen the route. The highest point of 898 m is reached in the 1,428 metre crest tunnel. After the tunnel, the track leads through the Fröschnitz valley to Mürzzuschlag (681 m) in a much less spectacular fashion.

For the most part, the original structures of the Semmering Railway have been preserved until today. After the Second World War, the viaducts and tunnels were in poor structural condition and extensive renovation work was required. As part of this, the original main tunnel was downgraded in 1952 to a single-track tunnel and in 1953 a second, parallel single-track tunnel was built to retain the capacity of a double-track line. After the renovation of the structures, electrification of the line followed, reaching completion in 1959. Due to their generous dimensions, it was possible to retain the complex design of the tunnel portals in their original form when realising the electrification. In contrast, the stone parapets of some viaducts had to be removed or the masonry surfaces plastered, impairing the original clarity of line.

Over the course of the decades, with rapidly growing traffic frequency, the station and operational buildings were repeatedly adapted to changing demands with more or less architectural sensitivity depending on the period. In Semmering, which became a tourist destination towards the end of the 19th century, the station building had to be expanded several times. On the other hand, the formerly 55 quarry stone linesmen's houses required for the continual monitoring of the route and built to a uniform design have been almost completely preserved.

The structural facilities necessary for the original steam-driven operation (service buildings such as boiler houses, workshops, turntables and water supplies) in Gloggnitz, Payerbach, Semmering and Mürzzuschlag were dismantled after the electrification of the route – except for the locomotive turntable and the 'Neue Montierung' hall with the transfer platform in front of it (all Mürzzuschlag), which were declared (Austrian) protected monuments in August 2006.

The track facilities at the stations were most affected by conversion work. As it became possible to operate longer trains with the more powerful locomotives, longer sidings were required in the stations. Most of the buildings used to handle freight transport (goods sheds, loading facilities) were dismantled, particularly after the Second World War and due to the shift of focus to road transport.

Since the inscription of the Semmering Railway in the UNESCO World Heritage List in 1998, all renovation and rehabilitation work on the line has been carried out after conferring with the Austrian Federal Office for Historical Monuments.

Operation and equipment

The Semmering Railway provided both passenger travel and freight transport between Vienna and the northern Adriatic coast, particularly for the region around Trieste. Today, both inland traffic, from Vienna to the southern states of Austria, and international travel to the neighbouring countries Italy and Slovenia flows over the Semmering. Passenger and express trains are in operation daily, as well as freight trains (80 passenger trains and 100 goods trains a day in 2003). The large number of trains in operation was the impulse, in the 1980s, to demands for a base tunnel. Due to legal uncertainties and the high capital investment required, the project is still in the planning stages.
In recent years, in addition to the scheduled daily operations with the current rolling stock, passenger trains with equipment from the 1960s and 1970s have been operated at weekends and advertised as nostalgia trains. Trains drawn by steam locomotives ply the Semmering line for these excursions. No rolling stock from the construction period has been preserved.

Comparison

The Semmering Railway and the Albula/Bernina line both belong to the category of railways that cross a massif from one side to the other, even though they display an essential difference in their gauges. The Semmering Railway, established in the early 1850s as a two-track main line in standard gauge marks a milestone in the history of rail building. It was planned in the early phase of steam locomotive operation, and the track parameters, such as maximum gradient, were designed for this mode of operation. In this respect, the 27 ‰ gradient used on the Semmering was virtually standard for steam-driven high-altitude railways even in later years. The Brenner Railway, for example, had a maximum gradient of 25 ‰, the Gotthard 27 ‰, the railway through Mont Cenis 30 ‰ and the Albula line 35 ‰.
In the half century which passed between the construction of the Semmering Railway and that of the Albula/Bernina line, railway engineering had experienced numerous changes and innovations. Thus the Albula/Bernina Railway illustrates in a unique way the manifold construction possibilities at the turn of the century, both in steam locomotive technology and electrical operation, which was new at that time. While the Albula line was constructed according to the track parameters usual for steam operation, the Bernina Railway demonstrates the capabilities of electrical railway operation. Not only does it have a maximum elevation which even today is the highest in a transalpine railway, but with a maximum gradient of 70 ‰ it is also twice as steep as the Albula line opened four years earlier.
Further, with respect to the techniques adopted for artificially lengthening the distance, in contrast to the Semmering Railway, the whole range of engineering possibilities for conquering a mountain range is found on the Albula/Bernina line. As well as sweeping into tributary valleys to overcome height differences – used for the first time in the world on the Semmering – these include the (cost-effective) open loops on a slope (Bernina) and the (costly) spiral and crest tunnels (Albula). During the brief time window between the 1870s and the 1910s spiral tunnels were the typical tunnelling method for high-altitude

railways. It was not possible to construct long crest tunnels before the invention of tunnel boring machinery, which was used for the first time on Mont Cenis in the late 1860s.

The Albula/Bernina illustrates in a unique way the differing technical solutions for constructing railways in mountainous regions at the beginning of the 20th century, as the Semmering Railway does for the middle of the 19th century. In this sense, the two lines are comparable and equal.

Switzerland

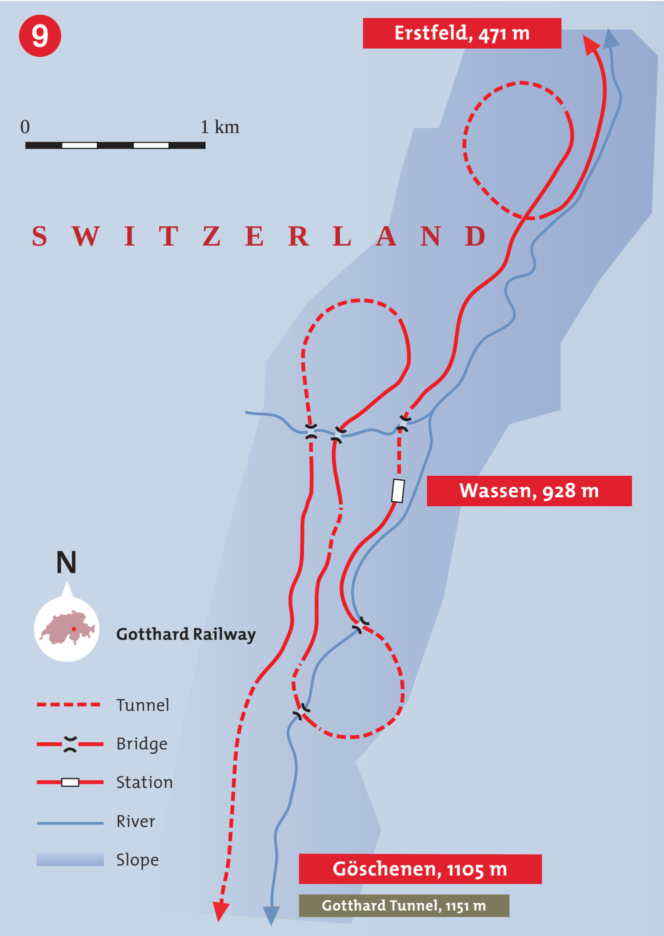
In comparison with other European countries, railway building began relatively late in Switzerland. The reasons for this are to be found in private rivalries, regional power struggles and in the challenging topography of large parts of the country making high capital investment essential. In 1859, the main line railway between the Lake of Constance and the Lake of Geneva was completed, with branch lines towards Basel and Lucerne. By the beginning of the First World War, a very dense network of private and state railways had been built. In 1909, the largest railway company, the *Gotthardbahn*, was nationalised and renamed the *Schweizerische Bundesbahnen* SBB (Swiss Federal Railways SFR).

The first high-altitude railway in Switzerland was opened as early as 1858, with the standard-gauge Hauenstein Railway which led in double tracks from Basel to central Swiss. However, its crest tunnel is at an altitude of only 559 m. In 1859 another railway leading into the Jura Mountains was brought into service. The starting point was Neuchâtel and it served principally to access the two high-lying watchmaking centres of La Chaux-de-Fonds and Le Locle. This is the only main line railway in Switzerland with a setting back track. It has a total of nine tunnels between the Lake of Neuchâtel (479 m) and the French border. The maximum elevation of the line is 1,048 m, at Converse, a height which was not exceeded until the construction of the Gotthard Railway.

North to south travelling in Europe must necessarily cross the Alps. In 1807, Napoleon I had the first transalpine carriage road constructed over the Simplon Pass. The Austrian and Graubünden pass roads over the eastern Alps followed. With the opening of the Suez Canal in 1869, the flow of goods was diverted from the Atlantic harbours to those of the Mediterranean, accelerating the construction of alpine railways. After railways had been over the Brenner Pass (1867) and through Mont Cenis (1871), the construction of an alpine crossing also became a top priority in Switzerland. Three versions were discussed: one through central Switzerland, another through eastern Switzerland and the third through the Canton Valais, starting from the capital, Bern. The first to be built was the central variant where, with the help of financial contributions from Germany and Italy and with construction workers from Italy, it was possible in 1882 to inaugurate the shortest European north – south connection with the Gotthard Railway, running from Lucerne to Chiasso. The route reaches a maximum altitude of 1,151 m. It was not until 1913 that the Lötschberg Railway, also standard gauge, running through Valais was opened; construction had been aided by French capital. Its highest point is 1,240 m.

The Lötschberg and Gotthard railways are among the most important standard-gauge north – south links in the whole of Europe. In addition to these, by 1926 more than a dozen narrow-gauge high altitude railways with culmination points in excess of 1,000 m had been built in Switzerland.

As a result of the shortage of coal during the First World War – imports from the surrounding European states had virtually come to a standstill – in 1916 the Swiss government decided on the electrification of the rail lines, which until then had largely been operated with steam locomotives. Switzerland had plentiful water power of its own for the generation of electricity. Thus an almost 100% electrically-operated rail network was created in Switzerland – the first in the world. In contrast to most other countries, Switzerland did not suffer extensive rail closures after the Second World War. Today there are 3,700 km of standard-gauge track and 1,700 km of narrow gauge.



Gotthard Railway > An important section of the line.
H.P. Bärtschi

Gotthard Railway > North ramp at Amsteg Swiss Federal Railways power station. Photograph 1988.
H.P. Bärtschi

Gotthard Railway > Biaschina south ramp with three track levels. Photograph 1997.
H.P. Bärtschi

Gotthard Railway > Single-track access section along the Lake of Lucerne. Photograph 1988.
H.P. Bärtschi

Mountain railways in Switzerland with highest points over 1,000 m

Country	Connection	Gauge	Highest Point 1) in m	Opened 2)
Switzerland	St. Moritz – Tirano (Bernina Railway)	Metre	2253, Ospizio Bernina	1910
Switzerland	Brig – Andermatt	Metre, Z	2163, Furka (mountain section)	1926
Switzerland	Disentis – Andermatt	Metre, Z	2045, Oberalp Pass	1926
Switzerland	Thusis – St. Moritz (Albula Railway)	Metre	1823, Albula Tunnel	1903
Switzerland	Chur – Arosa	Metre	1742 Arosa	1914
Switzerland	Landquart – Davos	Metre	1633, Davos-Wolfgang	1890
Switzerland	Visp – Zermatt	Metre, Z	1605, Zermatt	1891
Switzerland	Montreux – Lenk	Metre	1275, Saanenmöser	1905
Switzerland	Spiez – Brig (Lötschberg Railway)	Normal	1240, Lötschberg Tunnel	1913
Switzerland	Nyon – St.Cergue(– La Cure)	Metre	1233, La Givrine	1917
Switzerland	Erstfeld – Biasca (Gotthard Railway)	Normal	1151, Gotthard Tunnel	1882
Switzerland	Reichenau-Tamins – Disentis	Metre	1133, Disentis	1903
Switzerland	Neuchâtel – Le Locle	Normal	1048, Convers	1859
Switzerland	Stans – Engelberg	Metre, Z	1002, Engelberg	1898
Switzerland	Luzern – Meiringen	Metre, Z	1002, Brünig-Hasliberg	1888

1) various figures quoted for highest stations or culmination points
2) various figures quoted for part or generally continuous opening
Z cog system

Gotthard Railway

The choice of the *standard-gauge* Gotthard Railway for comparison with the Albula/Bernina line was based on the following criteria:

> Overcoming large differences in altitude (several vegetation levels)
> Use of spiral tunnels and long crest tunnels
> Attractiveness of the landscape it runs through (cf. 3.c.3)
> Still in operation
> Of major national significance

Construction history

The construction of the Gotthard Railway was begun in 1872. The access sections in Canton Ticino, south of the Alps, were completed as early as 1874, although it was not possible to finish the northern accesses Lucerne – Immensee and Zug – Goldau until 1897. Rises in construction costs and delays resulting from hectic changes to the plans and inadequate tenders drove the company responsible for building the line into financial crisis by 1875, and in 1878 the application for additional subsidies was refused by the Zurich electorate. A new variant of the project provided for the gradient to be increased using ramps and for a track course with tighter curves. The construction of the crest tunnel through the Gotthard massif alone claimed 200 lives. After the delayed completion of the great work in 1882, the Gotthard line developed into the most modern private railway in Switzerland. The Gotthard Railway Group, which had been heavily supported by the public purse, comprised a network of a total of 273 km on the opening of the Gotthard Railway.

Due to financial difficulties, the Gotthard Railway, which had been planned from the start as double-track, was initially constructed only as single-track, with the exception of the crest tunnel. The progressive expansion to double-track on the ramps took place between 1890 and 1896. Between 1912 and 1948 – the Gotthard Railway had been nationalised in 1909 – the feeder lines in the valleys on both sides of the Alps were also given a second track. The last gap in the double track over the Melide embankment was not closed until 1965, in the course of the motorway planning. The Gotthard Railway was converted to electrical operation following the Swiss Federal Railways Board of Directors resolution of 1916. The Lötschberg Railway in western Switzerland and parts of the network of the Rhaetian Railway had already been electrified with high voltage single-phase alternating current in previous to this. Two hydroelectric power stations for the railway were built in Amsteg and Ambri-Piotta, and in 1920 the high altitude section and in 1922 the valley lines were also electrified.

Rail track routing and railway structures

The difficulties in integrating the line into the topography were extraordinary in every respect: prolonged steep gradients on both ramps, construction of numerous helical and spiral tunnels for the first time in the Alps, elaborate layout with retaining walls and rock cuttings on steep slopes high above the valley floors and very extensive structures to guard against avalanches, rockfalls and mudflows. Highly varied construction methods were employed for the bridges, on which the big, broad-spanned traverses were formed as lattice constructions of riveted, welded iron. For years, the 16 km crest tunnel was the longest tunnel in the world. The magnificent layout of the line at Wassen with one spiral and two helical tunnels is an invariably fascinating experience, similarly the Piottina ravine at Faido and the Biaschina gorge, each with its two spiral tunnels almost on top of one other.

The overall structure has been adapted to developments in technology over the years. Thus, the contact lines were modernised and the floors in the tunnels were lowered in order to increase the clearance of the profile. In particular, all the original iron latticework suspension bridges were replaced by new constructions in compressed and pre-stressed concrete, and in places with concrete with granite cladding. However, the alignment is still original and the monumental structures of the Ticino valley railways of 1875 and a large number of the simple buildings in the mountain section from 1882. The Airolo and Göschenen stations at the two ends of the Gotthard tunnel were converted and extended repeatedly between 1954 and 1980 in connection with establishing a car-loading facility. The section along the Lake of Lucerne – one of the access lines – retains the most original parts from the time of the construction, as the second track was given a separate alignment.

Operation and equipment

The primary importance of the Gotthard Railway was and is that of a European north – south transit axis. Accordingly, there have been continuous conversions, adaptations and replacements, both of the installations and the rolling stock, and consequently of the operational structures as well. As with the Semmering Railway, the mountain segment was later converted to electrical power to replace the expensive operation with steam locomotives and the mechanical signalling facilities had to give way to the current electrical systems. A selection of historic rolling stock has been preserved and is employed for special excursions. In 1992, the Swiss electorate approved the construction of a second base tunnel through the Gotthard and the Lötschberg. The breakthrough on the Lötschberg was made in 2005, and the opening of the tunnel is planned for 2007. The Gotthard base tunnel, which, with its length of 57 km, is one day to become the longest rail tunnel in the world, is scheduled to be opened in 2014.

Comparison

The Gotthard Railway was opened a quarter of a century before the Albula/Bernina line. The highest point of the Gotthard Railway, which was designed as a standard-gauge transit line, is significantly lower than that of the narrow-gauge Albula/Bernina Railway, which serves regional and trans-Alpine and transnational access. Both the degree of difficulty of construction and the attractive integration into the natural topography of the Gotthard Railway is comparable with that of the Albula/Bernina line, where the density of civil engineering structures – tunnels, bridges, cuttings, embankments – is very high. Until the construction of the Simplon tunnel between Switzerland and Italy (opened in 1906) the Gotthard Railway had the longest tunnel in the world, while spiral tunnels were used for the first time in Switzerland. The track layout, sometimes overlaying itself three times, remains to this day, like that of the Albula Railway, a marvellous attraction.

The original alignment has been preserved, and the track has had to be repeatedly maintained and repaired because of the high train frequency. In particular, the steel latticework suspension bridges typical of the original Gotthard Railway have, without exception, been replaced by concrete bridges since the 1950s. This type of bridge construction aroused great controversy among contemporary observers. The bridges of the Albula Railway, which are still to a very large extent preserved in their original condition, in contrast, were singled out by contemporaries as “adapted to the environment in an exemplary fashion”.

Many of the Gotthard Railway structures are still preserved in their original condition, even if – as is usual for railways which are in daily operation – adaptation has been carried out continually. As a high capacity European line, the character of the Gotthard Railway differs essentially from the Albula/Bernina line. Continuation of the Gotthard mountain route after the opening of the base tunnel (scheduled for 2014) is planned, but the definitive decision has not yet been taken.

3.c.3 Comparison of the surrounding countryside

Railways often traverse regions whose landscapes have a unique character – such as high mountains or industrial zones. However, the specific links between railways and their respective (cultural) landscapes, such as the significance of impressive views from the railway or on to it against its surroundings, have rarely been addressed to date. Although there have been isolated surveys with the character of an overview, such as that by Wolfgang Schivelbusch on the phenomenon of perception during a railway trip published in 1977, there is still a need for a systematic and classifying treatment of the subject. The exemplary and very comprehensive ICOMOS study entitled *Railways as World Heritage Sites* from 1998 highlights the significance of the surrounding landscape in certain cases (Semmering Railway, Darjeeling Railway). And the three publications by the German ICOMOS national committee, which document the *Eisenbahn und Denkmalpflege* (Railway and Monument Preservation) symposia of 1990, 1992 and 1997, contain *one* basic paper on the topic of railway and landscape. On the other hand, treatments of the cultural landscape always completely exclude the impact of the railway itself, although pictures of landscapes that are at least partly characterised by railways may be used as examples to explain cultural landscapes. This approach is in complete contrast to the transport infrastructures of the inland waterways of the kind outlined within the scope of the *International Canal Monuments List* of ICOMOS. Canals form industrial landscapes and are regarded as being embedded in them.

The international comparison of the cultural landscape surrounding the Albula / Bernina railway corridor will therefore be preceded by conceptual considerations as well as the creation of an appraisal scheme with a number of analysis categories to indicate the differences with respect to the surrounding countryside of the various railways.

Landscapes, cultural landscapes and...

The emergence of tourism in the second half of the 19th century and the boom in travel guides advising travellers on what they should do and see, produced a shift from the previously used word “district” to the term “landscape”. The latter is understood as the surroundings perceived aesthetically and in an ordered way. The landscape must be observed and reflected upon from a distance and is consequently subject to changes in ideologies and fashions. So it must be mediated in order to be seen and appreciated. This mediation may assume various forms: as texts in the form of travel guides or novels, by word of mouth as well as visually by means of illustrations, picture postcards or advertising posters. If these visualisations produce “standard views with variations” then the travel books designed specifically for a railway trip bring aids to sightseeing and visual choreographies for looking out of the carriage window. But they also allow the otherwise unique experience of a perceived railway journey to be replicated: the prospective traveller can take an imaginary journey even *before* the real one – by reading the travel guide or looking at the illustrations. He or she can then enjoy the “right” views *during* the trip and thus recognise particular scenes. *After* the trip, travellers can enjoy a shared repertory of images with the aid of photographs or conversations with other travellers. But we can also see how the process of mediation brings out the hidden guiding ideas and motivation structures, values and norms, in brief, all the cultural associations of a landscape. So although the term landscape focuses on natural or man-made surroundings, it requires the observer to perceive it in something like a prejudiced or “artificial” manner, promoting an aesthetic appreciation of the surroundings. In recent decades, increasing research has been carried out into landscape, which has led to an ever greater differentiation of this concept and the associated identification of urban, agricultural and industrial landscapes. All these landscapes are subsumed by the term cultural landscape, which is in turn to be understood in opposition to the natural landscape untouched by man. Expert in cultural landscapes Gerhard Strohmeier defines a cultural landscape as follows: “A cultural landscape is produced by natural and social processes. Cultural landscapes develop from certain features of the natural space by means of social appropriation and the harnessing of natural dynamics. Not only is the cultural landscape itself formed by social activities, its perception is no less mediated by aesthetic images and ideas. This construct of dominant modes of perception of a landscape is generated by certain social interest groups who appropriate the landscapes in the form of specific images.”

The following study of ‘cultural landscape’ will start from this definition and move in two directions. On the one hand the surroundings changed by man’s diverse interventions with their respective elements that structure the landscape (agricultural utilisation, structures etc.), and on the other hand the perception and appreciation of the landscape (both cultural and natural landscape).

The physical character of the cultural landscape is moulded in many ways by its economic utilisation. The restricted space in mountain regions is a central defining feature, whereas the “cultivated landscape” of more extensive regions is synonymous with uniformity, elimination of dividing elements and massive interventions by man to level the land. The cultural landscape in the mountains is characterised by the restricted spaces caused by man having to take into account the numerous differences in the natural space when exploiting it in order to assure ecological stability. An unadapted mode of land use would aggravate the potential for geo-ecological hazards (e.g. due to flooding, mudslides and avalanches).

The spatial pattern underlying the cultural landscapes was developed since the beginning of the modern age in Europe. The imagination of space is centred on the mental image that evaluates the real environment as “landscape”. These mental images form the basis both for the discovery of the mountains and for the transformation of the new world from its perception as a “wilderness” to its appreciation as “landscape”.

The Alps and their “emblematic core”, the Alpine landscape, constitute a shared asset of European culture as a zone of widely differing and mutually interpenetrating cultural influences. Alpine researcher Werner Bätzing derives the attraction of the Alpine region for tourism from the contrast between the varied cultural landscape within a small area of the Alps and its surrounding nature: the perception of “beauty” with reference to the Alpine landscape

is only partially dependent on nature: to a significant degree it is due to the cultural landscape, which was ultimately created principally by the mountain farmers.
In North America, in contrast, nature provided the gauge and standard for the representation of landscapes – a nature which, on the basis of the Christian creation myth, was seen as an untouched primeval state that contributed to the self-portrayal of America almost as a projected wilderness which the advertising industry continues to exploit to the present day, on the lines of the Marlboro advertisement. Until the 19th century, however, the image of the new world had a European bias. Thus Europe provided the model for the perception of the phenomenon of '*alpine* glow' in the Sierra Nevada, as this local name indicates.
During the colonial era and the associated worldwide spread of the railways in the second half of the 19th century landscapes in Asia, Africa and South America were generally perceived from a European perspective.

...transport routes

In the case of railway lines, the surrounding landscape must always be seen in the context of the function of the relevant railway. Railways as a means of mass urban transport are embedded in totally different landscapes to tourist railways or those used to promote the colonisation of regions outside Europe. A distinction must be made between the following railway surroundings:

> economically exploited landscapes (agriculture; raw materials; industrial landscape)
> urban landscapes
> natural landscapes (the railway can promote the aesthetic perception of the landscape it runs through)
> landscapes already appreciated aesthetically before the railway was built (e.g. tourist attractions).

Perception acquires a special significance in the case of mountain railways: whereas the visual impact of the engineering and technical features is more immediate than with any other type of railway line, the 'romancing' of mountain landscapes also accentuates the symbolic value of the technology, and with it the symbolic significance of the landscape the railway runs through. This combination was the precondition for developing the conventional topos of the harmony of technology and nature, or a railway line that is adapted to the landscape. This is evident from the railway postcards that, besides major stations, focus primarily on mountain railways with their engineering structures.
The postcards of mountain railways show the surrounding countryside as an integral element of the motif: the viaduct across the Kalte Rinne of the Semmering Railway (Austria) with the landscape as a distant perspective; the route of the Gotthard Railway (Switzerland) winding across several levels at Wassen, the Landwasser viaduct on the Albula Railway (Switzerland), or the 'Train Jaune' (France) with the viaduct at Fondpédrouse are all 'variations on standard views'. The recurring topos is a bridge structure embedded in the landscape. A bridge essentially symbolises a linking element, so these series of images aim to mediate visually between nature and technology. What is more, the views of mountain railways in mountain panoramas, where settlements already existed before the railway was built, frequently incorporate elements such as ruins or old churches in the composition of the view. The dual image symbolism of nature and artifice is thus

extended to a trinity of nature, culture and technology, the latter being highlighted as a contemporary form of culture in contrast to the historic structures.

Another category of images focuses on the panoramic perception of the landscape as seen by a passenger during a railway trip in order to promote rail travel. In contrast to the static panorama of an all-round view, such as that seen from a mountain peak or in the all-round painted panoramas so popular in the 19th century, leporello foldouts generated a linear panorama along a section of a route from a single vantage point. In Europe, bird's eye views of particularly striking sections of a line were popular from the early days of the railway age. Special panoramic carriages were in operation from the second half of the 19th century: from the mid-1870s on scenic routes in the Alps (such as on the Salzburg – Wörgl route from 1875), particularly before the First World War in the USA on sections in the vicinity of the national parks and increasingly in Europe from the 1920s, such as over the Bernina Pass or on the Semmering. Panoramic carriages still run daily, for instance on the between Vienna and Zurich and Zurich and Milan routes as well as on trans-American lines such as the Canadian Pacific. Other examples are the Bernina Express from Chur to Tirano and the Glacier Express from St. Moritz to Zermatt.

Analysis scheme for a comparison of railway cultural landscapes

In addition to the physical characteristics of cultural landscapes, it is of fundamental importance for a comparative analysis to know how the cultural landscapes are perceived, which components are emphasised and which neglected and how this mode of perception changes over time. The Semmering Railway, the first high-altitude mountain railway worldwide (cf. 3.c.2), exemplifies this change of perception. It was already given a romantic spin with aesthetic panoramas and particular views when it first came into operation in 1854. This can be seen with particular clarity on an engraving from the early 1880s: in the foreground (left), imaginary rock pillars like those in the Elbsandsteingebirge and contorted tree roots are used to dramatise the impression of nature. This visual discourse ultimately led to the observation of a 'harmonious embedding of the railway in nature' from the 1920s. However, the enormous piles of rubble left behind when the railway was under construction, and still visible at the beginning of the 21st century, were carefully faded out of the picture.

An international comparison of the cultural landscape of the Albula/Bernina railway corridor with those of other railway corridors is discussed below according to the following four-module scheme specifying the importance of the buffer zone pursuant to Article 104 of the *Operational Guidelines* for the railway property:

> **Agriculture:** economic exploitation of the land to obtain plant products and subsequently also animal products (i.e. grazing land as a basis) with the relevant changes in the original natural landscape.
> **Structures:** material manifestations designed to fulfil social needs in the broadest sense on the basis of minor or major changes (i.e. from isolated buildings to urban agglomerations).
> **Transport routes:** infrastructures to permit the transport of people, goods and energy as well as information with the formation of a linear corridor.

> **Perception:** receptive awareness of the environment – both the natural and cultural landscapes – according to aesthetic criteria that are subsequently used to create identities oriented to the relevant environment (e.g. homeland, regional, national awareness, etc.).

Oceania, East and South Asia

Yunnan Railway, Vietnam/China

The trans-border Yunnan Railway runs from the port of Haipong in Vietnam to Kunming, the capital of Yunnan Province in China, at an altitude of 1,900 m. The line can be divided into two sections that also differ in terms of landscape: the Vietnam section from Hanoi to the border town of Lao Cai (Vietnam) or Hekou (China) is a valley railway running along the Red River. After leaving Hekou, the railway begins to climb up to the high plateau of Kunming, exhibiting the features of a mountain railway of the "Gebirgsbahn" type, before running through several valleys and crossing two passes.

Agriculture

The railway runs through several climatic and hence vegetation zones. The agricultural impact on the landscape consequently also varies: broad rice paddies and banana plantations predominate in the lowlands and in the Red River valley. The further the railway climbs into the rugged mountainous regions, the smaller the agricultural areas become. Cultivated fields are now found only in the immediate vicinity of the isolated settlements and have a very limited impact on the character of the landscape. Only after the high plateau is reached at Kunming, where the landscape broadens out, does the agricultural pattern change and larger fields begin to characterise the immediate environment of the railway corridor.

Structures

The buildings along the rail corridor display a wealth of diversity from colonial-style structures to the traditional buildings of the local inhabitants. In certain regions such as the mining areas of Lao Cai and Gejiu, industrial buildings have also had an impact on the cultural landscape. The Ta Tchen Ho valley in China is characterised both by railway structures and the trans-regional road as well as by numerous small power stations along the river that produce electricity. The valley of the Nam Ti, a tributary of the Red River, is a steep mountain valley, where railway structures play a dominant role, such as the lattice bridge over the Pei Ho gorge. The railway infrastructure makes a strong impact on the region that it traverses, especially due to the numerous bridges, which take the form of steel structures or stonework viaducts. However, there are no extensive structures to provide protection from landslides. The style of the railway structures shows French influence from colonial times; some station buildings, for example at Kunming or Kaiyuan, were replaced by new ones in the second half of the 20th century.

Transport routes

There is considerable variety in the standard of the structures along the transport routes in the various sections of the railway. The lowlands and the valley section along the Red River are well developed for traffic (roads and tracks, but also for boat transport on the river). The situation in the mountainous section is very diverse: in isolated regions with no settlements the railway is the only major transport route, whereas the Ta Chen Ho valley, for example, is characterised not only by the railway but also by the trans-regional road and the electric lines from the numerous river power stations. Again, the highland around Kunming is accessed by various roads and tracks. Another railway route, the new Kunming-Nanning standard-gauge section opened in 1997, accompanies the Yunnan Railway in the

Yunnan Railway > Between Pono-Tou and the Milati Pass.
P. Withehouse

Yunnan railway > Loop in a tributary valley at km 110. Illustration from: HULOT FRÉDÉRIC: *L'Indochine – le Yunnan* (Les Chemins de Fer de la France d'Outre-Mer, vol. 1), St. Laurent du Var 1990.

Yunnan Railway > Siu-Kia-Tou station building in the French style, about 1909. Illustration from: HULOT FRÉDÉRIC: *L'Indochine – le Yunnan* (Les Chemins de Fer de la France d'Outre-Mer, vol. 1), St. Laurent du Var 1990.

broad valley of the Si Chan Ta Ho, just before Kunming.

Perception

Perception of the landscape along the Yunnan Railway is characterised by the rugged mountain landscape and the colonial-style station buildings. The latter are usually featured on photographs as representative structures, as a rule with the rail tracks, locomotives and carriages in the foreground (i.e. station views from the track side are preferred). The section in the Nam Ti valley is particularly important for the perception of railway structures in the rugged mountainscape: major bridges cross the precipitous tributary valleys, such as the lattice bridge across the Pei Ho gorge at km 112, the steel trestlework bridge 'pont en dentelles' at km 83 and the stonework viaduct crossing the Nam-Ti valley at km 135. Views of the loops in the tributary valleys act as visual testimony to the efforts undertaken to surmount the great difference in altitude on this section. In both examples of views from the early period of this railway, the route marked by the railway structures is the cultural symbol of the colonial powers; their signature in a natural environment.

The Yunnan colonial railway provided access to the Vietnamese hinterland as well as to the southern Chinese province of Yunnan. The changing landscape so typical for mountain railways of this type is due to their crossing numerous climatic and vegetation zones (from sea level to 2,026 m.). The technically challenging sections and how they are overcome (e.g. by bridge structures) constitute the primary motif of perceiving the traversed surroundings as a cultural landscape.
Landslides after heavy rain repeatedly force the closing of sections of this line. Recently, the Chinese railway ministry decided to keep the narrow-gauge stretch for traffic between Kunming and Hanoi despite plans to build the new Trans-Asia railway from Kunming to Singapore.

Darjeeling Railway > Train in the upper section of the Batasia loop. The Himalayas in the background right. Photograph 2005.
A. M. Hurrel

Darjeeling Railway > The mountain section of the Darjeeling Railway runs along the road.
H.P. Bärtsc

Darjeeling Railway > A 'Toy Train' steam engine fills up with water.
M. Janich

South and West Asia

Darjeeling Railway, India

The Darjeeling Railway starting from Shiliguri (122 m) was built alongside the road as a transport railway for the tea industry in the vicinity of the British hill station at Darjeeling (2,076 m). The railway accentuated the ongoing process of increased agricultural exploitation of the region and thus led to an expansion of the local cultural landscape.

The Darjeeling Railway was listed as a UNESCO World Heritage Site in 1999. Its core zone comprises a 0.61 m wide and 87.48 km long corridor with the railway route running at its centre. A strip 3 m wide on the mountain side and 5 m on the valley side along the railway corridor was designated as the buffer zone.

Agriculture

The countryside through which the railway runs is extremely varied: it traverses the plain between Siliguri and Sukna along the first 10 kilometres, where farmland (plantations) alternates with areas of a more urban character. This is followed by a densely forested region between Sukna and Rongtong (some 11 km in length). Then comes a region of more intensive agricultural utilisation as far as Darjeeling; Himalayan spruce is an increasingly prominent feature of the landscape over the last 30 kilometres. Tea plantations dominate the view from the train.

The section between Sukna and Mahanadi is particularly vulnerable to damage in the event of stormy weather so that trees and shrubs have been planted at strategic points to stabilise the immediate environs of the railway.

Structures

The structures in the environment of the Darjeeling Railway, including the road running alongside the railway, date largely from the colonial era. But local cultural traditions are also reflected in the building styles: whereas Hinduism predominates in the valley settlements, Buddhism characterises the region around Darjeeling. Consequently there are different types of sacred buildings and monuments in the railway catchment area. The railway itself manages largely without major bridges or tunnels, the structures with the greatest impact on the landscape being the coiled loops built to gain altitude (at Chambatta, Tindharia and Agony Point).

Transport routes

About 1835, just 50 years before the railway came into operation, the *British East India Company* began to develop Darjeeling into a hill station: it became a popular summer refuge from the subtropical climate of the Ganges plain for the representatives of the colonial power.

At that time, the road was built (and extended) from the plain up to Darjeeling. Upon completion of the railway route from Calcutta to Siliguri in 1878, there was a sharp rise in road traffic to Darjeeling. When the traffic increased beyond the capacity of the road, the railway was continued as far the already well-established tea planting region and summer resort of Darjeeling.

The general increase in motorisation in conjunction with the building of more roads during the second half of the 20th century led to both goods traffic and a large proportion of private transport shifting to commercial vehicles and buses. Today, the Darjeeling Railway is primarily a key element in the development of tourism in the Darjeeling region.

Perception

The perception of the landscape along the Darjeeling Himalayan Railway centres on three aspects. Firstly on the exceptional railway structures, with the spectacular engineering achievement of the looped tracks and the route running alongside the road being of principal visual interest. Secondly on the panorama of the snow-capped Himalayas as a favourite backdrop; and thirdly on the tea plantations that reflect the image of a cultivated landscape.

The colonial importance of the Darjeeling Railway becomes clear from the context of the surrounding countryside. The advent of the railway intensified the tea cultivation already practised in the region and 'Darjeeling' finally became a synonym for tea in European countries. Access by railway also led to the hill station in Darjeeling established by the British East India Company becoming increasingly popular, acting as an impetus to tourism. The railway also links various cultural regions (the Buddhist highland regions with the Hindu lowlands).

Nilgiri Railway, India

The Nilgiri Railway from Mettupalaiyam (ca. 330 m) via Coonoor to Udagamandalam (ca. 2,203 m) was built as a colonial railway to promote the economic development of this Nilgiri Mountains. The advent of the railway led to changes in the utilisation of the surrounding landscape: the higher altitude settlements were favoured by the British as hill stations in the hot season. An increase in agricultural exploitation (primarily tea plantations) followed and a gunpowder (cordite) factory was set up in Aravankadu. The Nilgiri Railway became a UNESCO World Heritage Site in 2005. The core zone comprises a railway corridor 8.5 m wide and 45.88 km long. A strip averaging 25 m on both sides of the railway line was defined as buffer zone.

Agriculture

Various forms of agricultural exploitation characterise the landscape along the Nilgiri Railway. Plantations (palms) predominate in the first section as far as Kallar, some 7 km in length. The following section of about 19 km as far as Coonoor is virtually devoid of settlements and the steepness of the terrain prohibits agriculture; nor is forestry viable. In the immediate vicinity of the railway line, however, special drainage systems have been built to assure safe operation and the steep slopes that are liable to mudslides and landslides have been stabilised by afforestation. Along the third section of the railway from Coonoor to Udagamandalam, about 18 km in length, the appearance of the landscape changes again due to greater land use. In particular, tea and coffee plantations have been established since the advent of the railway, but flax, hemp, potatoes and fruit are also cultivated. Forests of eucalyptus and acacia also characterise the mountain landscape, which rises to an altitude of 2,637 m along this section.

Structures

Most of the structures along the Nilgiri Railway date from colonial times. Among them are houses in the English country-house style (including stone houses), hotels and St. Stephen‘s church in Udagamandalam. The only industrial plant in the Nilgiri Railway corridor (a gunpowder factory) is in Aravankadu. There was also an artificial lake in Udagamandalam at the beginning of the 20th century. In view of the high costs of building the railway, major structures were avoided as far as possible. The isolated bridges and viaducts, such as the Adderley Viaduct in largely natural surroundings, are the exceptions.

Transport routes

The British began to settle in the Nilgiri highlands about 1820, or just 80 years before the railway came into operation. At this time, goods were transported by mule or oxcart along rough tracks. The first plans for a railway from Mettupalaiyam to Coonoor date from the mid-1870s, but its construction had to wait until the early 1890s.
More extensive building of roads in the Nilgiri region started after the Second World War, ultimately leading to a shift from rail to road for goods transport.

Perception

The perception of the landscape along the Nilgiri Railway is determined partly by the ‘wildness’ of the section from Kallar to Coonoor and partly by the broad panorama of the higher altitude section from Coonoor to Udagamandalam.

Nilgiri Railway > A Nilgiri Railway train leaving Kallar station. Photograph 2005.
A. M. Hurrel

Nilgiri Railway > Steam train on the cog section of the line.
A. M. Hurrel

Very soon after the railway came into operation, it began to feature in the oral folk tradition of the Todas, the native inhabitants of the Nilgiri region.

In the context of its surrounding landscape, the Nilgiri Railway primarily reflects the British colonial influence: its construction led to the extension and rationalisation of local agriculture (tea plantations); summer residences were built and a gunpowder factory was set up, the first industrial plant in the region. The railway led to a marked inland migration of people from the lowlands; it also found its place in the folk tradition of the native inhabitants soon after it came into operation.

Eritrea Railway > The alignment ensures spectacular views of the mountainscape.
H. Hufnagel

Eritrea Railway > The geographical position means that the landscape either side of the railway is rather bleak.
H. Hufnagel

Eritrea-Bahn > Train about to enter Tunnel 26 just before Asmara. Photograph 2005.
H. Hufnagel

Africa

Eritrea Railway, Eritrea

The narrow-gauge railway came into operation in 1911 and runs from the harbour town of Massawa on the Red Sea to the Eritrean capital of Asmara in the Abyssinian highlands (2,343 m; seat of the Italian colonial administration from 1897). In the ensuing period, the railway was extended westwards, towards Sudan. The line as far as Biscia, some 220 km away, came into operation in 1932, but never actually reached the Sudanese border. Operation on the 31-km section from Agordat to Biscia was again discontinued in 1940. The railway line was largely destroyed during the thirty-year war of independence but was rebuilt after the end of the war in 1993 and started operation again in 2001.

Agriculture

The Eritrea Railway runs largely through a landscape of sparse vegetation. Its catchment area contains no industry and hardly any agriculture, and it was designed primarily for the provision of Asmara. Today, goods are transported by road on trucks. The first section of the line runs from the port of Massawa through the desert to the foot of the Abyssinian plateau at Nefasit. From there, the railway winds through the bleak mountain valleys to its highest point at 2,412 m, shortly before reaching the capital, Asmara. Agricultural exploitation is largely restricted to the immediate environment of the few settlements and is on a small scale, mainly providing for local needs, with the exception of the flat valleys at the foot of the plateau. Terraces have also been built (with dry-stone walls) to allow cultivation, particularly in the mountainous regions.

Structures

A wide range of structures is found along the railway corridor, the most striking being the buildings erected during the colonial period. Besides the stations and halts in the European colonial style, these also include railway utility buildings (engine depots and work sheds), but also monasteries (for instance at Debre Bizen) and religious structures (such as the Catholic cathedral in Asmara, completed in 1917 and the mosque in Nefasit). Colonial-era administration buildings in Asmara as well as the artistically decorated commercial buildings in the port of Massawa should also be mentioned. Houses built from clay are also found in the environs of the railway corridor in the more remote regions (such as in the Mai Atol valley).
Besides the buildings mentioned above, the railway also introduced numerous bridges and viaducts built completely of stone to the landscape. Some were destroyed during the civil war and rebuilt in the mid-1990s. A few railway buildings, also destroyed in the civil war, were merely patched up, such as the engine depot in Massawa that was rebuilt in corrugated iron.

Transport routes

The railway runs from the port of Massawa up into the mountainous hinterland. A network of roads criss-crosses the environs of the settlements, primarily providing limited access (only a few are suitable for motorised traffic). Development of the region around the rail corridor to traffic has given a trans-regional importance to the road from Massawa to Asmara, which has now been metalled. It is used for regular private and goods transport (buses and trucks).

Perception

Bleak images largely colour the perception of the landscape surrounding the railway, but the picture is also characterised by scattered eucalyptus forests, as in the region between the mountain pass and Asmara. The mountainous section between Ghinda and Asmara is also known as the 'Darjeeling of Africa'. Visualisations of the railway focus on the elaborate loops and railway motifs with bird's-eye views looking down to the floor of the valley some 1,000 m below. The image of the fourteen-arch viaduct across the seasonal riverbed of the Obel Torrent features on the Eritrean 10 Hakfa banknote. However, this stone built viaduct was partially destroyed during the civil war and rebuilt in the mid-1990s.

The Eritrean Railway line running from the port of Massawa to Asmara (and on to Agordat) is closely linked to the country's colonial past. Its planning began in 1897 with the relocation of the Italian colonial administration to the plateau near Asmara. The landscape traversed by the railway is characterised by a closeness to nature and a terrain that is largely untouched by man (strips of desert, inaccessible mountains) as well as by signs of human activity (settlements, religious structures and a limited degree of cultivation). The perception of this railway route – whose most spectacular part is also known as the 'Darjeeling of Africa' – is characterised by rugged mountain landscapes, plummeting views and elaborate loops of track. An image of the Railway features on the Eritrean 10 Hakfa bank note.

South America

Guayaquil & Quito Railway, Ecuador

The Ecuadorian railway line runs from the Pacific port of Guayaquil to the nation's capital of Quito in the highlands (2,817 m). Its construction took an unusually long time – building started in 1871, but full operation did not begin until 1908. Various sections along the entire route have been successively closed down over the last few decades and in some cases roads have even been built over the old tracks. Today only certain subsections are in operation for tourists, including the technically challenging section in the 'Devil's Nose' region. Latest developments indicate a reactivation of the railway in Ecuador.

Agriculture

The railway runs through numerous climatic and vegetation zones. In the first section it traverses the partly marshy lowlands around Guayaquil where the landscape is characterised by rice, sugar cane, cacao, coffee and banana plantations. As the Cordillera is reached, the pattern changes to small mixed-farming areas (pastures, forest, crop farming). Farming is reduced to a minimum in the mountain valleys and only practised on a very small scale in the immediate vicinity of the settlements. In the highest regions reached by the railway – its culmination point is at an altitude of 3,609 m – there is no cultivation due to the arid climate and poor soils (drift sand and volcanic ash). In contrast, the climate is mild and the soil very fertile on the highland around Quito. So this region has an intensively agricultural character with extensive pastures and small fields.

Structures

There is a wide variety of structures along the railway corridor, ranging from stonework buildings dating from colonial times (e.g. Quito, Yaguachi) to wooden huts in the lowland swamps, perched one and a half meters above the ground to escape the regular flooding. The many open-cast sulphur mines in the region around Alausi have left their mark on the landscape. The rail tracks run direct on roads through numerous towns, so the railway is closely integrated in the urban landscape. However, many of these sections were dismantled from the late 1990s, for example in Milagro and Ambato, within a short time. Otherwise, the railway has impacted the cultural landscape with its spectacular layout through the mountain valleys (setting-back tracks at the 'Devil's Nose') and the small steel bridges along the line. The utility buildings are built in wood or stone, though many of the old buildings have recently had to give way to new ones. The wooden station at Durán is named in honour of the former president of Ecuador, Eloy Alfaro (in office from 1895 – 1901 and 1906 – 1911; construction of the railway to Quito was completed during his presidency). In view of the importance of this personage, the government recently proclaimed the station building a national monument. This move was sufficient to prevent demolition, but the structure is in poor condition

Transport routes

The roads in the area near the railway are mere mule tracks unsuitable for motorised traffic, particularly in the mountainous regions. In recent decades there has been a massive expansion of the Ecuadorian road network across the country. This has had repercussions on the railway, as the drop in the number of passengers and the volume of

Guayaquil&Quito Railway > Tourist train before the spectacular Devil's Nose passage.
V. Barnes

Guayaquil&Quito Railway > Fork near Alausí.
Unknown

Guayaquil&Quito Railway > Section at the Devil's Nose. Illustration from: FEUEREISSEN G.: *Dampf über Südamerika. Die letzten Dampflokomotiven im Regeldienst zwischen dem Äquator und Kap Horn*, München, 1990.

freight carried led to the closing down of several sections of the line. The course of the old railway track was often used for road building. Public passenger transport between Quito, the capital, and Guayaquil has now shifted to the air or road (buses), and freight is transported by truck.

Perception

Perception of the landscape along the Guayaquil&Quito Railway focuses on two groups of motifs: the mountain region around the 'Devil's Nose' as well as the area around Chimborasso, the 6,267 m volcano. The first motif highlights the railway engineering challenge of overcoming the natural topographic difficulties of the steep and precipitous mountain valleys (setting-back tracks to surmount the great difference in altitude over a short distance and the sheer faces of the valley walls). The second motif links up with the visual imagery of snow-covered mountains as symbols of smooth integration in the aesthetic perception of a natural landscape.

Only a few sections of the Guayaquil&Quito Railway are still in operation. Across its full length, the railway line traverses a wide range of climatic and vegetation zones (from sea level to 3,609 m); the degree of exploitation of the landscape differs considerably. Plantations, fields and even mining have left their mark on the surroundings of the railway line. Especially the setting-back tracks on the technically challenging sections in a bleak, rugged mountainscape have made this stretch world-famous. Both factors, linked by technical mastery of the environment, are also of great importance to tourism: operation is therefore maintained on these most spectacular sections. Where the railway ran on roads in the towns, operation has been discontinued and the track has been used to widen the roads.

Cumbres & Toltec Scenic Railway >
Steam train at 'Windy Point' after the Cumbres Pass.
N. Holmes

Cumbres & Toltec Scenic Railway >
Animas Canyon at Silverton, 2,800 m.
P. Gloor

Cumbres & Toltec Scenic Railway >
The natural landscapes are the attraction on the Cumbres Pass route.
N. Holmes

North and Central America

Denver&Rio Grande Railroad (especially the Cumbres & Toltec Scenic Railway, USA)

More than 2,500 km of narrow-gauge railway were built by the *Denver&Rio Grande Railroad Company* from the 1870s to 1929 in the Rocky Mountains in the west of the USA. The southern route, over 300 km long, runs from Antonito to Durango, crossing the 3,053 m Cumbres Pass in the San Juan mountains. It was opened in 1880 (as far as Chama) and in 1881 (to Durango) only a short time after a road had been built across the pass at the end of the 1870s. Today most of this line has been closed down, but a stretch of some 112 km between Antonito and Chama is still operated temporarily as a museum railway.

Agriculture

The railway runs through a sparsely populated and, in part, rugged mountain region at altitudes between some 2,000 and 3,000 m. Farming of any kind is scarce here. The regions around Alamosa and Durango are very arid and only suitable for farming in a few places. Sporadic pastures, some in high-altitude areas near the pass, provide fodder for livestock (sheep and cattle) on a modest scale. Forests, separated in places by grassland, predominate near the pass itself.

Structures

The structures along the railway reflect the conquest of the American West by white settlers following the silver boom of the late 1870s: small settlements with buildings in local stone (e.g. lava at Antonito) or wood, extensive mining installations and processing industries (e.g. in Durango). Mines also began exploiting uranium ore from the middle of the 20th century.
The hot springs of Pagosa were already known to the native Americans (Utes and Apaches) of this region, who were increasingly forced onto reservations after the 1850s. The springs were declared government property in 1880 and were developed for tourism. Their bathing facilities are still very popular, largely thanks to the therapeutic effects of the waters.
The primary impact of the railway on the cultural landscape in the Alamosa-Durango section is made by its utility structures in various styles, but also by the layout of the route over the Cumbres Pass (partly valley loops). The impact is accentuated by various bridge structures along this stretch (in particular trestlework bridges such as those at Cascade Creek and Lobato) as well as the section along the Toltec gorge. A monument to US President James A. Garfield was erected at the western portal of the Toltec Tunnel in 1881, the year he was murdered.

Transport routes

Mule trails probably existed over the Cumbres Pass even before the advent of the settlers in the latter half of the 19th century. However, the taking of the land by the newcomers also led to the industrial development of the region (mines). There is no evidence for a passable route over the Cumbres Pass before 1876. A road was then built and a short time afterwards, in the early 1880s, the railway began to weave through the natural landscape. The railway, with its regular passenger and freight traffic, ceased operation in the 1950s. Only the scenically most impressive section between Antonito and Chama was retained as a purely tourist railway.

Perception

Perception of the landscape along the Cumbres Pass route (like the entire Denver&Rio Grande Railroad) is determined by nature: enormous spectacular rock formations, a diversity of flora and the multitude of colours changing with the seasons. In contrast, the mines with their impact on the landscape (particularly the slag heaps of waste rock) as well as the agricultural utilisation are only secondary features in the perception of the landscape. The aesthetic importance of the landscape for the railway was reflected from the outset, for example in the railroad company logo. The slogan 'Scenic Line of the World' became a brand name and the company name subsequently became a synonym for any railway running through a scenic landscape. Thus the Dunedin-Cromwell route in New Zealand is referred to as the "Denver&Rio Grande" of the southern hemisphere.

The Denver&Rio Grande Railroad with its crossing of the Cumbres Pass is the prototype of a railway route that exploited the scenic attraction of the natural landscape through which it runs as a brand name from the outset. As the 'Scenic Line of the World' it became the role model for railways running through attractive natural scenery the world over.
This specific promotion of the scenic beauty of the natural landscape along the railway relegated other elements of the cultural landscape (such as agricultural or industrial use) to the background. Considerable sections of the Denver&Rio Grande Railroad were decommissioned in the 1950s and only cuttings and embankments remain to recall something of the old railway. Today steam engines run in summer on the section crossing the Cumbres Pass as a tourist attraction.

Europe (without Switzerland)

Train Jaune, France

The electrically operated Train Jaune (Yellow Train) links the Roussillon region with the Cerdagne plateau in the eastern part of the French Pyrenees, running from Villefranche (415 m) to La Tour de Carol (1,230 m). The rail corridor links the two trans-national long-haul lines running north-south from Toulouse to Barcelona (Puymorens Trans-Pyrenean line) and from Montpellier to Barcelona (a standard-gauge line runs from Perpignan to Villefranche). The thermal springs, already known in Roman times, have been of great importance for the development of the region. Their therapeutic properties were used in water cures, particularly from the mid-19th century. The bracing air of the central Pyrenean highlands also makes them a favourite destination for wellness tourism.

Agriculture

The railway links strikingly different climatic zones, ranging from Mediterranean to montane or mountain type. Accordingly, land use is also very varied along the route. On the standard-gauge section between Perpignan and Villefranche, cultivated areas predominate with the accent on fruit and vines. From Villefranche to the watershed at the Perche Pass – at 1,592 m the highest point in France with rail access throughout the year – the railway follows the Têt valley through extensive deciduous forests. Meadows and fields lying fallow are also found close to the settlements and climatically favoured areas (south-facing slopes). After the railway reaches the central Pyrenean highlands, a fundamental change is seen: the valleys are now considerably broader and permit some fruit orchards as well as grazing and crop farming. Continuous forest starts only on the higher slopes. The low stone walls surrounding the pastures and fields at higher altitudes (particularly around La Tour de Carol) reflect the small-scale proprietary and utilisation structures typical of the local farming.

Structures

The structures along the Train Jaune reflect various epochs: the ruins of medieval fortifications are encountered particularly in the Têt valley (such as Citadelle Mont Louis and the twin towers of “El Bastida Nova”), underlining the importance of the region as border country. Luxury hotels, such as that at Font Romeu, were built with the surge in tourism and the construction of the railway in the early 20th century. But the railway itself contributes significantly to an appreciation of the cultural landscape with its mighty bridges – the suspension bridge at La Cassagne and the two-tier viaduct at Fontpédrouse– as well as the Bouillouses reservoir (built to produce electricity for the railway).

Transport routes

Along with the road network that was extended during the 20th century, the railway has made a permanent mark on the landscape, not only with its bridges but also with the technical installations along the line: whereas the conductor rail alongside the track recedes into the background in comparison with the overhead catenaries usual in today’s railways, the power lines from the generating stations to the railway trace another transport corridor. Because of the low-lying conductor rails, the railway corridor must be effectively isolated from its surroundings by a wire-netting fence for safety reasons. This strict separation has left a unique footprint on the landscape. Other salient features, such as long

Train Jaune> "Pont suspendu Gislard" at La Cassagne. Photograph 2000.
UTBM

Train Jaune > Layout of the 'Train Jaune' in the Cerdagne region. Photograph 2000.
UTBM

Train Jaune > Bridge over the river Têt near Villefranche. Photograph 2002.
UTBM

high-pressure pipes, reservoirs and power-station machine houses, recall what was needed to operate an electric railway in its infancy: great differences in altitude over short distances to generate the power needed for the railway.

Perception

The perception of the landscape along the route of the Train Jaune is characterised by the settlements and marchland fortifications together with the snow-capped mountains of the Pyrenees. Seen from the railway line, the two major bridges embedded in the forest landscape represent popular motifs. The Fontpédrouse two-tier viaduct, in particular, is the distinctive symbol of the railway line and has even featured on postage stamps. In view of its location in the Franco-Spanish border country, the Train Jaune has also played a role in forging a sense of Catalan identity in the Cerdagne region.

The cultural landscape along the route of the Train Jaune is particularly varied due to the various climatic zones it crosses as well as the rich local traditions. Thermal springs, fortresses and ruins as well as an artificial reservoir built to generate power for the railway exemplify the broad range of structures that constitute this cultural landscape. Agricultural exploitation has moulded the countryside both in the Cerdagne and the Roussillon district. The construction of luxury hotels concurrently with the building of the railway gave an impetus to tourism in the region. Ultimately, the railway also played a significant role in defining the identity of the people of the Cerdagne.

Semmering Railway > Viaduct across the Kalte Rinne. Photograph taken between 1890 and 1900.
Unknown

Semmering Railway > Viaduct across the Krauselklause.
P. Glitzner

Semmering Railway > Left the viaduct across the Kalte Rinne, right the viaduct across the Krauselklause.
P. Glitzner

Semmering Railway, Austria

The Semmering Railway runs diagonally across the Alps from Gloggnitz (439 m) through a crest tunnel culminating at an altitude of 898 m to Mürzzuschlag (681 m). The cultural landscape at the Semmering Pass and its perception are linked very closely to the railway. Interest initially centred on the Reichenau valley, which could be reached much more rapidly from the imperial capital with the opening of the Vienna-Gloggnitz railway in 1842. The second phase began in 1882, when the *Südbahn-Gesellschaft*, who owned the Semmering Railway, built a large hotel at the Semmering Pass, launching a building boom for both hotels and villas. Tourism virtually came to a halt at Semmering after World War I and only recently has there been a resurgence in day trips and weekend excursions.

The Semmering Railway was inscribed in the UNESCO World Heritage Sites List in 1998. The core zone consists of a railway corridor approx. 42 km long. The surrounding landscape was also included with a special focus on the hotel and villa colony at the Semmering Pass. Up to the present (2006), however, this cultural landscape has not been recognised as a World Heritage Site because the protection zones (core, buffer zone etc.) have not yet been delimited with sufficient precision.

Agriculture

The craggy landscape on the north side of the Semmering Pass is of only limited use for farming. Cereals are cultivated on the valley floor, as they used to be on climatically favoured slopes at Eichberg or near Klamm. More hardy vegetables like potatoes were grown on a small scale in all the valleys of the Semmering district as far up as Breitenstein. Until about 1900 vines were also cultivated at Gloggnitz. The main part of the Semmering region, particularly to the south of the pass, is covered with meadows and forests: the meadows are used both for grazing and as a source of winter fodder for the animals. The forest is used for timber, and fallen wood is collected for domestic fires. Felling is localised and therefore has a significant impact on the appearance of the landscape: forest clearance opens up the line of view until the clearings become overgrown, when they impede it completely. The orchards around the scattered farms (e.g. around Breitenstein) are another characteristic feature of the landscape.

Structures

Among the varied structures of the Semmering region, those from the end of the 19th and the early 20th century are the most striking. These include several large hotels (Südbahnhotel 1882, Hotel Panhans 1888, Hotel Erzherzog Johann, Kurhaus Semmering 1909, Palace Hotel 1912) and numerous villas (26 had been built by 1900). There are isolated farms in the environs of the Semmering Pass (e.g. at Breitenstein), villages (e.g. Spital), religious buildings (e.g. the church at Klamm, Spital at Semmering, the Maria Schutz pilgrimage church and other chapels in the district), industrial buildings (e.g. Schlöglmühl) as well as a ruin (Klamm). The oldest structures in the Semmering district are found along the mule track over the pass that can be traced back to the 10th century, particularly on the south side by Spital. On the north side of the pass, Schottwien, which experienced a boom before the railway thanks to its carriers, should be mentioned. Structures associated with the iron-processing industry are found to the south of the Semmering Pass in the Mürztal, near Schottwien and Reichenau (a charcoal blast-furnace dating from the early 18th century has survived at Edlach).

The railway structures have made a major impact on the cultural landscape of the Semmering region. Thus the massive railway viaducts, especially the one over the Kalte Rinne, have become characteristic landmarks of the region. Another imposing feature of the landscape is the layout of the line with its valley loops (e.g. at Payerbach) and rugged rock faces (e.g. the gallery in the Weinzettlwand).

Transport routes

As already mentioned, a mule track crossed the Semmering Pass from the 10th century. This was part of the trade route to the Mediterranean ports of Venice and Trieste. The first effective road over the Semmering Pass was undertaken in 1728 (parts of it still exist today). The 'new' Semmering road with its serpentine course was opened in 1841 with significantly gentler gradients than its predecessor. The stone bridge over the Myrthengraben was also built at that time and is still in use today. Shortly afterwards the first railways reached the edge of the Semmering region and the 'iron road' across the pass came into operation already in 1854. The boom in tourism towards the end of the 19th century promoted the construction of new roads and footpaths in the region, for example the 'new highroad' with its numerous panoramic vantage points between Semmering and Orthof. The electrification of the Semmering Railway after the Second World War, made the construction of a power supply line necessary and therefore generated a new transport corridor. The rapid rise in motor traffic culminated in the 1990s with the construction of a motorway: its impressive prestressed concrete bridge spanning the village of Schottwien and the Mürztal valley is now the dominant transport feature of the landscape.

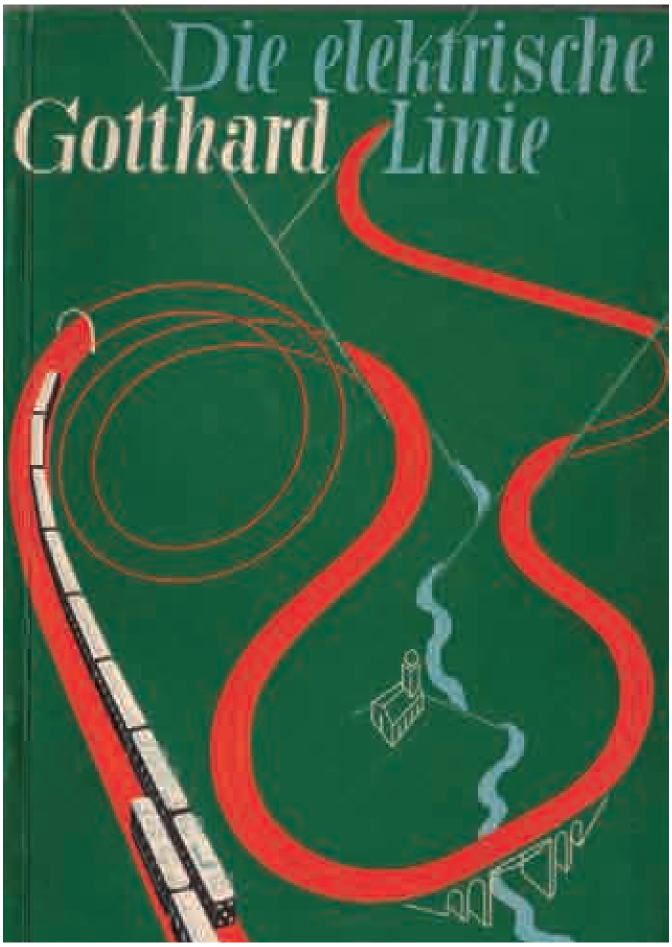
Perception

The Semmering region is a text book example of how the perception of the landscape changes in response to developments in the various modes of transport that traverse it. In the days of the mule track, the most important factor was simply to get across the pass safely. Then, Prince Liechtenstein had a garden with an artificial lake, a waterfall and a temple built in the Adlitzgraben gorge in the 1830s: these manmade features led to the raw and rugged nature in the background being seen – in their stark contrast – as the essence of wild Romanticism. Although the Prince's artificial garden was destroyed by the construction of the railway, the latter allowed a new panoramic appreciation of the mountain landscape it passed through. In this context, the Semmering route is also the prototype for the perception of mountain regions thanks to rail travel. The impression of the railway route as "linear" is reflected in the folded, linear panorama (Ghega 1854; the size and colour of this panorama may have changed over the years, but it has remained a constant element of the visual recall of the Semmering Railway to the present day). The viaduct across the Kalte Rinne seen against the precipitous landscape has become the 'trademark' of the region: this scene has been reproduced on postage stamps and bank notes. Early portrayals even included imaginary elements of the landscape such as rock columns: the addition of such dramatic props bears witness to the transfiguration of the landscape traversed by the railway. In the 1890s the Semmering region was even claimed to be on a par with Swiss tourist resorts like St. Moritz or Davos.
The region around the Semmering Pass is perceived much more as a cultural landscape than a natural one. The perception of nature is essentially limited to the representation of precipitous

crags and Alpine flora and led to the founding of the "Rax-Schneeberg" nature reserve in 1955, which also takes in the region traversed by the Semmering Railway.
The Semmering Pass, the Railway and the region as a whole also attracted artists and writers: thus Peter Rosegger recorded his impressions of the railway journey in his short story *Als ich das erste Mal auf dem Dampfwagen sass* of 1877, Adolf Loos built the Landhaus Khuner here in 1929 – 30 and Peter Altenberg left his collection of sketches entitled: "Semmering, 1912". Arthur Schnitzler, Oskar Kokoschka and Egon Friedell also spent several summers in Semmering in the years before World War I.

The Semmering Railway is considered to be the prototype of a railway in mountainous terrain. Its advent promoted agriculture and forestry in the region and led to a surge in local tourism. Great significance has been accorded to the perception of the landscape surrounding the railway from the outset: carefully arranged scenes still characterise the image of the railway and landscape today. Travel guides draw attention to the best views in advance. Panoramas of the entire railway line stimulate the visual imagination, and the bridges or valley loops shown against the backdrop of the surrounding landscape document the integration of railway and landscape to produce an interfused aesthetic perception. Various views of railway structures (viaduct across the Kalte Rinne) became hallmarks of the Semmering region and have been used on postage stamps and banknotes. Towards the end of the 19th century, the region around the Semmering Pass developed into a hotel and villa colony that attracted and inspired artists (Rosegger, Altenberg, Loos, Schnitzler, Kokoschka, Friedell).

The cultural landscape surrounding the Semmering Railway is still not part of the UNESCO World Heritage List because the area of the protection zones has not yet been defined precisely.



Gotthard Railway > A 1932 poster with a stylised drawing of the cultural landscape.
Collection G. Dinhobl

Gotthard Railway > The transport landscape around Wassen: 19th century railtrack with loops at three different levels; late 20th century motorway. Photograph about 1980. Illustration from: EGGERMANN ANTON [et al.]: *Die Bahn durch den Gotthard*, Zurich 1981.

Gotthard Railway > Original Kerstelenbach steel truss bridge, about 1881.
Collection G. Dinhobl

Switzerland

Gotthard Railway

The Gotthard Railway runs from Lucerne (436 m), located north of the Alps, via a 15 km tunnel (highest point 1,151 m) through the Gotthard range to Chiasso (226 m) on the southern rim of the Alps. A path crossed the Gotthard Pass already in the Bronze Age. The opening up of the Schöllenen gorge in the 13th century created the shortest north – south transit route across the Alps. The Gotthard route was further improved in the 16th century, indicating its great importance as a transit corridor at that time. Goods transport on draught animals became an important source of income for the local people. The road was extended in the first third of the 19th century – just like those across numerous other Alpine passes. The railway, built at the close of the 19th century, fundamentally changed the landscape around the Gotthard. About a century later, a four-lane transit motorway virtually took over the narrow mountain valley.

Agriculture

The Gotthard region comprises mountain valleys of widely different width and character. Cultivated areas dominate in the lower reaches of the valleys (principally pastures on the higher slopes, cereals and fruit lower down). Some of them, such as in the Ticino between Bellinzona and Locarno, were only won by straightening the rivers. In the southern sections of the route in Canton Ticino, the Mediterranean climate allows the cultivation of vines, chestnuts and figs. At higher altitudes, the picture is dominated by livestock farming with meadows and pastures. More than 100 hectares of forest have been planted along the Gotthard line since 1900 to protect the railway against avalanches and landslides. Numerous other protective structures have been erected above the tree line.

Structures

The Gotthard Railway runs from the northern cultural region with its German-Alemannic character to the southern zone marked by Italian-Romance culture, each with its own architectural preferences as regards both secular and sacred buildings: the two regions differ even in the structure of their settlements. Thus scattered communities prevail in the northern part whereas nucleated villages dominate in the southern section. Numerous castles and churches bear witness to the importance already enjoyed by the region as a transport corridor in earlier times. The castles of Bellinzona were inscribed in the UNESCO list of World Heritage Sites in 2000 (Monte San Giorgio, listed as a UNESCO Natural Heritage Site, is also located in the immediate vicinity of the Gotthard Railway corridor). In its central section between Erstfeld and Biasca, the railway led to a modest development of tourism, for example in Göschenen, Airolo and Faido. However, no grand hotels were built, like those at Semmering or in the Engadin.
The railway structures make a strong impact on the Gotthard region. Thus the Gotthard Railway was the target of criticism by the Swiss Heritage, movement formed at the beginning of the 20th century (cf. 2.a.4). They objected to the use of steel supplied from other regions rather than local materials to build the bridges and to the straight tracks which prevented the railway from harmonising with the landscape. Indeed, the Gotthard Railway even became a symbol of a technological structure that failed to integrate with the natural environment. Since then, all the original steel bridges of the railway have been replaced by pre-stressed concrete bridges. The

power-station structures built to supply the electric railway are examples of industrial installations in the Gotthard region (Ritom, Amsteg). The Gotthard Railway subsequently led to the construction and reinforcement of military fortifications of national importance: they were begun in 1886 and were upgraded, especially during World War II, to become the 'Gotthard Fortress'.

Transport routes

The Gotthard holds a strategic position in the trade between Italy (particularly the port of Genoa) and the countries to the north (particularly Germany). The local transport routes are essentially prefigured by the Reuss and Ticino valleys. The Schöllenen gorge above Göschenen was always a crucial point along the route. Until the 13th century, a mule track ran above the gorge and passed over the Bätzberg. The building of the Devil's Bridge allowed the gorge to be crossed direct, and the bridge soon found an echo in local folklore.

The railway visibly changed the valleys of the Reuss and Ticino rivers with its tunnels, bridges and the layout of the line. However, the construction of the motorway in the 20th century had a significantly more invasive impact on the landscape: in certain sections, such as at Wassen, the motorway and its access roads occupy the whole floor of the valley. Today, the road has ousted the railway as the transport structure that dominates the landscape of the Gotthard region.

Perception

Before the Gotthard Railway was opened, visual and literary perceptions centred on the difficulties involved in overcoming the barriers of the rugged mountainous terrain. The advent of the railway then shifted the focus towards the cultural landscape. The travel guides gave precise instructions on how to appreciate the scenery properly. Thus the widely used *Baedecker* guide of 1909 tells its readers: "Sit on the right from Lucerne to Amsteg, on the left from Amsteg to Faido, on the right again from Faido to Bellinzona". Travellers were urged to look both at the cultural sights – and especially at churches and castles – and at the mountains. But now, views of the Gotthard region placed the railway structures like bridges or the (reverse-track) loop systems at the centre of the composition, thus focussing – at an early stage – on the embedding of the railway in surroundings moulded by man. The image of Wassen church, which is encircled by several loops of the railway, was particularly prominent. Panoramas of the railway are presented as overviews of the landscape (unlike the earlier linear panoramas like for the Semmering line).

The Gotthard Railway gained great significance as a national icon, especially in the first half of the 20th century.

In the context of its surrounding landscape, the Gotthard Railway is primarily a transit corridor running right through the mountains: it allows faster and easier transport of people and goods from Italy to central and northern Europe and vice-versa. The railway is closely intermeshed with the cultural landscape either through its direct (track route) or indirect (protective forests and avalanche barriers up to very high altitudes) impact or by being visualised as embedded seamlessly in it (route pattern, the church at Wassen). Unlike some other railway lines (such as the Semmering Railway), the Gotthard Railway has had no significant effect on tourism in the region it traverses.

Summary

The cultural landscape of the Albula-Bernina railway corridor exhibits numerous features that can be seen, from the train, as typical for regions with mountain railways. In contrast, other aspects show a complete absence of similarities, so this railway corridor can be regarded as having a highly individual character. Precisely in its combination of numerous *unique* and *typical* elements, the surrounding landscape enhances the exceptional universal value of the Albula/Bernina railway.

Typical

The typical elements will now be presented as a summary of the preceding descriptions on the basis of the familiar analysis scheme.

Agriculture

Agricultural exploitation is frequently encountered in the environs of the railway. Some forms of cultivation already existed before the advent of the railway (highland farming in the Alps, tea plantations in colonial India), but they were largely intensified and expanded following its construction (although reduced transport costs for agricultural produce had a negative impact in some cases). In this respect, the cultural landscape of the Albula-Bernina railway corridor is eminently comparable with those of other mountain railways.

Structures

The structures along the railway routes indicate whether the surrounding cultural landscape existed before the advent of the railway or was created in the course of its construction. A particularly great diversity of structures is seen where a “historic” cultural landscape is complemented by the railway line. All the railways examined here are associated with tourism. Particularly in the Alps and Pyrenees, some tourist destinations already existed before the construction of the railway: tourism had already changed the “old” cultural landscape with the building of facilities such as hotels, footpaths and hiking trails. Existing tourist destinations expanded after being linked to the railways, while other regions only became accessible to tourists with their advent (such as the hotel and villa colony on the Semmering that followed the construction of the railway). Winter tourism in the Engadin began with the coming of the Albula railway, which assured accessibility to the region throughout the year as well as a reliable line of supply for the hotels. The railway structures themselves also leave their stamp on the cultural landscape. Precisely in the case of the mountain railways, it is often the outstanding bridges and viaducts which – embedded in the landscape – express the unmistakable character of the route and find an echo as its ‘trademark’: the Landwasser Viaduct and the Circular Viaduct at Brusio reverse-curve viaduct define the Albula/Bernina corridor, on the Semmering it is the viaduct across the Kalte Rinne, for the Train Jaune the two-tier viaduct at Fontpédrouse or the suspension bridge at La Cassagne, on the Gotthard the (no longer existing) lattice bridges, and on the Yunnan Railway the lattice bridge across the Pei Ho gorge. In this way, the railway can be seen as a visual cultural presence in the rugged mountain landscape.

Transport routes

The railways are surrounded by numerous transport routes. In most cases these are roads, often running alongside or at least very close to the railway or even together with it (as it passes through towns, as in the Guayaquil-Quito Railway and

the Bernina Railway, for example). The railway reduces the status of existing routes while new routes gain in importance. Whereas those transport routes that run along the railway corridor tend to lose importance, local transport routes are upgraded (such as connecting roads between stations and settlements, as in the case of Stugl/Stuls in the Albula valley or tourist resorts [cf. the routes from the station at Semmering to the top of the pass and the hotels], or scenic routes, but also roads to cultivated areas). Moreover, pipelines and power lines, as well as reservoirs, are also encountered near electrically operated railways (Train Jaune, in part the Semmering and Bernina railways).
The rapid spread of motor traffic especially in the second half of the 20th century saw the start of a new development, namely the dismantling of railways, especially where these ran straight through towns and villages (such as on the Guayaquil-Quito Railway). So the way the Bernina line runs through settlements represents a typical but no longer frequently encountered example of the intermeshing of road and railway.

Perception

In all cases, the construction of the railway led to an increased aesthetic appreciation of mountain landscapes. The perception of the landscape along the railway routes is particularly significant: certain features are highlighted when the railways are used for tourism. The heightened interest in landscapes beginning in the Romantic era played a major role in the way a railway journey was experienced. the diversity of impressions it afforded meant that the perception of the landscape during an excursion could be romanticised as a "ballet of views". The perception of the surroundings as a cultural landscape is reflected by the structures along the route: buildings already predating the railway such as churches (Mistail on the Albula, Klamm on the Semmering; Wassen on the Gotthard) as well as hotels that were built in the wake of the railway (e.g. Semmering, Albula, Train Jaune) or the bridges, viaducts and tunnel portals (e.g. Landwasser Viaduct on the Albula, Kalte Rinne on the Semmering, Gotthard Tunnel) frame the visual conjunction of railway and landscape. On routes with a relatively intact natural landscape, the railway is seen virtually as the signature of man (Denver&Rio Grande Railroad; Adderley viaduct on the Nilgiri Railway; layout of the line near the 'Devil's Nose' on the Guayaquil-Quito Railway; Bernina Pass). All these examples are the expression of seeing the surroundings of railway corridors in mountainous regions as a cultural landscape.

Uniqueness

This unique character of the Albula/Bernina line is due mainly to the diversity of the landscape and the numerous vegetation and climatic zones that it traverses that can be experienced from the train: compared with the other railways considered in this section, the Albula/Bernina line is the only railway – besides the Gotthard Railway – that crosses a mountain range in its entirety. Although the distance as the crow flies is about 80 km, the maximum difference in altitude traversed by the Albula/Bernina line is some 1,550 m on the north side and some 1,700 m on the south side. In contrast, the Gotthard Railway climbs no more than some 910 m. The Semmering Railway on the eastern flank of the Alps is short in comparison: a 'diagonal' Alpine transit route with a distance of some 21 km as the crow flies between the stations of Gloggnitz and Mürzzuschlag. It also climbs a mere 450 m, a distance associated with significantly less scenic variety. The Denver&Rio Grande Railroad over the Cumbres Pass is located in the Rocky Mountains and also has a considerably lower difference in altitude to overcome, namely about 660 m (Chama – Cumbres Pass). All the other railways examined in the comparison certainly climb considerable distances (some 3,600 m on the Guayaquil-Quito Railway, for example) with all the technical difficulties this entails, but they run without exception from lowlands (in some case from a seaport) to destinations in the mountains and thus do not *cross* a range of mountains. This aspect of crossing an entire range is particularly important with respect to the cultural landscape: mountains have acted as a barrier since primordial times, separating different cultures and distinct cultural landscapes from each other (the Albula/Bernina corridor passes from German, via Rhaeto-Romansh to Italian (cf. 2.b.8). The railway structures represent another feature of the unique character of the countryside surrounding the Albula/Bernina route. Soon after the line was opened, the stone viaducts of the Albula line were recognised by the Swiss Heritage Society as being in harmony with the landscape and thus exemplary, whereas the iron lattice bridges on the Gotthard were cited as a negative example. This also differentiates it from the Semmering Railway, where the harmony of engineering and landscape was not expressed until the beginning of the 20th century, decades after it had come into operation. However, the building of the Semmering Railway in the 1850s made it possible for the region it passed through to be aesthetically perceived as “landscape” whereas before it had been considered merely as a “district”: the Semmering Railway was seen as creating the cultural landscape, whereas the Albula/Bernina line was integrated smoothly into the existing cultural landscape.

	Technical data, condition - Year opened, originally operated by - Max. altitude - Gauge - Number of tunnels - Number of bridges - Safety structures	Reasons for building	Original and current operation	Railway type	Railway in the cultural landscape (original)	Technical innovation
Yunnan Railway	- 1910, steam operation - 2,026 m - Narrow gauge / 1,000 mm - 172 Tunnels - 107 Large bridges - Few safety structures	Trans-regional development for trade and passenger traffic by French colonial administration: Link between Hanoi, on the coast, and the Chinese provincial capital of Kunming	Originally passenger and freight traffic according to timetable; today regular operation only on certain sections; plans to restore through operation	- Colonial railway - Mainline character - Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions with a view to harmonically embedding the railway structures in the environs	Low to moderate structural outlay to reach a provincial capital in the mountains
Darjeeling Railway	- 1889, steam operation - 2,258 m - Narrow gauge / 610 mm - No tunnels - One major bridge - Hardly any safety structures	Regional development for trade and passenger traffic by British colonial administration	Originally passenger and freight traffic according to time table; today exclusively passenger traffic, mostly for tourism	- Colonial railway - Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions with a view to harmonically embedding the railway structures in the environs	Excellent example of a «light railway»
Nilgiri Railway	- 1903, steam operation - 2,094 m - Narrow gauge / 1,000 mm - Section with cog system - 16 tunnels - 32 large bridges - Safety structures	Regional development for trade and passenger traffic by British colonial administration	Originally passenger and freight traffic according to timetable; today exclusively passenger traffic, mostly for tourism	- Colonial railway - Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions with a view to harmonically embedding the railway structures in the environs	Example of combined system (cog / adhesion system)
Eritrea Railway	- 1911, steam operation - 2,395 m - Narrow gauge / 950 mm - 30 tunnels - 532 bridges and overpasses - Few safety structures	Regional development for trade and passenger traffic by Italian colonial administration: Link from the port of Massaua to Asmara, the capital	Originally passenger and goods transport according to timetable; today exclusively tourist traffic	- Colonial railway - Mainline character - Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions with a view to harmonically embedding the railway structures in the environs	Low to moderate structural outlay to reach a capital in the mountains
Guayaquil&Quito Railway	- 1908, steam operation - 3,609 m - Narrow gauge / 1,067 mm - No tunnels - Only few bridges - Few safety structures	Regional development for trade and passenger traffic: Link between Quito, the capital and the ports on the Pacific coast	Originally passenger and freight traffic according to timetable today only tourist traffic on isolated sections	- Mainline character - Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions with a view to harmonically embedding the railway structures in the environs	Adoption of the rarely used setting back tracks to gain altitude
Cumbres & Toltec Scenic Railway	- 1880, steam operation - 3,053 m - Narrow gauge / 914 mm - Two tunnels - Two larger bridges - Hardly any safety structures	Regional development for trade and passenger traffic; in particular mining products	Originally passenger and freight traffic according to time table today only tourist traffic on isolated sections	- Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions in the sense of railway buildings adapted to the environs; function as scenic railway is only recent	Low structural outlay to overcome a mountain pass
Train jaune	- 1911, electrically operated - 1,592 m - Narrow gauge / 1,000 mm - 19 tunnels - 106 bridges, including 14 larger bridges - Few safety structures	Regional development for trade and passenger traffic and linking of two transnational railway lines in the Pyrenees	Originally passenger and freight transport according to timetable; today only modest tourist traffic	- Narrow-gauge railway - Mountain railway, does not cross a range but climbs to a point in the mountains	No landscape forming intentions with a view to harmonically embedding the railway structures in the environs	Track alignment adapted to electrical operation (greater upgrades than for steam operation)
Semmering Railway	- 1854, steam operation - 898 m - Standard gauge / 1,435 mm - 15 tunnels (length up to 1.5 km) - 16 viaducts - Extensive safety structures	Trans-regional development for trade and passenger traffic Link between Imperial Vienna and the Mediterranean port of Triest	Originally and today passenger and freight traffic; planning of base tunnel to shift mainstream traffic in progress since 1989	- Mainline / transit - Mountain railway – crosses a range at low altitude	No comprehensive landscape-forming intentions in sense of railway buildings harmoniously adapted to the environs; link between railway engineering structures and landscape only becomes an issue in the wake of development of tourism	First example of a mainline trans-Alpine railway
Gotthard Railway	- 1882, steam operation - 1,151 m - Standard gauge / 1,435 mm - 80 tunnels (15 km crest tunnel) - 79 large bridges - Extensive safety structures	Trans-regional development for trade and passenger traffic Connection linking northern and southern Europe	Originally and today passenger and freight traffic; base tunnel to shift mainstream traffic under construction; opening planned for 2014	- Mainline / transit - Mountain railway – crosses a range at moderate altitude	No landscape forming intentions in the sense of railway buildings harmoniously adapted to the environs; bridges though to be progressive when built but soon considered inappropriate	Example of a mainline railway with spiral tunnel and a long crest tunnel through a massif; the Alps
Albula / Bernina Line	- 1903 / 1910, steam / electrical operation - 1823 / 2,257 m - Narrow gauge / 1,000 mm - 41 / 11 tunnels (Albula: crest tunnel just 6 km - 65 / 21 larger bridges - Extensive safety structures	Regional development for trade and passenger traffic (and tourism); integration in trans-regional railway network Bernina Railway as "side product" of electricity produced by the power stations	Originally and today, passenger and freight traffic according to full timetable	- Mainline character - Narrow-gauge railway - Mountain railway – crosses a range at high altitude	Landscape forming intentions in the sense of deliberate harmonious adaptation of railway buildings to the environs (e.g. by choice of local building materials)	Example of a (narrow- gauge!) mainline railway with spiral tunnels and lengthy crest tunnel, crossing a massif in its entirety, attaining high altitudes and operating 12 months a year from the later golden age of Alpine railway building; characteristic differences in the alignment due to choice of operating technology, particularly the electrical power system (Bernina: higher upgrades)

3.c.4 Overall view of the comparison

The analyses (cf. 3.c.2 and 3.c.3) revealed that, on a worldwide comparison, numerous features of the "Rhaetian Railway in the Albula/Bernina Cultural Landscape", could be identified as *unique* while others are *typical*. To enhance transparency, this overall view of the comparison has been broken down into the sections "Building Period", "Economic Importance", "Technical Importance", and "Present and Future Importance". In conclusion, the most important findings are summarised in the section "International Positioning of the Albula/Bernina line". A consideration of the "Cultural Landscape Importance" focussing on the surrounding countryside has been added.

Building Period

In the mid-19th century, mountain railway construction was still in the trial phase; the Semmering Railway was a trailblazing achievement in this respect. Tunnel building was mechanised in the second half of the 19th century. This made longer and special types (crest tunnels, spiral tunnels) feasible; a very early and most impressive example built in this period is the Gotthard Railway. Europe played a pioneer role in these technical innovations. At the same time, railways were being built to access the hinterland in various colonies; in the West of the USA the railway network spread out impressively. In the construction of all these railways political, economic (mining) and military interests provided primary impulse. At the beginning of the 20th century, railways built beyond Europe, relied on the tried and tested steam technology, whereas in Europe other sources of power for the railways were already being tested. In the first place it was electric traction that became increasingly important from the turn of the century. This had significant effects on the parameters of the railtracks, particularly on maximum upgrade. The Bernina Railway which was operated by direct current is a product of this trial phase in electric railways (like the Train Jaune or Little Yellow Train). In the 20th century, alternating current became the standard form of electrification (Albula Railway: from 1919). No later than in the second half of the 20th century, with the construction of the high speed trains (the Shinkansen in Japan or the TGV in France) electricity became the standard form of power.

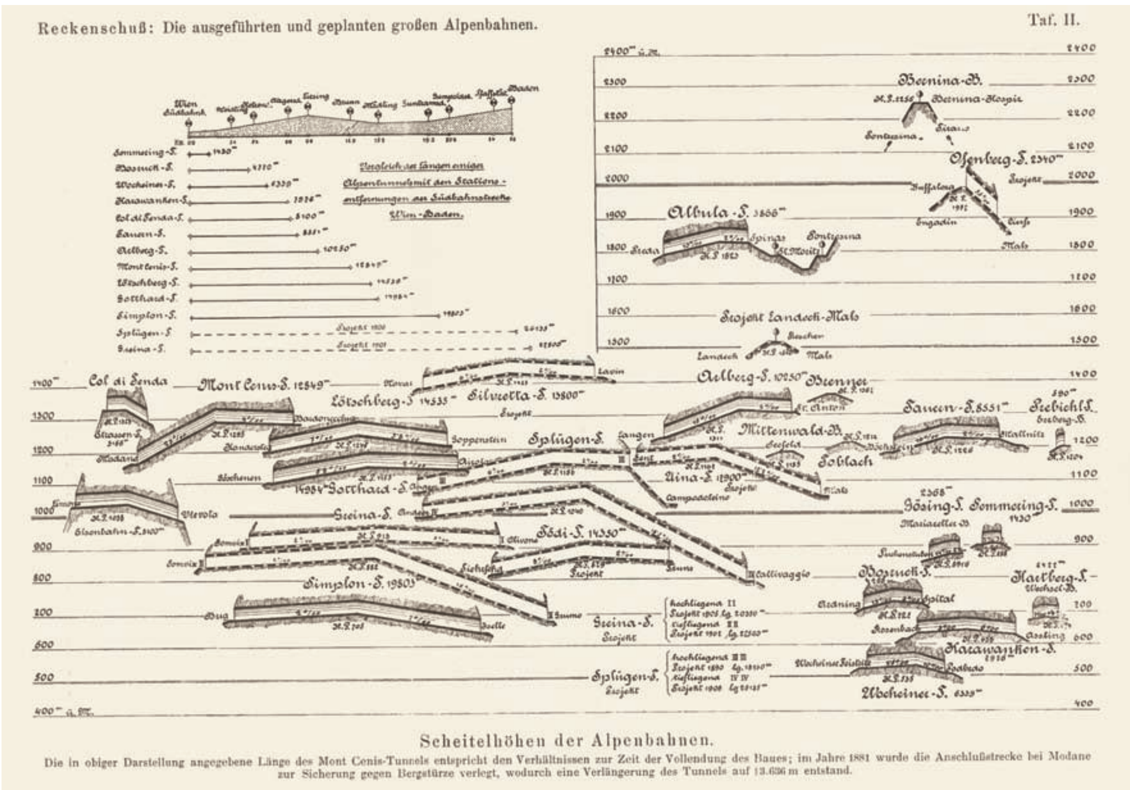
The Albula/Bernina line is rather special in the context of this development. Its 'uniqueness' derives from the Bernina Railway since at that time there were no precursors, no electrically powered railways at such an altitude. It is still the highest altitude transalpine railway operating all the year round and its significance for the electric railway is similar to that of the Semmering Railway in the steam operated mountain railway context. In the case of the Semmering Railway, which held the record for the highest railway culminating point for a decade, the capacity limit of steam locomotives was tested exhaustively and eventually raised, permitting access to mountainous regions throughout the world. It is the Albula line that is "typical"; the locomotion system and parameters were planned according to conventional steam-operated mainlines. A unique factor, however, is that on the Albula line all the technically

extremely complicated measures like spiral tunnels or lengthy crest tunnels used for standard-gauge mountain railways were used on a narrow-gauge railway.
The Albula/Bernina railways are early 20th century highlights in the overcoming of a mountain massif by rail. The Bernina line stood out in its choice of what was, at the time, a highly innovative electrically powered system; it would soon become standard. The Albula railway distinguished itself in the perfection of a conventional yet - in view of the adoption of special forms of tunnel construction - very extravagant mode of operation and its realisation on a narrow-gauge construction. What is more both railways are among those last Alpine railways whose “golden age” came to a halt with the outbreak of the First World War; after this interruption none of the planned transalpine railways were realised. If the Semmering Railway takes is a symbolic for the beginning of the mountain railway era, then the Albula/Bernina lines are the final highlight. Together they illustrate, emblematically, the development of mountain railway construction from the mid-19th century until the eve of the First World War. Only at the end of the 20th century were new transalpine railways planned and realised, in particular the new transalpine axis (NEAT) in Switzerland. However, this tunnels right through the alpine massif (Gotthard and Lötschberg base tunnel).

Economic importance

Economic considerations provided the primary impulse to build railways. In the comparative

High altitude layout and crest tunnel of the ‘great Alpine railways’: 1912



Plan from: **Robert Ritter von Reckenschuss:** ***Die ausgeführten und geplanten grossen Alpenbahnen,*** **Vienna 1912.**

railways in non-European regions, colonial power and the exploitation of mineral resources and agricultural surfaces were important grounds: Thus the Yunnan Railway, running from the Vietnamese port of Haipong to the south Chinese Kunming, reflects the former influence of the French colonial authority, the Eritrea Railway reflects the colonial influence of Italy and the Darjeeling Railway that of England. The Yunnan and Eritrea Railways like the Guayaquil&Quito Railway served both to access the hinterland of the ports and of the towns (Kunming, Asmara and Quito). The Denver&Rio Grande Western was built exclusively to facilitate the exploitation of mineral resources (silver, iron and anthracite). Two of the European comparative railways fall into the category "transit railway with large catchment area (Semmering and Gotthard Railways), while the third, the Train Jaune, was clearly built as a tourist railway. Tourism added value was also achieved in the case of the transit railways; this was more marked in the case of the Semmering Railway than for the Gotthard Railway.

The Albula/Bernina stretch has certain similarities with the Train Jaune with respect to economic dimensions: In both cases an existing or emerging tourist region is accessed by a railway for the first time and connected to a greater, transregional even transnational railway network. The importance of the region for tourism is greatly enhanced by the construction of the railway (development of all-the-year-round tourism in the Engadin). However, at the same time, these railways supply the region. For the Bernina Railway, strongly influenced by tourist issues, the value added factor of building power stations on the south side of the Bernina Pass was decisive. The power station was primarily constructed to generate power for the northern Italian industrial region around Milan, and only part of the current was required to operate the railway.

Technical importance

The comparative railways cover a broad range in the technical field. The type and extent of the technical refinements, are generally a direct quotient of the economic expectations linked with the construction of the railway, but they are naturally also dependent on what was technically feasible at the time. The response to difficult topography is a sophisticated alignment and numerous engineering structures like bridges and tunnels. Large and bifurcated mountain valleys can be overcome with normal upgrades (Denver&Rio Grande Railroad, or by loops curving into the tributary valleys (Semmering and Yunnan Railways). Narrow, steep valleys, in contrast, require setting-back tracks which complicate operation (Guayaquil & Ecuador Railway) or technically very ingenious – and very costly – spiral tunnels or a crest tunnel (Gotthard, Albula). Open loops, like on the Darjeeling Railway, or cog operation like on the Nilgiri Railway are exceptional technical solutions.

The choice of alignment parameters - gradient and curve radius - depends on the technology adopted: As a rule, originally steam operated stretches were not planned with gradients in excess of 35‰ to 50‰ (Semmering, Gotthard, Yunnan and Eritrea Railways). The degree of upgrade influences the length of the railtrack in mountainous terrain. On electrically operated stretches the gradient could be raised to 70‰ – doubling the upgrade and shortening the length of the railtrack proportionally (Train Jaune).

The Albula and Bernina line uniquely represents typical rail stretches from the "golden age" of railway building. The railtrack of the Albula line was designed only for steam operation and therefore integrated numerous large engineering structures like major (stone) bridges or technically complicated spiral tunnels and a long crest tunnel. At the same time, the choice of what was then most innovative technology (electric operation) for the Bernina Railway led to a completely new type of railtrack and a marked increase in upgrades. The change in technology on a stretch, as exemplified by the Albula/Bernina line, is not to be found on any of the comparative railways and is therefore of unique importance worldwide.

Current and Future Importance

Despite the much quoted "renaissance of the railway" in the 21st century, the current importance of the various railways is by no means uniform. All the comparative railways are still in operation, but often only over short sections and rarely do they fulfil their original role. In view of the increasing shift of traffic from rail to road, whole stretches of some railways have been closed down after the Second World War or remain under acute threat of closure. Only a 'survival' as tourist railway with a radically reduced or strictly seasonal schedule, enables their continued, if uncertain, existence (e.g. Eritrea Railway; Guayaquil&Quito Railway; seasonal: Denver&Rio Grande Railroad). With the exception of the two transit lines, Gotthard and Semmering, freight transport has been abandoned. On the Yunnan Railway certain stretches were seriously damaged by storms in 2002; they have not been replaced for the time being. The structural condition – like for most of the other comparative railways – is not up to standard throughout, although the ministry responsible for Chinese railways declared in 2004 that they do want to preserve the stretch. This despite the construction of a standard-gauge Trans-Asia railway from Kunming to Singapore.

The comparative transit railways Gotthard and Semmering switched to electric operation, like the Albula Railway, at the beginning of the 20th century; this meant that power lines had to be erected. The changes entailed by electrification are essential operative measures to maintain the railway in the long term. Other modifications were also made on the Semmering and Gotthard railways. On some of the Semmering viaducts the original bricked arches were rough cast and the original natural stone parapets replaced by simple railings. At present additional, technically essential, work is in progress that will alter the appearance of the viaducts. All the steel girder lattice bridges on the Gotthard, which were built in 1880, have been replaced by concrete constructions. Base tunnels for both railways are either at the planning stage (Semmering) or under construction (Gotthard). In both cases, the continuation of operations on the historic mountain stretch after the opening of the base tunnels is uncertain. The Albula/Bernina line still operates a full schedule that is, it is still used for both passenger and freight transport. Between Thusis and St. Moritz, a daytime express runs hourly - a rarity on European narrow-gauge railways. Seven pairs of trains run daily between St. Moritz and Tirano. Further, the "Bernina Express" operates on the entire length of the Albula / Bernina line throughout the year The engineering structures along the Albula and Bernina railway lies are outstanding monuments from the "golden age" of Alpine railway building: When they were built their stone bridges were considered to be the most durable and resistant option, in contrast to the steel bridges which required so much maintenance. They were also considered well adapted to the landscape since they used materials quarried locally. Today the bridges are largely in their original state. Designed to transport motor vehicles, and running parallel to the Albula line, the some 22 km Vereina line with its Vereina Tunnel, was built in 1999 as a complement to the Albula railway.

International Positioning of the Albula/ Bernina Line

The Albula/Bernina line is the 'youngest' of the great Alpine railways and was designed as a narrow-gauge railway. Whereas the Semmering Railway marks the beginning of mountain railway building, the Albula/Bernina line represents its zenith. After the First World War, no transalpine railways were built for two generations. Only since the end of the 20th century have new Alpine railways again begun to be planned or built; all of these are long base tunnels (Semmering, Gotthard, Furka, Lötschberg, Brenner). Railway building in the second half of the 19th century led to numerous innovations in tunnel building. Two forms - the spiral tunnel and the long crest tunnel – are particularly interesting; both types are found on the Albula line. In view of the enormous outlay, both in technology and in financing, these new models were usually only adopted for standard-gauge main line railways. Spiral tunnels are no longer used in contemporary tunnel building. The construction of such complex structures was dependent on special mechanical tunnel-driving machines, as were developed in the 1860s. The Semmering Railway tunnels, for example, were still excavated by hand from start to finish.
The switch in power technique on the Albula/ Bernina line is an excellent example of developments in railway technology. Whereas the Albula Railway, which was designed for steam power, used conventional technology, the Bernina Railway is an example of a 20th century technical innovation that is standard railway practice today: electric operation. The Bernina Railway demonstrated the inherent potential of the new technology. Prolonged, very steep upgrades and tight curve radii, together with a maximal crest height at an altitude of over 2,200 m are the key features of this stretch. Today, the Albula/Bernina line is still the highest altitude, transalpine section that is operating all year round. The Bernina Railway demonstrates impressively and clearly how the adoption of technical innovations also influences the alignment: the gradient of the Bernina is double that of the Albula Railway. On the Nilgiri Railway, the adoption of cog operation in conjunction with the steam power system was chosen to overcome steep sections. The Bernina Railway underlines Europe's pioneering role in technical innovation; only one comparative railway was electrically operated from the outset: the Train Jaune in the Pyrenees.
Unfortunately, the comparative analysis confirms that many of the comparative railways are in very poor condition and that their future is very uncertain. Regular passenger traffic on the narrow-gauge railways covered in the comparison is often only possible on certain sections or seasonally as a 'museum railway'. As a rule freight traffic has been abandoned. With respect to regular passenger and freight traffic, the only two exceptions, are the compared (standard-gauge) mainline railways over the Semmering and the Gotthard. According to recent press reports the Yunnan Railway is to be preserved for all the traffic between China and Vietnam.
One feature of the Bernina Railway that is unique worldwide is the alignment that was laid out in certain stretches to provide tourists with the best possible views. This deliberate intention, which was expressed already in the planning phase, emerged under the influence of the incipient boom in Alpine tourism that became apparent

in the 19th century. At the beginning of the 20th century, year-round tourism was given new impetus with the advent of railways that were not at the mercy of the elements.

The Albula/Bernina line is also unique worldwide thanks to the enthusiasm with which it was welcomed from the outset for being "embedded in the cultural landscape in exemplary fashion". Other railways and their structures were mostly appreciated only later as fitting into the surrounding landscape (Semmering, Denver&Rio Grande Railroad). The iron bridges on the Gotthard route were even condemned as a blot on the landscape. In some comparative examples the surrounding landscape was only appreciated once the trains had become purely tourist attractions (Denver&Rio Grande Railroad; Guayaquil&Quito Railway). Today, on virtually all the comparative railways, perception of the railway as part of the landscape is a primary feature. Unique combinations of railway, landscape and historic structures define ideal images of each line, and these images serve time and again in publicity. The Albula/Bernina line is unique above all for its engineering structures, which have largely been preserved in their original state, and for its embedding in a cultural landscape in existence long before the railway was built. The manner in which the railway traverses the mountain range, from one side to the other, establishing a link between disparate cultural areas and distinct cultural landscapes is most exceptional.

Cultural Landscape Importance

Railways and cultural landscapes are closely linked: They change already existing cultural landscapes just as they can generate new ones. In particular the above-ground railways together with civil engineering structures and buildings determine how the passing landscape is perceived from the windows of the moving train.

After the opening of all the comparative railways there was a change in the agricultural use of the surrounding countryside. As a rule, agriculture became more intensive (like the tea plantations alongside the Darjeeling Railway, as the railway made the transport of produce easier and therefore cheaper. However, the opposite trend was apparent in isolated cases, for example with the Semmering Railway, where viticulture declined when the railway began transporting imported foreign wines. The structures determining the cultural landscape – the railway structures – represent the modern as a complement to historic architecture (Train Jaune, Darjeeling Railway). In all comparative examples, the railway bridges make a significant mark on the cultural landscape and leave a lasting impression on the visual memory; in a few cases this applies for the whole alignment (Darjeeling Railway, Guayaquil&Quito Railway, Gotthard Railway).

Where the railway runs through a historic cultural landscape, motifs like "railway and ruined fortress" or "railway and church" play a special part in the visual imagery, e.g. for publicity; they celebrate the link between traditional and modern.

The comparative railways are surrounded by numerous other traffic infrastructures: roads, paths and lines. Particularly in the case of electrically operated railways (Train Jaune, Bernina Railway), pipework and high tension lines are striking 'companions' running parallel to the railways.

The Albula and Bernina lines have their numerous individual characteristics with respect to the importance of the cultural landscape, but they also have features in common: They run through a particularly large number of vegetation and climatic zones and cross a mountain range from one side to the other; among the comparative railways, this is only equalled, by the Semmering and Gotthard, which are also transalpine railways. However, because the Semmering has a clearly lesser difference in altitude to overcome – only about a quarter in comparison to the Bernina – it also traverses fewer distinct vegetation and climatic zones. The other comparative railways run from the plains (some from maritime ports) to destinations in the mountains and consequently also traverse a large number of vegetation and climatic zones. A railway that crosses a mountain range not only links low-lying regions at the foot of the mountains but also regions on either side of the mountains – and therefore quite distinct types of cultural landscapes. The Albula/Bernina line links the German-speaking cultural area to the north of the Alps with the Italian-speaking cultural area to the south of the Alps and runs through the Romansh-speaking cultural area in the mountains along the way.

Perception of the railway structures along the Albula/Bernina line is unique. From the outset it was pronounced "exemplary in its harmony with the landscape". In contrast, in the case of the Semmering Railway such a verdict was only expressed decades after it had been built. Meanwhile, the original iron girder lattice bridges used for the Gotthard were considered to be an artificial, manmade contrast to the landscape and therefore disturbing. The Albula/Bernina line proves that the construction of a railway in a historic cultural landscape acknowledged as valuable was realised with more respect and tolerance than where there was no such awareness. At all events, the mode of design of the Albula/Bernina line is in sharp contrast to the style of the colonial lines, where the motive force was to open up the hinterland.

It is rare for European railways to run on roads through towns like the Bernina Railway does. Overseas, this kind of layout was once more common, but those stretches have since been rerouted or closed down. One example of a line with urban stretches that has been partly closed down is the Guayaquil&Quito Railway. However, the Darjeeling Railway still has stretches running through built-up areas.

The Albula/Bernina line shows some similarities with comparative railways in the changes in agricultural utilisation, transport paths and the role of tourism (incl. the emergence of winter tourism from the beginning of the 20th century).

The visual qualities of the cultural landscape seen from the Albula/Bernina railway and the view of the railway from the cultural landscape are therefore of significant importance for the property. Consequently, great value has been placed on the special treatment of the buffer zone.

Albula line > The Bernina Express at Bergün/Bravuogn, in the background left the village of Latsch.
P. Donatsch

3.d Integrity and Authenticity

Authenticity of the core zone

The Albula/Bernina railway is authentic. All the characteristics inherent to its exceptional and universal value are found within the defined perimeter along the route. Both the track layout and the buildings and engineering structures have been preserved almost entirely in their original state and the railway still operates a full service schedule.

In the case of historic buildings, authenticity is primarily a question of "originality" with respect to the original substance. A railway is a technical system whose authenticity is, in the first place, defined by the degree of its functional integrity. In order to fulfil its function, this system is continually exposed to new demands, so that on-going adaptations of its structure are indispensable. The railway can be seen as a "living monument", like a cultural landscape, it must also undergo continual evolution if it is to remain viable. The *ICOMOS Study Railways as World Heritage Sites* (Coulls, Divall, Lee 1999) comments on the specific question of authenticity in this context as follows: "No operating railway can be wholly authentic from a strictly historical point of view; items wear out and are replaced, methods of organization and operating are adapted to changing circumstances. However, arguably continuity through change is part of what makes a railway landscape or location: railways are by their very nature evolving socio-technical systems. Indeed, the drive to modernize and become more efficient appears to be an imperative of modern railway management world-wide. The key challenge is to identify just what it is about a railway location that makes it worthy of World Heritage status. A focus on the purely physical aspects of structures or technologies arguably makes it more likely that a site will be deemed 'inauthentic' as modernization proceeds than if equal (or greater) weight is given to the historical continuity of a railway's socio-economic functions. This is not an argument for any weakening of the imperative of good management of those historic features which do remain. Co-operation between railway operators and conservation bodies can make sensitive development possible and ensure that the integrity of sites is maintained, as the example of the British network over the last two decades shows (Burman & Stratton 1997). It is, we suggest, preferable to have a viable and useful railway rather than one which faces an uncertain future." The Rhaetian Railway and its Albula/Bernina line are committed to this precept: the historic original state of the cultural asset is maintained meticulously and adapted to modern requirements with the greatest sensitivity.

The Albula/Bernina line of the Rhaetian Railway has been running for over a hundred years. It continues to fulfil its functions as a full-service railway for both passenger and goods transport. The alignment has hardly changed since the railway was built. The opening up of the Alpine valley of the Engadin and the continuation of the line into Italy are still original to-

Solis Viaduct > Classic Alpine Pullman Express. The Rhaetian Railway has an impressive number of historic railway wagons and locomotives.
P. Donatsch / Rhaetian Railway

Albula line > A historical train composition, authentic in every detail, on the 100 year old Landwasser Viaduct.
P. Donatsch / Rhaetian Railway

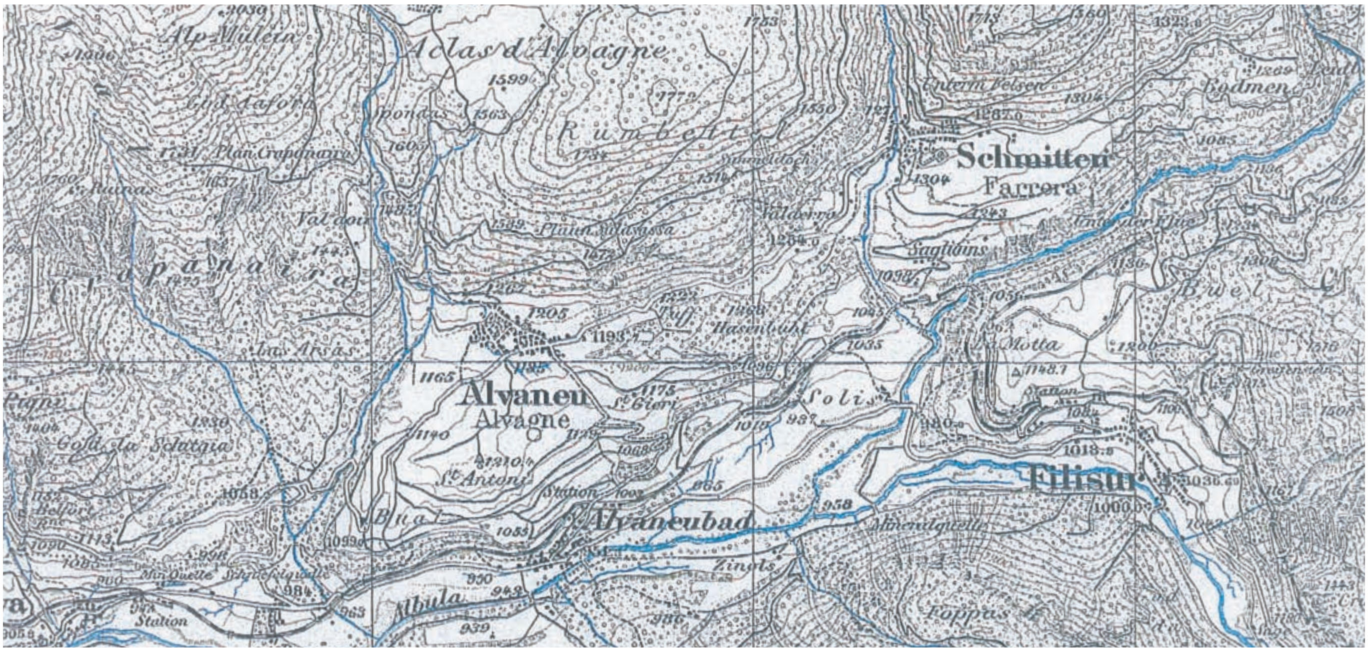
day, right down to the technical details. Only on the Bernina line were short sections realigned shortly after building was completed due to the introduction of winter operation and the associated natural dangers. The layout of this section was, from the outset, designed with a view to being changeable; the possibility of "empirical improvement" was already implied at the planning stage (cf. 2.b.6).

The engineering structures – tracks, bridges and tunnels along the entire route – have been preserved to a great extent in their original form and in the original materials (cf. 2.a.4).

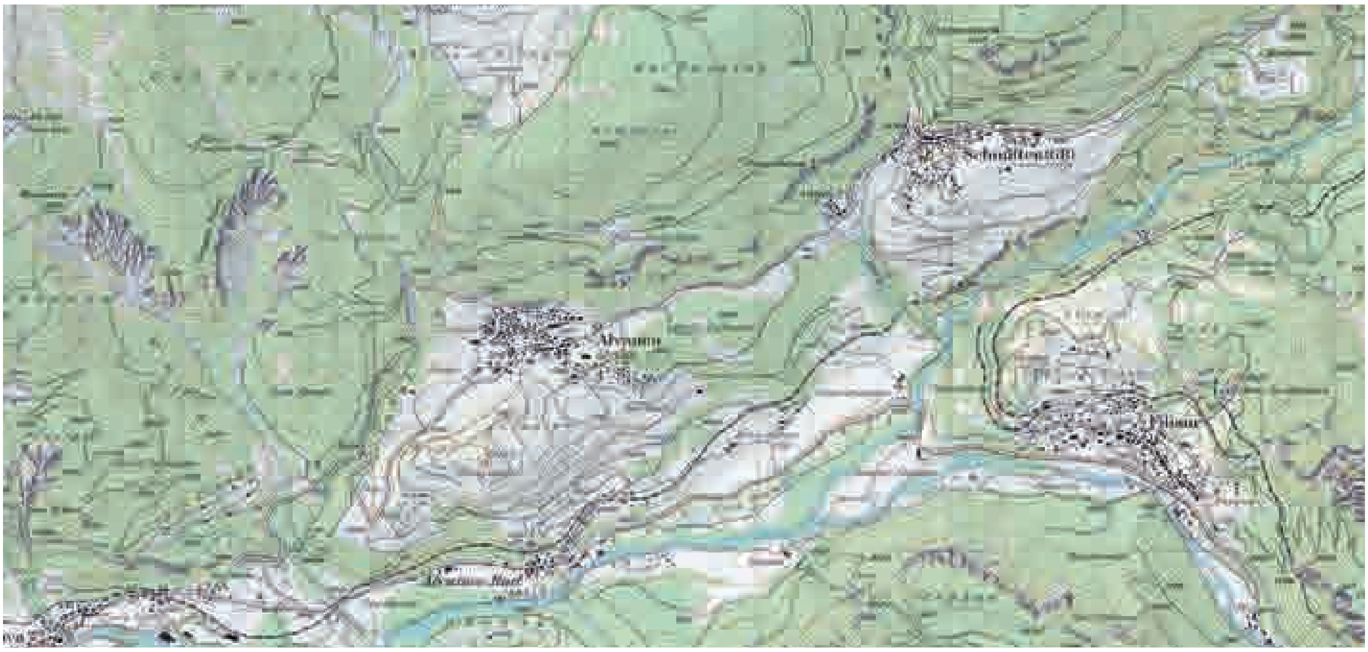
The railway buildings have also been extensively preserved as they were originally (cf. 2.a.5). The small railway stations on the Albula and Bernina line are mostly preserved in their original substance and form. However, progressive automation means that they are no longer permanently staffed. As a rule, the larger stations – like that in Bever for example – have also been preserved in their original form. The striking station building in St. Moritz was converted several times between 1902 and 2002 but is still a high-quality building complex and a special piece of railway history. The station at Samedan has been replaced by a new building. Other structures used for railway operation – halts, goods sheds as well as transformers and signalman's houses – have as a rule been preserved in the original. As they gradually lose their original function through changes in railway operation, these important witnesses of railway history are being used for new, compatible purposes.
The rolling stock includes an important number of historic railway carriages and locomotives. Thanks to the work of specialists and sponsor associations as well as the support of the railway, public funding (Graubünden Section for the Care of Historic Monuments) and private patrons, rail trips on historic trains can still be taken today on the Albula/Bernina route with locomotives and railway carriages that have been preserved and authentically restored, down to the smallest detail.

Authenticity of the buffer zone

Furthermore, the buffer zone (the surrounding landscape and the views of it) is also authentic. Protection of the landscape and nature, as well as treating existing buildings with respect, was already discussed while the railway was being built and was soon prescribed by law. Since then, the development of the landscape has, as a rule, proceeded on an appropriate scale in compliance with its character. Naturally, the landscape began to change long before the coming of the railway; we can even say it did so with the first settlement. Archaeological finds bear witness to the beginning of the cultural landscape in this sense (cf. 2.b.1). The surviving sacred and secular buildings along the Albula/Bernina route have frequently been preserved in their original material and shape, or else reflect, in their subsequently modified form, important historical periods when fundamental changes occurred in the region (cf. 2.a.6). The settlements have existed for centuries: the structure and substance of their historic cores are, to a very large extent (cf. 2.b.4), well preserved and new districts have gradually been added. The growth of settlements is characteristic of every living cultural landscape and is a sign of economic success – this is particularly true of the period after the Second World War. Today older and more recent settlement areas exist side by side and can be clearly differentiated. Modern



Map from 1938



Comparison of maps of the central Albula Valley from 1938 and 2004 > The character of the landscape is unchanged.

Map 1:25,000 > Status 2004
swisstopo, Wabern
(MB 062220)

road building with its bypasses (e.g. Samedan and Celerina) continues the development of the traffic routes that have run through the region for a very long time. They were supplemented and extended according to contemporary needs and means of transport (cf. 2.b.3): galleries, tunnels and protective structures were built, and rivers and streams realigned, to provide protection against natural hazards. Agriculture and forestry still predominate in the Albula/ Bernina landscape except in the Thusis area and in the Upper Engadin. The overall impression, the character, of the landscape is unchanged. The vistas of the natural and cultural landscape in the distance have hardly changed since the railway was built. There are a few exceptions here and there involving masts with power lines, cable railway installations or rockfall and avalanche barriers which do not impinge on the authenticity of the cultural landscape and the exceptionally varied scenic backdrop. In particular, there is no trace in the Albula/Bernina region of the widespread phenomenon of the "supermarket periphery" (urban sprawl or periurbanisation) with all its negative repercussions on the landscape that is so widespread elsewhere.

The immaterial authenticity is also safeguarded. Within a very short distance, the Albula/ Bernina railway runs through an area of exceptional cultural diversity. Various traditions and customs define the identity of the valley communities. The most striking feature is their linguistic diversity. German, Romansh and Italian are spoken in various idioms. Progressive mobility, and the consequent varied influences from outside, also partly due to the building of the railway, has led to slight changes in the language pattern. However, the disparate languages are still very much alive and much is being done to promote them (cf. 2.b.8).

Integrity

The integrity of the various sites is assured: the track of the Albula/Bernina line, with all its engineering structures and buildings, is inside the perimeter of the core zone. This covers the route from its starting point by the exit signal after Thusis station to the terminus in Tirano, Italy. As already mentioned, the surrounding landscape enhances the value of the sites with its exceptional vistas and other functional associations. The horizon traces the visual border of every landscape. Here it determines the limit of the buffer zone of the Albula/Bernina cultural landscape. In order to define practical protective regulations for the various sites in the buffer zone, this has been broken down into a primary buffer zone, a buffer zone in the immediate vicinity or 'near' zone and a visible 'distant' zone. So all the characteristics of the Rhaetian Railway that define its value in the Albula/Bernina cultural landscape are fully included within the perimeter of the candidature.