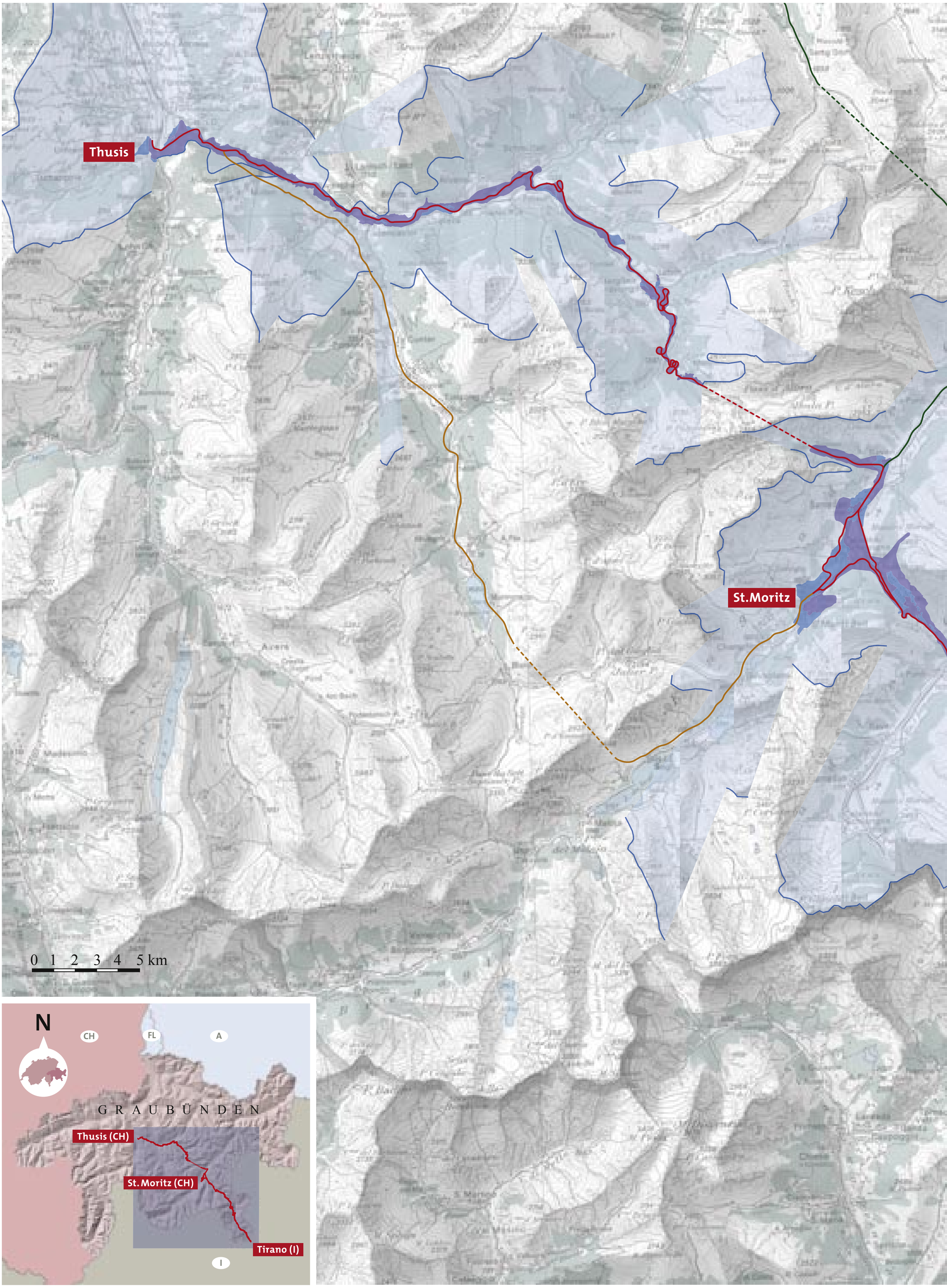
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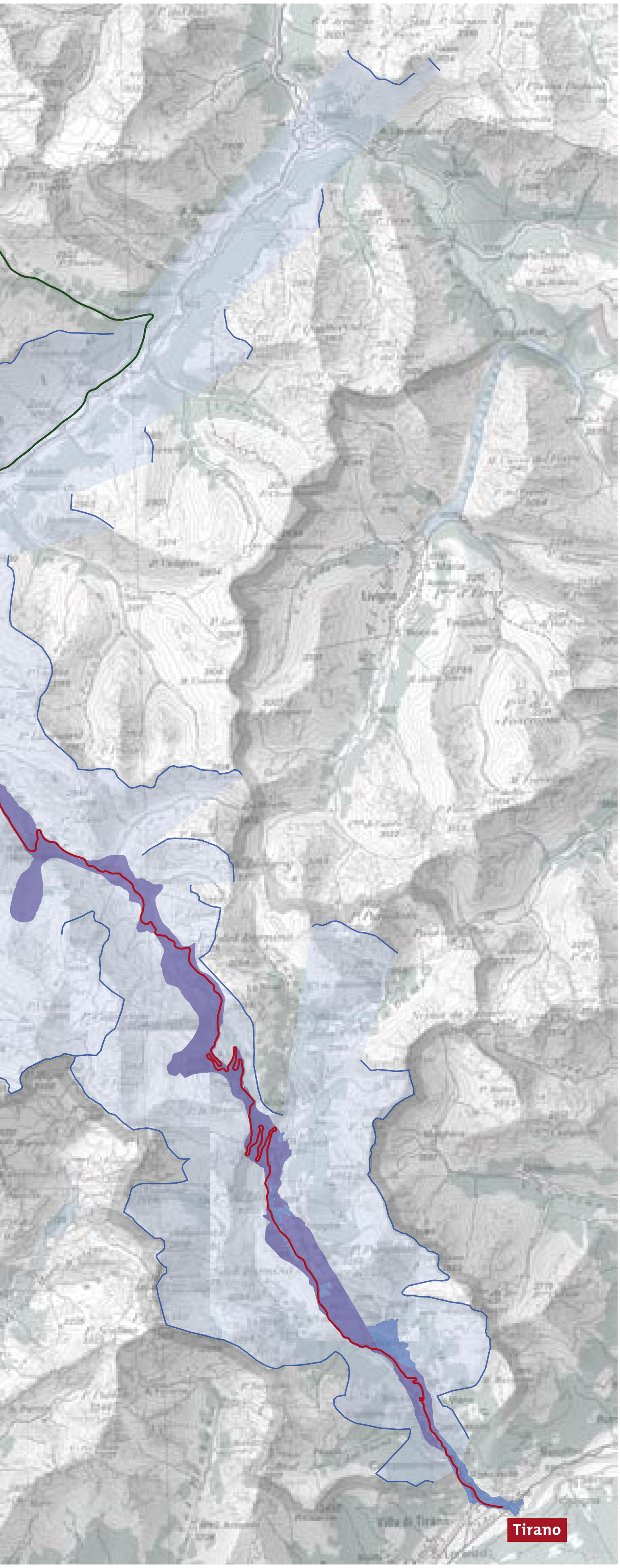

Railway construction projects for the Engadin

Scaletta railway 1890

Scaletta tunnel

Julier railway 1897

Grevasalvas tunnel

Core zone

Core zone with railway and cultural landscape

Buffer zone

Buffer zone in the near area

Buffer zone in the distant area (backdrop)

Horizon line

Other contents

Other stretches of the Rhaetian Railway

Sources:
Basic map: PK 200’000 swisstopo, Wabern
Geo-data: Amt für Raumentwicklung Graubünden
Thematic data: Gian Brüngger / Gion Rudolf Caprez
Design: Süsskind, SGD, Chur
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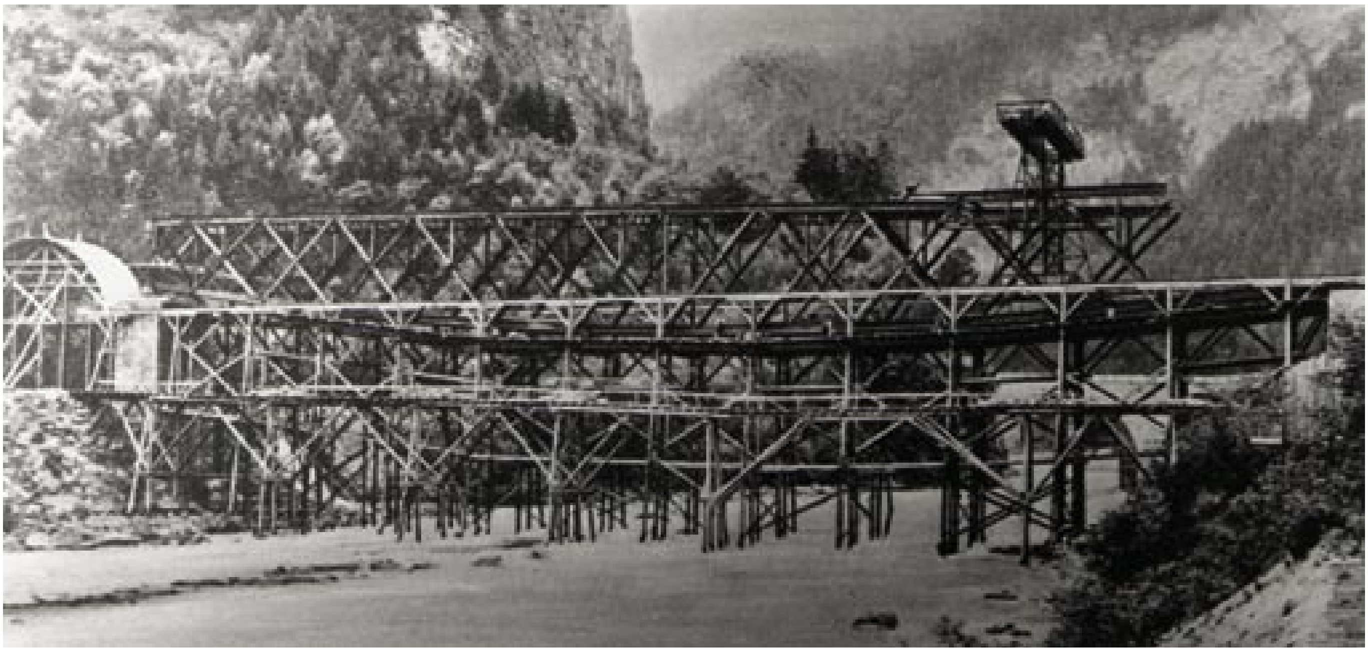
2.b.6 Railway construction and operation

The Albula line was constructed between 1898 and 1904 as a high-capacity, narrow-gauge railway providing access to the renowned holiday resorts of the Upper Engadin. The stretch was originally operated with steam engines but electrified in 1919. Despite continuous adaptations to changing requirements, the original alignment has been preserved virtually throughout and is still used for its original purpose.
The Bernina line was constructed between 1906 and 1910 as an electrified surface railway linked with the power stations on the south side of the Bernina Pass, and for better access to the natural scenery that is so attractive to tourists. However, modifications to the alignment and innovations in terms of snow clearance and protective measures for the track proved necessary to permit services to be operated all the year round.

Albula line

Project development

By 1860 a continuous network of main railway lines had developed in Europe extending as far as the foot of the Alps. This made travel into the Alpine area much simpler, even though the last part of the journey still had to be made by stagecoach or on foot. The use of narrow-gauge lines to open up access to the higher altitude holiday resorts, as provided in Switzerland with the lines to Davos (1890) and to Zermatt (1891), greatly increased the quality of access to the high mountain areas. From then on tourist centres which did not have a railway connection found that they were at a comparative disadvantage and sought to correct this.
The construction of the Albula line from Thusis to St. Moritz should be seen in this context. Since the middle of the 19th century the Upper Engadin had become an increasingly popular holiday destination for international visitors (cf. 2.b.9). Although travellers could use the stagecoach from Chur to reach the area, the railway link connecting Gotthard – Milan – Chiavenna with the onward road link over the Maloja Pass was more expedient for goods such as coal and for the construction material needed for new hotels. The cost of transporting a wagonload of coal over the section from Saarbrücken to Chiavenna was CHF 223.–, while for the section from Chiavenna to St. Moritz it was as much as CHF 250.–.
The decision to run the line along the Albula valley into the Engadin was the result of a lengthy selection process (cf. 2.b.5). Compared with the other options which were being discussed (the Scaletta and the Julier lines), the Albula line offered clear advantages from both geographical and engineering angles. The Scaletta line from Davos met with resistance from the central regions of the canton as well as from the Engadin itself; the primary reason was its peripheral location. What these areas wanted was their own direct connection to the standard gauge railway which, by 1858, had been completed as far as the terminus in Chur. A proposed Julier line running from Tiefencastel through the Oberhalbstein was rejected on financial grounds; the summit tunnel alone, due to its extreme length, would have involved enormous costs.
In 1889, the Graubünden cantonal engineer, Giovanni Gilli, prepared the initial design for a



Albula line > Construction of the bridge over the Hinterrhein at Thusis, 1901.
Rhaetian Railway

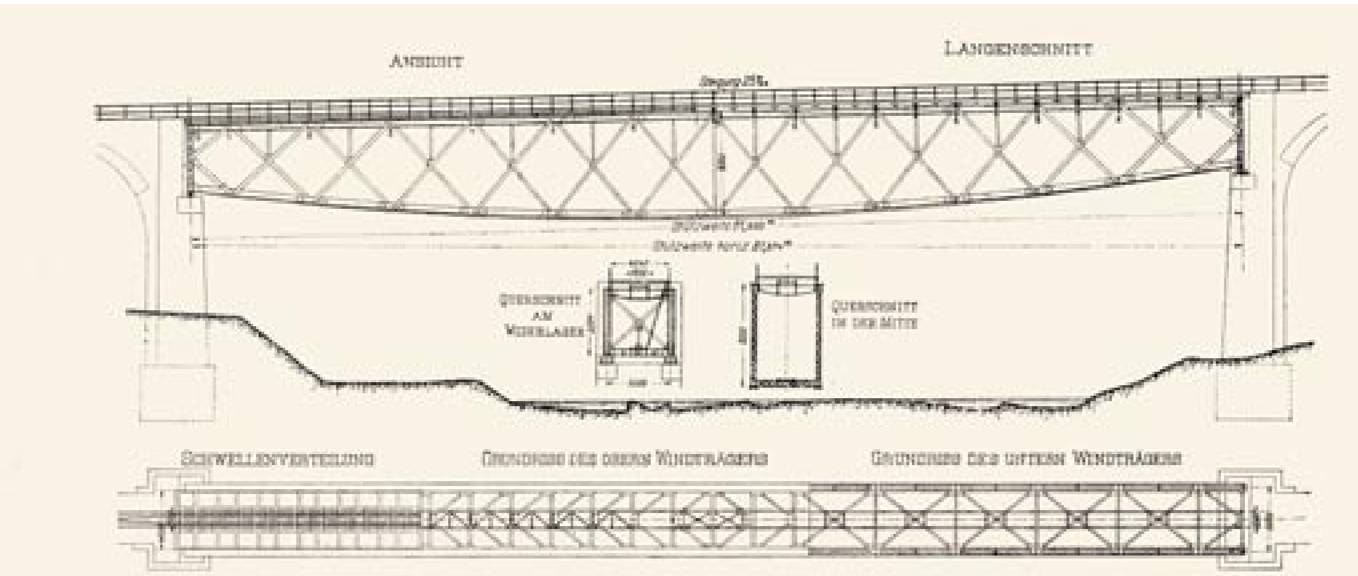


Abb. 3. Gesamtplan der Eisenkonstruktion, erbaut von der A.-G. *Theodor Bell & Cie.* in Kriens — Masstab 1 : 500.

Plan of the iron construction for the bridge over the Hinterrhein at Thusis. Plan (reduced in size) taken from: Friedrich Hennings: *Albulabahn. Denkschrift*, Chur 1908.

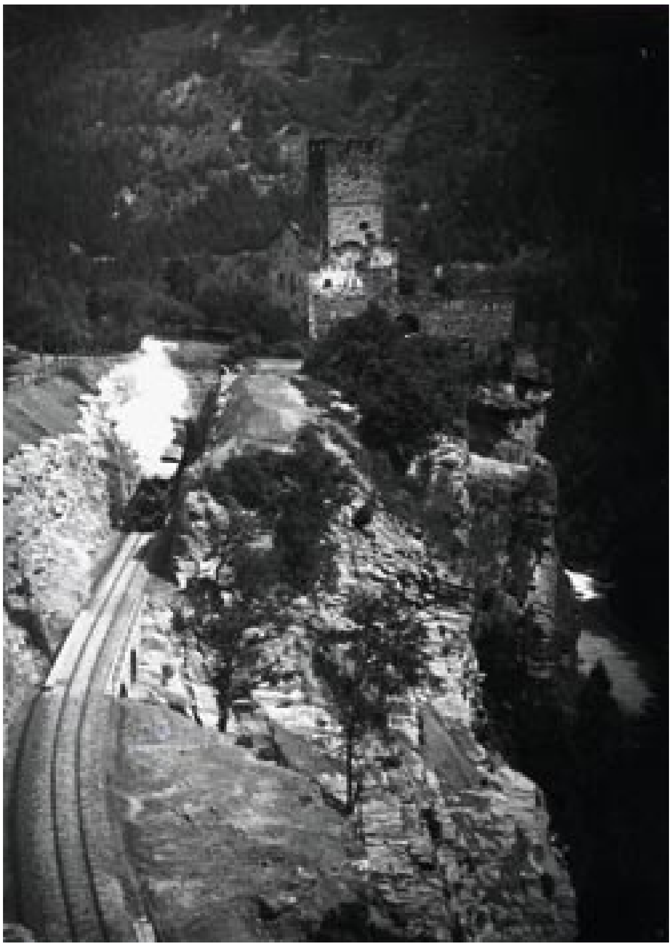
line through the Albula valley which would open up railway access to the Engadin. However, his plans for a narrow gauge Albula line between Filisur and Samedan show that it would not have had a high capacity. It would even have involved operating an 11.4 km section of the line as a cog railway with a gradient of 90 ‰ and the summit tunnel would have been so high that winter operation would scarcely have been possible. In 1890, an 'Albula line committee' was set up in Bergün/Bravuogn. Its members included well-known figures from the world of politics and the hotel trade. The committee asked the engineer Robert Moser to prepare a "technical study to investigate the construction of an Albula line and identify the most effective railway connection with the Engadin". In his report, Moser came to the conclusion that an Albula line, as "clearly indicated by the geography", would be preferable to the competing routes. His project proposed a narrow-gauge railway with a 45 ‰ gradient, similar to the line running from Landquart to Davos. Moser later reworked his design and showed that with little additional cost it would be possible to reduce the gradient to 35 ‰ significantly increasing the capacity of the line. In 1897, the Rhaetian Railway decided to go ahead with the construction of a line based on this design. Work on its construction began in 1898 under the direction of engineer Friedrich Hennings.

Finance

Graubünden's first narrow-gauge railway, the Landquart – Klosters – Davos line, which opened 1889/90, was mainly financed by the Schweizerische Eisenbahnbank (Swiss Railway Bank) established in Basel for this purpose; the bank held a majority of the relevant shares and bonds (cf. 2.b.5). It can be assumed that the investors expected to make a profit in the form of dividends or interest on bonds, or that they hoped at least to protect existing investments in hotels. In 1895 the application of stricter state regulations resulted in private shareholders threatening to drop out and give up their Graubünden railway shares. With the cantonal railway law of 1897 the canton took over the shares of the Landquart – Davos railway (renamed as the Rhaetian Railway) held by the Railway Bank and regulated the financing of what were called the 'priority lines'; this term referred to those sections of railway line in Graubünden (the lines between Reichenau and Ilanz and between Thusis and the Upper Engadin), which the canton wanted to get started without delay. These were no longer viewed as profitable investments, but rather as a means of implementing commercial and territorial policies.

The estimated costs of CHF 26 million for the construction of the priority lines was covered by share subscriptions: the Swiss government (CHF 8 million), the canton (CHF 4.3 million) and the communities (CHF 3.6 million), together with an issue of bonds for an amount of CHF 10.2 million.

The estimated cost of the Albula line was CHF 21.2 million; the final bill amounted to CHF 25.8 million, or some CHF 418,000.– per kilometre. Compared with the cost of the Gotthard line (completed in 1882 at a cost of CHF 1.1 million / km) and the Lötschberg line (completed in 1913 at a cost of CHF 1.6 million / km), the single track, narrow-gauge line through the Albula valley into the Engadin proved much cheaper to build, both in terms of the approach ramps and the summit tunnel; the narrow-gauge railway line between Landquart and Davos cost a mere CHF 150,000 / km. In terms of cost therefore, the Albula line lay somewhere in the middle between a simple narrow-gauge line and a full mountain railway.



Albula line > Alignment below the fort ruins at Campi near Sils i.D.
Rhaetian Railway

Albula line > Passmal Viaduct, Schin gorge, taken 1903/04.
Collection Wehrli, Eidgenössisches Archiv für Denkmalpflege, Berne

Albula line > Framework for the construction of the Solis Viaduct, erected by Richard Coray. Photograph 1901.
Rhaetian Railway

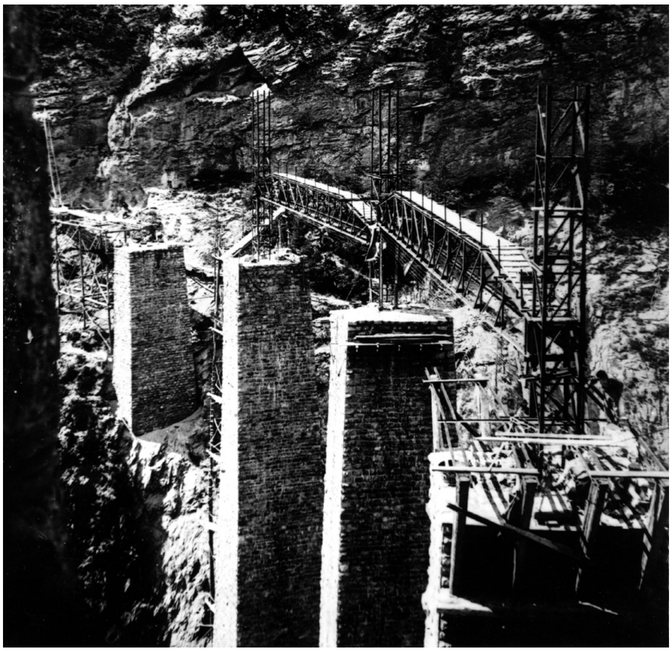
In 1906, chief engineer Friedrich Hennings defended the cost overrun of CHF 4.6 million in a memorandum pointing out the difficulties which arose during the construction of the Albula tunnel (and other cuts) due to the local geology, which gave rise to around CHF 3 million of additional expenditure. He also pointed out the design improvements made during the course of the construction, where the changes were intended to allow the line to cope with a greater volume of traffic and resulted in the final design of the Albula line approaching even more closely that of the large Alpine railways.

The construction of the railway

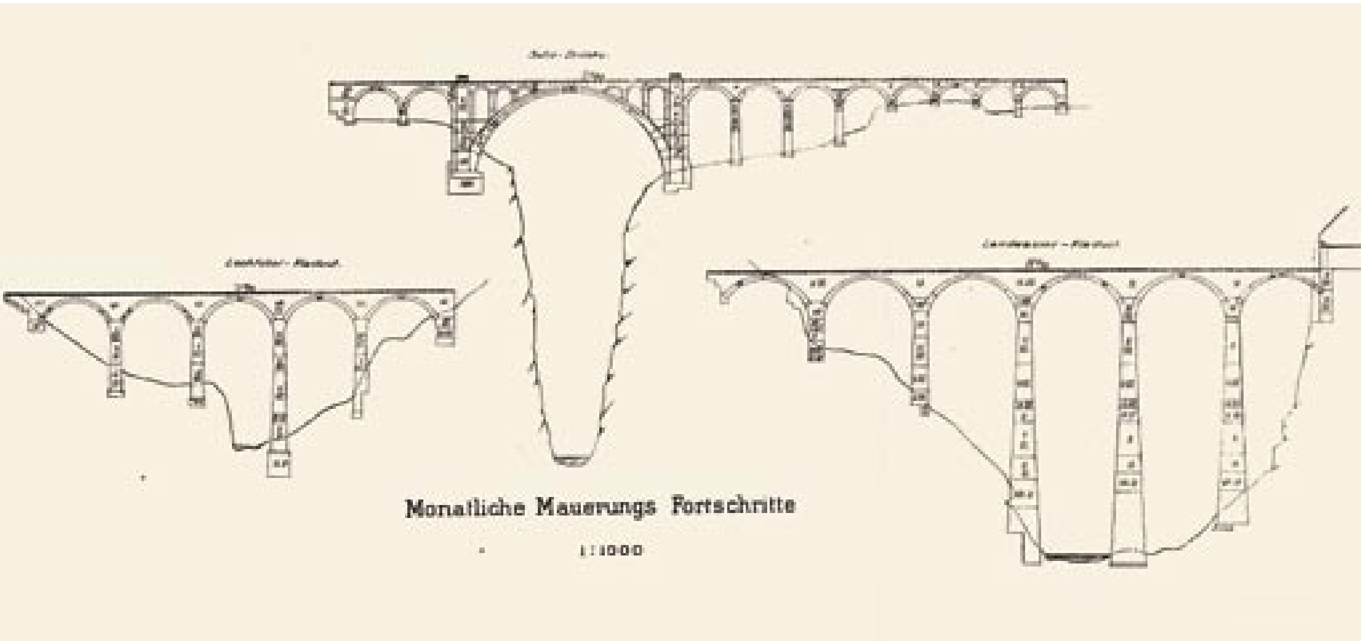
The engineering office in Chur began work in July 1898. The office was under the direction of Hennings and Giovanni Gilli, who had been appointed as Hennings' deputy. Initially, the task was to fix the precise alignment of the trackway through the terrain, using the general corridor alignment proposed by Robert Moser's design as a basis. Hennings introduced a number of changes to increase safety. At the same time the standards were developed which were to govern the construction of the works and the quality of construction. This provided the basis used for preparing the tender documents for the contractors to bid against. Factors used to determine the location of the stations called for political as well as engineering skills, particularly as the railway stations were not always constructed as close to the existing settlements as their representatives had wished. An estimate of the time needed to build the line showed that the construction of the Albula tunnel would be the main factor in determining when the line would be opened. For this reason the Rhaetian Railway began work on the tunnel as early as October 1898, even before the contract was awarded to a contractor, setting out the tunnel axis and working on the constructing of the base tunnel from both ends. Only such an early start on the construction of the summit tunnel gave any hope of opening the line in time for the 1903 summer season.

The full line was divided into three sections. The first included lots 1 – 4 from Thusis to Filisur, the second lots 5 – 8 from Filisur to the middle of the Albula tunnel and the third covered lots 9 – 11, from the middle of the Albula tunnel to St. Moritz. Each section had its own section engineer, who was in charge of the work. A site engineer and an assistant site engineer supervised the construction of each lot. The public viewing of design drawings in the various communities and the tendering and award of the construction of the track substructure all took place in the summer of 1900. Separate procedures were used for the tendering and award of the construction of the bridges over the Hinterrhein (Upper Rhine) near Thusis, for the construction of buildings and for the construction of the track superstructure. The design of the ironwork for the Rhine bridge in Thusis was planned, designed and carried out by the bridge construction company Theoder Bell & Cie. based in Kriens (Canton Lucerne). The assembly scaffolding was set up during the winter of 1900/01. Construction lasted from the beginning of May to the middle of August 1901 with bridge testing carried out on the 10th December 1901. The option selected for the section between Thusis and Solis did not require any forced alignment in the Viamala. Consequently the railway line had to run below the level of the road through the whole length of the Schin Gorge; it also meant that tunnels had to be built under the terraces of Campi and Freihof, even though these terraces were quite suitable for the construction of railway track. Consequently, the railway track now lay in an area of solid rock and

Albula line > Crane bridges were used for the construction of the Landwasser Viaduct. Photograph 1901.
Rhaetian Railway



Albula line > View for the Landwasser tunnel to the construction work on the piers for the Landwasser Viaduct, 1902.
G. Lorenz

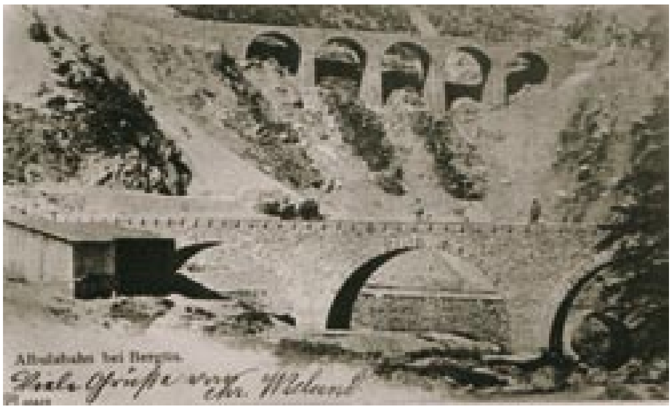


Progress on the construction of the Lochtobel and Landwasser Viaducts were recorded precisely, with graphics, in monthly reports. Plan (reduced in size) taken from: FRIEDRICH HENNINGS: *Albulabahn. Denkschrift*, Chur 1908.

was largely exempt from the risk of slope movements. The location of the railway line below the road also simplified the delivery of materials to the construction sites.
The foundations for the Lochtobel viaduct presented special engineering difficulties as the third of the central piers had to be sunk through the steep, unstable overlying material onto rock. Here, the sides of the 14 m pit, which was dug down to the level of the rock, had to be supported by extensive shuttering and the pit was filled in with debris from a mudflow while it was being excavated.
The engineers wanted to simplify the construction of the bridge over the Muttnertobel and avoid the construction of a particularly difficult section of track. Consequently the alignment was revised and improved after construction work had begun; the changes resulted in the Solis tunnel being extended by 127 m to a length of 987 m.
The material used for the attractive, dark, hard limestone ashlars of the Solis viaduct was obtained from locations very close to the bridge. The Munari, Cayre and Marasi company were able to construct the bridge in the surprisingly short period of one year. Construction costs amounted to CHF 125,000.
The original design of the Nisella tunnel foresaw a length of only 89 m, this, however, was later extended to 274 m in order to tunnel behind a scree which was exposed to rockfalls.
A number of factors were decisive in the design of the Filisur railway station. For one, it had to be positioned so as to keep the climb up to the Engadin as short as possible. The design also had to take into account the planned railway line between Filisur and Davos. Consequently, it would only be possible to keep to the maximum downgrade of 35 ‰ on the section Schmelzboden / Monstein – Filisur if the Filisur railway station was set at a relatively high level. Yet it was also important to make sure that the 35 ‰ slope did not begin before Surava railway station, as otherwise this station and the adjoining section of line would be forced to run along steep and difficult slopes and what is more the Landwasser viaduct would have to be built at an even higher level.
The station also had to be built at an accessible distance from the village; today's 50 m difference in altitude between railway station and village is still considerable.
If the principle normally followed in the construction of mountain railways had been applied, namely that the railway line should as far as possible be run along the valley floor, then the forced alignment of the line between Filisur and Bergün/Bravuogn would only have been necessary at the steep part of the Bergünerstein. However, comparative studies showed that a climbing section built in the terrain above Filisur would be feasible with shorter tunnels, which would save costs. The better geological conditions were obtained at the price of more difficult access to the construction sites, which now lay some 150 m above the bottom of the valley. Access was eventually provided by the use of existing tracks and newly constructed tracks and by way of a cable railway from Bellaluna to the Stulsertobel. The high location of the construction sites led to a rejection of the principle of balanced mass haul movements along the railway (that is, excavated material was disposed of locally) and to the use of dry stone walling wherever possible.
The construction of the Landwasser Viaduct lasted around 13 months. The work involved some 9,200 m^3 of masonry and cost CHF 280,000. Provision of the material used in the construction of the tall columns called for very complex organisation involving steel scaffolding that was set up inside the columns and connected to crane

Albula line > Alignment between the Tuoa and Zuondra spiral tunnel, 1902. The terrain alterations necessary prior to construction are hardly visible today.
Rhaetian Railway

Albula line > Construction of the Clix Viaduct, 1902.
Rhaetian Railway



Albula line > The Albula Viaduct I below and the Rugnux inclined viaduct above.
Rhätisches Museum, Chur

bridges. The construction site for the Landwasser Viaduct had electric lifts and electric mixing machines and boring machines were in use at the construction sites for the Albula tunnel. Together, these two sites offered what at that time were rare examples of mechanised construction sites.
On the 9th August 1901, during work on constructing the tunnel lining in the Greifenstein tunnel, the tunnel scaffolding near the upper portal collapsed; four workers were buried under the mass of debris. Section engineer Perbs was leading the rescue work when a second collapse took him unawares with fatal results.
The 333 m long Glatscheras tunnel was constructed in solid rock. Construction only took place after the railway line had been opened. The work lasted from 9th September 1903 to 28th January 1904 and was completed in only 144 days. Originally, the line here ran parallel to the cantonal highway and through a scree, which began to move uncontrollably in the spring of 1903. It was subsequently decided to build this bypass tunnel in order to safeguard the operation of the railway. Costs amounted to CHF 178,000.
The section between Muot and Preda proved to be difficult. Here, various alternatives for the track alignment were carefully weighed against each other in order to reach a solution that would provide an optimum balance in terms of ground conditions, the risk of rockfalls, avalanche tracks, landslides, exposure to the sun and – last but not least – construction costs. The final locations of the loops in the track alignment were substantially different from those in the original design.
The construction company Ronchi & Carlotti was awarded the tender to build the Albula Tunnel; from 1901 the Rhaetian Railway continued the work under its own name. It required extensive site installations at the headings in Preda and Spinas. Accommodation had to be built for the workers, supervisors and engineers; besides storehouses and workshops there were also buildings for the workers' canteen, baths, religious services, school, post office and so forth. Thus, residential settlements grew up at both ends of the tunnel, each with water supply lines and water hydrants; the colony in Preda even had electric lighting. The station buildings in Preda and Spinas were built as soon as the work on the tunnel was started; they served as site office and provided additional accommodation until the line was opened.
The railway also employed a railway doctor in Preda, where it set up a hospital staffed by an Italian nursing order who also ran a kindergarten for the younger children of the families in the residential settlement. The communities of Bergün/Bravuogn and Bever employed a teacher for the older children. In Spinas, the railway only needed to provide a sickroom for patients, as the nearby Samedan district hospital was available should the need for hospital facilities arise.
In July 1902 the number of workers employed in the construction of the Albula Tunnel reached its peak, with a total of 1,316 men: 984 in the tunnel and 332 in the open.
The tunnel was excavated using boring machines powered by water pressurised at 100 atü (the Brandt system). The water required for their operation was taken from Lake Palpuogna for the north side of the tunnel and from the Beverin River for the south side. The engineers had expected to obtain 200 HP on the north side and 150 HP on the south side, but the whole system had been designed on too small a scale; subsequently, as work on the construction was speeded up, the system had to be upgraded several times. It only later became apparent that during February – the harshest winter month – water power on the north side could only provide 140 HP, with

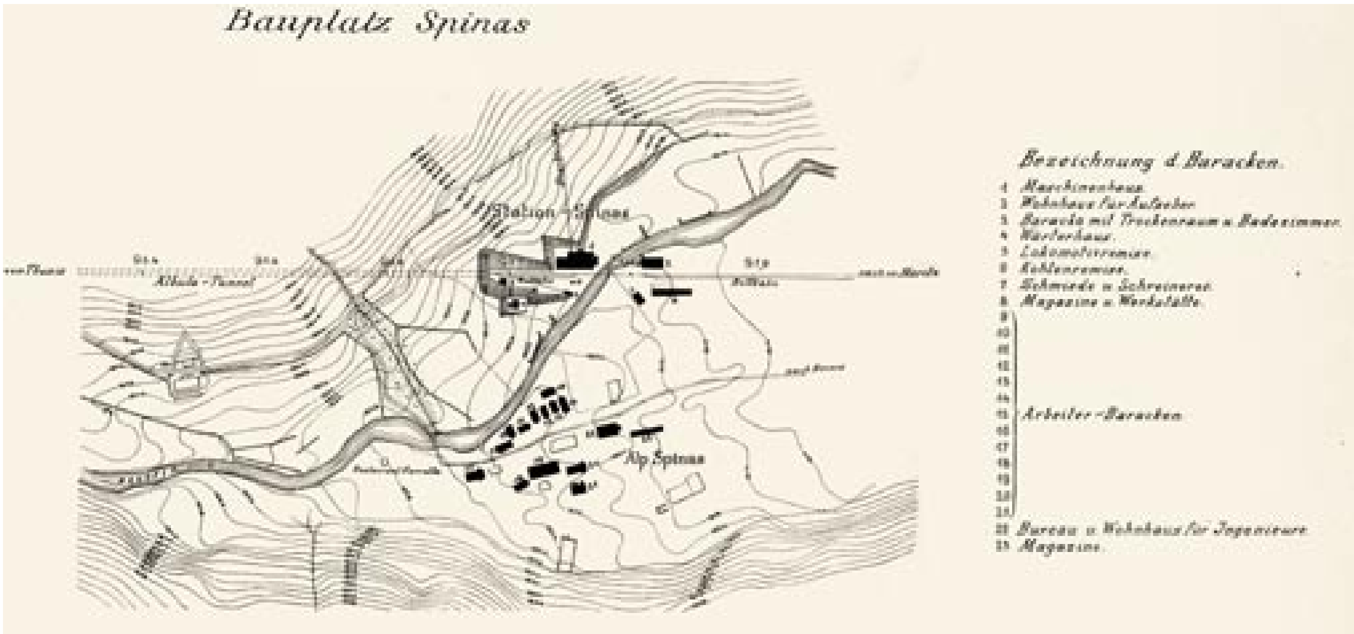
Albula Tunnel > Drilling team with the Brandt hydraulic drive drilling machine.

Albula Tunnel > The building team and the engineers collected in front of the building sheds at the Preda north portal for a photo session, 1902.
Rhaetian Railway

Albula Tunnel > A big show for the photographers at the south portal, about 1902.
Collection Peter Pfeiffer

the corresponding figure for the south side of only 100 HP. Eventually, two additional, 25 HP steam engines had to be set up in Spinas as a reserve which could be called upon when the water level was very low. For Preda, the water from Lake Palpuogna was led along a 560 m closed wooden channel 0.35 m wide and 0.35 m high with five ventilation shafts. The channel was routed alongside the cantonal road to the surge tank above the tunnel portal, from where the water was initially led by means of a 0.3 m wide iron pressure main to the turbines in the power house.
For the force account operation, three additional 0.2 m pressure pipes were later branched off from the surge tank; each led to a turbine which drove one of three coupled ventilators, each with a diameter of 1.5 m. It was essential for adequate ventilation of the tunnel that the ventilators and machine boring had independent power sources. When running at a speed of 1,550 rpm the ventilators could deliver at least 1 m^3 of air per second at the tunnel face through a wrought-iron pipe of 350 to 400 mm in diameter and 3,000 m long. This was sufficient, since the tunnel cross-section was only slightly blocked by scaffolding and was not lined over the last kilometre before the breakthrough. The pressure head between the surge tank and the turbines was 75 m and the difference in the water levels of Lake Palpuogna and the surge tank was 53 m. However, the latter had to remain unused even during the force account construction since by that time it was no longer possible to upgrade the whole system. The main turbine was designed for 160 HP, each of the ventilator turbines for 30 HP and the lighting turbine for 15 HP.
On the south side of the tunnel the Beverin River was blocked by a walled dam at a point where the river bed lay in the undisturbed rock; the water basin thus created was then covered with tree trunks as protection against avalanches and rockfalls. A sedimentation tank with an idle running fitting and an overflow was connected to the basin. A closed wooden channel 1,200 m long, 70 cm wide and 50 cm high led to the surge tank, from where the pressure mains branched off towards the turbines. The mains had a delivery head of 60 m and were 250 m long.
The workshops before each portal were equipped with lathes, drilling and milling machines. Two larger forges and a small brass foundry were connected to these for machine drilling, whilst special forges were set up for hand-drilling and for making other tools.
The selection of the site for the dynamite store and the construction of the store were subject to strict government regulations, whereby the handling of the material was always carried out in compliance with official rules and regulations. The construction railway used in building the tunnel had a track gauge of 750 mm. Around 10 km of track was laid, which weighed 15.5 kg per meter. 330 wagons were available for the construction, 75 of which were not fitted with brakes and 5 locomotives were acquired to move the wagons: one 40 HP, two 30 HP and two 25 HP.
On the south side, the base tunnel initially ran through saturated rock scree containing large erratic blocks and sand; this led to very uneven loading of the horizontal strutting und displacement of the tunnel installations. After 133 m of tunnel drive, work on the initial bore was stopped in order to excavate the tunnel out to its full dimensions up to this point. The excavation of the full face in this unstable mountain geology made only slow progress. On 19th November, when the drive had just reached tunnel meter (TM) 108 the installation of the last two rings gave way and the tunnel collapsed over a length of 12 m. The collapse created a 25 m deep, break-in funnel reaching up

Albula Tunnel > The construction workers in front of their plain huts in Spinas.
Staatsarchiv Graubünden



Overview of the Spinas building site. Plan taken from: Friedrich Hennings: *Albulabahn. Denkschrift*, Chur 1908.

as far as the surface. Fortunately no-one was injured. Reconstruction work was carried out by the Rhaetian Railway's construction supervision unit at Ronchi & Carlotti's expense and was only finished at the end of July 1900. By March 1900, the first tunnel drive had pushed forward to reach the firm glacial till at TM 170 and then granite at TM 260. This allowed machine boring to begin on the south side on 17th October 1900. At that juncture the construction company no longer felt able to deal with the difficulties presented by the construction of the tunnel and asked to be released from its contract. After a brief period of negotiation, the force account unit of the Rhaetian Railway took up the work on the 1st April 1901, under the direction of engineer Weber from Zurich.

By 25th August 1901, when work restarted on machine boring on the north side at TM 1260, the tunnel on the south side had reached TM 1485, so that some 3120 m of tunnel still remained to be excavated. In order to win back the lost time, the number of Brandt boring machines was raised to three, working simultaneously on each face of the tunnel shaft. The ridge cut method then being used was expensive and time consuming and presented problems in terms of the ventilation.

As an alternative approach, in November 1901 engineer Weber introduced the Firstschlitz (first cut) method at TM 1320 m from the north portal; from April 1902 this method was also used for the work on the south side. Using light scaffolding it was possible to work in the cut up to the roof of the tunnel using two stages in level, with boring heads aligned at a 45° angle to the portal. The excavation of the first cut was followed by full excavation and this in turn was followed by the tunnel lining, although this was rarely needed in a tunnel where long sections were cut through granite. Work on the south side was stopped on 23rd May 1902 in order to avoid an accident. The breakthrough took place on 29th May 1902 from the Preda side, 3030.5 m from the north portal and 2835 m from the south. The breakthrough resulted in the extremely low deviation (between the heads of the north and south tunnel drives) of 50 mm in longitude and 48 mm in height. The last excavation work was carried out in January 1903 in the area of the breakthrough and the tunnel lining was completed by the end of February.

The material excavated from the Albula tunnel was used to construct the embankments, which in some places were quite high and to build the mounds on which the station facilities were set up. The track bed was thus protected from the groundwater which lies close beneath the surface in the plain of the Upper Engadin.

The completion of the section between Celerina and St. Moritz was delayed by the discussion on the location of the St. Moritz railway station. The community wanted the station built above the English church, at 1800 m above sea level, so that the station would be in the centre of the village ensuring an uninhibited view of the lake. The Rhaetian Railway however wanted to place the station towards the upper end of the lake on account of the possible continuation of the line towards Chiavenna. The final location of the station was a compromise, decided upon by the Swiss government on 5th November 1901. The Albula line was opened as far as Celerina on 1st July 1903, whilst the rest of the section to St. Moritz only entered service on 10th July 1904, as a result of the delayed decision on the location of the station.

Rolling stock, from the opening of the line to its electrification

The Rhaetian Railway had already gained experience in the operation of a narrow-gauge mountain railway using steam locomotives on the Landquart – Davos line. The estimated passenger

(1'B)B Mallet locomotive, 1903.
Rhaetian Railway

(1'D) 102 steam locomotive, after 1921.
Rhaetian Railway

(1'D) 112 steam locomotive, about 1910.
Rhaetian Railway

numbers and freight tonnages led to the decision to purchase 12 steam locomotives, 54 passenger coaches, 8 luggage coaches and 129 freight wagons in advance of the opening of the priority lines (Reichenau – Ilanz and Thusis – St. Moritz). Their designs were based on the types which the Rhaetian Railway already owned. Type 1'C tank engines with three driving axles were purchased for light duties and Mallet type (1'B)B tank engines for heavy duty work on the Albula ramps. These had two articulated groups of two driving axles, and were better able to negotiate the tight curves. The passenger coaches had two axles and an open platform at each end. The third-class coaches had open interiors with a central corridor; sections of the first and second-class coaches had single compartments with a side corridor. All the passenger coaches procured for the Albula line were fitted with electric lighting and could be heated in winter with steam from the locomotive. The freight wagons included both closed and open types; the open types included wagons with low-walls and with half-height walls. In terms of load-carrying capacity (10 tonnes) and size they were identical with the standard-gauge freight wagons of the period, which simplified the transfer of ongoing freight. All the rolling stock was fitted with Hardy automatic vacuum brakes, which allowed more efficient operation of the line, since freight trains no longer needed any brakemen and the trains could be driven along downgrades at higher speeds. The uphill speed of the trains was limited by the power of the locomotive; speeds of 15 – 30 km / hr were achieved.

After only a short period of operation it became clear that the Albula line was attracting more traffic than had been predicted, with the result that the Mallet steam engines which had proven themselves over the shorter section between Landquart and Davos were no longer adequate for the operation of the line. A more powerful locomotive, more suitable for longer sections, was needed to carry passengers onwards from the Swiss Federal Railway's standard-gauge connecting trains.

As early as the autumn of 1902 test runs had been carried out on the Rhaetian Railway network using a Consolidation type 1'D-linked locomotive, which the Swiss Locomotive and Engineering Works (SLM) in Winterthur had developed for the line from Djibouti to Addis Abeba in Abyssinia (today Ethiopia). These had four connected drive axles: two could be shifted laterally within the same frame. Placing the coal and water supplies on a tender meant that it was possible to increase the size of the boiler (and therefore the power of the locomotive) without increasing the locomotive's weight. Between 1904 and 1915 the Rhaetian Railway purchased a total of 29 units of a modified version of these 'Abyssinian' locomotives. The 1'D steam engines bore the main burden of train operations on the Albula line up to the time the line was electrified. These double-headed locomotives could haul a train of 190 tonnes, the length of which matched the passing track length of 200 m exactly. Two engines of this type and several wagons dating from the first years of operation are still in working condition today.

The acquisition of coaches took into account the growth in traffic and the comfort standards expected. New passenger coaches had four axles, whilst for the fast trains the Rhaetian Railway even acquired coaches which had concertina connections like those on European luxury trains. When pulled by a 1'D locomotive, the 1913 Engadin Express, which had only first-class coaches and a luggage wagon, took only 2 hours and 42 minutes to travel from Chur to St. Moritz! Freight wagons delivered after 1911 had a load-

Albula line > The avalanche walls and snow catchers above Muot are almost snowed under.
Rhaetian Railway

Albula line > The Crasta Mora avalanche buried the track and tore down the catenary in Val Bever 23.12. 1919. A steam snow blower removing the compact snow brought down by the avalanche.
Rhaetian Railway

Albula line > Crasta Mora avalanche 23.12.1919. The top layer of avalanche snow had to be shovelled away before the steam snow blower could start work.
Rhaetian Railway

bearing capacity of 15 tonnes, the same as the newer, standard-gauge wagons.

Winter operation

When the Albula line was being designed the engineers involved could call on more than 30 years of experience in the operation of steam-powered mountain railway lines in winter. Moser and Hennings closely studied the characteristics of a number of existing railway lines, including the American trans-continental railway line through the Sierra (opened in 1869), the Gotthard and the Arlberg lines and the Rhaetian Railway line between Klosters and Davos. The idea proposed by the Albula line builders was that it should be possible to operate the line all year round, with a high level of safety and yet with costs kept as low as possible. And in fact the Albula line provides an outstanding example of a railway which, thanks to being suitably designed from the very beginning, was able to keep the costs of winter operation down to a minimum. Chief engineer Hennings had an admirable skill in estimating natural hazards and dealing with them appropriately. To increase winter safety the summit tunnel had been constructed at as low a level as possible and both the approach sections were sited on those sides of the valleys which were exposed to the sun. Extensive traverses across the terrain were made to optimise the alignment of the line along the sections most at risk of avalanches between Bergün/Bravuogn and Preda and between Spinas and Bever. Special engineering structures and other measures were provided to increase winter safety. These included stabilisation of the Muot slope with walling and afforestation measures, the walled avalanche galleries in Muot and Maliera, a number of other steel and timber avalanche galleries, diversion barriers and shelter walls. The risk of avalanches occurring along both flanks of the valley in the section between Spinas and Bever was considered to be so high that it was decided to locate the railway line on an embankment in the middle of the valley floor. Experience with snow-clearing operations between Klosters and Davos led to the decision to create enough space between track and revetment wall to dump the snow and to provide snow trenches on both sides along slopes, where possible. In the tunnels, care had to be taken that the mountain water run-off did not freeze and risk derailing. For this purpose, the Albula and Regnux Tunnels were closed with doors after a train had passed through; groups of workmen then removed the ice from the tracks and the run-off ditches were covered with snow to provide some insulation.

The rolling stock was also equipped for winter service. Experience taught that in winter only the more powerful engines should be used on the mountain sections and these should be fitted with a fixed snowplough. In this way new snow was constantly removed from the track creating walls of snow on the mountain side of the track which groups of workers then shovelled away. During heavy snow falls a wedge-shape snowplough with a pusher locomotive was used to clear the section. These track ploughs (procured from 1906 onward) removed the hardened snow between the rails which could otherwise have led to high levels of rolling resistance and even caused derailing. In 1913 the Rhaetian Railway purchased two steam snow blowers, which not only pushed the snow to the side but were also able to clear a greater width and blow it beyond the line. The blowers could even remove compacted avalanche snow.

All these facilities for winter operation have proved their value over time. Apart from downtime after a few rare, major avalanches the Al-

Electrification of the Albula line > Spinas portal of the Albula tunnel, G 3/4 steam engine in front of a Kummler & Matter assembly train.
Archives Hermann Kummler)

Electrification of the Albula line > Catenary works-train between Surava and Tiefencastel: photograph about 1918.
Collection G. Brüngger

Electrification of the Albula line > Tiefencastel station: photograph 1919.
Archives Hermann Kummler

bula line has continued to operate all year round to the present day without any long interruptions. Extensions were added to the protective structures in the area of the avalanche barriers in Muot, Maliera and Valetta. When the line was electrified the exposed catenary masts were protected by means of timber or concrete avalanche breakers.
A pioneering step was taken in 1958, with the purchase of a diesel snow blower. This unit, which is lighter and faster than the steam powered version, has a higher output and can also be shifted laterally widening the cleared channel.

Electrification and rolling stock after 1919

At the time the Albula line was constructed nobody had given any thought to electrifying the section. The alignment, the location of the intermediate stations and the workshops in Samedan were all entirely designed for services operated by steam locomotives. Even with the increase in traffic during the years of operation up till 1914 the requirements for providing the train services do not seem to have exceeded the performance of the modern 1'D steam engine.
In 1905 the Rhaetian Railway joined the Swiss commission which was studying the question of electrified railway operation with a view to deciding on a suitable system for the main railway lines. In 1910, the Board of Directors of the Rhaetian Railway decided to electrify the Bever-Scuol line which was then being constructed, together with the two existing lines between Bever and St. Moritz and between Samedan and Pontresina; the electrification system to be used was the 10 kV 16 $^{2}/_{3}$ Hz single-phase system recommended by the study commission. In terms of the system selected, the fixed installations and the traction units, the electrification of the Rhaetian Railway matched the state of technology then in use for high-performance electric main railway lines. The power supply was provided by the Kraftwerke Brusio AG (today, the Rätia Energie AG) by means of a high-voltage line routed over the Bernina Pass to the new converter substation in Bever. The catenary system was constructed by the German company Siemens and consisted of steel masts with cross-arms, catenary wire and contact wire. The performances of the two locomotive types (type 1'B1' und 1'D1') were the same as that of the existing type 1'C and type 1'D steam locomotives. However, the drop in traffic after 1914 meant that the electrified Lower Engadin line was never used to its full capacity, although it certainly gave the Rhaetian Railway valuable experience in the operation of an electrified railway in mountain areas and also an opportunity to compare the suitability of different types of locomotive.
In view of the shortage of coal during the First World War there was a consensus that the railways in Switzerland should be quickly and completely electrified. The first priority was to extend those electrified systems already in existence. This applied to the Rhaetian Railway. Around 1920, a debate took place in Graubünden as to whether the use of hydroelectric power in the canton should be in private or public hands. As the Rhaetian Railway did not construct any power stations of its own, but rather obtained the electricity it needed from a number of power companies (cf. 2.b.7), it did not openly take sides in the debate. The electrification of the section between Bever and Thusis was completed in 1919. Operation initially continued with locomotives which were already available and by using power from the converter substation in Bever and the Viamala

C'-C'-Locomotive > The "Crocodile" locomotives have become a Rhaetian Railway trademark. A Crocodile in front of the Landquart depot, shortly after delivery, about 1921.
Rhaetian Railway

Bo'Bo' > After 1947, passenger trains were hauled by the Bo'Bo' locomotives, permitting higher speeds.
Collection G. Brüngger

Ge 4/4 III > The latest generation of electric locomotives.
P. Donatsch

power station in Thusis, which belonged to the Rätischen Werke für Elektrizität. The design of the catenary system was based on the model provided by the Lower Engadin line, but with the difference that, because of the shortage of material, the masts were built in timber rather than steel. Brick-walled switch houses based on the Engadin model were constructed at several of the stations.
In 1920, the Rhaetian Railway estimated the costs of electrifying the Bever – Thusis and the Filisur – Davos lines at CHF 64,000 per km; since the locomotives and the substations required already existed, this sum probably only covered the cost of constructing the power supply lines. Cost comparisons between steam-powered and electrical operation were made both during the period while the detailed design was being prepared and again ten years later; they did not indicate any clear advantage in terms of electrical traction. The electrified option only became more favourable when other factors were taken into consideration, such as the elimination of smoke in the tunnels.
The decisive factor in the acquisition of new locomotives for the electrified Albula line was the increase in capacity. The locomotives that came into service after 1921 were of the C'C' type; 15 of these were purchased. However, one of these alone was as powerful as two of the strongest steam locomotives working together and could by itself pull a train that was as long as the passing tracks. Depending on the load hauled they could reach a speed of 30 – 45 km / hr along a section with an upgrade of 35 ‰ and could also be operated by one man. The C'C' – "Crocodile locomotives" – have even become a symbol of the Rhaetian Railway: where they once stood as a symbol of modernity, today they evoke a hint of nostalgia.
After 1939, trains ran using light railcars and from 1947 at higher speeds using the Bo'Bo' locomotives. Today fast trains and freight trains on the Albula line are pulled by Ge 4/4 III locomotives – the latest traction unit generation. These can achieve a speed of 50 km / hr when hauling a full load of 300 tonnes up the Albula ramp.
The catenary system was given steel masts in 1930 and has been completely renewed since 1980. Today the electricity is provided via a 66 kV ring main. The Sils im Domleschg power station has a feeder point for the Albula line, which means that hardly any physical traces of the electrification of the Albula line section have been preserved, although the line continues to operate with the electrical system selected a hundred years ago. It is therefore still possible today to use first generation rolling stock from the early days of electrified operation.

Changes

The Albula line has hardly been changed since it was first constructed. To date, the increases in capacity required have been achieved by means such as electrification, the lengthening of passing tracks, new control and safety installations, a new, stronger permanent trackway and new rolling stock. The start of services on the second railway link into the Engadin through the Vereina tunnel, in 1999 entailed a further increase in capacity, yet without the need to introduce material changes to the physical structure of the Albula line. In consequence, the Albula line, in its present well-maintained state and good operating condition, is protected against the two great risks a historic railway line is normally confronted with, namely closure due to too little traffic, or complete new alignment and redesign due to too much traffic. The number and locations of the intermediate stations on the Albula section have remained unchanged. The passing length of 120 m at the passing stations was originally designed for a

Preda > Extended stretches of double track, like here in Preda, make it possible for trains to cross without stopping.
A. Badrutt

Landquart > The north side of the Albula line has been controlled from the 'Rail Control Center' (RCC) in Landquart since 2005.
P. Donatsch

train with two engines and ten coaches, which would have been sufficient for the demand forecast at that time. Following the purchase of the longer and more powerful tender locomotives, most of the passing stations were extended to 200 m, the work being completed by 1908; this passing length proved to be quite adequate even many years after the line was electrified. Between 1965 and 1990 work was carried out in stages to increase the passing lengths at all stations to 250 – 300 m. The introduction of the "Bahn 2000" synchronised timetable meant that lengthened, twin-track sections would be needed at the passing points for the fast trains in Thusis, Filisur and Preda, so that trains can pass each other without having to stop.

Initially, operation of each intermediate station involved several staff; the stations used to offer a full range of services for both passenger and freight traffic. Today, however, they have been converted to unmanned, remote-controlled passing stations. The facilities in the fast-train stations (Thusis, Tiefencastel, Filisur, Bergün/Bravuogn, Preda, Bever, Samedan, Celerina and St. Moritz) were extended, with higher platforms and also in some cases with grade-separated pedestrian access to the platforms and renewed buildings, whilst the facilities in the smaller stations were cut back.

This substantially increased the capacity of the Albula line for the first time since its electrification. A further increase in train densities was made possible by a system of 'section blocking', introduced in stages between 1961 and 1969. Five block points were constructed to divide the longer sections. The St. Moritz station had been provided with an electrical switch control centre as early as 1951; when section blocking was introduced all the other railway stations and crossing stations were given 'Integra Domino 55' – type track plan control centres.

Remote control facilities were set up at both sides of the Albula tunnel in 1968; one in Filisur for the north side of the section and one in Samedan for the Bever and Spinas railway stations on the south side. The remote control system in Filisur was taken out of service in 2005. Since then the north side of the Albula line has been controlled from the Rail Control Center (RCC) in Landquart.

Up till 1989 the operational concept for the Albula line included fast train services (some of which were year-round services whilst others only ran in the holiday seasons), regional trains with facilities for freight transport which operated all year round and freight trains, some of which ran with passenger coaches. One speciality of the Albula line is the transport of cars on flatbed wagons between Thusis and Samedan. When road conditions are poor this service even has to put on extra trains.

The Swiss Railway's synchronised timetable has been introduced in stages since 1982, when it brought in an hourly fast train service in both directions all year round on the Albula line. Now only freight trains run between the fast trains while the Glacier Express and Bernina Express are operating in the peak season.

The future

The present Rhaetian Railway operational concept for the Albula line foresees that the hourly Regio Express in each direction should continue in the future. The current time table means a heavy load on the Bever – Samedan section, that occasionally leads to delays. In order to overcome this problem a design has been developed for a new corridor between Val Bever and Samedan; this project would include a short tunnel. Another alternative proposes widening of the Bever – Samedan section to two tracks; this

Bernina line > The Bernina railway has been using open goods wagons as panorama wagons from the beginning. A train composition in the Montebello curve about 1920.
A. Steiner/Rhaetian Railway

project would require modernisation of Bever railway station.

The track facilities and safety equipment in Bergün/Bravuogn do not fully comply with today's safety regulations, nor do they meet customers' current expectations. In the mid-term, this station will have to be provided with facilities to allow passengers to access the central platform without having to cross the tracks. The former arsenal (behind the station building) is now empty and is to be converted into the Railway Museum (cf. 5.h). A modern vehicle shed is to be constructed on the station square; the shed will be used to house historic rolling stock and will have a connecting track to the main line.

Separate facilities will have to be provided for passenger and freight traffic in St. Moritz. A modern freight transfer facility was constructed in Samedan in 1999 to serve the whole of the Upper Engadin; one consequence of this is that the demand for freight transfer in St. Moritz is no longer very high. A master plan for St. Moritz station also includes proposals for improving the facilities for the Bernina line.

The engineering structures on the Albula line have remained almost unaltered. The only loss has been the steel bridge over the Hinterrhein near Thusis, which was replaced by a twin track, concrete arch bridge in 1991. The viaducts and tunnels on the Albula line are over a hundred years old and many are in need of renovation (cf. 4.a.1). In future, the rehabilitation work will include fitting the trackway on the viaducts with a concrete trough, which should prevent the penetration of water and resulting damage to the masonry. The vaults of the tunnels will also have to be renewed. The Albula tunnel in particular is in need of structural rehabilitation. However, extensive reconstruction work or the construction of a new, parallel tunnel will be required to bring it up to the standards of today's safety regulations for long railway tunnels.

Bernina railway

Project development and financing

At one time the Bernina Pass was of national importance, as it provided a link between Graubünden and the Veltlin and Venice (cf. 2.b.3). The road from Samedan to Tirano was completed in 1865. However, given the high level of the crest of the Pass and the steep southern slope, for a long time the idea of constructing a railway line over the Bernina Pass was not considered, as the route over the Maloja Pass seemed much more suitable for the continuation of the line from the Engadin towards Italy.

The concession for an electrified line routed alongside the Samedan – Campocologno road was awarded to the construction company Froté & Westermann in 1899. A direct-current, surface railway with railcars operating alone allowed the construction of sections of line which, in terms of gradients and curve radius, could be based on the typical values for roads and not subject to the constraining values for steam-powered railway lines. Following the construction of the great railway lines it had been generally assumed that the bulk of traffic would shift from road to rail; the construction of a road trackway was therefore seen as a chance to add a new use to the recently constructed Alpine roads and so help to pay back the capital invested in them.

As design work began on the construction of a trackway along the Bernina pass road, planners started to consider using the hydro-power available in the Poschiavo valley (cf. 2.b.7). In 1904, the Kraftwerke Brusio AG (KWB; today Rätia Energie AG) and the Bernina railway were founded; both had the same shareholders – the Basel-based

Pontresina > Steam train on the section between Samedan and Pontresina, the starting point for the Bernina line, a station which was built by the Rhaetian Railway.
Archives Engadin Press

Pontresina > The railway station about 1910.
A. Steiner/RhB

Bernina line > Winter operation is a real challenge. The Number 5 engine has only a very narrow passage to keep traffic moving. Taken in 1926.
A. Steiner/Rhaetian Railway

Schweizerische Eisenbahnbank (Swiss Railway Bank). The Bernina railway had not been foreseen in Graubünden's railway law of 1897, with the result that it was financed entirely from private sources, without any contribution from the canton. The railway and the power station projects were weighted quite different from time to time. When design work began, the railway stood in the foreground, but later the power stations became more important in terms of capitalisation, profit and economic significance. By 1905 the construction company Albert Buss & Co. AG had re-worked the first design for the Bernina line, which now proposed a line that would have a considerably higher capacity than the line originally planned. Instead of simply following the mountain pass road, the line from the Bernina Pass to Poschiavo would now follow a separate corridor via Alp Grüm. This route was more attractive in tourism terms and was also suitable for transporting materials for the power station stages above Poschiavo. The construction of the Bernina line was only finally assured when the definitive decision was taken to set up the KWB.
In both cases financing was provided by the Alioth electricity company, based in Münchenstein, Basel. The funds needed had been set aside as early as 1905 so that it was possible to begin work on the construction of the railway line in 1906.
The general contractor, Buss & Co., took on the construction of the Bernina line for a lump sum of CHF 12 million, half of which was covered by shares and the other half by bonds. The company's management report for 1910 broke down the CHF 14 million in construction costs incurred up to the opening of the railway line as follows:

> Substructure	CHF 6.2 million
> Track superstructure	CHF 1.9 million
> Engineering structures	CHF 0.7 million
> Electrical installations	CHF 2.2 million
> Rolling stock	CHF 1.5 million

Of the CHF 2.2 million expenditure on the electrical installations, the transformer station accounted for 0.2, the machines in the hydroelectric plants for 0.7 and the high tension cables for 1.3. 2/3 of the rolling stock costs, i.e. CHF 1.0 million were spent on railcars.
A comparison with the costs of constructing those sections of the Rhaetian Railway which were built at the same time is quite illuminating. The electrical installations on the Lower Engadin line (Bever – Scuol), with high-voltage AC current and main line catenary system, were even somewhat cheaper than the simple DC installations and timber masts of the Bernina line. The real potential for savings in what were considered to be low cost surface railways lies in their alignment, which could be kept simple thanks to the use of railcars. And in fact the trackway for the Bernina line, which after all runs through a high altitude mountain region, cost only CHF 135,000 per km, whilst the Lower Engadin line, which was designed for operation by locomotives, cost more than CHF 300,000 per km; the proportion of engineering structures on this line was higher.
By 1914, construction costs had increased to CHF 16 million, of which CHF 2.7 million had to be financed by short-term bank debt. The reasons for exceeding the budget were the need to widen the facilities and to add to the rolling stock, plus the additional investment required for winter safety. After agreement with the general contractor, in order to repay the debt, the share capital was partly written off and priority shares had to be issued.
Although public subsidies had already been provided in 1913 for avalanche protection measures along the Bernina line, the railway had to approach the communities and the canton again in the 1920s and 1930s for contributions to help

Bernina line > Inclined Viaduct next to the lower Cavagliasco bridge. Photograph from: E. Bosshard: *Die Berninabahn*, Zurich 1912 (*Schweizerische Bauzeitung*, offprint).

Bernina route > A G3/3 tramway steam locomotive, as construction work engine, crosses the largely complete bridge. Photograph taken about 1908 from: E. Bosshard: *Die Berninabahn*, Zurich 1912 (*Schweizerische Bauzeitung*, offprint).

Bernina line > View of Poschiavo and the Lago di Poschiavo. Photograph from: E. Bosshard: *Die Berninabahn*, Zurich 1912 (*Schweizerische Bauzeitung*, offprint).

cover the cost of maintaining winter services. Furthermore, after 30 years of operation there was a growing need to replace the rolling stock and to renew track systems and power supply, whilst at the same time income was sinking due to the Second World War. However, for political and military reasons it was necessary to ensure uninterrupted operations. Under these circumstances the Bernina line found itself no longer able to operate the line independently, with the result that the Rhaetian Railway took it over in 1944.

The construction of the Bernina line

The Bernina Railway was built between 1906 and 1910. The construction company Buss & Co, mentioned above, was the general contractor, the electrical company Alioth supplied and installed the electro-technical equipment; they were also responsible for the rolling stock. The construction contract was based on the 1905 design as re-worked by Buss. Compared with the initial project, this design included alterations which added to the price. These alterations were the lengthening of the trackway, reduction in the maximum gradient from 82 ‰ to 70 ‰, elimination of the setting back tracks originally planned near Pontresina and Cavaglia, lengthening of the usable passing lengths from 45 m to 90 m, the addition of new station halts and new passing tracks and the creation of an option to allow the later addition of passing sections at various points on the line, without excessive additional cost. These improvements had been demanded by the KWB investors, who wanted to use the Bernina line not only for tourist traffic but also as a freight supply line for the construction of their power stations along the section.
Two separate construction offices were set up to manage the construction of the railway, one in Celerina for work on the north side and the other in Poschiavo. Up to 2,500 workers, mostly Italian, were involved in the construction of the railway. The hard working conditions traditionally found in the construction of a railway line were added to here by the difficulties associated with the remote location and with the Alpine climate. In May 1907, 1000 workers on the Engadin construction sites went on strike; military forces were eventually called in to suppress the strike.
The stone material used for the visible surfaces of the engineering structures was almost exclusively granite, which could be found in excellent quality at various locations close to the trackway, for example near Montebello, Ospizio Bernina, Cavaglia and Brusio. The superstructure had to be completed first to permit the delivery of the quarry stone direct to the site.
The most technically demanding structures were the Charnadüra tunnel (the only long tunnel on this line) and the tunnels and bridges along the Cavagliasco loop. Even the shorter tunnels presented difficulties, since the tunnel shaft had to be driven upwards along the steep upgrade and ventilation in such circumstances was very difficult. Here, the low temperatures on the mountain section resulted in the dynamite freezing; it is highly explosive in this state.
Parts of the line were opened before the whole route was completed; the Pontresina – Bernina Suot and Poschiavo – Tirano sections in the summer of 1908 and the St. Moritz – Pontresina and Bernina Suot – Ospizio Bernina sections in the summer of 1909. Trains could travel along the full length of the Bernina line from 5th July 1910.

The construction of the electrical works

The supply of electricity was provided by the Campocologno power station, completed in

Bernina line > Stablini curve against the backdrop of the Palü glacier and Piz Cambrena. Taken shortly after the Bernina line was opened in 1910.
A. Steiner/Rhaetian Railway

Bernina line > The Bernina line runs through the hamlet of S.Antonio like a tram. Photograph 7th April 1927.
A. Steiner/Rhaetian Railway

Pontresina > BCe 4/4 3. Photograph 4th August 1948.
Collection G. Brüngger

1906/07, with the Robbia power station near Poschiavo available as a reserve from 1910. Both facilities belonged to KWB. There were twelve generators in Campocologno, three providing power to the local mains network and to the Bernina railway. Electricity was supplied to the converter substation near Campocologno railway station at the output voltage from the generators of 7,000 V / 50 Hz, which the substation converted to 23,000 V and then fed to the high voltage line from Campocologno to Pontresina, from where it was sent to the three other converter substations in Poschiavo, Ospizio Bernina and Pontresina. Part of the power supply was converted down to 500 V and then used to run the transformer which provided the DC supply to the catenary system.

The construction of the high tension wires Campocologno – Pontresina was independent of the construction of the railway; it had to be finished early as the plan was to start work on certain sections on the north side as soon as the high tension cables were in place. The line was erected during the summers of 1907 and 1908 by groups of workers who lived in tent encampments. Food, masts, insulators and even cement, water and sand had to be laboriously transported by mules using bridleways; in some cases the old mule tracks were improved while others were newly-constructed.

The four converter substations with buffer batteries provided the catenary system with 750 V DC current. The substations were all identical, both in terms of their technical equipment and in terms of their architecture. The quarrystone masonry of the building in Ospizio Bernina has been left exposed, whilst the façades of the other buildings have been plastered. Window sills and lintels are in exposed brickwork. The intention had been to build these stations where the electricity demand was highest, along the steep ramps. The substations, however, were eventually constructed at the larger railway stations because the rotating motor-generator sets required constant monitoring by an engineer; a house was even built next to the converter substation in Ospizio Bernina as accommodation for the engineer. Shortly after the start of services it became evident that the power supply was not sufficient for peak traffic times; both the north and south sides were then given a simple station battery which was linked only with the DC feed line.

The catenary system matched the standard design developed by the Alioth company for DC railways, where simple, swung-out, T-iron cross arms were attached to impregnated timber masts. The overhead conductor lines were suspended from cross wires and consisted of two adjacent round copper wires; at the passing stations one wire was run over each track. At larger stations the cross wires were tensioned between iron lattice pylons and an additional feed line was attached to the masts. Where the railway track runs along a loop, the supply line was often routed along a more direct corridor. The electrical return was via the track rails, which were connected by copper bands at the butt joints. The bands were hidden below the fish plates to prevent copper pilfering.

The overhead power line over the pass proved itself in practice so that the Rhaetian Railway too decided to take the power for its electrified railway lines in the Lower Engadin from the KWB. For this purpose, the KWB took over the high voltage line from the Bernina line in 1912 and built a second supply line along a separate corridor up to the converter substation in Bever.

Rolling stock

By 1917 some 17 bogie railcars with second and third class compartments had been purchased

Bernina line > The first Rhaetian Railway electric snow blower: 1943. Here it is in operation between Arlas and Ospizio Bernina.
Rhaetian Railway

Bernina line > Historical photograph of snow clearance at the Alp Grüm station.
Rhaetian Railway

Bernina line > The R 1051 steam snow blower, built in 1911, in front of the Alp Grüm reception building.
Rhaetian Railway

as tractive units; three of the railcars also had a luggage compartment. With four 75 HP motors they were quite powerful and could haul a load of 17 tonnes up the steep sections of the track (the equivalent of two, two-axle passenger coaches or a loaded freight wagon) and still reach a speed of 18 km/hr up the steep incline. There were no plans to run several railcars as sets. Since the simultaneous control of two connected but independently-operated railcars in the upgrade was difficult, the railcar drivers were provided with a system which allowed them to communicate with each other by alarm bells. The towing and shunting attachment and the Hardy vacuum brakes were compatible with those in use on the Rhaetian Railway. The railcars also had a short-circuit resistance brake and magnetic rail brakes. The Bernina line also had a two-axle freight railcar and two, two-axle assisting locomotives. The number of passenger coaches and freight wagons available was relatively low, respectively 16 and 28.

Winter operation

In contrast to the costly mountain railways, it was not possible to provide for all the necessary for winter safety measures during the initial project phase of the Bernina railway, which was built with relatively low capital expenditure; the objective of all-the-year-round operation was only achieved thanks to subsequent interventions guided by practical experience. In the first two years, there was no train service on the Bernina line between Ospizio and Poschiavo during the winter months; a sleigh service was used instead. In the 1911/12 winter season it was possible to reduce the sleigh service on the Alp Grüm – Cavaglia stretch and in the following year passengers only had to use sleighs on a few days. It was not until 1913/1914 that an uninterrupted year-round service was available between St. Moritz and Tirano. The necessary measures taken by 1914 to ensure winter operation along the whole line comprised the construction of snow galleries at exposed points along the pass, extension of the tunnels by means of snow galleries, replacement of the wedge-shape snowploughs by steam snow blowers, which in turn required strengthening of the bridges and construction of watering stations and turntables. The slopes of Alp Grüm were protected by walling and afforestation measures following the example offered by the Albula line.

New investments in winter operation were made in the years following 1927; these involved the relocation of two exposed sections near the top of the pass, the acquisition of a special snowplough locomotive, a clearer (which in turn meant that the trackway had to be widened) and the use of mortar bombs to trigger avalanches. In the hard winters of the 1930s the railway company threatened to discontinue the winter service across the Bernina if the subsidy from the public purse did not materialise. From 1950, the Rhaetian Railway made significant efforts to increase winter safety along the section. Galleries were built on the section between Alp Grüm and Cadera to protect the track. The use of new, electrically-powered snow blowers and track ploughs increased the speed of snow clearance work whilst at the same time the number of workers could be reduced.

Even today great efforts by men and machines are required to keep the Bernina line open in winter.

Modifications

From St. Moritz to Montebello and from Scala to Tirano the Bernina line still largely runs along its original corridor; this has been straightened a little at only a few isolated points. Along Lake

Bernina line > Early morning at Lago Bianco.
R. Pedetti

Bernina line > Alpine winter landscape between Bernina Lagalb and Arlas.
P. Donatsch

Poschiavo, a longer section of the line still runs in its original position alongside the road (cf. 2.a.3). In the summit area of the pass, however, between Montebello and Scala, the line underwent quite a number of modifications. In 1934, in order to avoid the hazardous area near the broad avalanche slope on the Piz Alv, it was relocated to the Alp Bondo side of the valley, which is better protected against wind and avalanches. Near Scala, between Ospizio Bernina and Alp Grüm, the original alignment proved to be too expensive for winter operation and a new section was constructed in 1923. This was located on an embankment and had a crossing with the old section which thereafter remained in service for some years during the summer periods.

The increasing volume of motor traffic initially only led to problems for those parts of the line which were embedded in the road direct, like a tramway. However, as traffic densities increased problems spread to the areas where the line ran (like a surface railway) alongside the road. Characteristics similar to those of a tramway can still be seen today in S. Antonio, Le Prese, Campocologno and Tirano. The line still runs directly beside the highway over the sections between Montebello and Bernina Suot and between Li Curt and Le Prese.

Technical developments in the field of electrical engineering allowed the expensive converters to be replaced by smaller and much more powerful mercury vapour rectifiers. In 1936, after the catenary system had been renewed and its cross-section increased, it was possible to increase the catenary voltage from 750 V to 1,000 V. The line has continued to operate using DC voltage, although as time passed the power supply system was renewed a number of times and modified to bring it up to the latest state of technology.

When the new ABe 4/4 III railcars came into service all the rectifier stations had to be strengthened and additional new rectifier stations built. Today, a static rectifier can be found at almost every passing station between Pontresina and Tirano, feeding current into the catenary system.

Train radio providing direct communication between the railway stations and the trains was introduced in 1971 as a means of increasing capacity. This tool has proved to be very useful, particularly in snow clearance operations. However, it will only be possible to increase capacity without upgrading the line, if section blocking is introduced. In 1977, section blocking came into service along the section from St. Moritz to Poschiavo. Since then the intermediate stations have been monitored and remotely controlled from Pontresina. Initially, only the exit signals (block signals) were taken up by the safety system. Section blocking was extended to the section from Poschiavo to Tirano in 1985. Work is presently in progress to give each of the intermediate stations a remote-controlled signal box; this is expected to be completed by 2008. All the points on the main tracks are being fitted with electric drives and the railway stations fitted with entry signals. This means that it will eventually be possible to control all the passing stations from the Rail Control Center (RCC) in Landquart and in future also from the remote control centre in Samedan, which is presently being designed.

The rolling stock in use on the Bernina Railway was up to 2.5 m wide and therefore 0.2 m narrower than those of the Rhaetian Railway. In order to be able to make free use of Rhaetian Railway rolling stock, the line was gradually widened to take a vehicle width of 2.7 m; the related improvement work took several years to complete, particularly in the tunnels and in the sections edged by retaining walls and rock faces.

Bernina line > A trip with the Bernina Express is an unforgettable experience.
P. Donatsch/Rhaetian Railway

Bernina line > Passenger and goods traffic take the same train on the Bernina line.
P. Donatsch/Rhaetian Railway

Bernina line > Passing over the circular Viaduct at Brusio is one of the highlights of a trip from St. Moritz to Tirano.
P. Donatsch/Rhaetian Railway

The concept of the Bernina line as a surface railway meant that new station halts could be opened or closed at will. The construction of the cableways to Diavolezza and to Piz Lagalb led to the construction of new halts close to the cableway valley stations. The two adjoining halts of S. Antonio and Annunziata were later merged to become the station halt of Li Curt.
The four-axle passenger railcars and the two-axle trailer coaches originally purchased proved to be quite suitable for the Bernina line services, both in terms of their number and their capacity. Additions to the existing rolling stock were only needed in isolated cases (and financially acceptable). In 1928, a freight locomotive was acquired for the transport of material for the construction of power stations. Two dining cars were delivered in the same year; these were combined with two passenger coaches which had concertina connections (and were already available) to form the St. Moritz – Tirano fast trains.
Since 1973, the Rhaetian Railway timetable has included a direct train connection, known as the 'Bernina Express', from Chur via Pontresina to Tirano. In recent years the Express has become the trademark of the Bernina line. The panorama coaches acquired for this train in 2000 ensure passengers travelling from Chur to Tirano can enjoy the magnificent views of the landscape unimpeded.

The future

The tight curves and the traction force needed for the inclines mean that the length of trains operating in either direction on the Bernina line cannot exceed 200 m. In order to make the best use of the opportunities offered by the line, the Rhaetian Railway is attempting to lengthen all the passing stations to a usable length of at least 200 m. The modification of the stations to the standards required today for inter-track spacing and platform heights will change the appearance of the stations which until now have largely preserved their original form.
Over the next few years the Rhaetian Railway plans to acquire 15 three-section, twin-drive tractive units for their main network and for the Bernina line. Together with the ABe 4/4 III units, these railway vehicles will maintain the future services on the Bernina line.
Despite constant maintenance the engineering structures, which will soon be a hundred years old, are in need of repair (cf. 4.a.1). The viaducts will be fitted with a trough under the track ballast, which should prevent the penetration of water and so avoid corrosion. In addition, the metal galleries must be cleaned of rust and the domes of the tunnels will also gradually require comprehensive renovation.