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Railway infrastructure and its environmental effects in the Alps (1945 - today)

A Master's Thesis submitted for the degree of
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Affidavit

I, **HANNAH GRATZER, BA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "RAILWAY INFRASTRUCTURE AND ITS ENVIRONMENTAL EFFECTS IN THE ALPS (1945 - TODAY)", 85 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

This thesis is dedicated to the historical development of railway infrastructure since the Second World War. Geographically, the Alpine region is covered, specifically Austria, France, Italy and Switzerland. The first part of the thesis deals with the impact and long-term consequences of the European Recovery Programme (ERP) on railway infrastructure until 2021. For this purpose, original documents from the National Archives in Washington and original reports from the OEEC were analysed. The second part of the work deals with the environmental aspects of the entire life cycle of the railway infrastructure. Current developments and projects in the Alpine region are presented and evaluated in terms of their environmental impact.

Research has shown that the ERP has shaped the railway infrastructure in the Alpine region in the long term. Many developments of the last 70 years can be traced back to the missions under the programme. Although railway infrastructure has undeniable environmental impacts throughout its life cycle, they are the alternative transport method of the future compared to road, air and maritime transport. Especially because technologies - such as electrification - make it possible to minimise emissions. Numerous organisations and initiatives are dedicated to this and other issues in the field of Alpine environmental protection and sustainable mobility.

Table of contents

List of abbreviations

AC	Alpine Convention
ALPARC	Alpine network of protected areas
CBD	Convention on Biological Diversity
CH_4	Methane
CIPRA	Commission Internationale pour la Protection des Alpes
CO_2	Carbon dioxide
ECA	Economic Cooperation Administration
ECE	European Commission for Europe
EEA	European Environment Agency
EES	Energy, Environment and Sustainability
EIA	Environmental impact assessment
ERA	European Union Agency for Railway
ERP	European Recovery Program
ERTMS	European Rail Traffic Management System
ESO	European Standardization Organization
EU	European Union
EUSALP	EU Strategy for the Alpine region
GDP	Gross domestic product
IEA	International Energy Agency
N_2O	Nitrous oxide
NMVOC	Non-methane volatile organic compounds
NO_x	Nitrogen oxides
NRLA	New Railway Link through the Alps
OEBB	Österreichische Bundesbahnen (Austrian Federal Railways)
OEEC	Organisation for European Economic Cooperation
Pkm	Passenger-kilometres
PM	Particulate matter
RTSE	Rail Technical Strategy Europe
SBB	Schweizerische Bundesbahnen (Swiss Federal Railways)
SCI	Site of Community Importance
SEA	Strategic environmental assessment
SNCF	Société nationale des chemins de fer français (French Railways)
TEN	Trans-European Network
TEN-T	Trans-European Transport Network
Tkm	Tons-kilometres
UIC	International Railway Union
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working group
WW2	Second World War

Acknowledgements

I hereby want to express my deepest appreciation and thankfulness for receiving original, unpublished archival data from Mag. Dr. Robert Groß. I have processed these data to the best of my knowledge and belief and hope to be able to offer a valuable contribution to the research situation. Chapters 2.3.2 - 2.3.5 are mainly based on these files from the National Archive in Washington DC and on original OEEC reports from 1950.

Furthermore, I want to thank my supervisor Univ.-Prof. Ing. Dr. phil. Verena Winiwarter for her support and numerous recommendations during the writing process of this thesis.

1. Introduction

1.1 Aims and scope

After WW2, the Alpine region experienced the most substantial phase of industrialization in its history (Kopp, 1969, 484). The mobility sector's expansion improved the accessibility of the Alps (Kopp, 1969, 485). Increased traffic allowed the Alps to become an industrial area in its own right, with multilane roads and transversal railways. Projects such as the New Railway Link through the Alps (NRLA) in Switzerland, the Brenner base tunnel in Austria and the Mont-Cenis base tunnel in France epitomize transit traffic in the Alps in the first decades of the 21st century (Kanitscheider, 2014, 140). While modern transportation has several positive effects on economic development, it comes with unintended effects on the environment. Among other things, toxic pollutants such as nitrogen oxide, fine particles and lead, as well as noise pollution, the reduction and destruction of natural habitats of animals and plants endanger Alpine nature (Veit, 2002, 229). Transportation is also a prerequisite for mass tourism, which comes with its own set of side effects.

This work will analyse the historical evolution of Alpine railway infrastructure since the Second World War and, particularly, the long-term processes set in motion by the ERP. The ERP was a program by the United States of America to provide aid for 16 European countries after WW2, including the transfer of financial support and knowledge.

The following research questions structure the investigation:

1) Which role did the ERP play in the development of Alpine railway infrastructure?
2) Which long-term processes were set in motion?
3) What are current developments and projects regarding railway infrastructure in the Alps?
4) What are environmental impacts of railway infrastructure generally and in the Alps specifically?
5) Which initiatives focus on reducing negative impacts from Alpine mobility infrastructure? What are limiting factors for the success of such initiatives?
6) Which are basic prerequisites for a sustainable mobility concept in the Alps?

1.2 State of research

Libraries and the internet offer monographs, theses and journals about the Alps in general. The geographical definition, history and political aspects have been extensively studied. Natural scientists have already done a lot of research about climate change and global warming in the alpine area. The extent and effects of railway infrastructure in and on the Alps, especially railways and roads, can be deduced from available data, but these data have only partially been analysed.

To identify and quantify the European Recovery Program's projects for electrification and industrialization in the Alps, reports by the Organisation for European Economic Co-operation (OEEC) and files from the National Archives in Washington DC serve as primary sources for interpretation and investigation. These reports include the Technical Assistance Program, being used as the main source for Chapter 2.3.2. Since the archival documents have never been investigated, the work will produce new data.

There is abundant information about protective initiatives and institutions. For instance, the Framework-Alpine Convention is published online, including all protocols, declarations, ratifications, and working programs. On the Convention's website, the section "News and Publications" offers downloadable data collections.

1.3 Research concept

Monographs, theses, journals available in public libraries and internet sources serve as the basis for the research chapters. To gain an overview of the Post WW2-beginning of Alpine industrialization with a focus on railway infrastructure, data from 100 original files from the National Archives in Washington DC are processed. OEEC reports are quantitatively analysed for information on the funds allocated from the European Recovery Program for the Alpine area. To study the environmental consequences of railway infrastructure in the Alpine area, the literature on natural sciences, available at the Technical University Vienna, serves as a basis. Knowledge acquired in courses during the second academic year of the program "Environmental Technology and International Affairs" is included.

2. History of Alpine railway infrastructure since WW2

This chapter is dedicated to the geographical delineation of the Alpine region and gives the reader an introductory overview of the core components of transportation, the Second World War and its aftermath in the Alps, the ERP and the UIC. Subsequently, the Technical Assistance Act of the ERP, in particular Mission 14, is discussed in more detail and the long-term effects up to the present day are analysed. The chapter concludes with a status quo, presenting current developments and trends.

2.1 Geographic context of research: The Alps

The Alps are a 1200 kilometres long mountain massif whose 220.000 km² area stretches from the Gulf of Genova to the Danube. Eight states have a share of the Alps, namely Austria, France, Germany, Italy, Liechtenstein, Monaco, Slovenia and Switzerland. Language groups comprise German, Italian Romanic, Rhaeto-Romanic, Slavic as well as Gallo Romanic languages in various dialects. (CIPRA, 2018)

The Alps consist of several mountain ranges in different shapes and forms. Some are wooded hills, and some are covered with snow and ice. The mountains are generally distinguished into Northern, Southern or Central Alps. While the Northern and Southern Alps are chalky, the Central Alps are crystalline. The Central Alps are mostly dry, the Northern and Southern ranges have high precipitation. (Küster, 2020, 9ff) The line High Rhine - Lake Constance - Alpine Rhine - "Hinter-"Rhine - Hüscherenbach - Splügen Pass - Liro - Mera - Comosee - Lower Adda is considered as the border between the Eastern and Western Alps (Ausmann, 2020). Scientists distinguish between three levels of vegetation in the Alps. The colleen and sub-montane level, ranging from 0 to 800m, mostly consists of natural deciduous forests. The montane level is the transition zone between deciduous, mixed and coniferous forests. Its maximum altitude ranges from 1500 to 2000m. In the sub-alpine level, located between 1500-1800m (minimum) and 1700-2400m (maximum), coniferous forests and crooked wood co-exist. The alpine level stretches between the timber- and the snow line. Its highest points lie between 2400m and 3000m. The nival level always lies above the local snowline and is therefore covered in snow most of the year. Only a few grassy patches and special vegetation, adapted to the extreme weather conditions, colonize this zone. (Deutscher Alpenverein, 2015)

The Alps are located in Southern- and Central Europe. As illustrated in Figure 1, only parts of the eight countries mentioned above make up the Alpine area (apart from Liechtenstein). Bern in Switzerland, Vienna in Austria and Ljubljana in Slovenia are the capitals closest to the Alps. Other than that, the capitals are located in non-alpine regions of the respective countries. However, several main cities such as Zurich, Milan and Munich are situated in the Alps. (Küster, 2020, 19)

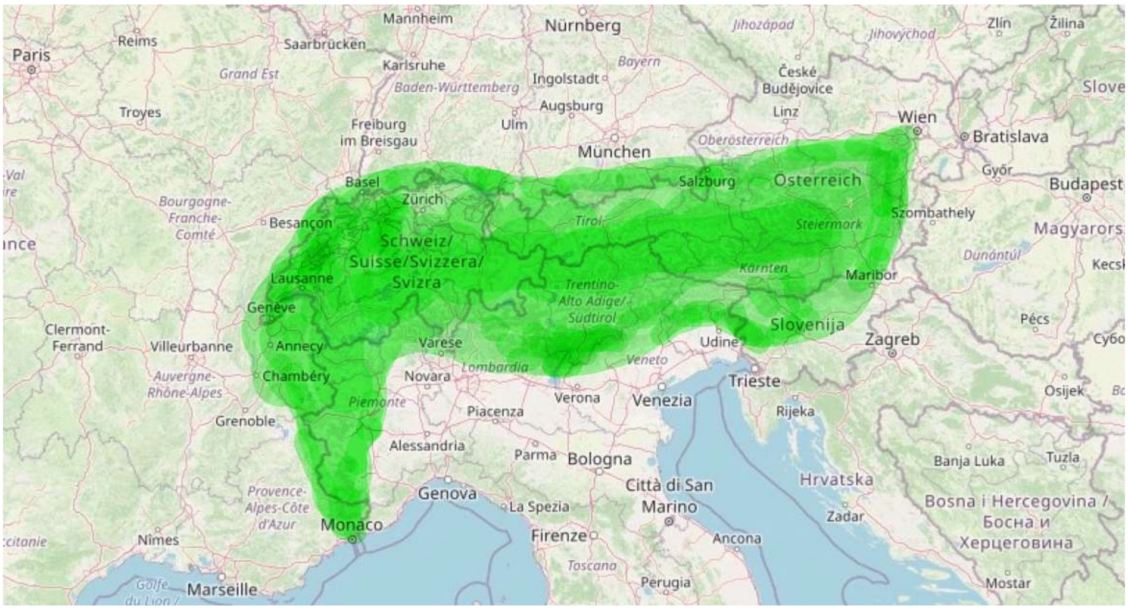

Figure 1. The Alps. (OpenStreetMap, 2021) with illustrations in green added by author.

Table 1 shows the percentage distribution of Alpine area per country. The first column shows how many km² of the respective countries are considered Alpine. The second column puts that into relation to the total area of the county. The last presents the share each Alpine country has of the total Alpine area of 220.000 km². The biggest share of the Alps (89,7%) lies in Austria, France, Italy and Switzerland. (Berggenuss, 2008). Therefore, this work will focus on these four states.

Table 1. Alpine area distribution in the eight Alpine countries. (Berggenuss, 2021)

Country	Alpine surface in km^2	Alpine surface of country (%)	% of Alps (220.000 km^2)
Austria	**61.500,0**	**73,4**	**28,7**
France	**40.802,0**	**7,5**	**21,0**
Germany	11.131,0	2,8	6,0
Italy	**59.990,0**	**17,3**	**27,0**
Liechtenstein	160,0	100,0	0,01
Monaco	2,0	100,0	0,29
Slovenia	6.766,0	33,4	4,0
Switzerland	**25.170,0**	**60,9**	**13,0**

2.2 Technical context of research: Core components of transportation

Transportation is defined as the "movement of people or goods from one place to another" (Cambridge Dictionary, 2014). Four components constitute transportation. First, transport modes differ by the conveyances. They are mobile elements carrying passengers and/or freight. Second, transport infrastructure is the physical support of transport, including routes and terminals. Third, transport networks are the systems of linked locations that connect different locations. Fourth, transport flows are the movements of passengers and/or freight over the respective network. Flows always have origins and destinations, many have intermediary locations that serve as a transit hub. Transport can either be conducted on land, air or maritime routes. (Rodrigue, 2021)

This work focusses on rail transport within which mobile elements, namely wagons or carriages, run on metal rails and wheels. This system is known as a train, which is usually powered by an engine locomotive running on coal, diesel or electricity, as presented in Chapter 3.2.3. Rail transport has fixed routes and route networks, schedules, signalling systems and terminals. Both passengers and freight can be mobilised over urban and cross-country networks. (The Economic Times, 2021) The main components of railroad tracks are rails, sleepers, ballast and subgrade. Rails are made from steel and lead the rolling stock moving forward. They provide the minimum resistance of contact between rails and wheels while withstanding heavy pressure. They disperse the loads to railway sleepers, ballast and subgrade. The sleepers support the rail and maintain the position of the rail. They are either made of wood, concrete or plastic. The railway ballast forms the track-bed for sleepers, made of crushed stones. It withstands the pressure transmitted by the sleepers and distributes it evenly on the roadbed. The ballast further fixes the position of the sleepers and drains the rainwater around and below the sleepers. The subgrade is the layer underneath the railroad track and is composed of native materials. (Agico Group, 2020)

2.3 Developments of Alpine railway infrastructure since WW2

2.3.1 The war's aftermath in the Alps

The Alpine region experienced short-term attention and appreciation directly after the war. Production sites were strategically located in Alpine valleys where already existing businesses were repurposed. (Kopp, 1969, 481) At the same time, the Alps often seemed to be neglected by the urban centers due to their peripheral location. (Mathieu, 2013)

Especially Austria, France and Italy had to rebuild their industry, infrastructure, finance system and assets after the war. Austria suffered from a humanitarian catastrophe of extreme hunger with its peak in spring 1946. In addition, Austrians had to cope with shortages of industrial raw material. Cooperation with food producers from neighbouring Eastern Europe was put on hold due to increasing tensions between the Eastern and the Western political blocks. Agriculture was only half as productive in the first two years after the war as compared to 1937. (Bischof, 2021) Although the French Alpine region was not as affected as other regions in France, the entire country was standing still. Less than ten percent of the railway network was functioning; many streets and bridges were destroyed. (Pfeil, 2015) Switzerland had not been directly involved in the war hence there was enough food, infrastructure and a functioning banking system enabling many Swiss citizens' assets to remain stable. In the second half of the 20th century, Switzerland was among the wealthiest countries in the world. (Küster, 2020, 184)

2.3.2 The European Recovery Program

The European Recovery Program (ERP), also known as "Marshall Plan", was a program by the United States of America to provide aid for 16 European countries after WW2. War-torn Europe and its economy were largely damaged or destroyed after 1945 (US Embassy in Austria, 2018). The war caused widespread structural damage, dislocations, payment imbalances and shortages arising from human and material destruction as well as scarcities of fuel, housing and food. Also, dollar shortages occurred due to too few exports and too many imports from the U.S. (Machado, 2007, 3)

Since the collapse of the European economy was foreseeable, the ERP aimed to rebuild Western Europe and to foster long-term economic growth. The initiator of the ERP was Secretary of State George C. Marshall, who prioritized the reestablishment of equally wealthy economies within Europe and deemed the linkages between agriculture and industry as well as that between farms and cities vital. (Machado, 2007, 8)

The ERP consisted of investments in tourism, agriculture, electricity- and heavy industry in the form of long-term, low-interest loans. In 1947, George C. Marshall observed that the recovery of Europe's economy had been far slower than expected which endangered the foundations of western civilisation. According to him, aid from the U.S. was of uttermost importance in order to avoid the demoralising effects of hunger and poverty. (Groß, 2013, 3f)

Marshall pointed out that Europe had to take responsibility for setting up reconstruction plans, and that the U.S. would support Europe's efforts by financial aid: "They provide aid to help Europeans help themselves" (Prentzas, 2011, 33) As a result, the OEEC was founded in 1948. With the economically well-developed U.S. as a role model, the OEEC worked on a joint reconstruction plan for Europe. (Groß, 2013, 5) The plans of the OEEC's member states were forwarded to the federal Economic Cooperation Administration (ECA), a U.S. government agency that took the final decision on the allocation quota for the countries. (Prentzas, 2011, 46)

Interest of Americans in the industrialisation of Europe

The ERP was not only a humanitarian program to aid Europe in the aftermath of WW2 but also a political program for U.S. Americans. The U.S. experienced a prosperous economy until shortly before the end of WW2. The per capita GDP increased steadily from

1940 to 1944. (Maddison, 2010) One reason for this development was the transition from a coal-based to an oil-based social-ecological regime. Another one was the participation of the U.S. in the war which enhanced the production of related machineries and weapons. (Groß, 2013, 4) After the war, the GDP per capita decreased until 1947. Concerned politicians in the U.S. believed that financial, fiscal and political stability in Europe should be promoted, accompanied by stimulated world trade, expanded U.S. markets and a multilateral trade world dominated by U.S. economists. Ultimately, the U.S. American depression was forestalled. The ERP helped the Americans to integrate themselves into Europe, reduce nationalism and foster federation in Europe. (Gimbel, 1976, 1) Entering the European market allowed the U.S. to increase their shares in foreign (European) imports. (Haas, 2007, 127)

In addition, the U.S. aimed to create conditions for long-lasting peace, transatlantic cooperation and partnership within Europe on common economic and democratic values. Last but not least, the ERP prevented the Soviet Union from gaining an even stronger influence in Europe. (Haas, 2007, 126f)

Allocation of ERP-funds

The ERP supplied around USD 13 billion in aid between 1948 and 1952, roughly equal to USD 100 billion in 2011 dollars. These funds were used to provide humanitarian aid, finance rebuilding and to increase agricultural and industrial production in Western Europe. Over the period, critically needed materials to kick-start production were made available by the aid scheme. (Prentzas, 2011, 82) The exact amounts identified as having been allocated to the Alpine countries vary among scholars. According to Paul G. Hoffmann, the Alpine countries received economic assistance under the ERP from 1948 to 1952, as presented in Table 2 (not converted into 2006-dollars). The table puts into relation the percentage share of the Alps and the received financial aid, showing that Austria with the biggest Alpine area and the highest share of the Alps received the least amount. France received the most, however, one can assume that due to its small Alpine area the economic assistance was of minor importance for Alpine industrialization. The funds allocated to Italy are likely to be more relevant in that regard, since this country, with almost one fifth Alpine area, received the second highest amount. As mentioned in Chapter 2.3.1, Switzerland was a prosperous state not involved in the war. Therefore, it did not receive funds through the ERP.

Table 2. Alpine area distribution and ERP fund allocation. (The George Marshall Foundation, 1952)

Country	Alpine Area of Country (%)	% of Alps (% out of 220.000 km^2)	ERP funds (Mio. USD)
Austria	73,4	28,7	678,0
France	7,5	21,0	2.714,0
Italy	17,3	27,0	1.509,0
Switzerland	60,9	13,0	none

Technical Assistance Program

Technical assistance was supplied as part of the ERP, with U.S. American businesses sharing their technology and managerial practices with European countries. (Sanford, 1982, 15) This "Exchange of Persons in Industry" was used to increase European productivity and to introduce more efficient methods and organization of production as well as to improve labour-management relations. (McGlade, 2001, 194) Technical Assistance Missions allowed the pooling of practical expertise in different fields, especially agriculture and industry, through the exchange of information and personal contacts between experts of various countries. There were three types of missions, to the U.S. from member countries (Type A Mission), to the member countries by experts from the U.S. (Type B Mission) or to member countries by experts from other member countries (Type C Mission). (OEEC, 1951 a, 2)

The first railroad study (Mission 14) organised by the OEEC, started in September 1950. 12 participating European countries studied U.S. rail transportation methods, techniques and equipment for six weeks. This mission will be further discussed in Chapter 2.3.4. Mission 36 focussed on coal, coke and fuel problems and aimed at the exchange of information between participating countries. Within Mission 69, starting in May 1951, 16 weeks were dedicated to highway improvement. (OEEC, 1951 b, 10-16)

France organised missions on a wide range of purposes. In April 1950, observations and discussions of issues of road construction took place (OEEC, 1951 b, 86). In 1950, a one-year mission started on simplification, standardisation and specialization and in 1951, a six-week mission on railway equipment took place (OEEC, 1951 b, 90-92). Other missions in France were dedicated to electric power, agricultural productivity, steel pipes tubes, fuel and power utilization, heavy electrical machinery manufacturing, hydroelectricity, productivity, small electrical equipment industry, steel and malleable iron foundries, shipbuilding, forestry research, rural engineering, heavy iron and steel industry, road transport, metal mining and plant protection. (OEEC, 1951 b, 82-99). Italy organized missions on agriculture, forest administration, industrial technical publications, organization of geological services and industrial organization (OEEC, 1951 b, 131-140). Austria made use of several missions with different purposes. In April 1950, Austrian experts went to the U.S. to seek aid in modernisation of the Austrian power industry. Other missions focussed on city traffic, forest and agriculture surveys, textile industry, iron and metal ware industry, chemical industry, agricultural electrification and plant preservation. (OEEC, 1951 b, 24-30)

Counterpart funds

The Counterpart Fund, a condition for the participating countries to receive the ERP fund, proved to be of lasting importance. In order to participate, countries had to provide an equivalent in national currency of the value of imports financed under the ERP. This money was deposited in special accounts in the importing countries. The funds could then be used as a supplement to ERP monies as domestic sources of capital. (Miward, 2005, 83). The procedure of Counterpart Funds started with U.S. payments for selected goods and services needed by Western European countries, provided in U.S. dollars. The U.S. requested the recipient countries to deposit amounts equal to the grant expenditures in their national currencies. This amount was then deposited in a special account which was primarily obtained from firms which imported goods and services of the same value. The majority of the special accounts (9/10) was then available for withdrawal by the depositing country for uses approved by the U.S. The remaining 1/10 was set aside for the U.S. to pay for administrative expenditures and information programmes. (Bischof, 2017, 118).

The investments of the ERP counterpart funds by sector are shown in Figure 2. The electricity, gas and power sectors received the biggest share of ERP counterpart funds, followed by the transport, communication, shipping and agriculture sector. The electricity, gas and power sector had difficulties in gaining private long-term capital investment for reconstruction or to finance their own investment. France used the Counterpart Funds mainly for electricity, gas and power (around 40%) and coal mining, mining and quarrying (around 18%). Italy used around 45% for transport, communication and shipping and Austria for transport, communication and shipping (32%). The Counterpart Funds supported government investment in immediate reconstruction tasks such as railways, transport system and the repair of public utilities. (Milward, 2005, 83)

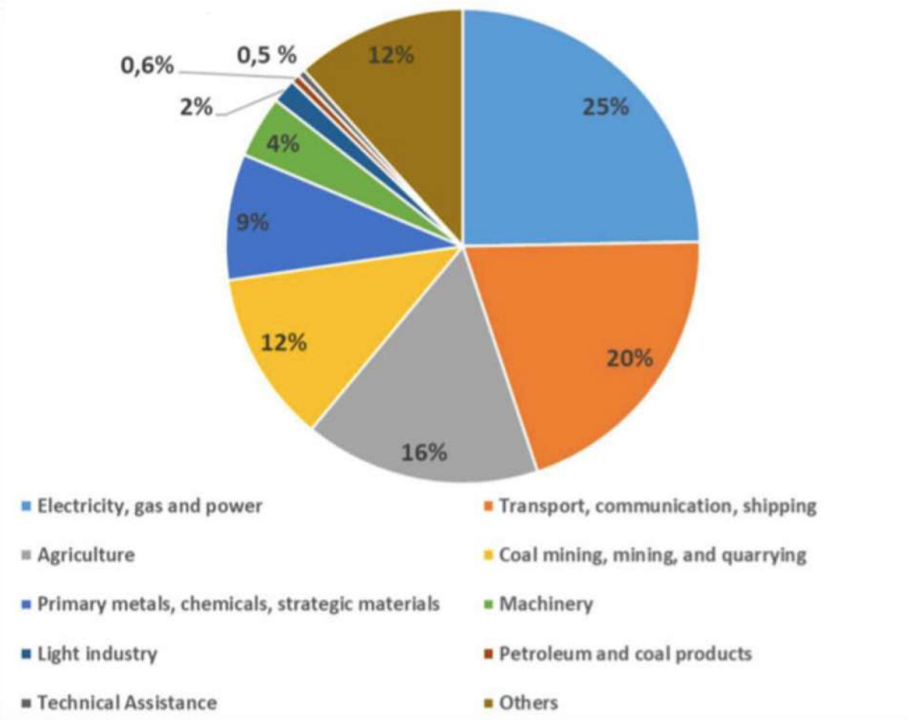

Figure 2. ERP Counterpart Fund allocation by sectors in Europe from 1948-1953. (Groß, 2019)

ERP objectives and their fulfilment

The ERP initiative had four main aims, all of them were at least partially fulfilled. First, the goal of increasing production in Western Europe was fulfilled, since industrial and agricultural production increased in the period between 1948-1951. The second aim was the expansion of foreign trade. This goal was met partially, since trade first rose and then fell after 1949. The object was completely fulfilled a decade after the beginning of the Marshall Plan, when the European Economic Community was created in 1957. Third, the initiators aimed to enhance internal financial stability by reducing inflation, budget deficits and unemployment. This goal was fulfilled at the time of the expiration of Marshall Plan Funding in 1951. The fourth goal was the development of European economic cooperation. This was fulfilled, as a European Payments Union was created, enabling different currencies to become convertible. However, the establishment of the European Union took place over 40 years after the Marshall Plan and cannot be directly attributed to the Plan. The fifth and last goal was the support for Western Europe to re-arm within the framework of an expanding economy. With the establishment of NATO and a conversion of ERP funds into military assistance, this goal was also met. (Gardner, 2001, 121)

2.3.3 The role of the International Railway Union (UIC) in the ERP

During international conferences held in Portorosa in 1921 and in Geneva in 1922, the idea of creating an international organisation that would bring together all railway companies was born (UIC, 2014 a). The international conference that founded UIC took place in Paris in October 1922. The Union had, by 1951, 36 railway administrations as members. Today they have 204 members (UIC, 2014 b). They represented 310.000 kilometres of track, a staff of 3,9 million people and traffic amounting to 237.000 million passenger-kilometres and 266.000 million ton-kilometres in 1951. Their primary aim was the standardisation and improvement of the equipment and operating methods of railways with a view to international traffic. Their priorities were passenger traffic, goods traffic, frontier-transit problems, rolling stock, track equipment, signal equipment, electric traction, staff and organisation questions, statistics, costs and accounting. The main governing body of the UIC was the Managing Committee. Its decisions could either be mandatory or optional and were published as "Memoranda". International developments then caused the UIC to extend the scope of its activities further. They focussed on standardisation, including the interchange of spare parts and the introduction of standard European tracks, general work on future railway practice and the coordination of different forms of transportation. They also fostered unified actions by European railways, putting the UIC into the position as the sole representation of railways with international organisations. The UIC had already had Consultative Status B with the United Nations before 1951. (OEEC, 1951 a, 24f)

Today, according to their self-description, the UIC focusses on passengers (promoting passenger rail as the "green" and customer-friendly mode of transport for the future), freight (harmonising business, operational and information processes to make international freight products and services more competitive), safety, sustainable development, rail systems (creating innovative and sustainable technical solutions for the railway business), standardisation, research, expertise development and security. (UIC, 2014)

2.3.4 Mission 14: "Railroads in the U.S.A. in 1950"

82 experts, divided into eight groups, were sent on Mission 14 in autumn 1950. The Mission was jointly organized by the ECA and the OEEC. (OEEC, 1951 a, 5) From the Alpine countries covered in this work, France and Italy were members of the Mission. (OEEC, 1951 a, 13) Eight different groups were formed for the following objectives. "Mechanical" (wagons, carriages, locomotives, main lines), "Operation" (main lines, yards, terminals, freight stations and motor transport), "Communications and Signals", "Permanent Way and Structures", "Statistical", "Tariffs, Economics and Traffic", "Electrification" and "Manufacturing". The majority of experts was concerned with technical questions surrounding railway activities. "Statistical" and "Tariffs, Economics and Traffics" studied the administration and the commercial policies of American Railroads as well as the overall economic activities of the country. The group "Manufacturing" consisted of experts from railway equipment industries. Every group was accompanied by an escort consultant from the special field of interest. These experts were highly appreciated in their respective fields and aimed to "make the programmes as valuable as possible for each group". (OEEC, 1951 a, 14)

The concluding recommendation by the mission's experts was to conduct a wider study of different subjects undertaken by appropriate inter-European bodies rather than copying the American system and policies on the governmental and railways' level. (OEEC, 1951 a, 15).

Differences between European and American railway systems

Comparing the U.S. American with the European railway system, differences in geography, history, legal and financial backgrounds had to be considered. The geographical characteristics of the continent in terms of distances, heights and others, the role of shipping as well as the supply of raw materials differed between the U.S. and Europe. While U.S. railways played the major role in the transport between mines and industry, shipping was the preferred way for that purpose in Europe. Hence, landbound means of transport - especially railways - played a more important role in the U.S. than in Europe. Also, the construction of most of the U.S. American railways had been taken place through "virgin land", which was actually native American land, to open up territories for settler population and to foster the economic development of the territory through which their tracks had been laid down. (OEEC, 1951 a, 16) These factors led to technical differences in terms of bigger dimensions of rolling stock and heavier axle loads due to motive power and passenger rolling stock (OEEC, 1951 a, 18).

Coordinating and regulating bodies

Prior to the UIC, several coordinating and regulating bodies had already been established in Europe. On the governmental level, the "Office Central des Transports Internationaux par Chemins de Fer" supervised the execution of the Bern Conventions, inaugurated in 1886, for passengers and goods, an international transport law. Further, the Inland Transport Committees of the OEEC in Paris and the European Commission for Europe (ECE) coordinated action between European governments on railway matters until 1950. The "Unité Technique", another governmental body, set up the basic rules governing the running of trains across Europe. These organisations were later supported in the preparation of their work by the "Union Internationale des Chemins de Fer" (UIC) and other railway organisations. (OEEC, 1951 a, 23f)

Possible European developments in the years after the war

The recommendations and suggestions for future European developments, established during Mission 14, entailed the "Coordination of Railway Transport Policies", "the Coordination of Tariff Policies and Establishment of Statistics on Costs and Financial results", the "Coordination of Railway Operating Practices", "Economics of Mechanisation", "Diesel Traction" and the "Coordination in technical, economic and operating matters". For the purpose of this work, the areas "Economics of Mechanisation", "Diesel Traction" and "Coordination in technical, economic and operating matters" will be presented in detail.

Economics of mechanisation and standardisation

In the view of the experts, as long as wages were lower in Europe than in the U.S., the benefits of increased mechanisation could not be as high as in the U.S. who profited from a greater volume of goods required for their home market. The experts considered it more economic to invest large sums in tooling equipment to be able to cut the labour costs. Therefore, machines could be produced more cheaply in relation to wages than was usual in Europe. These benefits were not possible in Europe because the savings were smaller, the time required to pay off the capital costs of the mechanisation equipment was longer and the degree of mechanisation economically justifiable was less. However, any such practices from which economic advantages or greater productivity would result should be considered in Europe. (OEEC, 1951 a, 27)

The mission expert's reasoning went as such: Apart from the immediate effect of labour saving, mechanisation increases the productivity, hereby also influencing the economic prosperity of other industries and of other means of transport. Furthermore, mechanisation promotes standardisation and an increase in production, leading to lower prices of the products. (OEEC, 1951 a, 28) Other advantages are an improved service to the public due to faster work, saving of space and more efficient use of rolling stock. (OEEC, 1951 a, 42) Mechanisation goes hand in hand with industrialisation. Lowering the costs of basic materials and of finished products while increasing the overall productivity of labour and the purchasing power of the whole field can be achieved by the specialisation of industries which can serve one single European market. (OEEC, 1951 a, 28)

Interchangeability and standardisation of design as well as the pooling of orders and a coordinated purchase policy were considered as being preconditions for mass production. To achieve that, the experts on Mission 14 acknowledged that design and pooling should be rationalised within each country and integrated on a European basis. They were convinced that a unified and free market would lead to a higher standard of prosperity. (OEEC, 1951 a, 28) To achieve standardisation, a preliminary plan was drawn up by the UIC. The first stage was to restrict the range of designs for each manufacturer in each country with an unlimited number of common items to meet the requirements of European railways. The second stage were meetings of the railway authorities and representatives of the leading manufacturers to agree on one set of pooled designs or specifications to cover all fields of railway materials. For the last stage, experts planned to develop a common, agreed upon set of designs or specifications among the European countries, organised by the UIC. Furthermore, the formation of an integrated or mass market was considered a requirement to fully reap the economic benefits of rationalised manufacture and mass production. (OEEC, 1951 a, 29) The interchangeability of the spare parts of wagons and of parts such as underframes, roofs and sides should be combined with a co-ordinated purchase policy. (OEEC, 1951 a, 36) Standardisation and a greater cooperation in technical, economic and operating matters were necessary for the UIC members to take a common stand in the economic sphere of European railways. The experts recommended to establish close relations between the Office of Research of the UIC with the railway materials industry, as joint research and development would lead to maximum progress on European railways. (OEEC, 1951 a, 31f)

Dieselisation

With conventional diesel locomotives, the horsepower generated in the diesel engine is transmitted to the wheels by mechanical transmission. In the case of diesel-electric locomotives, this is done by electric transmission. (Satish, 2013, 437)

The idea of replacing steam engines by diesel engines was one of the key technical outcomes of Mission 14. The two main advantages of the switch considered were fuel savings and the availability of diesel oil. (OEEC, 1951 a, 30) In contrast to Europe, the U.S. benefited from an abundance of oil at the time. European countries generated the electricity either from coal deposits or from new developments in the area of waterpower resources. In the 1950s, the relative prices per unit weight of home-produced coal and imported oil in most European countries were as favourable to oil as in the U.S. When oil is used in diesel locomotives, it has a much higher thermal efficiency than either coal or oil in steam locomotives. (OEEC, 1951 a, 31) One big advantage of diesel engines lies in the interchangeability of small, incorporated parts. This leads to a high availability of the diesel engines but also of the electrical equipment and power bogies or trucks through which power is transmitted universally. Electrical controls enable the coupling of units to form powerful locomotives controlled by single crews. Even if the initial capital costs were high, the high availability obtainable from diesel-electric locomotives could be usefully employed in particular circumstances. (OEEC, 1951 a, 38)

Rail electrification

The European layout of the railway systems and the economic situation were favourable to railway electrification, hence Mission 14 experts recommended that countries should carry out large-scale electrification programmes and seek schemes for the cheapest equipment to maximize the advantages of electrical traction. Some features of the American electrification technique were considered a role-model for the European process. Among them was the almost standard system of interconnection between the sources of power production. As a consequence, railroad companies which generated their own current became rarer. The universal use of remote control for power distribution sub-stations was another issue considered, allowing manpower to be saved. Technical details such as the general use of single-anode rectifiers, standardisation of traction motors rated at 500 H.P. and a high-quality standard in the mass production of generators and traction motors could also serve as examples of the standardization issues discussed for electrification. (OEEC, 1951 a, 51)

2.3.5 Long-term effects of the ERP until 2021

European cooperation

As mentioned in Chapter 2.3.3, the UIC had existed since 1921. A few joint facilities between European countries had been established by the end of WW2. Among them were the "Brenner Route #44" between Austria and Italy, "Buchs/St. Gallen Route #1" between Austria and Switzerland, "San Candido Route #114" between Austria and Italy and "St. Margarethen Route #48" between Austria and Switzerland. (Austrian Railway Systems, 1949, 1) However, the European Cooperation on Railway Transport gained momentum only after WW2.

Trans Europ Express (TEE)

In 1957, the UIC decided to include a modernization strategy of international freight transport into their programme and created an international body called "Groupement Trans Europe Express". The trains were collectively called "Trans Europ Express" (TEE) and had to fulfil several requirements. Apart from power and speed requirements, they had to fulfil common regulations governing signs, itineraries and the livery of trains, public address systems for the communication with passengers and lastly, a schedule that was of maximum convenience to traveling businessmen and women. In order to strengthen the competitiveness of rail in cross-border freight traffic, TEEs should have particularly short journey times and, later on, establish the connection of European production and consumption centres with uniform speed maxima. The initiative was successful, as the length of TEEM-connections increased from approximately 32.000 to 141.000 within 10 years. (Hassel, 2016, 4ff) The Groupement represented inter alia the French, Swiss and Italian railway administrations. Their aim was to prevent the encroachment of air transport and to connect business centres by rail over the main European traffic arteries. Figure 3 shows how the TEE connected relevant production and consumption centres, especially in France, Italy and Switzerland. From 1964 onwards, the TEE served the most economically active areas within the Common Market and Switzerland. (Chapman, 1968, 286) The TEE mainly served first class travellers. In 1987, the EuroCity started offering also second-class coaches (Show me the Journey, 2021).

Figure 3. The route network of Trans Europ Express in 1965. (Chapman, 1968, 285)

Trans-European Transport Network (TEN-T)

The TEN-T with its policies was established together with the Maastricht treaty in 1996. Its aim is to improve economic and social cohesion by connecting peripheral with central regions in Europe by land, air, sea and inland waterways. The network developed guidelines covering the objectives, priorities and identified projects in “common European interest”. (Eurostat, 2018) Article 13 of the Regulation 1315/2013 sets the priorities for railway infrastructure development. It includes the common migration to a uniform nominal track gauge, the mitigation of impacts of noise and vibrations caused by rail transport, the enhancement of interoperability and an improved safety of level crossings. (EU, Ch. 2, Section 1, 2013)

Two networks were designed with this regulation to improve the use of infrastructure, reduce environmental impacts of transport, enhance energy efficiency and increase safety. The Core Network, to be completed by 2030, includes all main connections between important nodes. The Comprehensive Network will cover all European regions and will be completed by 2050. (EC, 2021) In 2018, a proposal for a regulation of the European Parliament and of the Council on streamlining measures for advancing the realisation of the trans-European transport network was published. The proposal emphasises the importance of the timely completion of the TEN-T, which faces delays and uncertainties due to "suboptimal organisation of permit granting procedures and difficult regulations of the existing legal framework" (European Commission, 2018). Streamlining the measures should accelerate TEN-T completion by changing existing instruments (e.g., by developing a series of guidelines), by implementing a limited binding action at national level and defining an EU framework for authorisation of TEN-T core network projects. (European Commission, 2018) Currently, within the Ordinary Legislative Procedure, the Council's 1st reading position is awaited. (European Parliament, 2021).

European Union Agency for Railways (ERA)

The ERA was founded by the EU in 2004 as an "engine for change driving the Single European Railway Area" (SERA). It was set up with the task to harmonise railway safety, remove technical barriers by devising the technical and legal framework, and improve accessibility and use of railway system information. It is to act as the European Authority under the 4th Railway Package. This package, which issues vehicle type authorisations and safety certificates, contains changes in order to improve the functioning of a revitalised SERA without borders. (European Parliament, 2016) One important achievement of the Agency was the creation of an One-Stop Shop (OSS) in 2019. An OSS is defined as one single establishment where many different services or products are available (Collins English Dictionary, 2021). In this context, the OSS by ERA should serve as the future single European entry point for applications for single safety certifications, vehicle type authorisations and track-side approvals. "Single safety certificates" serve as evidence for the establishment of a safety management system which complies with of the agency's legal obligations. All railway undertakings who aim to operate on railway infrastructure within the area the EU have to apply for such a certificate. (ERA, 2019)

Standardisation

The UIC has played an important role in the standardisation of the design, construction, operation and maintenance of railways. In 1951, the "EUROP Wagon Pool" was established which aimed to bring together the railways of France and Germany and then expand to include more networks and sleeping carpools. (UIC, 2021) In 1957, the UIC had the aim to allow crossing borders of European countries that had used different kinds of voltages and current types. The UIC started using special trainsets and electric locomotives that were capable of operating at two or more different voltages. By 1975, 41 out of 43 TEE trains were electrically powered. (Cook, 1975, 69)

In 1978, the responsibility of two international agreements on freight and passenger traffic (RIV and RIC) was gradually transferred to the UIC. All activities within these agreements (including technical, operational and legal measures) are aimed to simplify and streamline the running of these RIV and RIC unions. (UIC, 2021) In the 80s, a European Rail Traffic Management System (ERTMS) was discussed for the first time. Limited to high-speed rails, the EC Directive 96/48/EC introduced the concept of an interoperable control and command system in 1996. In 2006, the same idea was established for conventional rail systems in the EC Decision 2006/679/EC. In 2012, both high-speed and conventional systems were merged within the Commission Decision 2012/88/EU. (European Commission, 2021)

The role of railway standardisation has changed throughout the years, mainly as a consequence of liberalisation and the establishment of the SERA. In 2014, the UIC founded the "Rail Technical Strategy Europe" (RTSE) as a key part of the "Challenge 2050", which highlights how the interoperability of European Trains should look like by 2050. (UIC, 2016, 4) The RTSE comprises the following elements: Control Command and Communication, Infrastructure, Rolling Stock, Energy Supply and Consumption, Information Management, Railway People, Security and Safety (UIC, 2014 c, 4).

According to the UIC, two types of railway standards exist today. The first type are process-related standards that are general application principles used for a wider range of stakeholders within the railway system. These entail functional and system requirements for specific processes, such as key safety and quality criteria methods for braking performance. The second type, product-related standards, contain functional and system requirements for specific technical components, such as key safety and quality criteria for brake blocks or discs. (UIC, 2016, 11) The following bodies have prominent roles in the standardisation process. (1) The ERA as the enabling agency to assist the EU and the member states in implementing directives, (2) the European Standardisation Organisation (ESO) responsible for preparation, publication and marketing of norms as well as (3) the UIC as the standard setting organisation. In publishing so-called "Leaflets" (today known as International Railway Solutions), the UIC has constantly been improving standardisation processes. The leaflets define common rules to ensure safety and efficiency in the design, construction, operation and maintenance. (UIC, 2016, 12) The four Alpine countries use the same "Standard" Track Gauge of 1435mm, defined as the distance between the inner faces of the rails, allowing interconnectivity between Austria, France, Italy and Switzerland (Marian, 2021).

Electrification

Within the investment program of the Austrian Federal Railroads, approximately 660 million Schilling (ATS) were invested in rail electrification in Austria from 1950 to 1952. In comparison, only 18,1 million ATS were invested in the electrification of roadways and structures. (Seidler, 1950 a, 2) According to a report, this investment seemed to be economically beneficial since the operation of electric locomotives cost only half as much as heavy diesel locomotives (the latter cost an average of 21,05 Schillings for 1000 metric gross ton kilometres operated, while electric locomotives cost only 10.62 Schillings for the same distance). (Seidler, 1950 b)

The following arguments were brought forward in favor of electrification over dieselisation. The investment for the purchase of diesel locomotives and construction of facilities for the shipment, storing and handling of diesel fuel as well as the comparably higher cost of repair were larger than the purchasing and maintenance cost of electric locomotives. Generally, the gross investment needed greatly depended on the length of the line, its inclination and on the amount and degree of curvature. The economic viability of electric operation also depended on the traffic density of individual lines. On long but not heavy frequented lines, electrical operations were expected to be less economical. This limit was "definitely lower in Central Europe than in the United States" (Seidler, 1950 b, 18), especially on mountainous railroad systems. Thus, the electrification program in Austria included only heavy frequented basic long-distance mainlines and lines carrying heavy local and commuter traffic. (Seidler, 1950 b, 18ff) The introduction of electric motive power faced serious technical impediments due to the variety of currents being used in areas with different geographical characteristics. (Chapman, 1968, 286) At the same time, European electrification projects focussed on mountainous regions for several reasons. Firstly, coal supply did not meet the demand for steam locomotives due to coal shortages during WW2. Secondly, hydroelectric power was abundant and thirdly, electric locomotives provide more traction on steeper lines. (Frey, 2012, 43) In Switzerland, electric trains capable of operating efficiently on four distinct types of direct and alternating currents were implemented in 1961. France joined three years later with the development and operation of trains powered by polyphase alternating current engines. (Chapman, 1968, 286) The SNCF of France, the national state-owned railway company, found that the performance of alternating current was sufficiently developed to allow all its future installations to be of this standard. This decision was influential in the standard selected for other European countries. (Frey, 2012, 43f)

As of 2017, 60% of the European railway lines were electrified. (European Commission, 2017, 14) As illustrated in Table 3, the share of electrified rails in three out of the four selected Alpine countries lie above the European average. The first column shows the total length of the railway network, the second one the length of electrified lines as of 2018 and the last one the percentage share. The data have been calculated and visualised with the UIC Statistics tool "Railisa" via https://uic-stats.uic.org/. The table also shows that, as of 2018, Switzerland had by far the biggest share of electrified lines in their rail network. With 58,8%, France had the smallest share.

Table 3. Share of electrified rails in chosen Alpine countries. (UIC, 2019)

Country	**Rail System length (km)**	**Electrified (km)**	**Share (%)**
Austria	4.955	3.560	71,8
France	28.241	16.627	58,8
Italy	16.780	12.018	71,6
Switzerland	4.046	3.646	90,0

2.3.6 Status quo: The call for high-speed rails

High-speed rails are different from other rails in terms of speed and technology. The European Council defined lines equipped for speeds generally equal to or greater than 250 km/h or 200km/h, depending on the infrastructure as high-speed. (Brunello, 2018, 9) The importance of such rails has increased during the last decades. Capacity and speed have been the main motivations for the development. With much higher average operating speeds than before, railways can compete with air transport and, due to new standard gauge lines, larger rolling stock had become possible. Other objectives in the development of high-speed rails for France and Italy are prestige, political integration and supporting the supply industry. However, both countries did not see environmental betterment as an objective. (OECD/ITF, 2014, 16f)

High-speed rails are environmentally beneficial as they emit a reduced amount of greenhouse gases per ton-km compared to conventional rails. However, environmental issues along the routes include noise, vibration, land use and its impact on biodiversity and water courses, severance and visual intrusion. (OECD/ITF, 2014, 20) These factors will be presented in Chapter 3.

In Austria, the most modern high-speed train is the Railjet with a top operational speed of 230 km/h. It connects not only all of Austria, but also neighbouring countries, inter alia Italy and Switzerland. (OEBB, 2021 c) All of their high-speed trains are powered by electricity produced using renewable energy. (Railjets, 2021) The TGV is the high-speed train operating in France. It has a maximum operational speed of 320 km/h and connects France with neighbouring countries, amongst others Italy and Switzerland. (Eurail, 2021) Italy's high-speed train is called "Alta Velocità" and runs at a maximum operational speed of 300 km/h. Lines connecting Italy to other European countries are currently under construction or merely planned, inter alia the connection between Turin and Lyon, discussed in Chapter 3.3.1 "Current railway projects". (Italiarail, 2021) In Switzerland, the domestic high-speed train is the "InterCity Neigezug", running within the Country. The ICE, RailJet, EuroCity and TGV connect the four Alpine countries discussed. (Interrail, 2021)

Table 4 shows the percentage of high-speed railways in the respective rail networks in the chosen Alpine countries. The first column illustrates the total kilometres operating as high-speed lines as of 2020. The second column presents the length of high-speed lines under construction or planned in the future. The third is the sum of the two and the last is the percentage share of the total rail network in the respective country.

Table 4. High-speed railways in the selected Alpine countries. (UIC, 2020 b)

Country	High-speed rails in operation (km)	High-speed rails under construction/planned (km)	Total (km)	Share of total network (%)
Austria	254,0	351,0	606,0	9,8
France	2.734,0	1.725,0	4.459,0	14,9
Italy	921,0	327,0	1.248,0	7,4
Switzerland	144,0	15,0	159,0	2,9

Table 4 shows that in case of high-speed lines, France is in the leading position and Switzerland has the lowest percentage. This is opposite to Table 3, as Switzerland has the biggest and France the smallest share of electrified lines.

3. Environmental impacts of railway infrastructure

This chapter is dedicated to the environmental impact of railway infrastructure. First, the indicators used for this purpose are presented and applied on the basis of the infrastructure's life cycle. Then the environmental impacts in Austria, France, Italy and Switzerland are presented based on currently implemented railway projects. Finally, this chapter compares railways to other means of transport (road, aviation, maritime navigation).

3.1 Indicators for the environmental impact assessment

The relevant indicators for the analysis of environmental impacts of railway infrastructure are Primary Energy, Carbon Dioxide (CO_2), Particulate matter (PM_{10} and $PM_{2,5}$), Non-Methane volatile organic compounds (NMVOC) and Nitrogen oxides (NO_x).

Measured in MJ-equivalents, Primary Energy describes the direct energy consumed during train operation. It includes upstream energy production processes and losses from electric power generation and distribution. The combustion of coal and diesel-oil will be highlighted in Chapter 3.2.3. as one important part of the primary energy demand. Measured in grams per m^3, the emission of CO_2 results from the combustion of fossil fuels. Together with other greenhouse gases, CO_2 significantly contributes to the anthropogenic greenhouse effect which causes the currently observed change of climate and heating up of the atmosphere. The consequences for humans and the environment are to be strongly emphasised yet will not further elaborated in this work. Measured in grams per m^3, PM includes all airborne solid or liquid particles with aerodynamic diameters from 2,5 ($PM_{2,5}$) to 10 (PM_{10}) micrometres. They can originate from natural sources such as pollen, and a variety of anthropogenic sources such as combustion or abrasion. PM poses a serious risk for human respiratory and cardiology apparatus. Measured in grams per m^3, NMVOC are organic materials that are volatile. They exist in gaseous form at ambient temperatures and are emitted into the atmosphere, being responsible for tropospheric ozone ("summer smog"). Further, some NMVOC are carcinogenic substances. Measured in grams per m^3, NO_x is a mixture of the two gaseous oxides of nitrogen. There are two different oxidation states of nitrogen and nitrogen-oxygen compounds, which can occur in different proportion, hence the abbreviation NO_x. NO_x is formed whenever nitrogen is exposed to oxygen under external energy input, mostly during combustion processes. (Tuchschmid, 2011, 5-7)

3.2 Environmental impact analysis on the life cycle of railway infrastructure

Environmental consequences of rail infrastructure depend strongly on the specific conditions of the respective locations. Therefore, specific impacts in the Alpine countries are presented in Chapter 3.3.1 "Current railway projects". Chapter 3.2. outlines the general environmental impact of rail infrastructure, including both intended and unintended effects.

The European Commission decided that the year 2021 should be dedicated to rails. They are considered a sustainable, innovate and safe means of transport and should contribute to a reduction of greenhouse gases caused by the transport sector within the EU by 90% until 2050. Moreover, rails should enable the EU to become a coherent and functioning network with a strong political cooperation. (European Commission, 2021 b) However, there are relevant environmental side-effects that accompany railway infrastructure. To assess the environmental impact, the following indicators are chosen by the author. CO_2 with its global warming potential, PM_{10}, NMVOC and NO_x, described in detail in Chapter 3.1. The system boundaries are the construction of rail infrastructure and of rail vehicles, traction and power generation. Furthermore, noise, land-use, ecosystems and chemical contamination are presented. At the end of the chapter, an overview of the environmental impact of Alpine railway infrastructure is presented.

3.2.1 Construction of rail infrastructure

To level the underground and to build a foundation layer of gravel and sand, earthwork is needed. Especially in mountainous regions like the Alps, bridges and tunnels are important. The construction of bridges involves concrete, steel and excavated earth as construction material, the transport of the material to the site and the energy for the construction. Mining and open-pit are two different methods for tunnelling, with the first method involving drilling and excavation of material. For the construction of open-pit tunnels, the earth above is removed for the construction and filled back in afterwards. Both processes also involve construction material, the transport of the material to the site and the energy for construction.

Sleepers are cross braces supporting the rails on the track that are either made of wood, concrete or iron. Another form is closed lanes or ballast slabs. In that matter, the construction material, transport to the site and the disposal are important processes. The rails, as the most important part of the track, are all made of high-quality steel alloy. There are different types of rails, with "UIC 60" as the European manufacturing standard. The speed of the trains depends on the weight of the rails - the heavier they are, the faster the trains can run. The current for electric locomotives is collected by overhead systems that consist of concrete- or iron masts, catenaries and wirings. Signalisation and communication are essential for the safe operation of the rail tracks since they inform the train-driver if the section is free. The ETCS of high-speed lines have become the standard in Europe. Railway stations, stops for local trains, stops for freight trains, sites for freight trains, sites for maintenance/repairing and transformer substations are relevant parts of the railway infrastructure. (Tuchschmid, 2011, 19-27)

Table 5. Emissions from different phases of railway infrastructure construction. (Tuchschmid, 2011, 19-27)

Indicators	**CO_2**	**PM_{10}**	**SO_2**	**NO_x**	**NMVOC**
Tunnel, double track (t/y*km)	475.585	723,36	703,49	1.065,99	173,3
Rails, UIC 60, double track (t/y*km)	12.180	36,58	26,87	27,60	4,37
Earthwork, new double tracks) (kg/y*km)	9.791	10,51	15,94	110,78	16,11

Table 5 presents the most- and least emission intensive processes during the construction of rail infrastructure, based on Tuchschmid's calculations. For simplification, the emission during other phases (construction and maintenance of relevant buildings, signalisation and communication, bridges, sleepers, masts and overhead wirings) are excluded. It shows that the construction of tunnels is the most emission-intensive process in the construction of rail infrastructure for all indicators. The second most important source for all indicators is the construction of rails. The least emission-intensive source for CO_2, PM_{10}, SO_2 and NMVOC is the earthwork.

3.2.2 Construction and maintenance of rail vehicles

Tuchschmid analysed local-, intercity-, high-speed- and freight trains. For comparison, he assumes that a train with double weight also has double impact. All four types have a lifespan of 40 years. (Tuchschmid, 2011, 28) Table 6 presents the least- and most emission-intensive train types. If the indicators are measured in kg/y*unit, it seems as if emissions from high-speed trains are inordinately large. If, however, the emissions are measured in g or mg per gross ton kilometre (Gtkm), the opposite is the case, illustrated in Table 7. Gtkm is a commonly used measurement for the efficiency of a railway system. The difference makes it clear that the construction and maintenance of a high-speed train is the most emission-intensive yet its impact per Gtkm is the lowest. The impact from the construction and maintenance of freight trains is the highest for all indicators except for NMVOC.

Table 6. Impact from construction and maintenance of train vehicles in kg/y*unit. (Tuchschmid, 2011, 28)

Indicators	**CO_2** (kg/y*unit)	**PM_{10}** (kg/y*unit)	**SO_2** (kg/y*unit)	**NO_x** (kg/y*unit)	**NMVOC** (kg/y*unit)
Regional train	8.982,0	17,01	42,31	24,08	9,6
High-speed train	95.768,0	78,7	252,5	172,5	144,6

Table 7. Impact from construction and maintenance of train vehicles in g or mg/Gtkm. (Tuchschmid, 2011, 28)

Indicators	**CO_2** (g/Gtkm)	**PM_{10}** (mg/Gtkm)	**SO_2** (mg/Gtkm)	**NO_x** (mg/Gtkm)	**NMVOC** (mg/Gtkm)
High-speed train	0,288	0,237	0,761	0,520	0,435
Freight train	0,623	1,428	2,099	1,456	0,423

3.2.3 Traction and power generation

In general, approximately 85% of total energy consumed by the rail sector is used directly as traction energy, including catenary losses of 5-10%. The remaining 15% is used for workshops, buildings, signalling and others. (Ledbury, 2015, 15) While having a market share of over 8,5%, rail transport consumes less than 2% of the total energy used for the transport sector. It is the only major transport mode than can function independently from fossil fuels since using electricity allows a range of renewable power sources.

Transport is one of the three crucial sectors where action is needed for using less and cleaner energy and reducing its negative impact on the environment in order to meet the long-term energy goals. The EU envisages to increase the share of renewable energy to 27% and to save 30% of energy compared to 2007. From 2005 to 2010, the EU railway sector has doubled the share of renewable energies, reduced its dependence on coal and coal products and oil products. The EU aims to reduce the oil use in transport by 70% by 2050 from 2008 levels. (Ledbury, 2015, 11-15)

A coal-powered steam locomotive with 1.500 horsepower consumes 1,5 tons of coal per hour when moving on level ground. In mountainous regions, it needs twice as much. (Ziegler, 2019) The combustion of coal produces CO and SO_2. CO poses, due to its soporific and suffocating effects, a risk to humans and the environment. It is very short-lived and changes quickly into CO_2. Further, coal has a poor ecological value since it releases several emissions, including greenhouse gases, when being extracted from the ground. (Erstfeld, 2014) Diesel oil is a substance obtained from crude oil during distillation. It consists of hydrocarbons. (Erstfeld, 2014) CO_2, CH_4, CO, NOx, N_2O, SO_2, NMVOC, PM and HC are the main pollutants emitted from diesel-powered locomotives during combustion. (Silva, 2017, 83) Yet also when exploited, extracted, processed and transported, crude oil pollutes the environment. Furthermore, for the infrastructure required for the production and transport of crude oil, forests are often cleared, and coastal regions are destroyed. (Greenpeace) On average, a diesel locomotive consumes 300 liters diesel per 100 km (Paribus Capital GmbH). According to a calculation by Ecoscore, 2640 grams of CO_2 per liter diesel are emitted, corresponding to almost 800 kilograms per 100 km (Ecoscore, 2021)

Electric rails, if powered by renewable energies, can operate without causing any emissions. As mentioned in Chapter 2.3.5, between 58% and 90% of the rails in Austria, France, Italy and Switzerland are already electrified. However, as illustrated in Table 8, the source of electricity plays an important role with regard to emissions. (Drawdown, 2021) The table presents hydropower as the least emission-intensive form to generate electricity and hard coal as the one with the biggest impact. One can see that the 247-fold amount of CO_2 is emitted when using coal instead of hydropower.

Table 8. Impact from different electricity sources per kWh. (Tuchschmid, 2011, 29)

Indicators	**CO_2** (g/kWh)	**PM_{10}** (mg/kWh)	**SO_2** (mg/kWh)	**NO_x** (mg/kWh)	**NMVOC** (mg/kWh)
Hydro-power	3,8	15,7	5,7	13,9	2,5
Hard coal	986,5	82,9	910,0	981,0	65,1

In Austria, more than 73% of the electricity used in the railway system was produced from hydro- and renewable energy in 2019. In the same year, 20% of the French electricity came from hydro-and renewable energy and 71% from nuclear energy. Italy produced approximately 64% of its electricity from fossil energy and 36% from hydro- and renewable energy while 62% of Switzerland's electricity was produced from hydro-and renewable energy and 36% from nuclear energy. (IEA, 2021) However, as mentioned in 3.1.1, the electricity-mix for rail operation makes a crucial difference in terms of emissions. For instance, both in Switzerland and in Austria more than 90% of the rail-electricity are generated from hydropower in 2020. (SBB AG, 2020, 45; OEBB, 2020 b, 42)

As already mentioned, rail is the major mode of transport that is able to shift from using fossil fuels to renewable energy without the need for further technological innovations. However, massive investments in infrastructure are required to electrify the entire European rail network. If the EU reaches its goal of full decarbonisation by 2050, rail becomes the first zero-carbon transport mode. Additionally, since railways are often the biggest users of electricity in a country, the choice of source can influence far-reaching purchase decisions and encourage investments in green forms of energy production. (Ledbury, 2015, 21f)

3.2.4 Further environmental effects

Noise

Railway operation causes noise pollution in form of airborne sound and/or vibration. There are three major sources for noise emissions by rail: up to 80 km/h, the engine's sound is predominant. Between 90 km/h and 270 km/h, the wheel sound is relevant and above 300 km/h, the wind sound of high-speed trains is the most important noise source. In addition, sounds of brakes, curves, uneven rails and ventilation play a role in noise emissions. (AC, 2007, 101) In mountain areas, noise cannot travel as far as in flat areas. The effect of the noise generated by trains in mountainous areas is higher in valleys, when valley width is less than the height of the mountains surrounding it. In addition, frost can make the ground hard and impede sound absorption while fog prevents noise from dissipating. (Silva, 2017, 82) Data from studies in Switzerland show that - in the case of the Gotthard line - at night-time noise is dominated by the higher frequency of freight trains and their double length compared with passenger trains. Freight trains are more responsible for rail noise also during the day, even if passenger trains pass more frequently. (Alpine Convention, 2012, 101)

Even though all major modes of transport are responsible for noise pollution, roads affect by far the highest number of people. Table 9 presents results from a study conducted by the EEA in 2007, concluding that road traffic noise in urban Swiss areas affected six times as many people as rail traffic. Further, the study shows that the perceived noise pollution of road traffic varies noticeably during day and night while it is almost constant for rail traffic. The levels 55 dB during the day and 50 dB at night are threshold levels for excess exposure defined by the EU. (Ledbury, 2015, 33)

Table 9. Noise pollution caused by road vs rail traffic. (Ledbury, 2015, 33)

	Levels > 55dB during day (million people)	Levels > 50dB during night (million people)
Road traffic	68	48
Rail traffic	10	8

Noise caused by rail infrastructure and rail surroundings can be mitigated in several ways. Welded long rails, grinding techniques of rail heads, noise absorbers and concrete sleepers as well as noise barriers can reduce noise emissions. Quiet braking technologies and brake blocks made out of composite material enable combating noise directly at the source. Newly developed "whisper brakes" can halve the rolling noise for the human ear. In Austria, all freight wagons operated by the ÖBB subsidiary Rail Cargo Group will be using the quiet brakes by the first quarter of 2021. In Switzerland, all loud wagons were banned in 2020. (Transport WG, 2019, 51)

Land resources

Generally, transport networks add to the fragmentation and degradation of habitats due to the barrier effect of infrastructure. Technological developments such as the extension of basic transport infrastructure can take up land resources and therefore result in their degradation. (European Parliament, 2009, 9)

However, road transport is the largest consumer of land within the transportation sector, being responsible for 93% of the total area of land used for transport in the EU, while rail traffic only takes 4% of land. The ratio between land used and the traffic carrying capacity of the infrastructure, the so-called "land-take efficiency" is 3,5 times as high for road transport than for rail per passenger-kilometre. That is due to the higher throughput of people in a given unit of time, especially with high-speed rails. This type of rail uses approximately 3,2 ha/km while an average motorway uses 9,3 ha/km. The impact can further be reduced if new rail lines are laid parallel to existing motorways. (Ledbury, 2015, 23f) For instance, the high-speed line between Paris and Lyon occupies as much space as the Paris airport at Roissy. In addition, railway corridors are narrower than the those of roads, implying a lower loss of habitats. (Barrientos, 2017, 5f)

Ecosystems and biodiversity

Rail corridors can be a hazard to ecosystems and can be responsible for the loss of biodiversity. Ecosystems can be degraded by land consumption, landscape fragmentation, barrier effects and emissions. With the expected spatial expansion of passenger and freight rail transport, the risk to biodiversity is growing. Many critical services within the rail infrastructure depend on healthy ecosystems, such as soil stabilisation, flood attenuation, visual screening and carbon sequestration, hence it is in the rail infrastructure managers' interest to enhance biodiversity conservation on railways and thereby these important services. (UIC, 2020 a) Wildlife can further be directly affected by collisions with trains, electrocution, wire strikes and rail entrapment (Barrientos, 2017, 11). It has to be noted that trains endanger not only small animals. Bears are a common carnivore killed by trains in Central Europe, several train accidents with bears were reported in the Abruzzo mountains in Italy. (Santos, 2017, 14) In the Swiss Alps, the collisions with trains or cars were the third most relevant cause of mortality among eagle owls, amounting to 30% of the anthropogenic mortality. (Santos, 2017, 17)

Chemical contamination

Several chemical contaminants arise during the lifecycle of railway infrastructure. Potential contaminants are pesticides, such as biocides and herbicides, which are commonly used to treat railroads. (Rails to trails conservancy, 2021) Biocides are used to impregnate sleepers made of wood. Used in biocides, creosote is a mixture of numerous compounds and contains polycyclic aromatic hydrocarbons, which are classified as persistent, bioaccumulative and toxic by the European Chemicals Agency. As mentioned in Chapter 4.2, where different environmental regulations are presented, the European Union established a regulatory framework for the use of biocides to protect humans and the environment from harm. (Pfabigan, 2015, 89) Furthermore, the high demand for the operation of railway tracks can only be met if the ballast bed is free of vegetation in order to mitigate any danger to railway operation. (Müller, 2001, 3) The NGO "Global2000" argues that herbicides contribute either directly or indirectly to insect mortality. They either kill them directly when applied or cause reduced vitality, reproduction and orientation and increased their susceptibility to diseases. (Global 2000, 2020, 12) Conventional herbicides are still the most cost-efficient and effective method of vegetation control on railway tracks. (UIC, Institute for Future Studies and Technology Assessment, 2020, 2) In their strategy on the Future of Vegetation Control, the UIC aims to progress from this single-method-based concept to an integrated, flexible, multi-method-based approach with alternative, herbicide-free methods. The UIC has defined an acceptable degree to which the presence of vegetation can be tolerated, depending on the track category and priority, requirements for track quality and actual operational patterns. (UIC, Institute for Future Studies and Technology Assessment, 2020, 3)

For many decades, asbestos was used as brake and clutch lining for railways. The mineral is a carcinogenic substance that breaks down into small fibres that continue to split lengthwise and are thus easily inhaled. This poses a health risk to workers along the train infrastructure. (EUR-Lex, 2009) The time span between exposure to asbestos and diagnosis of cancer is 20-50 years. (Selby, 2021) As mentioned in Chapter 4.2, the European Union established a directive prohibiting activities during which workers are exposed to asbestos.

Other contaminants can be coal ash, containing lead and arsenic, spilled or leaked liquids such as oil, gasoline and fossil fuel combustion products. Further points of origin for contamination are air compressors, transformers and metals. (Rails to trails conservancy, 2021)

3.3 Environmental effects of Alpine railway infrastructure

3.3.1 Current railway projects in Austria, France, Italy and Switzerland

This chapter discusses place- and project- specific impacts, while Chapter 3.2. gave an overview regarding environmental consequences of railway infrastructure in general.

The reader is introduced to railway projects that are either currently planned, under construction or have recently been finished. It will elaborate the particular environmental impacts in the areas where they are established.

Figure 4 shows the location of the presented projects. The Semmering base tunnel lies between the Austrian cities Vienna and Graz. The three base tunnels Lötschberg, Gotthard and Ceneri are located in Switzerland. The Mont Ceneri base tunnel is situated at the French-Italian border, halfway from Lyon to Turin.

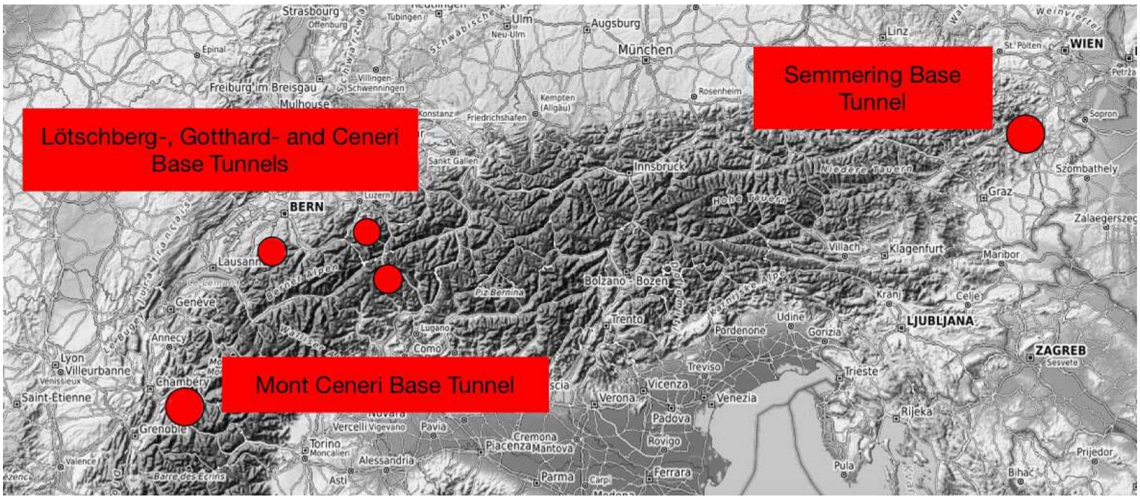

Figure 4. Major railway projects under construction or planned in the Alps in 2021 (OpenStreetMap, 2021) with illustrations in red added by author.

Mont Cenis base tunnel/Turin-Lyon high-speed railway (France/Italy)

Overview of the project

The high-speed railway line between Turin and Lyon is designed to cross the Alps and the Susa Valley, located at the border between France and Italy. Planning started in 1999, the project has since been continuously updated and redesigned. (Zucchetti et al., 2016 ,142) It is part of the TEN-T network. However, it has faced strong opposition by the population and the local authorities of the Susa Valley. They do not only highlight the environmental consequences of the project but also the high costs which to them do not seem to be in relation to the benefits deriving from the line. (Debernardi and Grimaldi, 2011, 9)

The project intends to construct a 65-kilometre-long cross-border section from Susa to Saint-Jean-de-Maurienne through the Mont Cenis tunnel. It aims to "control road transport and promote alternative modes of transport on the Italian-French border (given that transalpine goods traffic has doubled over the last 30 years); encourage commercial exchanges along the Italo-French axis with the European TEN-T network through the Mont Cenis tunnel; strengthen Turin's railway freight hub; develop the underground (metro) service in the city, with neighboring territories and the airport for passenger traffic." (FS Italiane Group, 2021)

The total investment for the tunnel is € 8,6 billion, co-financed by the European Union (40%), Italy (35%) and France (25%). The construction of the 57,7km long Mont Cenis base tunnel, enabling the line to cross the mountain massif at the border, started in 2018 and is planned to be finished by 2029. A cost-benefit analysis was conducted in 2012, estimating an annual reduction of greenhouse gas emissions of approximately three million tons of CO_2 equivalents and the transfer of one million heavy goods vehicles from road to rail. (FS Italiane Group, 2021)

Affected Area

The Susa Valley is the widest valley in the Western Alps and is recognised as a Site of Community Importance (SCI) by the European Commission "Habitats Directive" (92/43/EEC). It is considered as one of the most developed Alpine valleys with its well-established economy and infrastructure. It is home to several tourist and sport resorts, industries such as mining, as well as to 90.000 inhabitants. It is characterised by semi-natural and wild areas with a diverse Alpine fauna, ranging from deer, chamois, boars to eagles and hawks, partridges and wolves. Also, four regional nature parks, two natural reserves and many areas of European interest feature a very rich diversity of flower species. Furthermore, the valley attracts thousands of tourists per year due to its ancient history and several archaeological sites, Roman villas, churches and abbeys, castles and fortresses. (Giunti et al., 2012, p. 362f)

The main base tunnel will be used for freight and high-speed passenger railway. It is a twin tube with a diameter of 10,5 metres. Its difference in height is 300m with a maximum gradient of 1,25%. For excavation, tunnel boring as well as drilling and blasting machines are used. It entails safety features such as cross passages every 333m and sveral safety stations. Additionally, three entrances ("adits") serve as access adits, survey gallery and/or safety stations. They were also excavated by tunnel boring machines and drilling and blasting methods. (Tunneltalks, 2021) By the end of 2020, ten of 65 km were already dug. (Tunnel Euroalpin Turin Lyon, 2020)

Semmering base tunnel (Austria)

Overview of the Project

The existing Semmering Railway line is a bottleneck, with a capacity that does not meet the needs of the new corridor. The bottleneck will be eliminated by the construction of the base tunnel. (Häfliger, 2010, 9) The tunnel is an essential piece of the puzzle in the modernisation process to enhance the value of geographically disadvantaged south-east and south of Austria as a business location. It will connect the economic centres of Vienna, Graz and central Carinthia. (Kordina, 2010, 2) The Semmering base tunnel is part of the new Southern Line in Austria, which aims to create a fast and safe connection between Lower Austria and Styria. It ranks amongst the most complex tunnel building projects in Europe, demanding innovative solutions from the Austrian Railway Infrastructure. The tunnel has been under construction since 2012 and is expected to start operating in 2027. It is 27 kilometres long, employing 1.200 people during the construction phase and in the long term 11.000 people in Austria. According to the proposers, each Euro invested in the tunnel delivers five Euros in growth. (OEBB, 2021 a) It belongs to the Trans-European Network (TEN). (IC-Group, 2021)

The Semmering is an important part of the Danzig-Bologna freight transport corridor within the European railway transport system.

Affected Area

The Semmering base tunnel is located between Gloggnitz (Lower Austria) and Mürzzuschlag (Styria). In 1923, the Semmering Railway was declared as a historic monument by the Republic of Austria. The Landmark Protection Law implies that the preservation of the Semmering Railway is of public interest and the railway has to be considered a listed monument. In 1997, it was declared as a UNESCO World Heritage Site. (Häfliger, 2010, 6) In Gloggnitz, Lower Austria, new infrastructures have to be built. This includes the adjustment of the topography of the tracks, construction of the tunnel portal, bridges and power supply facilities, adaptation of the flood-protection features, noise and drainage measures as well as maintenance facilities and the demolition of an old guard house. (Häfliger, 2010, 10) In Mürzzuschlag, Styria, several adjustments are planned. Modifications in the rock topology, a new access line to the tunnel, a lowered tunnel portal, new facilities for power supply, maintenance and running of the line and the removal of some facilities from early tunnel building phases. (Häfliger, 2010, 12) It is constructed with a cut-and-fill method, with which the amount of excavated material is used to fill nearby embankments. (OEBB, 2021 b)

NRLA New Railway Link through the Alps (Switzerland)

Overview of the project

The New Rail Link through the Alps (NRLA) is one of the largest transport projects for decades in Switzerland. It aims to connect the northern and southern parts of Europe with new tunnels through the Lötscherg, Gotthard and Ceneri mountain massifs in combination with modernised connection routes. The project has been planned and hotly discussed ever since 1950. The construction started in 1999, after the federal government's decision in 1990. (Swiss Federal Archives, 2021) As part of the European Rhine-Alpine rail freight corridor, running from Rotterdam and Antwerp to Genoa, the NRLA will enhance Switzerland's growth and its integration into Europe. According to official Swiss sources, the country will benefit politically and economically from the project, for instance due to shortened journey times. Furthermore, it will bring the different parts of the country closer together. According to the FAO, the new high-performance rail infrastructure will contribute to a head-on tackling of imminent streams of traffic. The project also aims to contribute to transferring transalpine freight traffic from road to rail. (Federal Office of Transport, 2021)

Figure 5 shows the forecast of increase in millions of trips (y-axis) per year with and without the project. The thick graph shows the forecast without the project, the bright red graph with the project with the respective opening years. By 2040, 13,5 million trips per year are expected after the completion of the project, more than double the trips that would take place without NEAT.

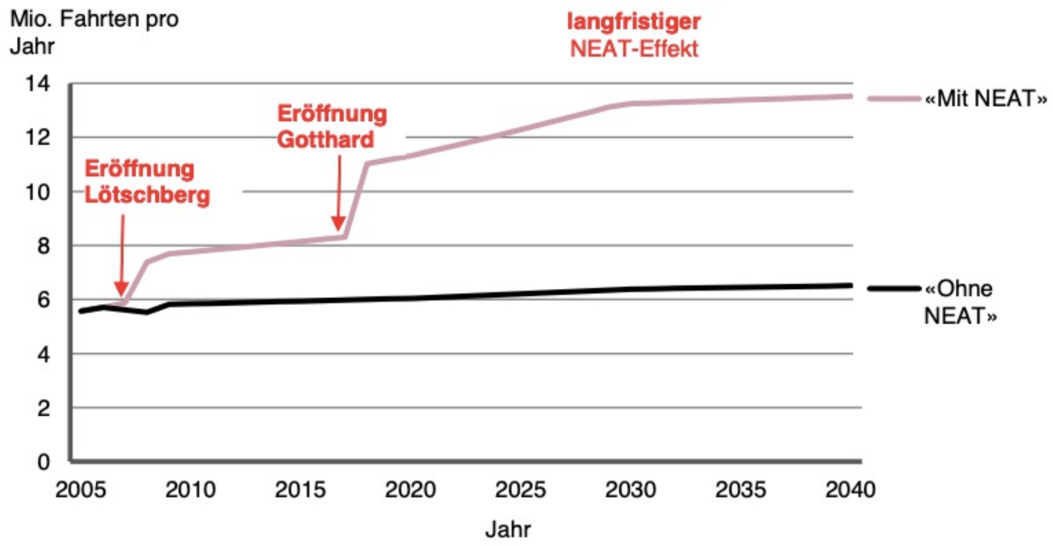

Figure 5. Forecast of increase in millions of trips per year. (Ecoplan & Infras, 2011, 11)

The Lötschberg base tunnel has been operating since 2007 and the other two, Gotthard and Ceneri base tunnels, since 2016. The Gotthard base tunnel is the longest rail tunnel in the world. In order to approach the routes to the base tunnels, auxiliary infrastructure and new signalling systems had to be constructed. In total, the three base tunnels and the expansion of approach routes cost 21,5 billion Euros in prices as of 2019. (Federal Office of Transport, 2019, 1)

Affected Area

The Lötschberg base tunnel is 34,6 kilometres long and runs between Frutigen (Canton Bern) and Steg (Canton Wallis). It traverses the Bernese Alps in Switzerland. The Gotthard base tunnel is 57 kilometres long and connects the cantons of Uri and Ticino. It crosses the western Glarus Alps, central Lepontine Alps and the eastern Gotthard massif. (Federal Office of Transport, 2019, 1) The most technically challenging construction section of the Gotthard base tunnel is 800m below Sedrun, a small vacation destination during the winter season. It is located in the Graubünden canton in eastern Switzerland and it has been undergoing environmental, economic and social changes within the framework of the project, presented in the sub-chapter "Environmental impacts". (Strauf and Walser, 2005, 2) The 15,4-kilometre long Ceneri tunnel is located in the canton of Ticino and traverses the Monte Ceneri mountain. (Federal Office of Transport, 2019, 1)

3.3.2 Environmental impacts of tunnelling

In general, the main ecological justifications of railway projects are energy savings and the decrease of pollutant emissions associated with the shift of freight and passenger traffic from road to rail. However, a careful analysis of the energy and material flows involved over the entire project life cycle is necessary to confirm the claimed virtuosity of the train. (Giunti et al., 2012, 363)

In this chapter, the adverse effects of tunnelling on the environment are presented. The analysis is based on the case study conducted on current railway projects in the Alps, presented in Chapter 3.3.1. The assessment gives an overview of specific environmental impacts during the construction and operation phases of the Mont Cenis Base Tunnel, Semmering Base Tunnel and the Lötschberg/Gotthard/Ceneri Base Tunnels. Several assessments conducted by experts are consulted. The International Journal of Ecosystems analysed the Mont Cenis base tunnel. Commissioned by the Austrian Federal Ministry for Traffic, Innovation and Technology, Kordina ZT GmbH studied the Semmering base tunnel.

Construction phase

All presented projects require over ten years of construction work, thousands of heavy-vehicle kilometres for transportation of material to and from the sites, the safe deposition of several million tons of excavated material, thousands of tons of iron and concrete, and interference with underground and surface waters. (Giunti et al., 2012, 364)

In the case of the ***Mont-Cenis base tunnel***, the route passes through zones with high presence of asbestos and uranium, which will necessarily be interacting with the hydrogeological environment. A fraction of the resulting excavated material will be disposed of in two open-pit mines in the Susa Valley, implying the dispersion into the environment of radioactive material. This has the potential to contaminate water and soil. The local population would be exposed to collective doses of several thousands of milli-sieverts per persons due to the action of meteorological agents such as the resuspension of polluted dust. The main source of radiation exposure is radon (^{222}Rn), a colourless, odourless radioactive noble gas. It is formed by the radioactive decay of uranium in rock, soil and water. Its half-life is approximately four days; it emits ionising radiation in decaying (as alpha particles) as well as metallic short-lived decay products. They stick to dust and other tiny particles due to their chemical reactivity and electric properties. If inhaled, they are fixed to pulmonary mucosae leading to lung damages. Alpha-emitting decay products are proven to increase the risk of lung cancer. (Zucchetti et al., 2016, 145) Several surveys found asbestos fibres with a high tendency to defibrillation in more than half of the rock samples tested in the Susa Valley (Giunti et al., 2012, 366). As presented in the assessment, the excavation activities may drain or divert the superficial water springs that are located in many villages in the Susa Valley. This can either leave the population without water supply and/or polluted sources, which make the water undrinkable and unusable. Also, several high-pressure water jets together with an underground lake of hundreds of thousand cubic meters have been found during the construction of a hydroelectric power plant in the area. These hydrological sites may be intercepted during excavations. (Giunti et al., 2012, 366)

During the construction phase of the ***Semmering base tunnel***, the experts mentioned light pollution due to construction lighting at the construction side (Kordina, 2010, 10), additional dust and nitrogen oxides at locations with cramped conditions (Kordina, 2010, 12), vibrations caused by construction machinery (Kordina, 2010, 13), emissions of harmful gases such as methane and hydrogen sulphide, exposure to asbestos used in brake linings and fire-resistant materials (Kordina, 2010, 17), an adverse influence on the quality of the water and consequent significant short-term impairment of aquatic biotic communities, damaged water ecology due to the relocation of the Longsbach in the area of the Longsgraben landfill site and strong interference with fisheries' interests (Kordina, 2010, 19). In 2019, 25 meters of slurry and rocks collapsed during blasting operations during the construction of the Semmering base tunnel, causing a water ingress and a 100-meter-deep crater. ([Anon.]/orf.at, 07.05.2019) In the same year, a water intrusion occurred in Göstritz, Lower Austria. The consequence was a turbid, even muddy Auerbach river. ([Anon.]/Die Presse, 09.07.2019) Breeding facilities of a fishing club in Gloggnitz, Lower Austria, were flooded with the white sediment. Only a small stock of trout could be saved. According to the OEBB, however, the water conditions were harmless and comparable to a situation after a heavy rainfall. ([Anon.]/Der Standard, 09.07.2019) In 2020, a construction worker was buried and killed by a loosened layer of soil. ([Anon.]/Die Presse, 01.05.2020)

At the beginning of the construction of the ***Gotthard base tunnel***, several environmental concerns for Sedrun were raised. The construction is a large-scale intervention into valuable landscapes and residential areas, biotopes, and the ground water supply. Further concerns are landfills and emissions, consumption of land, raw materials and energy as well as site-driven increased transport volume. (Strauf and Walser, 2005, 9) Also, accidents and failures during the construction phase bear the risk of having long-term consequences for the surrounding flora and fauna. Sustainable material management was among the most important considerations in the concept for the Gotthard Base Tunnel. 25% of the 24 million tons of excavated materials was re-utilised as concrete and shotcrete aggregates and was put back into the tunnel. (Strauf and Walser, 2005, 5) Other than that, compensatory projects were mainly positively assessed so it was concluded that the project was managed "in an environmentally-compatible" way. (Strauf and Walser, 2005, 13)

Operation phase and long-term consequences

According to the authors of the impact assessment of the ***Mont Cenis base tunnel***, a considerable amount of energy will be necessary during the operating phase (Giunti et al., 2012, 364). The authors of one assessment of this tunnel claim that gross estimates of impacts show that the hypothetical use of the line for freight transport is very energy intensive compared to trucks but less energy intensive than passenger transport by car. Rebound effect phenomena (and Jevons paradox) are foreseen: "increased time use efficiency and longer distance run within the time fraction allocated to travel are estimated to increase the number of trips and trains on the same route, thus causing global higher energy consumption and CO_2 emissions." (Zucchetti et al., 2016, 145)

Among long term consequences of the ***Semmering base tunnel*** are the risk of deposition of otherwise usable mineral raw resources due to roadway excavation (Kordina, 2010, 22) and the impairment of individual water use in both quantitative and qualitative terms (Kordina, 2010, 23). "Alliance for Nature", a nature, culture and landscape conservation organisation highlights further long term consequences of the Semmering base tunnel.

According to them, at least 450 litres per second (38 million litres per day) of water are to be drained over the long-term. This would lead to a permanent impairment of the water balance in the region. They foresee the risk of mountain water intrusion of the water supply due to the complex geology of the Semmering region. (Alliance for Nature, 2015) The complex geology of the Semmering massif is composed of different types of rock. There are porous, leafy and deformed types of stone, which cause high instability. These stone layers can absorb a particularly large amount of water. Concrete injections are required to reduce the risk of water ingresses. Larger water deposits are removed from the tunnel with pumps. Excavators and blasting are necessary to excavate critical rock. Anchors, steel grids and shotcrete are needed to secure the rock. (OEBB, 2020 a) In order to avoid water intrusions into the area, water supply facilities have to be built in the very region because it is water from the artesian wells in the limestone massif bordering the Semmering area that was used to supply Vienna with water. This poses a severe risk for springs that serve as habitats for rare or protected animals and plants. A reduction in the flow of numerous springs, the drying up of streams, the destruction of wetlands, damage to fauna and flora as well as to forests and the disruption of the water regime of the Fröschnitzbach, Mürz and Mur (Styria) and the Schwarza (Lower Austria) are predicted. (Alliance for Nature, 2015)

An environmental impact assessment on the ***Lötschberg base tunnel*** was conducted. It presented several long-term consequences for the soil, flora and fauna, landscape, forests, waters as well as the air in the region. A permanent loss of approximately 74.000 square metres of rich soil and 7.000 square metres of large wetlands along the Rhône river were expected. Due to the construction of bridges, the encroachment on vegetation along the Rhône river and the clearance of 34.800 square metres of forests, essential landscape elements were predicted to be lost. As a result of the construction of bridges in groundwater areas, the experts expected a warming of Kander and Engstligen rivers and further impacts on groundwaters in the region. (Bundesamt für Raumentwicklung, 2012, 77f). Environmental protection measures such as recultivation of soil, restauration of flora and fauna, greening of infrastructure facilities, reforestation, replacement of the nearby Almbach river and processing of excavated material were "fulfilled in the best possible way" (Bundesamt für Raumentwicklung, 2012, 79).

3.4 Overview of transport emissions in the selected countries

Table 10 presents the carbon emissions during the different phases of railways' lifecycle in the Alpine countries. The numbers for Italy, France and Switzerland are based on Mathias Tuchschmid's report for the year 2008.

Table 10. CO_2 Emissions from railway infrastructure in four Alpine countries. (Tuchschmid, 2011, 34 ff; *OEBB, 2019, 43)

CO_2 Emissions from	Construction (in g per pkm | tkm)	Operation (in g for train per pkm | tkm)	Train production and maintenance (in g per pkm | tkm)	**Total Emissions (in g per pkm | tkm)**	Operation of buildings (in g per pkm | tkm)
Austria	*No data*	*No data*	*No data*	***8,2 | 2,2****	*No data*
France	11,0 | 15,0	11,2 | 11,0	0,7 | 1,5	**22,9 | 27,5**	5,2 | 7,1
Italy	12,1 | 16,3	54,5 | 22,7	0,6 | 1,3	**67,2 | 40,3**	5,9 | 8,0
Switzerland	8,5 | 6,7	0,4 | 4,5	1,0 | 1,3	**9,9 | 12,5**	5,2 | 4,1

*Since the data for Austria is not only incomplete but also from 2019, Austria has to be excluded from comparisons. The author distinguishes between emission per passenger-kilometres (pkm) and tonnes-kilometres (tkm) for passenger and freight traffic respectively.

Two interesting features are visible in the table. Firstly, Switzerland emits the smallest amount of CO_2 in all phases except for the train production and maintenance with a total of 9,9 g/pkm and 12,5 g/tkm. Secondly, with 67,2 g/pkm and 40,3 g/tkm, Italy emits by far the most CO_2. (Tuchschmid, 2011, 34ff) The large differences in the sum of emissions are due to the different electricity mixes in the four countries (see Chapter 3.2.3 "Traction and power generation").

In the 27 EU countries, the transport sector was responsible for 31% of CO_2 emissions from fuel combustion in 2011. Within the transport sector, rail transport is responsible for less than 1,5% while having a 8,5% market share. (Ledbury, 2015, 5)

Table 11 presents the share of the four transport modes and their respective CO_2 emissions in the 27 EU countries in 2011. It shows that the CO_2 emissions are not parallel to the modal share of each transport sector. For instance, road traffic had almost the twelvefold share of passenger and more than the fourfold share of freight traffic while being responsible for the 48-fold share of CO_2 emissions when compared to rail traffic. (Ledbury, 2015, 6)

The UIC announced that European railway companies will further reduce their total CO_2 emissions from train operation by 50% by 2030 and strive towards carbon-neutral train operation by 2050. (Ledbury, 2015, 3) To achieve these targets, the shift from road to rail is inevitable. The envisaged goal of shifting 50% of medium distance intercity passenger and freight journeys from road to rail and waterborne transport by 2050 would result in a reduction of 238 million tonnes of CO_2 per year. (Ledbury, 2015, 8) In connection with Table 11, the UIC assumes that a doubling of rail freight transport, when shifted from road to rail, could result in a reduction of 45-55 million tonnes of CO_2 per year. The main argument for that calculation is the significant difference in emissions between road and rail, as presented in the table. (Ledbury, 2015, 8)

Table 11. Transport modal share and GHG emissions in EU. (Ledbury, 2015, 6)

	Passenger (%)	Freight (%)	Total (%)	**CO_2 Emission (%)**
Road	83,6	46,9	70,3	**71,9**
Aviation	8,8	0,1	5,7	**12,6**
Navigation	0,6	41,9	15,5	**14,4**
Rail	7,0	11,1	8,5	**1,5**

The Austrian rail company OEBB claims that due to their operation, the emission of 3,6 million tons of CO_2 can be prevented per year by providing an alternative to road and airborne traffic. In Austria, the relation of CO_2 emissions of rail passenger traffic to road traffic is 1:27 and even 1:51 to airborne traffic. (OEBB, 2020 b, 43) The French rail company SNCF has pledged to reduce its CO_2 emissions by 26% by 2030. (SNCF, 2019) According to the Italian railway company Trenitalia, 55 billion euros were invested to improve infrastructure and services with approximately 20 million tons of CO_2 prevented from being emitted into the atmosphere from 2010 to 2020. (Trenitalia, 2020) In Switzerland, the rail company SBB decided to reduce its greenhouse gas emissions from fuels, combustibles and coolants by a net 29% by 2040, compared to 2018. By generating more than 90% of the electricity from hydropower, the SBB saves approximately 5 million tons of CO_2 per year, which equals 10% of the country's total emissions. (SBB AG, 2020, 45) With the Swiss Lötschberg tunnel, a reduction of 230 car journeys per day can be achieved, summing up to 15 million car kilometres per year. This causes an annual reduction of 2.950 tons of CO_2, 5,4 tons of NO_x and 0,2 tons PM_{10}. (Bundesamt für Raumentwicklung, 2012, IV)

Furthermore, the pollutants NO_x, PM, SO_2 and NMVOCs decreased during the period 1990 to 2010 in spite of a growth in transport activities. Among other factors, tighter regulations regarding the usage of diesel oil in railway locomotives contributed to that trend. Road traffic continues to play a major role in the generation of particulates and other contaminants despite technological and efficiency improvements and changes in fuel consumption. (Ledbury, 2015, 27) According to the EEA, the transport sector accounted for 27% of $PM_{2,5}$ emissions in 2009, of which 1% is caused by railways. One gets a similar picture from the NO_x emissions, namely 58% consumed by the transport sector of which 2% are attributed to railways. The European railway sector has pledged to reduce their total exhaustion of NO_x and PM_{10} by 40% in absolute terms compared to 2005 and to entirely cut them by 2050. The sector is looking at new combustion technologies and efficient transmission systems for diesel traction, which is still used for 20% of European rail traffic. The aim is to ensure that rail diesel traction becomes more environmentally friendly since diesel propulsion is expected to play an indispensable role in the European transport systems in the near future. (Ledbury, 2015, 29f)

4. Environmental initiatives and organisations

This chapter presents various institutions and organisations dedicated to the protection of the Alpine region and sustainable mobility. The Alpine Convention is an international treaty between the Alpine States that was established in the 1990s. It serves as the legal foundations for many protective initiatives and organisations revolving around the protection of the Alpine environment. Inter alia, embedded in the Alpine Convention, the Alpine Climate Board founded the Alpine Climate Target System 2050 which aims at resilient and climate-neutral Alps until 2050. (Federal Ministry of Sustainability and Tourism (AUT), 2015, 6) Other relevant institutions and/or partners of the Alpine Convention are the United Nations Framework Convention on Climate Change, Mountain Partnership, Convention on Biological Diversity, European Environment Agency, EU Strategy for the Alpine Region, International Commission for the Protection of the Alps. (AC, 2020 e) The topics covered by the different initiatives have a wide range, including energy, transport and mobility.

4.1 The Alpine Convention

The Alpine Convention (AC) is an international treaty that aims at the sustainable development of the Alpine region. It pursues the preservation and protection of the Alps. The AC applies principles of prevention, the "Polluter Pays" principle and cooperation and a prudent and sustained use of resources. (AC, 1991, Art. 2.1) The contracting parties of the AC are the Federal Republic of Germany, the French Republic, the Italian Republic, the Republic of Slovenia, the Principality of Liechtenstein, the Republic of Austria, the Swiss Confederation and the European Economic Community. (AC, 2020 a)

In the 1950s, the non-governmental organisation "Commission Internationale pour la Protection des Alpes" (CIPRA) presented the sustainable development of the Alps as their mission. They defined an international treaty between the Alpine states as their main priority hence they established, together with the European Commission, a draft convention in 1988. At the first Alpine Conference in 1989, six Alpine countries (Germany, France, Liechtenstein, Austria, Switzerland and Italy) agreed on the establishment of an international treaty between the six Alpine countries and the European Union. The AC entered into force on March 6th, 1995 after it was ratified by Austria, Germany, Monaco, Liechtenstein and Slovenia. Italy was the last Alpine state that ratified the treaty in 1999. (Heuck, 2013, 17f)

In order to connect the relevant Alpine territory of 220.000 km^2 with the aims and scope of the Alpine Convention, info points in the respective contracting states have been established. Their goal is to involve the inhabitants, administrations, tourists, institutions and organisations. They act as the main connection between the territory and the Convention. Info points exist in Villach (Austria), Tolmin (Slovenia), Mojstrana (Slovenia), Morbegno (Italy), Domodossola (Italy), Gran Paradiso (Italy) and Chamoix (France). The two Permanent Secretariats are in Innsbruck (Austria) and Bolzano (Italy). (AC, 2020 b)

The relevant institutions within the Alpine Convention are the Alpine Conference as the political decision-making body (AC, 1991, Art. 6), the President (AC, Art. 15), the Permanent Committee as an executive body (AC, 1991, Art. 8.2), the Permanent Secretariat (Heuck, 2013, 41) and the System for the Observation and Information on the Alps as the scientific network revolving about topics relevant for the Alpine region. (AC, 2020 c)

The Alpine Climate Board is one of the conventions' thematic working committees that has its head office in Austria. Several experts from all Alpine countries consolidate initiatives and contributions to an emission-neutral Alpine area. During the 2019-2021 mandate, the Climate Board is working on a climate-action plan for the 16th Alpine Conference as well as the implementation, facilitation and development of the Alpine Target System 2050. (BMLRT, 2020) The document "Alpine Climate Target System 2050", approved by the 15th Alpine Conference, contains the background, overall structure, general principles, overall and sectoral strategic targets, communication pillar and recommendation. (Federal Ministry of Sustainability and Tourism, 2015, 4)

The structure of the Alpine Climate Target System 2050 is illustrated in Figure 6. The system is embedded in the legal framework of the Alpine Convention. Furthermore, it is guided by the overall targets of the Paris Agreement and the UN Sustainable Development Goals. All activities of the Alpine Convention are guided by General Principles with respect to climate change mitigation and adaption. The System has two overall strategic targets, climate-neutral and climate-resilient Alps until 2050. The Alpine region will reduce its greenhouse gas emissions and it will minimise negative effects of climate change vulnerabilities and impacts. Transport is one of the 12 sectoral climate targets.

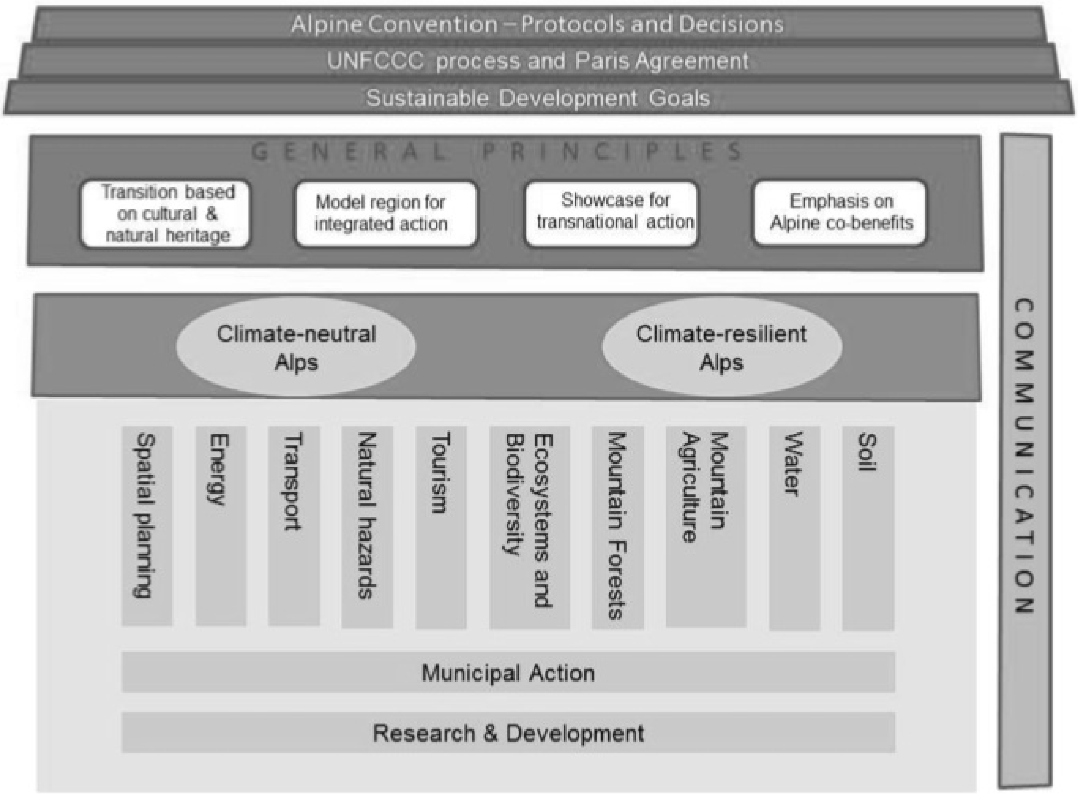

Figure 6. Overview of the Alpine Climate Target System 2050. (AC, 2019, 4)

The ***Transport Working Group*** is of special interest for this work. It is one of the Alpine Convention's thematic working bodies with the objective to "pursue a sustainable policy which will reduce the negative effects of and risks posed by intra-Alpine and transalpine transport to a level which is not harmful to people, flora and fauna and their environment and habitats" (AC, 2020 d, Art. 1a). The working group assesses and internalises the real cost of road and rail transport and establishes sustainable passenger mobility, innovative logistics solutions, a general modal shift, methods to combine different modes and alternative fuel infrastructure. They are in close cooperation with other bodies focussing on transport in the Alps. (AC, 2007) Their mobility solutions and ideas will be presented in Chapter 4.5.

4.2 The role of the European Union

The EU has developed the so-called ***Cohesion Policy*** which aims to promote and support the overall harmonious development of the member states. In the policy for the time 2014-2020, one of the eleven thematic objectives is sustainable transport and the removal of bottlenecks in key transport infrastructures (Objective 7). Within this objective, the EU aims to support a multi-modal Single European Transport Area by investing in the TEN-T network, to enhance regional mobility by connecting secondary and tertiary nodes to the TEN-T network, to develop and improve environmentally friendly and low-carbon transport systems and to develop and rehabilitate a comprehensive, high-quality and interoperable railway system. (European Commission, c, 2015) From the total financial funds for this thematic objective, Italy received 8,2% and France 3%. Austria and Switzerland were not allocated funds. (European Commission, 2015)

Furthermore, the EU adopted several directives relevant for railway infrastructure. The Council Directive 97/11/EC on the assessment of the effect of public and private projects on the environment provides information for competent authorities who take decisions on a projects impact on the environment. The ***Environmental Impact Assessment*** (EIA) is a fundamental instrument that aims a high level of protection of the environment and the integration of environmental consideration within projects. (European Council, 1997, (1)) Environmental Impact Assessments were conducted on all railway projects in Chapter 3.3.1 “Current railway projects”. The 2001/42/EC Directive on ***Strategic Environmental Assessment*** (SEA) applies to public plans and programs. The assessment is mandatory for plans/programs for certain areas, such as transport. It includes an environmental report about likely significant effects on the environment and reasonable alternatives for the proposed plan/program. Public and environmental authorities are consulted. The difference between the SEA and the EIA are the consultation of environmental authorities and the scope. (European Commission, 2003)

The Directive 98/8/EG of the European Parliament and of the Council deals with ***biocidal products.*** Its aim is to protect humans and the environment while ensuring the proper functioning of the internal market. National authorisation bodies are mandated to decide on the authorisation before the products are used and placed on the market. Authorisation may not be granted if the product is carcinogenic, mutagenic, toxic for reproduction, persistent, bio-accumulative or endocrine disrupting. (Pfabigan, 2015, 90)

The Directive 2009/148/EG, established by the Parliament and the Council, prohibits all activities during which workers are exposed to ***asbestos***. (European Parliament and Council, 2009, Art. 1 and 3)

Directive 2002/49/EC concerns the ***Assessment and Management of Environmental Noise***. As the commission addresses noise in the environment as one of the main environmental problems in Europe, the directive aims a high level of health and environmental protection by reducing noise. (European Parliament and Council, 2002, (1)) "This Directive should inter alia provide a basis for developing and completing the existing set of Community measures concerning noise emitted by the major sources, in particular road and rail vehicles and infrastructure." (European Parliament and Council, 2002, (5)).

In 2011, the European Commission published a roadmap to a ***Single European Transport Area*** which should be competitive and resource-efficient. In terms of transport, the commission aims to shift 50% of medium distance intercity passenger and freight journeys from road to rail and waterborne transport by 2050. Among other initiatives, this should lead to a 60% cut in transport emissions by then. In addition, all core seaports will be sufficiently connected to rail freight and the EU aims to be a world leader in safety and security of transport in aviation, rail and maritime. (European Commission, 2011)

In 2020, the commission published their strategy for a Sustainable and Smart Mobility in the frame of the European ***Green Deal***. The new strategy incorporates a doubling of high-speed rail traffic across Europe by 2030 and of rail freight traffic by 2050 as well as a fully operational TEN-T network by 2050. Their flagships entail 82 initiatives for sustainable transport, smart innovation and digitalisation and resilience. (European Commission, 2020 a)

4.3 Further relevant institutions

The ***European Environment Agency (EEA),*** founded in 1993 as an agency of the European Union, is one of the AC's partners. In their collaboration they exchange data and information about the Alps. (EEA/Permanent Secretariat of AC, 2016) The partnership agreement was signed in 2012 and includes a two-year work programme. The EEA maintains the Platform Climate-ADAPT, a Climate Adaptation Platform in which the Permanent Secretariat of the AC is involved, too. Also, the European Environmental Information and Observation Network (EIONET) supports the EEA in data collection and harmonisation. (AC, 2020 e)

The ***Convention on Biological Diversity (CBD)*** was founded in 1993. In 2008, the AC, the CBD and the Carpathian Convention established a Memorandum of Cooperation because the Alpine region plays an important role in regard to of biological diversity. Together they facilitate the exchange of information and experience between the parties. The CBD's mission is "safeguarding life on Earth" hence it promotes nature and human wellbeing. Its main goals are the conservation of biological diversity, sustainable use of the components of biological diversity as well as fair and equal sharing of the benefits arising from the utilisation of genetic resources. (AC, 2020 e)

The European Council has established a "Macroregional Strategy" which is an integrated framework that may be supported by the European Structural and Investment Funds. It is called the "***EU Strategy for the Alpine Region***" (EUSALP) Their aim is to address common yet unique challenges of the member states in the Alpine region by improving cross-border cooperation and identifying common goals to tackle economic globalisation, demographic trends, climate change and the energy challenge in the Alps. Seven members of the AC are also members of the EUSALP, namely Austria, France, Germany, Italy, Slovenia, Liechtenstein and Switzerland. The bodies of the EUSALP are the General Assembly, the Executive Board, Observers as well as Action Groups. "Mobility" is one of the nine Action Groups. (EUSALP, 2021) In 2020, EUSALP has published a Manifesto of the States and Regions involved in the framework. The title is "Together to shape a sustainable and resilient Alpine Region". Their goals include accelerating the energy transition in the Alpine region (EUSALP, 2020, Art. 11 a-g), developing sustainable transport and mobility solutions (EUSALP, 2020, Art. 12 a-g) and stimulating transition to sustainable year-round tourism (EUSALP, 2020, Art. 13 a-g).

During the Johannesburg World Summit on Sustainable Development, the voluntary alliance “***Mountain Partnership***” was set up. Its mission is to create a platform for cooperation among all states, organisations and NGOs who deal with mountainous sustainability. Article 42 of the Johannesburg Action Plan and Article 13 of Agenda 21 are the legal basis for the establishment. The AC is, together with 50 governments, 16 intergovernmental organisations and 143 major groups, including the Albanian Alps Alliance, CIPRA and International Scientific Committee on Research in the Alps (ISCAR), part of the Partnership. (AC , 2020)

The ***Alpine Space Programme*** was established as a transnational cooperation programme for the Alpine region and provides a framework for various institutional levels (academia, administration, business and innovation and policy making). It provides economic, social and environmental cooperation between seven Alpine countries. The funding derives from the European Regional Development Fund (ERDF) and through national public and private co-funding of the Partner states. (Alpine Space Programme, 2007-2013)

The ***International Commission for Alpine Protection*** (CIPRA) is a non-governmental, independent and non-profit oriented organisation established in 1952 with its headquarters in Liechtenstein. Its goal is the protection and the sustainable development of the Alps. CIPRA is politically engaged, gives impulses for cities and municipalities and communicates multilingually and evidence-based. As mentioned in Chapter 4.1, CIPRA initiated the establishment of the AC. Guided by the Protocols of the AC, the organisation empowers the political actors to adopt appropriate measures. CIPRA was the co-initiator of the AC and helped creating an international political body for sustainable development and protection of the Alps. Apart from working for a good life in the Alps in national and transnational political bodies, CIPRA contributes expertise in the Compliance Committee and Working Groups. It also calls for civil society to be involved in the cooperation between the Alps and the surrounding regions and cities, embedded in EUSALP. (CIPRA, 2018)

Within the ***United Nations Framework Convention on Climate Change*** (UNFCC), the AC has been active with the goal to raise awareness of climate negotiators of the particular vulnerability of the Alps to climate change. With the contracting parties and the Permanent Secretariat, the AC has been participating in side-events in most Conferences of the Parties since 2011. (AC, 2020 e)

The ***Alpine Network of Protected Areas*** (ALPARC) was founded in 1996. It is an association under French law and their Protected Areas cover most of the Alps. They organise events and workshops, facilitate the dissemination of information, cooperate with other relevant bodies, develop and coordinate international and notably European projects and offer different services to pursue their goal of promoting the exchange of expertise, techniques and methods among the managers of large, protected areas in the Alps, including nature parks, reserves, tranquillity zones, UNESCO World Heritage Sites and parks. Their actions cover Biodiversity and Ecological Connectivity, Regional Development and Quality of Life as well as Education for Sustainable Development in the Alps. (ALPARC, 2020 a) They contribute to Article 12 of the Protocol “Nature Protection and Landscape Conservation” as they work closely with the Convention’s Permanent Secretariat on several topics. They act as an intermediary between protected areas and actors in the Alpine region. Additionally, they are an official observer of the AC and they signed a Memorandum of Cooperation with the Permanent Secretariat of the AC in 2013. (ALPARC, 2020 b)

The UIC opened the ***Energy, Environment and Sustainability (EES) Platform*** that is open to all members of the international railway network. It consists of a Core Group and five Working Groups, focussing on emissions, noise, energy and CO_2, sustainable land use and sustainable mobility. The “Sustainable Mobility Expert Network” aims to promote the rail industry as the leading light for sustainable development and thus to achieve a more sustainable transport system. The “Emissions Expert Network” focusses on the impact of Diesel and other local emissions, air quality and the impact of brake materials on human health and the environment. The “Energy and CO_2 Expert Network” is in charge of all aspects of energy efficiency and CO_2 emissions. Their goal is to ensure that rail transport keeps its reputation as the most environmentally friendly mode of transport. The “Noise and Vibration Expert Network” takes technical leads on transport noise and vibration policies. The “Sustainable Land Use Expert Network” is concerned with biodiversity and the impact of railway lines, vegetation management and soil pollution. They establish mitigation measures, balance safety, cost and nature protection and ensure updated technical knowledge of railways. Additionally, it envisages the railway as a naturally integrated part of nature. (UIC, 2018, 5-7)

4.4 Limiting factors for the success of protective initiatives

The idea behind the Alpine Convention and the implementation by the member states are to be judged separately. The objective of uniting all Alpine countries under a common organisation has been achieved and several provisions of high importance have been agreed on, especially in the view of major environmental development projects. For instance, the Alpine Convention has been able to prevent the construction of a transit motorway through the Alps until today. However, the effectiveness of the convention suffers from several structural and legal shortcomings. First, the organisation was founded with a "Top-Down"-approach which systematically excluded the target regions which are most affected from decision-taking processes. Additionally, the first impulses came from Bonn, a city far from the Alps which gave the concerned Alpine regions a feeling of external control. This management style took long to be renewed in Austria, Italy and France. Switzerland refuses until today the "experienced patronage" and considers the development of the Alps as their very own task. This offside position of Switzerland weakens the efforts by the Alpine Convention until today. Furthermore, the legal implementation of the convention has been on a tough but positive path towards a clear and satisfactory solution. In that regard, Austria has taken a leading position by incorporation the convention into national law and by using its protocols even in court disputes. (Bätzing, 2016, 23-28) The environmental protection organisation WWF demands that the goals of the convention are put into practice and sees shortcomings especially regarding soil consumption, constructions along ecologically valuable rivers and in untouched landscapes. They judge that infrastructure penetrates the Alpine region and endangers the open spaces as retreats for flora and fauna and unique recreational areas. Furthermore, they request transnational, overarching spatial planning and effective instruments against unsustainable land use. Sustainable approaches in agriculture, tourism and forestry are to be promoted and the role and visibility of reviewing parties needs to be strengthened. (WWF, 2019)

The Environmental Council published an appraisal in which deficits on a European level are pointed out. They conclude that the targets of new regulations and their integration are often insufficient. On the level of the member states, directives must be implemented more adequately, and environmental regulations enforced more effectively and timely. The council sees a main blockade due to ubiquity, for instance regarding noise pollution.

Noise is a persistent problem that affects all European member states, hence strategic action on EU-level in form of regulatory frameworks is required. (Sachverständigenrat für Umweltfragen, 2020, 485) Another issue is the problem of subsidiarity concerning traffic planning. Even though the EU set the goal of making transport more climate-and environmentally friendly, they waive binding European requirements and leave planning and transformation to member states. (Sachverständigenrat für Umweltfragen, 2020, 487) Greenpeace judges that the Green Deal by the EU Commission aims to shift road freight to rail yet neglects to connect Europe by rail for passenger transport in order to provide a viable alternative to aviation and road traffic. (Greenpeace European Unit, 2019)

Without legal binding force, protection initiatives are well-intentioned yet often empty constructs. To the author, it seems as if there are countless partnerships with the same goal, namely the protection and sustainable development of the Alpine region. Research, knowledge exchange, work programmes and proposals are only effective if they are heard and taken seriously by decision-makers. A transport concept is only sustainable if green infrastructure is not only planned but also implemented. Without consistent shoulder-to-shoulder cooperation between politics, industry and research, all goals are merely ideas and ossify, while emissions continue to rise and the Alpine Space suffers as a result.

4.5 Outlook: sustainable mobility concept

Common Alpine Transport Policy

Three main issues have to be conciliated by Alpine transport policies. The request for accessibility at various scales and in various fields, the difficulty to mobilise funds for large public infrastructure investments and the specific Alpine environment that has to be protected from all kinds of negative impacts of transport. Therefore, Alpine countries need a coherent inter-modal policy aiming at reducing road freight traffic including the implementation of new rail infrastructures as well as pricing and regulation measures. Furthermore, the policy needs specific regulations for tourism mobility, for instance through cooperation between public transport companies, local authorities and tourism operators. Integrated spatial planning policies are necessary considering the strategic objective of reducing the structural need of transport. Local provisions of services and goods have to be enhanced, settlement patterns and infrastructure better coordinated, and accessibility and efficiency of public transport facilitated. (AC, 2007, 140)

Freight traffic

In 2020, 68 of 224 Mt of freight (i.e., 30%) cross the Alps per rail annually. According to the Transport Working Group 2019-20, rail infrastructure is not expected to stabilise the rail share of transalpine traffic at that level. Even though transalpine traffic growth is higher than the growth of freight inland traffic in the EU, the rail mode growth was reduced to 0,6%. However, major rail works such as the Lyon-Turin link or the Ceneri/Gotthard base tunnels are currently underway to ensure easier crossing of the Alps. According to assumptions taking by the Working Group, the Lyon-Turin (presented in Chapter 3.3.1) link could capture 50% of the current traffic through both French-Italian tunnels and 25% of the traffic registered in the affected area (Ventimiglia), summing up to 18 Mt per year. Alongside other assumptions, transalpine traffic is expected to top 300 Mt per year of which 30% in rail mode. (Transport Working Group, 2019, 35f) Additionally, grievances regarding the rail system, that concern mainly the reliability and regularity of the services, could be reduced by establishing combined transport terminals and shuttle services that are based on market expectations and by targeting departments at regular intervals. (Transport Working Group, 2019, 42) Efforts in research and development should be increased in the areas of rail/road shipment management (Transport

Working Group, 2019, 55). Further recommendations include improvements regarding interoperability that enables the transit of longer trains and further standardisation of gauges. Moreover, non-noisy wagons and lean lorries powered by alternative fuels should be privileged to circulate in the Alpine range. (Transport Working Group, 2019, 49-51) Adjusting road and rail pricing in order to give rail a good competitive chance also developing alternatives to Alpine transit using marine routes are additional approaches by the AC (AC, 2007, 137).

Mobility for Alpine population and passenger traffic

Several demographic factors have contributed to a sharp increase in the demand for road infrastructure, ownership of private cars and larger settlements. Higher availability of public services, reliable accessibility standards, expanded public transport, lower need for motorised transport by appropriate urban planning and joint learning processes across the entire Alpine region could tackle these challenges. (AC, 2007, 138)

Since most passenger transit occurs on the road and present cross-border railway links are often not well coordinated between the national railway companies, technical interoperability and coordination have to be improved in order to enhance competition between international passenger train companies. Rail infrastructure has to be further improved for higher speed and capacity, tariffs and booking systems have to be adjusted. (AC, 2007, 138)

Accessibility and mobility for Alpine tourism

Since tourism is an important sector within the Alpine economy, it accounts for a large share of Alpine passenger traffic. The vast majority of tourists travel by car, often due to remote locations and poor connections to and from their destination. Another reason for taking the car is autonomy and flexibility at the destination. (AC, 2007, 139) These challenges could be tackled by a holistic mobility management, origin-destination car-free service chains as well as the creation of strategic partnerships between the tourism industry and transport companies. Offers, incentives and information systems help to promote sustainable mobility. (AC, 2007, 139) For instance, logistic chains for luggage, offers combining public transport and cycling as well as an integrated tariff-system can promote tourism based on sustainable mobility. (AC, 2007, 124)

5. Summary and conclusions

The ERP, organised by George C. Marshall, enabled striking developments of Alpine railway infrastructure. Apart from financial (counterpart) funds issued by the U.S. in order to provide aid for warn-torn Europe, the Technical Assistance Program was of high importance for the industrial development in Europe. Chapter 2.3.4. specifically highlights one mission, namely "Mission 14: Railroads in the U.S.A. in 1950". In the course of this mission, U.S. American experts were sent to several countries in order to give recommendations for their respective railway infrastructure. Especially regarding mechanisation, dieselisation, international coordination and electrification, long-term processes were set in motion. By the establishment of the Trans Europ Express (TEE) in 1957, the Trans-European Network (TEN-T) in 1996 and the European Union Agency for Railway (ERA) in 2004, the European cooperation on railway transport gained momentum and would be indispensable for current developments. Furthermore, several standardisation processes, documented in so-called "Leaflets" by the UIC, established common rules to ensure safety and efficiency in the design, construction, operation and maintenance of railways. This led, for instance, to a standard track gauge and a standardised train control system within Alpine countries. Regarding electrification, mountainous regions were particularly relevant as the chosen Alpine states had electrified 58% (France) to 90% (Switzerland) of their railway networks by 2018.

As presented in Chapter 2.3.6, high-speed rails have gained importance during the last decades. The high-speed rails in the chosen Alpine countries have top operational speeds between 230 km/h in Austria and 320 km/h in France. In order to elaborate current developments, the chapter introduces three high-speed railway projects in the chosen Alpine countries. Being either planned, under construction or recently finished, all projects involve base tunnels in the respective states. Despite rightful ecological justifications for the projects in general, the base tunnels peculiarly impact the affected area. Negative side effects include land-use, radioactive excavation materials and hydrological risks, discussed in detail in Chapter 3.3.2.

Chapter 3.2. introduces the reader to further environmental consequences that can be attributed to railway infrastructure in general. Emissions occurring during different phases of railway's lifecycle are to be considered, especially during the construction of tunnels and rails as well as earthwork. Furthermore, impacts from the construction of train vehicles differ considerably between the types of trains, particularly between regional trains and high-speed trains. Regarding traction and power generation, there is not only a considerable difference in released greenhouse gases between coal-, diesel and electric powered trains yet also between the different sources of electricity used for electric rails. Hydropower is the most harmless form in terms of CO_2 emissions while hard coal combustion the most emission intensive. In the four Alpine states the electricity mix differs considerably. While more than 90% of the electricity for rail operation in Austria and Switzerland is generated from hydropower, nuclear energy and fossil fuels still play important roles in France and Italy respectively.

Furthermore, noise pollution is especially present in mountain valleys. However, noise caused by road traffic affects far more humans and living beings both during the day and at night. In addition, there exist several protective measures to operate rails quietly, being already used in Austria and Switzerland. Railway infrastructure can add to the fragmentation and degradation of the environment by taking up land resources, however, road transport is still a much larger consumer of land. In comparison, the "land-take efficiency" is almost three times as high with rail traffic as with road traffic. The operation of rails corridors can therefore be responsible for the loss of biodiversity and damage to ecosystems while being heavily dependent on a healthy ecosystem. The usage of pesticides, creosote, asbestos and other chemical agents for different safety measures, such as vegetation control, poses a risk to flora, fauna and humans.

However, as presented in Chapter 3.4., rail traffic is responsible for only 1,5% of all CO_2 emissions while having a market share of over 8%. In the Alpine states, Switzerland emits the smallest and Italy the highest amount of CO_2 per pkm/tkm. In Austria, 3,6 million tons of CO_2 can be prevented by railway operation per year. From 2010 to 2020, over 20 million tons of CO_2 could be prevented from being emitted by the operation of the Italian railways. Switzerland's railway infrastructure saves approximately 5 million tons of CO_2 per year. Also, France pledged to reduce their CO_2 emissions by 26% by 2030. In all countries the pollutants NO_x, PM, SO_2 and NMVOC had strongly decreased until 2010 in spite of growth in transport activities and railway infrastructure plays a disappearing role in that respect.

Apart from the Alpine Convention as the legal foundation for all protective measures in the Alpine region, several other institutions or organisations with different topics and aims exist. Chapter 4 presents the Alpine Convention and its important partners, namely the European Environment Agency, Convention on Biological Diversity, EU Strategy for the Alpine Region, Mountain Partnership, Alpine Space Programme, International Commission for Alpine Protection, UN Framework Convention on Climate Change, Alpine Network of Protected Areas and the Energy, Environment and Sustainability Platform by the UIC. Furthermore, the EU has adopted several protective directives relevant for this work, including two different Impact Assessments (EIA and SEA) and others, concerning biocidal products, noise, transport and the European Green Deal. Criticism regarding the effectiveness of such initiatives, institutions and organisations includes structural and legal shortcomings, insufficient incorporation in the respective countries or regions, deficits in the targets and their legal integration, the lack in viable alternatives to aviation and road traffic as well as the absence of cooperation between politics, industry and research. Chapter 4.5 gives an outlook about basic prerequisites for sustainable mobility in the Alpine region. It emphasises the importance of a common Alpine Transport Policy with pricing and regulation measures, improved reliability and regularity of the rail system in order to give it a good competitive chance in terms of freight traffic, and higher accessibility and reliability of public transport for Alpine populations. Additionally, a holistic mobility management for Alpine tourism is needed. This should incorporate origin-destination car free service chains, strategic partnerships between the tourism and transport industry as well as logistic chains for luggage.

To conclude, the exchange of expertise and the financial assistance from the U.S. appear to be ground-breaking for the development of the railway infrastructure up to 2021. Many of today's most important characteristics of railway infrastructure can be traced back to the recommendations from Mission 14. Railway infrastructure has considerably changed in Austria, France, Italy and Switzerland since WW2. The developments during the last 80 years are remarkable, and the role of rail transport has been growing. The expertise from the U.S., initiated by the ERP, and their railway network as a model were decisive for a sustainable, cross-border railway network in Europe and especially in the Alpine region. The recommendations of U.S. experts regarding standardisation, dieselisation and international cooperation have been and are being implemented throughout the countries discussed in this work.

Although the construction, maintenance and expansion of railway infrastructure is associated with various undesirable side effects, the switch from road to rail is indispensable and an opportunity to minimise the environmental impact of traffic and transport. Today's technologies, especially with regard to electrification, make the railway the most ecologically justifiable mode of transport. This fact is part of the missions of all organisations and initiatives that have set themselves the goal of protecting the Alpine region, being visible when considering that Austria, France, Italy and Switzerland are above the EU average in terms of electrification.

These developments are far from complete. A lot of innovation is still needed to allow a holistic switch from road to rail. The UIC and national railway organisations are constantly developing new projects, technologies and ideas to optimise railway transport services for the entire Alpine population. Sustainable transport concepts should succeed in convincing the general population of having railways as the first choice of transport mode without restricting their flexibility and autonomy. Furthermore, the Alpine Convention and other environmental organisations need a stronger status in order to be taken seriously by decision-makers. Therefore, a consistent shoulder-to-shoulder cooperation between politics, industry and research is required to implement all initiatives and concepts that focus on the protection and sustainable development of the Alpine region. With 2021 designated as the European Year of Rail, European countries have an incentive to join forces on legislation and decision-making within the mobility sector to minimise ecological damages and maximise environmental protection and the quality of life of all living species.

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List of tables

List of figures