Potential analysis of existing and new technologies for the promotion of a sustainable passenger transport in the Alpine region

Final Report

Transport Working Group of the Alpine Convention

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LIST OF ABBREVIATIONS

API	Application Programming Interface
ASTUS	Alpine Smart Transport and Urbanism Strategies
DB	Deutsche Bank / German Railway
EU	European Union
LEC	Low Emissions Corridor
LIFE	L'Instrument Financier pour l'Environnement / EU's funding instrument for the environment and climate action
MaaS	Mobility as a Service
NEAT	Neue Eisenbahn-Alpentransversale / New transalpine rail link
ÖBB	Österreichische Bundesbahnen / Austrian Federal Railways
OECD	Organization for Economic Cooperation and Development
P+R	Park and Ride
SASA	Städtischer Autobus Service AG / Municipal Autobus Service AG
SBB	Schweizerische Bundesbahnen AG / Swiss Federal Railways AG
TEN	Trans-European Networks
TUM	Technische Universität München / Munich University of Technology

INTRODUCTION

The Alps are one of the largest contiguous natural areas in Europe. Due to their specific and diverse nature, culture, and history, the Alps are deemed to be an excellent living, economic, cultural and recreational area located in the centre of Europe. Linked by this common territory and the identical challenges posed by their region, all eight states of the Alpine region (Germany, Austria, France, Italy, Liechtenstein, Monaco, Switzerland, and Slovenia) as well as the European Community have signed the Convention on the Protection of the Alps (the so-called Alpine Convention). The Alpine Convention entered into force in 1995. In the Alpine Convention, the Alpine countries commit themselves to the implementation of a transport policy in terms of sustainability and among others characterised by the elements listed here in the following:

- Cross-modal mobility design contributing to the sustainable development of the living and economic space as the basis of life for the population residing in the Alpine region.
- Ensuring intra-Alpine as well as trans-Alpine traffic through the increase of the effectiveness and efficiency of transport systems and the promotion of environmentally friendly and resource-conserving transport methods at economically viable costs.
- Ensure fair competition conditions between the different transport methods.

Today more than ever, the Alpine Convention aims at the protection, preservation, and development in terms of sustainability of this mountain region. During the month of April 2019, the ministers of the Alpine countries therefore adopted the Alpine Climate Target 2050, which aims at the achievement of climate neutrality in the Alp region by the year 2050.

To concretise the Alpine Convention, eight protocols including regulations on sectoral issues were adopted and corresponding working groups were established.[1] In the current mandate of the Transport Working Group , the focus was placed on passenger transport. As representative of the German delegation, the Federal Ministry for Digital and Transport, in close cooperation with the Bavarian State Ministry of Housing, Construction and Transport, commissioned the company TÜV Rheinland InterTraffic GmbH to prepare a study concerning the potential of the existing and new technologies for a sustainable passenger transport in the Alp region.

The aim of the said study is to show which types of the existing and new technologies are particularly suitable in the Alpine region, which are the challenges associated with the introduction of technology and its daily application, and which are the concrete recommendations for action you can deduct from it.

[1] Further background information on the Transport Working Group is available on the following website: https://www.alpconv.org/de/startseite/organisation/thematische-arbeitsgremien/detail/arbeitsgruppe-verkehr/.

1 OBJECTIVE AND FOCUS OF THE STUDY

According to the demarcations made by the Alpine Convention, the Alpine arc has approximately 13 million inhabitants living in a space of 190,912 km². The Alpine arc consists of approximately 100 regions and 6,200 municipalities. The Alpine region is heterogeneous in terms of settlement structure as well as of population density. On the one hand, it is characterised by local centres (urban agglomerations as well as tourist communities) and on the other hand by a structurally weaker hinterland (abandoned side valleys as well as mountain slopes). This aspect also influences the situation in terms of traffic. From the glance at the respective objective of the route, the following traffic-related division may be deducted:

- Commuter traffic (business, education, and work)
- Tourism and leisure traffic (for example leisure activities, shopping) and
- Transit traffic (road and rail).[2]

The Alpine Convention aims at the protection of the Alps as a habitat as well as an ecosystem and at the reconciliation of the same with the aspects relating to living, working, economy, infrastructure and tourism in the Alpine region. One of the six priorities of its work programme 2020-2022 consists of the promotion of sustainable transport. However, depending on whether we are talking about urban centres, rural areas, tourist centres or depopulated mountain regions, the related requirements for action are different. Accordingly, sustainable mobility concepts must consider aspects like geographical location, population density, settlement structure, economic strength, and ecological features.

The objective of the present study consists of the analysis of the potential of new and innovative technologies in the area of passenger transport in the Alpine region. The collected findings will be put at disposal of all states, municipalities, and regional actors in the passenger transport according to the Alpine Convention.

For this purpose, existing innovative projects when it comes to passenger transport in the Alpine region were identified and then discussed in a workshop on the basis of practical examples. In accordance with the categorisation of the practical examples according to the above-mentioned transport purposes, these are summarised under Chapter 5. In this context, also their potential when it comes to the application in other Alpine regions is shown. On this basis, general recommendations relating to the mobility development in the Alpine region will be formulated.

[2] Cf. (Prof. Dr. Stopka 2004) .

2 ALPINE SPECIFICITY AND SUSTAINABILITY

The identification and selection of transport projects implementing new and innovative technologies in the Alpine region was based on the following criteria: The projects had to (1) aim at the promotion of sustainable transport, (2) be innovative and implement new technologies, and (3) consider the specific features of the Alpine region.

2.1 ALPINE SPECIFICITY

In the context of this study, the term "Alpine specificity" describes the extent to which transport and infrastructure measures particularly consider the geographical, ecological as well as economic features of the Alpine region.[3] In this context, the following alpine-specific features may be quoted:

- Special topographical conditions which, on the one hand, have a separating effect on natural and settlement space and, on the other hand, influence the climatic conditions existing in valley as well as mountain regions.[4] For example, settlements and transport axes are generally concentrated in more or less narrow valleys. Only a few settlements are located on slopes or alpine pastures (formerly glacial trough shoulders).
- Heterogeneous, small-scale climatic conditions at different altitudes as well as valley-mountain deviations.[5]
- Traffic volumes subject to a strong fluctuation depending on the season due to tourism, for example as a result of winter sports activities or of hiking in the course of the summer months. Tourist travel accounts for 75% of the CO_2 emissions caused by annual tourism; 84% of holiday trips to Austria, for example, are made by car.[6]
- A special ecosystem and biodiversity have a crucial impact on humans and the environment.
- A pronounced "natural dynamic" typical of high mountains, characterised by erosion processes, unstable rock layers as well as natural events such as floods, avalanches, or landslides.[7] In terms of transport, this means that there is a need for securing the infrastructure.

[3] Cf. (Essl, et al. 2014, p. 26f.) .

[4] Cf. (Tischler and Mailer 2014, p. 140) .

[5] Cf. (Central Institute for Meteorology and Geodynamics 2020) .

[6] Cf. (Astelbauer-Unger 2011, p. 8) .

[7] Cf. (Bätzing 2003, p. 42) .

2.2 SUSTAINABILITY

The present study defines sustainable transport projects as resource-conserving, low-emission, energy- and land-efficient mobility design initiatives and the use of suitable transport methods and systems.[8] In this context, the prerequisites must not be cumulative. In fact, the relevance of one sustainability-related criterion will suffice.

The following table contains an explanation of the sustainability-related indicators by also including examples in terms of operationalisation.

Table 1: Sustainability Indicators

Indicator (criterion)	Explanation	Operationalisation (examples)
Reduction of harmful emissions	These include air pollutants being harmful to health, such as nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), lead (Pb) and particulate matter (PM_{10}). The mentioned air pollutants form smog, result in the ozone formation and may contribute to ecological impairments such as the acidify-cation of lakes and soils.	• Electrification in the railway sector • Replacement of diesel railcars by hydrogen trains or electric railcars • Replacement of diesel buses with fuel cell or electric buses • Use of e-cars in the car-sharing sector
Reduction of greenhouse gas emissions	Under the Kyoto Protocol, these include emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen trifluoride (NF_3) and fluorinated greenhouse gases (hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)).	• Electrification in the railway sector • Replacement of diesel railcars by hydrogen trains or electric railcars • Replacement of diesel buses with fuel cell or electric buses • Use of e-cars in the car-sharing sector
Energy consumption reduction	The energy consumption is measured by the number of different fuels (electricity and hydrogen) to be used.	• Reduction of fuel consumption • Increase in terms of energy efficiency

[8] Cf. also the OECD definition of environmentally sustainable transport (Wiederkehr, et al. 2003, p. 3f.) .

Indicator (criterion)	Explanation	Operationalisation (examples)
Reduction of surface and/or land use	This concerns the potential separating effect of a project and/or measure, the use of existing infrastructure and the type of land use.	• Use of the existing infrastructure • The reduction of the land use to a minimum level • Assessment of the project effect in terms of separation
Reduction of travel time or increase of travel quality	The sustainability criterion of travel time was supplemented by the criterion relating to travel quality by including, for example, intermodality of transport methods or digitalisation measures.	• Expansion of intersections • Ticketing concepts • Use of apps • Digitization (for example inside the vehicle) • Sharing models

3 METHODICAL APPROACH

3.1 INVENTORY

A comprehensive inventory formed the basis for the selection of practical examples which were then used for the formulations of recommendations for action. The projects were identified through desktop research and an online survey.

3.1.1 Desktop Research and Online Survey

Sustainable transport projects in passenger transport were researched in the course of the desktop research. In this context, not only projects with alternative drives or technologies were included since also projects dedicated, for example, to the change in terms of user behaviour or the creation of intermodal transport services were part of the research.

The said projects were recorded and categorised on the basis of the criteria listed below:

- Project specifics (project leader / contact person, project content and objectives, project period, country, allocation (valley, mountain, city))
- Technical and transport features (target group, means of transport, role of intermodality, promotion of alternative forms of mobility or shared mobility, infrastructure requirements and technologies)
- Assessment of costs and impacts (potential displacement effects, applicability under Alpine-specific conditions, noise pollution, and transferability to other Alpine regions).

The project research was carried out on the basis of publicly accessible, especially internet-based sources. To complete the research and to highlight the practical significance of the projects, an online survey was conducted in parallel in the German and English languages. The participants were asked to name the characteristics which according to their opinion were relevant in terms of sustainability and Alpine specificity. In particular, state authorities, interest groups, scientific and research institutions, transport associations and public transport authorities as well as transport companies were included.

A total of 111 actors were contacted and asked to participate in the survey. Among them 29 actors completed the entire survey. This corresponds to a response rate of 26%.[9]

Most responses came from Austria, Switzerland, and Germany (66% in total). 8% of the respondents did not assign themselves to any country, but to a transnational organisation.

[9] Note: Within the scope of the survey, there was no obligation to answer all questions entirely. For this reason, the number of answers per question may vary. The number of participants varies per question; thus, “n” was always indicated; however, the indicated “n” may vary per question.

Of a total of indicated 53 institutions, organisations, and interest groups as well as local authorities represent the largest group of respondents with 21% and 19% respectively. 15% of the participants come from the branches of public transport authorities, transport or tariff associations or represent the fields of science and research. Approximately 13% of the participants come from transport companies. The lowest response rate concerned the business community, municipalities, and regional authorities.

3.1.2 Inventory Analysis

A total of 112 sustainable projects in the Alpine region emerged from the inventory analysis. These were analysed according to the aspects listed below:

(1) Regional distribution,

(2) Project focus,

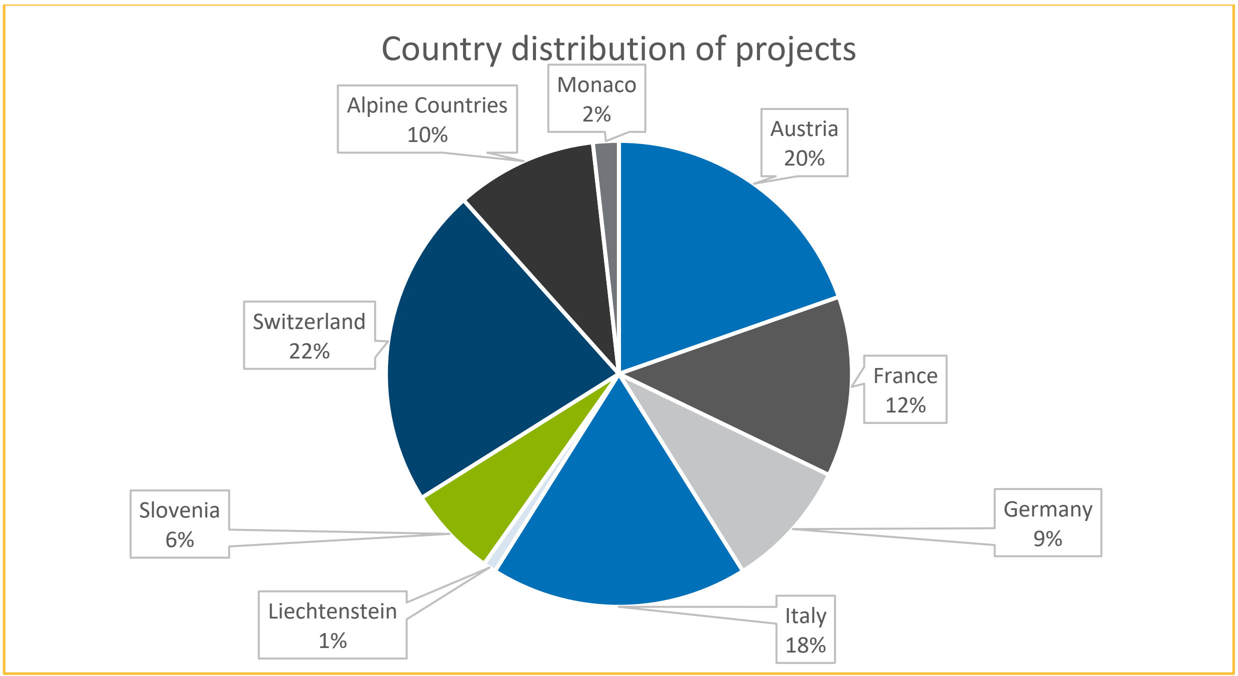
(3) Use of innovative and new technology, and

(4) Basic transferability of the projects to other Alpine regions.

Regional Distribution

The regional distribution of the projects roughly corresponds to the area shares of the Alpine Convention signatory states. Almost two thirds of the projects are located in Austria, Switzerland and Italy, while a good quarter come from France, Germany and Slovenia. A total of 3% comes from the states Monaco and Liechtenstein. If a project spanned several countries, it was assigned to the country where it was largely based in. Otherwise, it was assigned to the category of "Alpine countries" as a transnational project.[10]

Figure 1: Country distribution of projects indicated percentage



[10] Ten projects researched belong to individual countries of the Alpine Convention, but do not geographically belong to the Alpine region.

Focus of the Projects

A significant part of the projects aims to steer the demand for mobility, often motivated by tourism, more towards climate-friendly offers. This in turn requires the creation of a corresponding range of low-emission, environmentally friendly mobility (the so-called "Soft Mobility").

Most of the projects researched were carried out or started during the last ten years. The focus is on the design of sustainable road-based mobility being the objective of almost two thirds of all projects. These primarily include measures aimed at the reduction of tourism-induced car traffic and range from charging and rental systems for electric vehicles and the use of buses with alternative drives to the ticketing and shuttle systems to reduce individual traffic and pilot testing of the use of automated vehicles in local public transport.

Around one seventh of the projects relate to the rail sector and include both infrastructural measures for the new construction and expansion and the revitalisation of rail lines and the use of innovative technologies. Another category of measures includes ticket offers aimed at directing demand for mobility to rail.

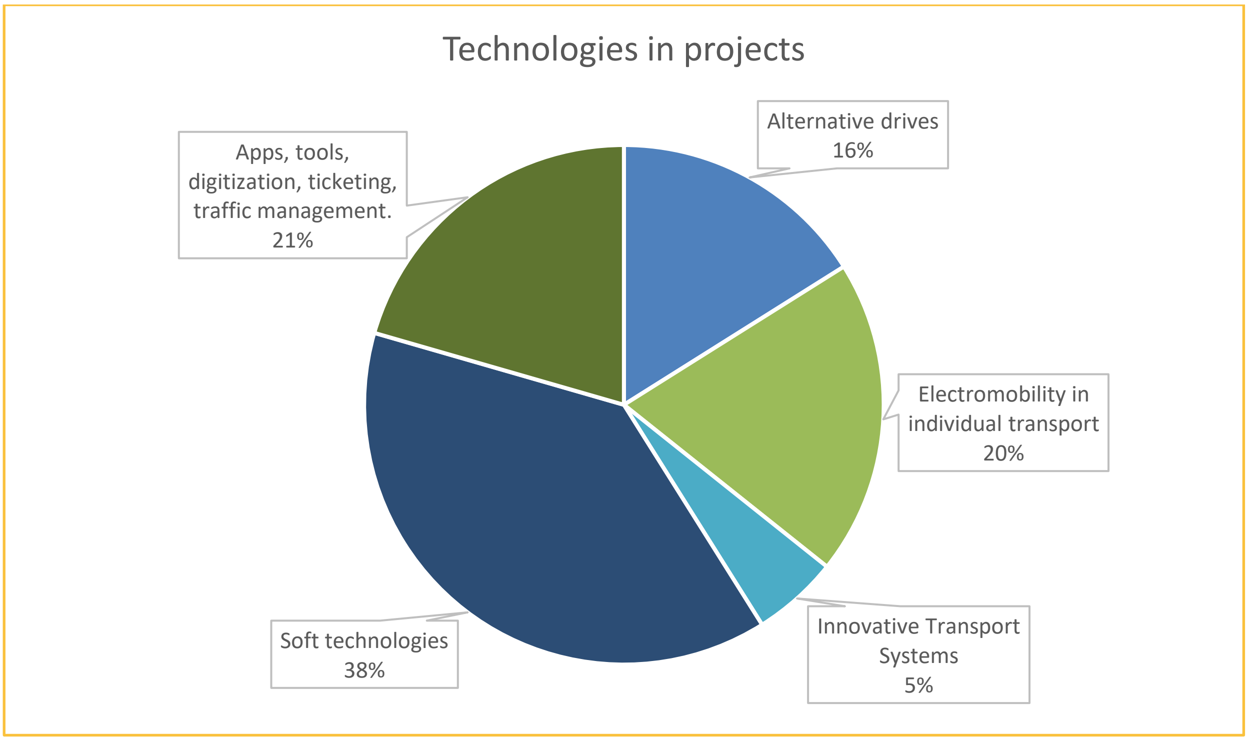
Finally, a third group, comprising about one fifth of all projects, includes various cross-modal projects for the further development of regional mobility. A notable proportion of these are measures aimed at the development of concepts for sustainable mobility and information as well as ticketing systems.

Use of Innovative and New Technology

A wide range of new and climate-friendly technologies are being applied. For example, around one fifth of the projects each deal with the decarbonisation of individual transport, in particular through the use of electric bicycles and electric cars, and public passenger transport. The latter group includes the use of battery-electric and hydrogen-powered buses and rail vehicles, but also other innovative transport systems, for example based on cable car or air cushion technologies.

However, most of the technological focus is in the area of digital-based applications and the use of other "soft" technologies as a bundle of methods, processes and organisational applications for the provision of mobility services[11]. Their spectrum ranges from guest card systems providing access to the extensive public transport services, to travel information and traffic management systems, to platform-based mobility services and the development of corresponding mobility apps. These groups account for around three-fifths of all the projects considered.

Figure 2: Application of Technologies in Projects



[11] Cf. (Deakin 2009) .

Basic transferability of the projects to other Alpine regions

A further focus of the analysis consisted of the particular identification of those projects whose results have a distinctly representative character and can consequently serve as an example for other regions and municipalities in the Alpine region.

The table below illustrates the extent to which transferability of lessons learned, adequate practices, and results may be ensured in the project categories listed below.

Table 2: Project categories and degree of the criteria fulfilment

Bus / Shuttle	• In the meantime, various regions have gained experience with electric drives and hydrogen buses and are implementing the expansion of the conversion to low-emission vehicles. Examples of this are the hydrogen buses, the electric bus fleet, and the e-bus filling station of SASA South Tyrol or the electric bus strategy of the transport association in Lucerne. • The application of the said technologies in different Alpine regions is possible, and the corresponding project know-how may be transferred. Important factors for deciding on the suitable form of propulsion are, for example, the total distance travelled daily, the altitude metres to be covered and the availability of adequate charging locations.
Cable car	• The transferability of ropeway projects to different Alpine regions depends on the respective conditions. The choice of ropeway technology and vessel sizes is to be adapted to the specific framework conditions existing in each individual case.
Railway	• Large railway infrastructure projects pose a particular challenge in mountainous regions due to topographical, geological, and technical aspects. Large-scale projects carried out in Switzerland show in an exemplary manner how the expansion of rail infrastructures in mountain regions is possible, feasible, and meaningful. • In the rail sector, diesel vehicles are gradually being replaced by battery-powered railcars, hydrogen trains or electric vehicles. A suitable moment in time for the procurement of new vehicles is, for example, the conclusion of new transport contracts. The decisive factors for the technology-related choice include the degree of electrification of the existing route, the traffic performance and the availability of the corresponding refuelling and charging infrastructure. Examples of this are the battery-powered railcars of ÖBB (Austrian Federal Railways) and the hydrogen trains of the Zillertalbahn.

Motorised individual traffic	• Car sharing services with conventional drives and e-cars are also used in the Alpine region and its surroundings, for example in Bled (Slovenia), Munich and in Moos in the region of Merano.
Individual traffic	• Bike sharing as well as e-bike sharing offers have already been implemented in many ways in small communities and towns throughout the Alpine region. In this regard, a tariff-related link with public transport use or carpooling offers may be useful.
Carpooling	• Individual carpooling projects in the Alps show that they are perceived as interesting. In addition, they show that these types of projects can be implemented both by phone and app booking. • Examples are the projects Taxito in Bern, the Gesäuse Sammeltaxi (shared taxi) project in Admont and the Dorfbus (village bus) in Kleinmürbisch. In this context, the connection to the existing public transport services is crucial so to avoid the creation of a competitive situation.
Autonomous driving	• Two autonomous driving projects have been identified within the Alpine region. The said projects include a test phase comprising an autonomous shuttle in Merano and the Smart Shuttle of the company Schweizer Postauto AG in Sitten / Sion, Switzerland. In addition, among others, outside the Alpine region, the test operation of an autonomous minibus in Bad Birnbach was taken into consideration. • An important challenge for the application in the Alpine region is due to the climatic conditions, the altitudes as well as the existing connections to satellites and communication technology.
Information systems	• Traveller information systems or websites providing information about existing mobility offers and ticketing systems are also used. In this context, the linking and compatibility of different systems may often be problematic.
Traffic management	• To mention some examples, this system includes the establishment of environmental zones, the parking space management, or the improvement of traffic flows. Generally speaking, the said measures are transferable although they require complementary measures such as the provision of P+R parking spaces and the expansion of public transport services.

3.2 PROJECT CATEGORISATION

During the next step, the researched projects were subjected to an analysis exclusively focusing on aspects relating to sustainability and also assessed in terms of quality. The assessment was carried out on the indicators described above:

- Reduction of emissions harmful to health,
- Avoidance and reduction of greenhouse gas emissions,
- Reduction of energy consumption,
- Sustainable use of the existing space and
- Reduction of travel time or promotion of travel quality.

The objective of the categorisation consisted of the capacity relating to the improved categorisation and consequently to the better comparison of the researched projects internally on the basis of the presented assessment grid. On his basis, a comprehensible selection of practical examples should be carried out whereby the said examples must be particularly suitable for a presentation in the context of a workshop with regional actors.

General statements based on sustainability

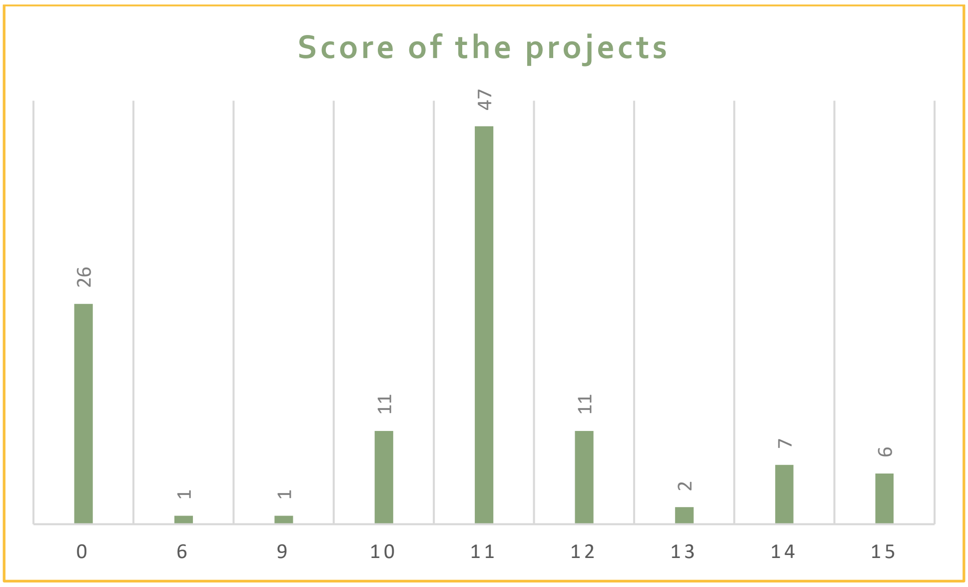
The projects were assessed on a school grade scale from 1 to 5. In Figure 3 on the X-axis the points of the projects and on the Y-axis the number of projects having received this score are shown. The lower the score, the more sustainable the project was assessed according to its measurement by means of the 5 mentioned indicators. All project scores ranged from 6 to 15 points[12]. For a number of projects, an assessment based on the comparatively narrow set of criteria proved to be less useful one. To mention an example, this was the case with planning methods and information systems which cannot be adequately operationalised by using the selected sustainability indicators. In the assessment, these projects were set to “0”.

Overall, the average project score is of 8.4, and if you exclude the projects having the score 0, the average score achieved will be 11.

The figure shows that a large project proportion is positioned in this range. 12% of the projects were rated better than average while 23% of them obtained a score beyond the average value.

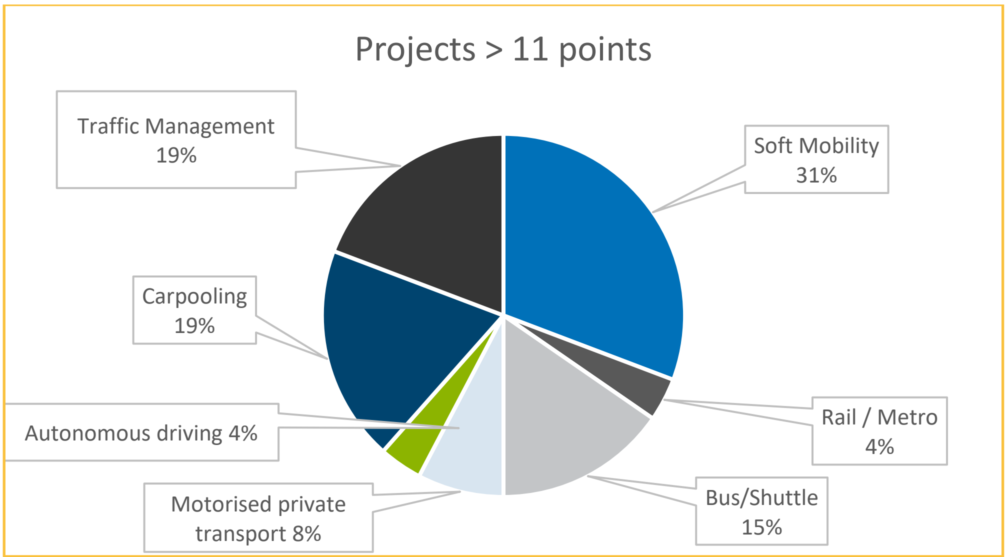
[12] Note: A higher score says nothing about the usefulness or meaningfulness of an individual project. Rather, the assessment of the projects according to the five selected sustainability criteria permits comparability so to ensure a comprehensible project selection for the workshop during the next step.

Figure 3: Project assessment



Projects obtaining a score of 11≥

Figure 4: Distribution in terms of percentage of projects per traffic type obtaining more than 11 points

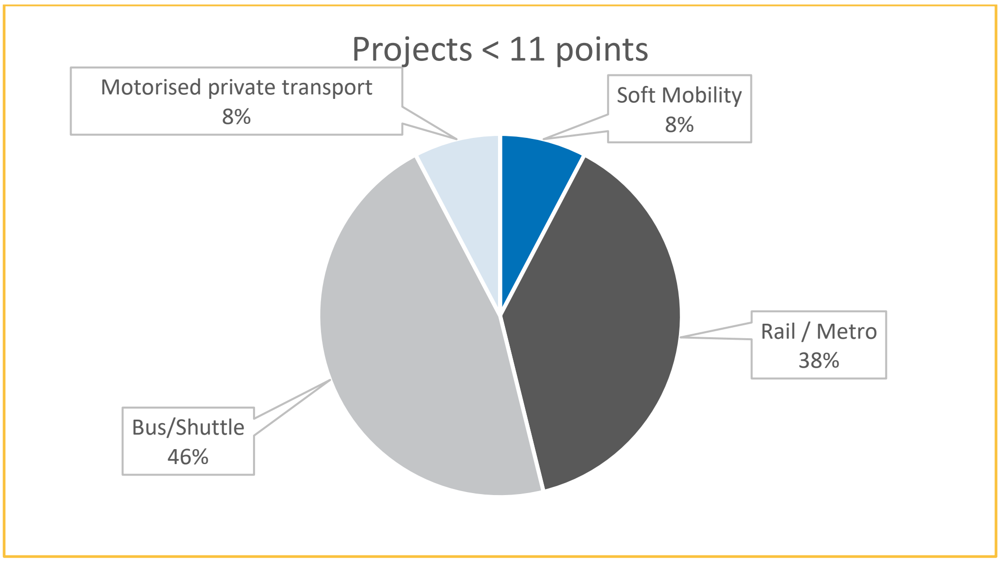


Projects obtaining a score beyond the average value particularly relate to projects in the areas of traffic management, carpooling with conventional drives (i.e. without alternative drives), and soft mobility. The said projects received higher scores in particular due to the use of drives with conventional combustion engines in the areas of emissions and energy consumption or in relation to the aspect relating to the “reduction of travel time and/or the promotion of travel quality”.

Car sharing and carpooling tended to achieve higher scores since it was assumed that they rarely cause modal shift effects by consequently having a comparatively little impact on the emission-related reduction.[13] The energy consumption was also frequently assessed at a medium level because in almost all cases there wasn't any switch to alternative propulsion systems, for example electric or hydrogen propulsion. Furthermore, the land use rarely changes if only individual users give up their own cars (shown in Figure 4 as motorised private transport). Depending on the type of car sharing (station-based or in the open road space) as well as the availability, a minor increase in terms of travel time compared to private cars may usually be assumed.

Projects obtaining an above-average rating

Figure 5: Distribution in terms of percentage of projects per traffic type obtaining less than 11 points



Projects for the use of alternative drives in the areas of rail / metro and bus / shuttle received an above-average rating to a level of 10 points. They scored very well overall in terms of the reduction of emissions, the energy consumption and the use of existing infrastructure. In this context, only in the area of travel time medium points have been awarded. However, projects relying on other innovative approaches or technologies, such as car-free communities offering an additional range of alternative forms of mobility in combination with electromobility, also reached a good performance level, in particular when it comes to the emission reduction and to the aspect concerning the land use (cf. Figure 5).

[13] Cf. (Dr. Wolff, et al. 2019) .

3.3 SELECTION PROCESS OF THE PRACTICAL EXAMPLES

The projects presented were intended to provide examples in terms of the application of innovative technologies in the Alpine region concerning defined sustainability aspects. The basis consisted of the project categorisation described above. In a first step, practical examples with an (above)average rating were selected.

Table 3: Benefit analysis for the selected projects

Project specifics		Sustainability indicators					Score
Number	Project (country)	Reduction of harmful emissions	Reduction of greenhouse gases	Reduction of energy consumption	Land use	Improvement of the travel time or quality	Total score
1	Subway Serfaus (AUT)	1	1	1	1	2	**6**
2	E-bus strategy St. Gallen (CHE)	2	2	2	2	2	**10**
3	Léman Express (CHE)	2	2	2	2	2	**10**
4	Zillertalbahn (AUT)	2	2	3	1	2	**10**
5	Gotthard Base Tunnel (CHE)	3	3	2	2	1	**11**
6	Autonomous minibus Bad Birnbach (DEU)	2	2	2	2	3	**11**

In addition, within the feasible limits, the selection of practical examples should reflect the different transport methods, the countries involved in the Alpine Convention and the various transport-related objectives (commuter traffic, tourism and leisure, transit traffic).

As already outlined above, for some projects an assessment based on the sustainability indicators used was not feasible. Regardless of this aspect, these projects can make a crucial contribution to the success of the mobility transition in the Alpine region, for example by advancing the digitalisation process by means of the development of new planning methods, information systems and apps.

Automated and networked or autonomous driving also represents a new and forward-looking technology, so that this area should also be represented by adequate practical examples.

Accordingly, the following projects were selected for more detailed consideration:

- *Brenner Lower Emissions Corridor (ITA)*: With its focus on the reduction of emissions in transit traffic, this project has achieved a good rating except for the criterion relating to the “reduction of travel time and/or quality” (12 points in total).
- *LinkingAlps (AUT)* - Passenger information systems aimed at the improvement in terms of cross-border traffic (without assessment)

- *CO_2 L-Tool and TUM Accessibility Atlas (DEU)* - Alpine Smart Transport and Urbanism Strategies (ASTUS) research project (without assessment)
- *ArcMobilité (CHE)* - Digitisation in public transport (without assessment)
- *mybuxi (CHE)* - Bridging the “first / last” mile with an on-demand ride service (including the development of an app) (without assessment).
- *ECOTRAIN (FRA)* - Autonomous driving on rail in rural areas (including the programming of new software for the autonomous operation of shuttle trains) (without assessment).

4 WORKSHOP

In this context, a one-day workshop was held in Munich in September 2020 in order to exchange experiences on already implemented projects involving forward-looking technologies and innovations in the field of passenger transport. The event was embedded in a meeting of the Transport Working Group of the Alpine Convention. Due to the Corona pandemic, the workshop could only be held as a hybrid event. In total, almost 30 participants participated in it on site and another 30 or so online from the majority of the Alpine Convention countries.

The following practical examples were presented in the course of the workshop:

Table 4: Programme of the workshop held in September 2020

Commuter traffic	Tourism and leisure transport
• Zillertalbahn (AUT) – Hydrogen fuel cell vehicles in rail transport • Léman Express (CHE) – Transnational development of urban rail systems • ArcMobilité (CHE) – Digitisation in the field of local public transport • CO_2 L-Tool and TUM Accessibility Atlas (DEU) - Research Project Alpine Smart Transport and Urbanism Strategies (ASTUS)	• mybuxi (CHE) – Driving service on demand in rural regions • St. Gallen (CHE) – Integration of e-mobility in cities • Serfaus (AUT) – Introduction of a subway in small community
Transit traffic	**Autonomous driving**
• LinkingAlps (AUT) – Passenger information systems for the improvement of cross-border traffic • BrennerLEC (ITA) – Technologies for the reduction of emissions in the field of transit traffic • Gotthard Base Tunnel (CHE) – Infrastructure project supporting the shift of traffic from road to rail	• Bad Birnbach (DEU) – Autonomous driving in the context of the public transport system in Germany • ECOTRAIN (FRA) – Autonomous driving on rail in rural areas

The practical examples were presented (both on site and online) by the actors responsible for the projects and then discussed together with all participants (both on site and online).

The discussion also included the current projects, such as a study conducted in Tyrol, Austria, on the topic of "Mobility-as-a-service (MaaS)"[14]. Among other things, the study aims at the creation of a range of different mobility services (for example, public transport, shuttle and sharing services) tailored to individual requirements.

Furthermore, an innovative model for the estimation of the accessibility of a destination by public transport was presented. The said model shows and analyses operational obstacles in the field of public transport on selected routes.[15]

[14] In the context of the workshop, Dr. Rumana Islam Sarker (University of Innsbruck) presented the study entitled "Mobility-as-a-service (MaaS) in Tyrol, Austria".

[15] During the workshop, Prof. Cavallaro (Politecnico di Torino) presented the article entitled "An innovative model to estimate the accessibility of a destination by public transport" (as published in Transportation Research Part D: Transport and Environment, vol. 80, March 2020, pp. 102-256).

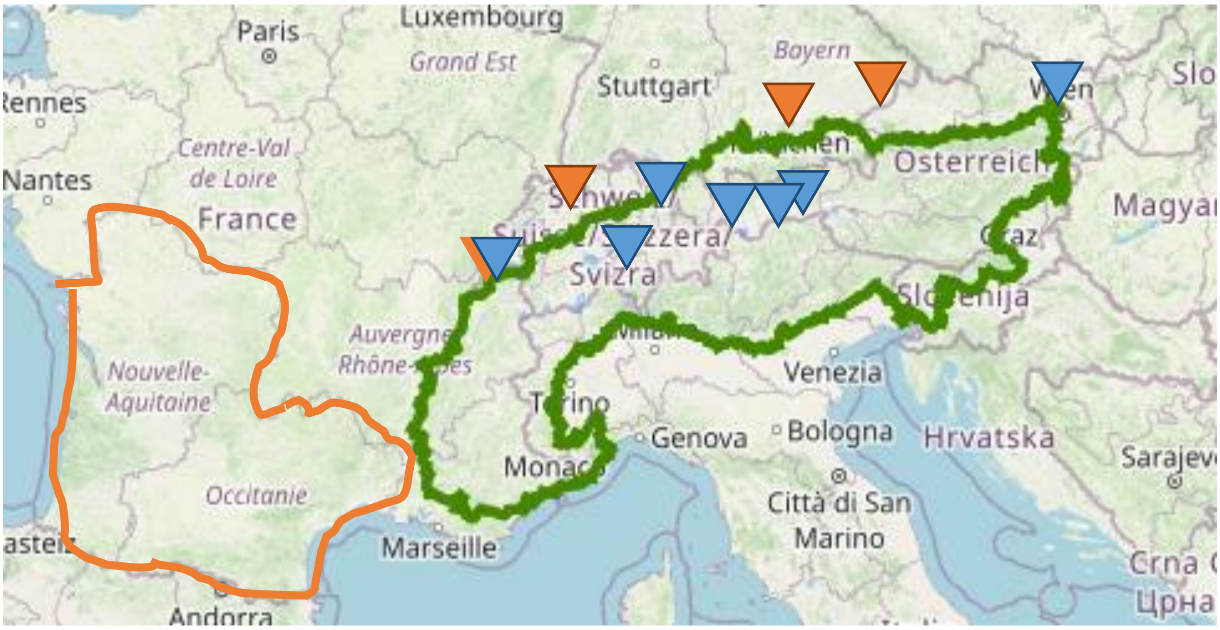
5 PRACTICAL EXAMPLES OF TECHNOLOGIES AND INNOVATIONS TO PROMOTE SUSTAINABLE PASSENGER TRANSPORT

Here in the following, 12 of the projects discussed in the workshop will be examined in more detail. After the brief description of the content or subject matter of the respective projects, the challenges, the objective, the taken measures, and the implemented technologies and will be introduced. On the background of the sustainability indicators, an attempt will be made to identify potential impulses of the respective project for the design of sustainable mobility.[16]

On the said basis, both the strengths and weaknesses of each project and its potential for transferability to other Alpine regions will be identified. Recommendations for action will be developed for the actors in the Alpine region (including project promoters, regional and national decision-makers) who wish to apply new technologies and innovations in the field of passenger transport with a view to the promotion of sustainable mobility in their respective regions.

Figure 6 outlines the geographical distribution of the introduced projects. Seven of the presented projects are located inside and five outside the perimeter of the Alpine Convention.

Figure 6: Overview of all presented projects



16 The presentation of the practical examples is based, among other things, on the presentations in the context of the workshop and on the documents, which have been provided for this purpose.

5.1 PRESENTATIONS OF PROJECTS RELATING TO COMMUTER TRAFFIC

Zillertalbahn (AUT) - Hydrogen fuel cell vehicles in rail transport

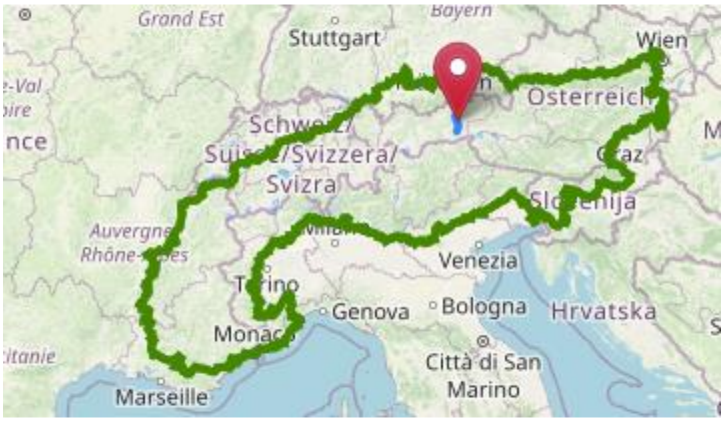


Figure 7: Map view of the Zillertalbahn

1. Project Description relating to the hydrogen train of the Zillertalbahn

	The hydrogen train of the Zillertalbahn
Description and problem statement:	The Zillertalbahn is an Austrian narrow-gauge railway equipped with a gauge of 760 mm, representing the backbone of the public transport in the Austrian valley of Zillertal. The diesel vehicles which are currently in use are from the years from 1980 to 1984 and from the year 2004. The said vehicles cover approximately 0.6 million train kilometres yearly and require approximately 0.9 million litres of diesel. On average, this means 1.49 litres of diesel per train kilometre and associated CO_2 emissions of approximately 2.4 million kilograms per year for the whole fleet. The generally strong increase in traffic in the valley of Zillertal, resulting in congestion on the existing road infrastructure (especially on the line B169), causes car drivers to switch to the train. These are driving forces of the considerable passenger growth of the Zillertalbahn (28.6% more passengers between 2012 and 2018). As a result, the Zillertalbahn has become the fourth largest regional railway in Austria (by passenger numbers) with its current number of 2.83 million passengers (2018) per year. The future objective of the Zillertalbahn is to meet passenger demand and to reduce travel times by at least 10 minutes. However, the acceleration behaviour of the currently operating diesel railcars is too low to achieve the planned reduction in terms of travel times. Consequently, vehicles equipped with modern drives will be absolutely necessary. As a result, a new vehicle procurement was initiated for the replacement of the existing diesel vehicles. In this context, the use of the following technologies was compared within the framework of an economic feasibility study: entire electrification of the line by equipping it with electric multiple units, the overhead line battery hybrid multiple units to bridge the overhead line-free sections in sensitive areas such

	The hydrogen train of the Zillertalbahn
	as town crossings and hydrogen electric multiple units for the overhead line-free operation on the entire line.[17] The technology comparison showed that operation with hydrogen electric multiple unit trains is more cost-efficient over the entire life cycle than the operation with electric multiple units (pure electric multiple units or catenary battery hybrid multiple units), as the additional costs of the hydrogen electric multiple unit trains and the additionally required hydrogen infrastructure are offset by the savings of the expensive overhead line infrastructure which is not required. Another advantage offered by the use of hydrogen electric multiple unit trains is the opportunity of using the hydroelectric power plant in Mayrhofen for the production of the hydrogen.[18]
Objective:	Renewal of the existing fleet in order to achieve the reduction of travel times by 10 minutes in normal service and by 19 minutes on the high-speed line (REX).
Measures:	Procurement of five four-car hydrogen electric multiple unit trains and construction of the necessary hydrogen tank infrastructure.
Technologies / innovations:	Hydrogen electric multiple unit trains of the company Schweizer Stadler Rail AG, proton exchange membrane water electrolyser (PEM) for the generation of hydrogen, hydrogen storage and fuel columns for refuelling.
Sustainability-related aspects:	• Emissions: The emissions can be significantly reduced by the used of the hydrogen electric multiple unit trains compared to diesel vehicles. The actual emissions depend on the type of electricity required for electro-lysis. In the case under consideration, the electricity is generated with low emissions by the existing hydropower plant. • Land use: The existing rail infrastructure can be used without taking any conversion measures. The hydrogen production requires the construction of a new electrolyser near the hydropower plant in Mayrhofen. For the hydrogen storage and supply, fuel pumps and hydrogen tanks will be built in Mayrhofen and Jenbach. • Travel time / quality: The new vehicles will reduce the travel times, by making the use of local rail passenger transport more attractive in comparison with motorised private transport.
Speakers:	Dr. Nikolaus Fleischhacker, FEN Systems GmbH Dr. Helmut Schreiner, Zillertaler Verkehrsbetriebe AG

[17] Cf. (Schreiner and Fleischhacker 2018) .

[18] Cf. (Schreiner and Fleischhacker 2018) .

2. Project Assessment

The resulting strengths and/or success factors seem to be the following:

- Strengthening of the local value chain by the generation of the electricity needed for hydrogen production in the region through the nearby hydroelectric power plant located in Mayrhofen.
- Future use of the existing infrastructure as well as expansion of the same with the hydrogen-specific infrastructure (fuel pumps, hydrogen tanks, and electrolyser).
- Successful cooperation of local actors (politicians, power plant operators, and railway operators).
- Reduction of local emissions through the replacement of diesel railcars with hydrogen railcars.
- Introduction of the potentially more extensive use of hydrogen technology in the region (for example, zero-emission buses, and snowcats for the maintenance of the ski resorts).

The resulting weaknesses seem to be the following:

- Risk of delays and problems relating to the vehicle delivery and operation due to new technology.
- Dependence on good functionality of the local hydrogen production.

Alpine specificity:

- Low-cost green power generation by the hydroelectric power plant for hydrogen production.
- Protection of the tourist region: reduction of CO_2 emissions, preservation of the landscape thanks to the avoidance of the construction of overhead lines.
- Further regional applications of hydrogen technology (for example, emission-free buses and snow groomers for the maintenance of the ski resorts).

3. Potential Analysis of the Project:

The example of the Zillertalbahn shows that there is a great potential when it comes to the use of hydropower for the transport sector in the Alpine region. Due to the special topography of the Alpine region, there are numerous hydropower plants[19] which can promote the economic use of alternative drives, such as the hydrogen technology. The potential of the said energy production from renewable sources should also be increasingly exploited for the mobility sector.

[19] In the Alpine region, 1,019 hydropower plants (from 5 MW) are operated. Cf. (Baumgartner and Schönberg 2017) .

4. Recommendations for Action:

In case of existing railway lines operated with diesel railcars, the following is recommended to the project promoters[20]:

- Consideration of the use of alternative propulsion technologies such as hydrogen electric railcars,
- Examination of the existing funding opportunities in the field of hydrogen technology.

The regional or municipal territorial units[21] are recommended to cooperate with the regional energy industry in order to permit

- The examination of the opportunities offered in terms of local production of green hydrogen and in particular for the inclusion of the use of hydroelectric power plants.
- The exploration of the further potential uses of hydrogen (for example, hydrogen refuelling stations for cars and trucks) and
- The exploration of the opportunity in terms of a development of local and/or regional hydrogen networks.

[20] In the present case, the project promoters may be the following institutions: public transport authorities and railway undertakings in the countries of the Alpine Convention.

[21] The administrative organisation and structure of the eight member states of the Alpine Convention differs greatly. Various levels of government are attributed different economic and administrative competences. In this context and in the following discussion, the term "territorial authorities" and the addition of "regional" or "municipal" are used as an attempt to designate the adequate government level.

Léman Express (FRA / CHE) - Transnational development of urban rail systems

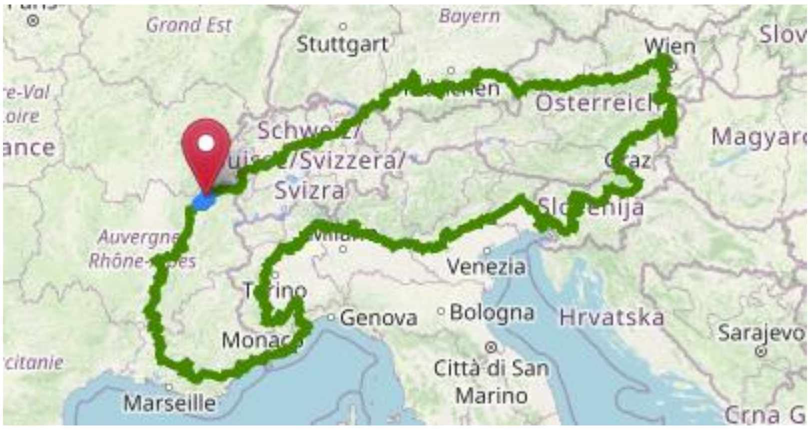


Figure 8: Map view of the Léman Express

1. Project Description Léman Express

	The Léman Express
Description and problem statement:	The traffic flows of the Auvergne-Rhône-Alpes region and the Swiss cantons of Geneva / Vaud are characterised by a high volume of commuters and traffic. According to an estimation, approximately 500,000 commuters daily cross the French-Swiss border.[22] A cross-border urban railway has been built since 2005 to encourage the shift of road traffic to rail. The Léman Express has been in operation since December 2019 and serves 45 stations on six lines, with a total length of 230 kilometres. 214 kilometres of railway line were already in place and used by other com-muter / regional trains before the Léman Express. In the course of the regular services, during the weekdays, (from 05:00 am to 0:30 am) up to six trains per hour run on the main line between Geneva and Annemasse now. At weekends, a 24-hour train operation is applied. In September 2020, the Léman Express service was already being used by 25,000 passengers per day while according to expectations 50,000 passengers per day may be reached.[23] The following figure will give an overview in terms of route map:

[22] Cf. (Léman Express 2021) .

[23] Cf. (Léman Express 2021) .

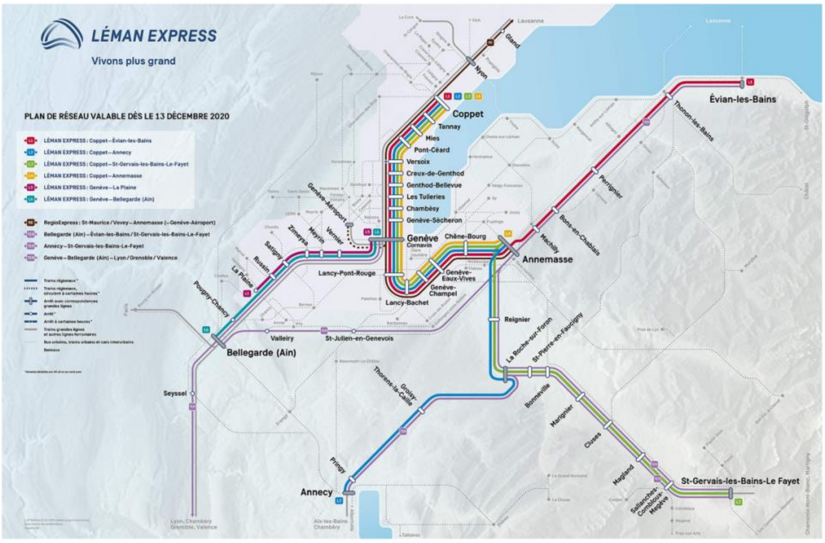


Figure 9: Route map of the Léman Express[24]

Objective:

The objective of the project consists of the reduction of use of private transport in the region by 12%.

Measures:

Expansion of the cross-border public transport through the set-up and extension of a cross-border "S-Bahn network" between Geneva-Annemasse, Geneva-Évian-les-Bains and Geneva-St-Gervais-les-Bains-le-Feyet.

The infrastructure-related expansion will be linked to a redesign of the tariff system and the creation of multimodal connection points. Several urban and regional bus and tram lines (approximately 50) will be connected to the said points.

For the implementation of this project, 16 kilometres of new track, including two kilometres in France and 14 kilometres in Switzerland were laid. In addition, five new metro stations were built. An eight-kilometre network gap between Genève-La Praille and Eaux-Vives was largely closed via underground-tunnelling.

Technologies / innovations:

17 four-unit Régiolis electric multiple trains by Alstom and 23 four-unit electric multiple trains, model FLIRT, by Stadler are in operation. All trains can run on both mains voltages and are approved both in Switzerland and France.

[24] Cf. (Léman Express 2021) .

Sustainability aspects:	• Emissions: The use of electric multiple trains, which thanks to their dual-frequency capability are operable in both countries, means that diesel multiple trains can be dispensed with. In addition, a crucial CO_2reduction is expected through the shift effect from private to regional passenger rail transport. • Energy consumption: Modern electric rail vehicles have lower energy consumption and better efficiency than, for example, diesel vehicles, often used in cross-border regional services for the simplification of the infrastructure compatibility (in particular in terms of grid voltage). • Land use: Use of existing infrastructure with a new line of 16 kilometres. • Travel time / quality: Due to the densely timed S-Bahn network on most routes and against the background of the high traffic volume on the roads during peak hours, longer travel times in public transport (in comparison with a travel time by car with low traffic volume) may be negligible. Furthermore, the positive effects generated for commuters, resulting in a stress-free journey, in predictable travel times and in the high comfort of the new vehicles, should be mentioned at this point.
Speaker:	Prof. Dr. Laurent Guihéry, Université de Cergy-Pontoise

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- Largest cross-border urban railway in Europe comprising a total route network of 230 kilometres.[25]
- Use of the existing infrastructure for the most part. The said infrastructure was partly supplemented by closing gaps, modernised by construction measures and/or adapted to new routing.
- Comprehensive upgrade of the whole system through the construction of new stations, the merger and expansion of existing lines and the procurement of modern regional trains.
- The rail infrastructure expansion will permit the creation of an integrated local transport network. The stops and stations of the Léman Express will be connected by several (approximately 50) urban and regional bus and tram lines. Furthermore, a cross-border fare system has been implemented for the routes.

The resulting weaknesses seem to be the following:

- The Swiss Federal Railways AG SBB and the Auvergne-Rhônes-Alpes region have not procured uniform rolling stock, which means that the trains cannot be coupled together (for example in the event of towing or extension of the train set).

[25] Cf. (Fumagalli and Oesch 2019) .

- The currently used passenger information system needs improvements to be implemented in terms of reliability and quality of passenger information.
- On some routes, the railway lines are outdated so that partly only a single-track operation is feasible. For this reason, not all regions / stops are served by the Léman Express by offering the same level in terms of quality.[26] In the future, the said bottlenecks must be eliminated.

Alpine specificity:

- Protection of the Alpine region: reduction of the CO_2 emissions by shifting private transport from road to rail.

3. Potential Analysis of the Project:

The Léman Express shows that cross-border public transport projects between rural and metropolitan areas can be successfully built and operated. This applies in particular if they can rely to a large extent on the already available infrastructure. However, the transferability to other border regions of the Alpine region seems to be subject to certain limits.

4. Recommendations for Action:

The following is recommended to the project promoters [27]:

- The analysis, by means of studies, whether there is a demand for cross-border public transport connections and in which manner this offer can be made user-friendly and attractive, for example, via uniform ticketing systems and passenger information.
- The examination of the extent to which the already existing infrastructure can be used and, if needed, extended to offer smooth cross-border local transport.

The operating companies are given the following recommendation:

- To ensure the technical interoperability of the trains to perform smooth cross-border services.

[26] Cf. (Fumagalli and Oesch 2019) .

[27] Here: Cities or regions that are close to the border and want to offer cross-border transport.

ArcMobilité (CHE) - Digitisation in local public transport

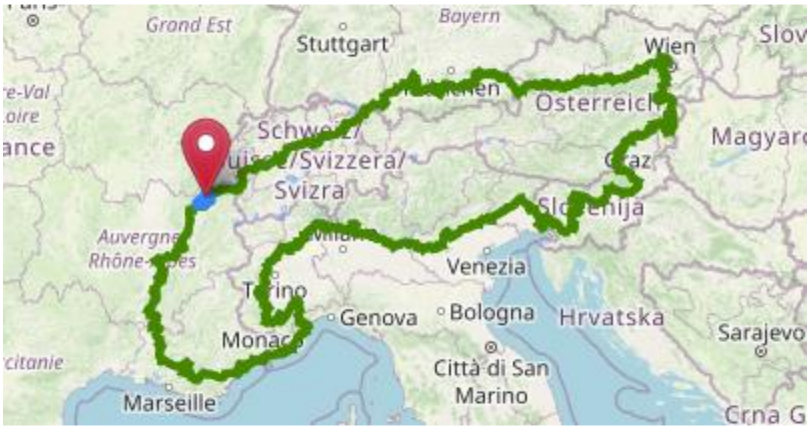


Figure 10: Map view of the project Arc Mobilité

1. Project Description:

	Digitisation in local public transport: The Arc Mobilité project
Description and problem statement:	The Geneva-Lausanne conurbation is equipped with a well-developed and efficient public transport system. However, the volume of commuters leads to a high traffic load both in local public and in motorised private transport. At the same time, people's mobility behaviour is changing.[28] The demand for flexibility when it comes to the choice of means of transport, in order to choose the best transport method in different areas of life (work, shopping, leisure, travel) and to combine different transport means in a smart manner, is constantly increasing. A cross-provider tariff and distribution system already exists for the local public transport in the region. The same applies to the automatic ticketing via a cross-provider pay-per-use model. However, especially the private mobility service providers have not yet been integrated into these systems. For this reason, in the context of the pilot project "ArcMobilité" initiated by Schweizerische Bundesbahnen AG SBB, data from public and private mobility providers should be linked to enable multimodal mobility.
Objective:	The pilot project "Arc Mobilité" pursued the following three main objectives: 1. Creation of incentives for citizens to use new multimodal mobility forms. 2. Enablement of the public and private actors, through the establishment of a digital mobility platform, to network their mobility offers in a simple way. The created platform is open to all means of transport. 3. Exploration of innovative forms of financing for the provision of mobility services for cases in which purely commercial approaches would fail.

[28] Cf. In his interview on 24 February 2021, Andreas Fuhrer stated: "The biggest winner of the networked mobility is the public transport" (Alliance SwissPass 2021) .

Measures:	The pilot project started in April 2020 with preliminary tests. Subsequently, a user community of mobility providers and end users was created. The technical solutions, the mobility offers, and the organisational framework were completed in 2021.
Technologies / innovations:	Platform-based public digital infrastructure (website or mobile app).
Sustainability aspects:	• Positive effect on emissions, energy consumption, and land use in the case of increased use of local public transport via the platform use. • Travel time / quality: Improvement of travel time and quality through better information and seamless links between the mobility services.
Speaker:	Andreas Fuhrer, SBB AG

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- Provision of a range of mobility services (MaaS) tailored to individual needs.
- Creation of a common platform for providers made of various private and public mobility providers.
- Promotion of the cooperation between the private sector and the government actors.

The resulting weaknesses seem to be the following:

- A major challenge is usually to win customers for such offers. A critical mass of transport providers and end users would be required to generate positive effects following the platform implementation.
- A potentially elevated requirement in terms of coordination due to the large number of involved partners.

Alpine specificity[29]:

- Protection of the tourist region and improvement of the living conditions of the local population: reduction of CO_2 emissions if there is a shift from the private transport to rail or other local public transport services.

[29] The project Arc Mobilité in the region of the Geneva Lake is not located in the area geographically covered by the Alpine Convention. However, as the canton can be geographically located in the Alpine region, alpine-specific characteristics are nevertheless given.

3. Potential Analysis of the Project:

The objective of the pilot project is to link public and private mobility providers in order to enable multimodal mobility. The idea of the platform developed for this purpose could be taken up, adapted, and applied by other regions of the Alpine region. The project is already considering the taking-up of project results and their transfer to other European regions.

4. Recommendations for Action:

The following is recommended to future providers of similar services:

- The securing of the interest of the highest possible number of mobility providers already present on the local market - by including private mobility service providers - in the approach and the securing of their participation,
- The adaptation and ("openly") further development of the already existing solutions (if possible, in a "technology-open approach"), if this is doable and meaningful, and
- If needed, the definition and highlighting of special advantages of use (for example more attractive tariffs when the platform is used in comparison to the conventionally applied tariffs).

CO_2 L-Tool and TUM Accessibility Atlas (DEU) - Research Project Alpine Smart Transport and Urbanism Strategies (ASTUS)

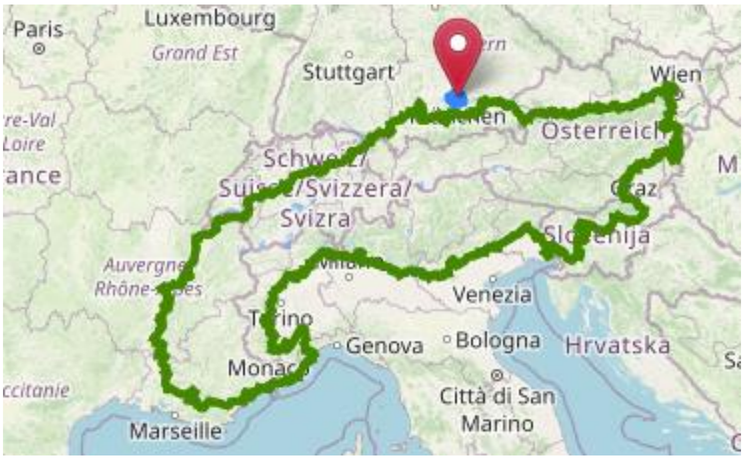


Figure 11: Map view of the project ASTUS

1. Description of the Research Project ASTUS

	ASTUS for the Munich region
Description and problem statement:	In the framework of the Interreg[30] funding call “Spatial Development and Governance” in the Cooperation Area “Alpine region” the ASTUS research project was carried out by 12 partners from 5EU countries[31] between 2016 and 2019. The general objective pursued by ASTUS consisted of finding innovative mobility solutions, the creation of awareness for sustainable mobility and settlement planning, the development of planning tools for the CO_2 reduction and offering support to local decision makers when it comes to the development and implementation of sustainable measures. The German partners in the project were the Technical University of Munich (TUM), the Munich Transport and Tariff Association (Münchner Verkehrs- und Tarifverbund) and the City of Munich (Stadt München)[32]. The contributions made by the TUM to the research project are presented in this context. Among other things, this part of the project was motivated by the demographic development of the metropolitan areas in the Alpine region. These are often faced with the challenge of having to deal with demographic growth and with the increase of the number of commuters and the volume of leisure traffic. With partly missing or low-level local public transport services, the high dependency on the car often results in an overloaded road

[30] The Interreg programs are part of the European structural and investment policy. They aim at the promotion of cross-border cooperation between regions and cities in areas such as transport, labour market and environmental protection. Cf. (Ahlke, Kurnol and Thul 2021) .

[31] France, Austria, Germany, Slovenia, Italy.

[32] For more information on the partners: https://www.alpine-space.eu/projects/astus/en/about/project-partners-observers.

	transport infrastructure by causing a higher quantity of CO_2 emissions as well. The following challenges had to be faced in the German pilot regions involved in the project: • Districts of Fürstenfeldbruck and Starnberg: Due to the non-existent or inadequate direct connections to the neighbouring districts, many passengers must use the Munich S-Bahn with a detour through the city. The objectives pursued by the districts consists of ensuring a flexible, intermodal mobility in the region. • District of Munich: The district's climate targets are to be met. • District of Ebersberg: Ebersberg would like to become a model region for the comprehensive car-sharing in rural areas.
Objective:	In the long term, the ASTUS project aims at the improvement of the provision of public transport, sharing services (car and bike sharing) and electric mobility, and at the initialisation of integrated intermodal mobility options as an alternative to private cars.
Measures:	The TUM developed practical planning tools for sustainable, integrated and low-carbon transport and settlement planning, the so-called "CO_2L-Tool" and the "TUM Erreichbarkeitsatlas / Accessibility Atlas" (see below). On the basis of said tools, the following measures were taken into consideration: • Districts of Fürstenfeldbruck and Starnberg: The introduction of tangential (e-)express bus routes around Munich is planned. In addition, the creation of a range of flexibly combinable mobility services is planned. For this purpose, the establishment of a comprehensive network of mobility stations is planned to ensure a smooth transfer between different transport methods. • District of Munich: The regional bus service, which had already been expanded in recent years, needs a conversion to alternative drives (use of green electricity). • District of Ebersberg: The use of the car sharing services is to be increased step by step. At the beginning of the research project, there were already eight car sharing associations with 800 members. In the course of the research project, three municipalities and 100 members were added. Among other things, the said increase was specifically supported by the fact that the carsharing vehicles were made available as close to home as possible and across the board, as well as by the reduction of the number of parking spaces put at disposal in new development areas.
Technologies / innovations:	The CO_2L-Tool can be used for any study area to quantify and graphically display the CO_2 emissions or savings based on parameters such as trip frequency, modal split, trip length, occupancy rate, and emission factors. Spreadsheets and databases support the identification of innovative and sustainable measures in the field of

	urban planning and mobility and the estimation of their effects in scenarios.[33] The “TUM Erreichbarkeitsatlas / TUM Accessibility Atlas” enables the calculation and visualisation of accessibility levels in the Munich Metropolitan Region based on the data relating the settlement structure and transport supply. The tool is intended to support decision-making processes in connection with both integrated settlement structure and transport planning. It can display maps of catchment areas based on a defined travel budget and then analyse the effects of planning options.[34] All instruments resulting from the research project are available on the following website: https://www.alpine-space.eu/projects/astus/en/project-results/decision-making-tools/co2-minimizer-toolbox.
Sustainability aspects:	• Potential in terms of reduction of emissions, energy consumption and land use, provided that sustainable offers can be established by means of the findings. • Travel time / quality: Improvement of the travel quality by the establishment of new mobility services.
Speakers:	Dr. Julia Kinigadner, Technical University of Munich Dr. Benjamin Büttner, Technical University of Munich

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- Development of interdisciplinary assessment approaches for spatial, settlement and transport planners.
- In a region explored by the study, all transport options are evaluated and included in the problem solution (integrated approach).
- By means of the instruments, planning variants can be compared and assessed in terms of their sustainability aspects.

3. Potential Analysis of the Project:

The planning tools developed by TUM can be applied in any region in the Alpine region and beyond as they are able to identify, evaluate and, if needed, optimise new mobility solutions. For this purpose, the “TUM-Erreichbarkeitsatlas / TUM Accessibility Atlas” must be adapted by entering the specific data of the target region.[35] The “CO_2L-Tool” can be used for any study area

[33] Cf. Project Fact Sheet “CO_2 L-Tool”, (Kinigadner, Büttner and Volpers 2019) .

[34] Cf. Project Fact Sheet “TUM Accessibility Atlas”, (Büttner, Kinigadner and Ji 2019) .

[35] The Accessibility Atlas has currently only been compiled for the Munich Metropolitan Region.

to show both CO_2 emissions and savings by consequently contributing to the enablement of lower-emission mobility if needed.

4. Recommendations for Action:

The following is recommended to regional and municipal decision-makers:

- The more extended use, where needed, of tools supporting the calculation of accessibility levels and the CO_2 impact of relevant measures.
- The discussion of proposals developed on this basis and, if needed, the examination of their feasibility.

5.2 PRESENTATIONS OF PROJECTS RELATING TO TOURISM AND LEISURE TRANSPORTS

mybuxi (CHE) - Driving service on demand in rural areas

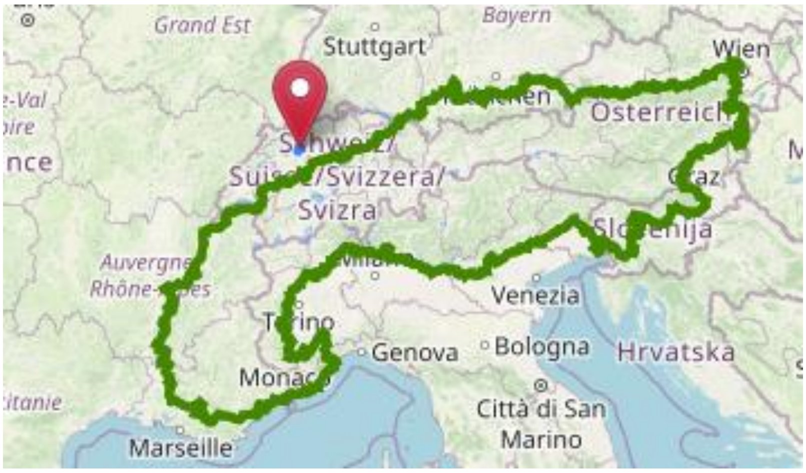


Figure 12: Map view of Herzogenbuchsee / Switzerland - 1st location of mybuxi

1. Project Description

	Driving service on demand in rural areas
Description and problem statement:	In rural areas of the Alpine region, due to the limited local public transport offer, the residents often depend on the use of their (own) car. Where the local public transport is available, the Alpine region may also be characterised by topographically induced long travel times and by a lacking connectivity between the individual routes. mybuxi[36] is an on-demand driving service for sprawling, rural residential areas. Door-to-door transport services can be ordered via app or phone. The associated IT system bundles ride requests to efficiently manage both costs and routes. The transport prices are based on those applied by the local public transport. The mybuxi service was launched in Herzogenbuchsee in 2019 and is currently being tested and introduced in other Swiss municipalities. For this purpose, the objectives of the service are being defined in cooperation with the involved local stakeholders so to ensure their ideal adaptation to local needs. In the Swiss valley of Emmental, an integrated driving and delivery service is now being established step by step.
Objective:	Bridging of the “first / last mile” of passenger transport especially for young people who have not obtained their driving licence yet for the elderly people who do not drive a car any longer.

[36] The artificial name Buxi is a combination of bus and taxi. This is intended to reflect the feature of a public bus combined with the advantages of the flexible door-to-door availability of a taxi.

Measures:	Development of an app for the offered services, procurement of vehicles, and construction of charging infrastructure for e-vehicles. Among other thing, the project is financed through state and private start-up aids, a supporting association, and the rental of “virtual” stops, for example, to hotels, shops, etc.
Technologies / innovations:	Minibuses partially equipped with electric drive, and demand management via an IT system.
Sustainability aspects:	• Emissions: Where possible, efforts will be made to use pure e-vehicles. If the mybuxi operation results in a lower use of private cars, this can make a contribution to a general reduction in terms of CO_2 emissions. • Land use: The existing transport and charging infrastructure will be used; additional e-parking spaces with charging points may be needed. • Travel time / quality: A high level of travel quality is offered to passengers through modern vehicles, an 18h/day service and the “door-to-door” option. Due to the shared journeys, the travel time may be slightly longer in comparison with the own car.
Effects on public transport:	• mybuxi can act as a feeder and thus promote the use of regional local public transport. According to the operators, 2.5 times as many people use the bus service in Herzogenbuchsee than before the introduction of the mybuxi driving service.
Speaker:	Dr. Andreas Kronawitter, mybuxi

2. Project Assessment

The resulting strengths and/or success factors seem to be the following:

- Flexible driving services combined with a simple or innovative customer interface (via app or phone) can make their contribution to mobility improvements at a regional level.
- The service complements the local public transport on the “last mile” by consequently increasing its attractiveness.
- High attractiveness also for tourism transport: Especially smaller and remote accommodations get the change of organising the pick-up and drop-off service for their guests very flexibly via such driving services.
- Extensibility to delivery services of the local retail trade: This advantage secures the supply of the population and the survival of local shops.

The resulting weaknesses seem to be the following:

- Predominantly electric vehicles are to be used for the operation. However, the charging infrastructure is still partially lacking. Furthermore, no electric all-wheel-drive minibuses are (yet) available on the market which means that regions having a challenging topography can only be served by conventional drive systems, especially during the winter months.
- To ensure the smooth functioning of the service, mobile phone network coverage must be guaranteed throughout the country, as the mybuxi driver receives his orders through his / her mobile phone. And this is not (yet) the case everywhere in the rural areas.

- The start-up and permanent financing of the services represents a challenge. For their maintenance, new business and financing models have to be found when it comes to the economic efficiency for providers and users. This aspect also includes the deployment planning because there are both volunteer drivers receiving an expense allowance and permanently employed drivers.

Alpine specificity[37]

- Protection of the Alpine region: reduction of CO_2 emissions through the replacement of shared and (in the foreseeable future) zero-emission vehicles.
- Increase of the inhabitants' quality of life: Improved connection of remote areas which were previously difficult to reach in terms of transport and supply. Provided that the electricity of the e-drives can be generated sustainably, for example, from local hydropower, on-demand ride services show to be an attractive zero-emission mobility solution also for remote regions of the Alpine region.
- Preservation of tourist attractiveness: In particular, the flexibility in the arrangement of stops and the comparatively small vehicle size appear to be advantageous for the Alpine region when it comes to the requirements of hiking and ski tourism (good connections to leisure, accommodation and catering facilities, and high frequency at peak times).

3. Potential Analysis of the Project:

The example of mybuxi shows that in the rural Alpine region the potential for the use of on-demand driving services for both residents and tourists is great. Due to the special topography, the settlement structure as well as the largely limited local public transport offer, there are numerous communities for which the offer of such a driving and potential delivery service seems to be meaningful. If the charging infrastructure is available throughout the area, cross-border operation may even be conceivable. However, transferability to other rural regions does not appear feasible without ensuring the public or private start-up financing. New business and financing models adapted to the respective regional conditions are also indispensable when it comes to the economic viability of the service.

[37] The mybuxi project in Herzogenbuchsee is not located in the area geographically covered by the Alpine Convention. However, as it can be geographically located in the Alpine space, Alpine-specific features are nevertheless given.

4. Recommendations for Action

The following is recommended to future providers of similar services:

- The detailed determination of the demand potential in the targeted service areas and the development of scalable entry models,
- The securing of the financing basis by involving public or private sector stakeholders (for example, municipalities, ski lifts, and accommodation providers),
- The examination of existing funding opportunities for the procurement of e-vehicles and the needed charging infrastructure,
- The entering into cooperation with private-sector stakeholders, for example with suppliers of daily necessities so to enable the combination of passenger and freight journeys, if needed, by consequently optimising the economic viability of the service.

The following is recommended to municipalities:

- The active involvement of local mobility service providers from the outset in order to counteract any competitive situations between the existing (local public transport and taxi) providers and to actively promote a cooperative interaction between all relevant stakeholders,
- The active support of the use of the service through advertising, discounts, etc. - especially at the beginning because this can help to lower the acceptance threshold in the population,
- The provision of the new service with sufficient time to take root and the creation of the design of the public support services accordingly.

St. Gallen (CHE) - Integrating e-mobility in cities

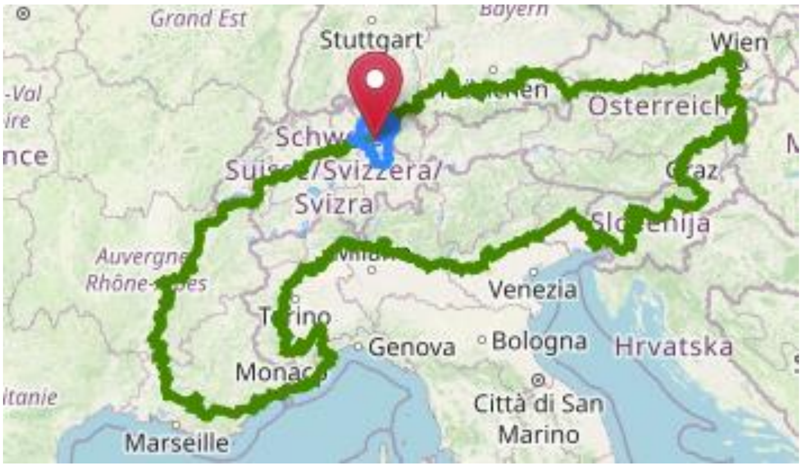


Figure 13: Map view of St. Gallen

1. Project Description

	Use of electric buses in local public transport
Description and problem statement:	The canton St. Gallen has set itself the long-term goal of using 100% electric buses or buses equipped with alternative drives in local public transport and to operate these exclusively with renewable energy. For the implementation of the said objective, the independent research and consulting company INFRAS was commissioned to prepare a study[38], a so-called e-bus strategy. In the study various vehicle types such as night chargers, so-called “opportunity chargers”, trolleybuses (with overhead line) and combi-chargers (mix of night and opportunity chargers) with diesel buses were compared for a selection of bus routes. The conclusion of the study was that the ideal e-bus option depends on the infrastructural conditions of each individual line. The workshop presentation focused on the case study of line 151 (Gossau - St. Gallen) of the canton with three different routes (Gossau Bhf. - St. Gallen Spisertor: 12.7 km; Gossau Bhf. - St. Gallen Spisertor (via Oberdorf): 12.5 km; Gossau Bhf. - St. Gallen Bhf.: 11.7 km) on which articulated buses are also used.
Objective:	Determination of the ideal e-bus fleet for a given line.
Measures:	In the specific case of line 151, various vehicle types were examined, assessed on the basis of various criteria (such as costs, and passenger comfort) and compared with each other. On the said basis, the opportunities and limitations of each type, the estimated costs, and the potential implementation paths were outlined by considering the technical developments.

[38] From the following link you can gain access to the study: https://www.infras.ch/media/filer_public/41/47/4147ce14-1031-40c6-bf76-b768d043dc86/schlussbericht_e-bus-strategie_kanton_stgallen.pdf.

	For what concerns line 151, a mixed fleet of battery-powered trolleybuses and night chargers seems particularly suitable thanks to the existing trolleybus network.
Technologies / innovations:	Trolleybuses with overhead line and night loader for line 151
Sustainability aspects:	• Emissions: A significant reduction in terms of emissions will be achieved through the use of e-buses. The used electricity will come from renewable energies. • Energy consumption: Modern electric buses show a lower energy consumption than diesel buses. • Land use: The existing infrastructure will be used. • Travel time / quality: For passengers, the use of modern buses can result in an increase in terms of travel quality, for example through quieter vehicles, without any change concerning the travel time.
Speaker:	Cornelia Graf, INFRAS AG

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- The study recommends and develops differentiated solutions for each individual bus line.
- The assessment methodology is not limited to energy consumption and emissions, but also includes economic and infrastructural aspects. Consequently, the study makes the attempt to find solutions on the basis of the existing infrastructure, for example the continued use of the overhead line network of line 151.

The resulting weaknesses seem to be the following:

- In some cases, the charging infrastructure for the operation of electric vehicles is still missing.
- There are elevated investment and acquisition-related costs for the operator. However, most Alpine Convention countries have support programmes for the acquisition of e-buses in local public transport.

Alpine specificity[39]:

- Protection of the Alpine region: reduction of CO_2 emissions through the replacement (in the foreseeable future) by zero-emission vehicles.
- Increase of the quality of life of the residents and preservation of the attractiveness for tourists: Reduction of CO_2 emissions as well as noise and pollution (especially in the city) through the use of low-emission vehicle technology. Provided that the electricity for the e-drives can be generated sustainably, for example from local hydropower, e-buses in public transport appear to be an attractive zero-emission mobility solution.

[39] St. Gallen is not located in the area geographically covered by the Alpine Convention. However, as the canton can be geographically located in the Alpine region, Alpine-specific characteristics are nevertheless given.

3. Potential Analysis of the Project:

The example of the e-bus strategy implemented in the canton St. Gallen shows that the choice of the most suitable variant for each location / line through the different e-bus variants is feasible. The same can be said when it comes to achieve an emission-free urban and interurban local public transport whereby this applies provided that the needed investments are made. Consequently, the e-bus strategy from the canton St. Gallen can serve other (Alpine) regions as an example when it comes to the way operators can approach the introduction of e-buses in the field of local public transport.

4. Recommendations for Action:

The following is recommended to regional and municipal decision-makers:

- The examination of the feasibility of using different variants of e-buses,
- The execution of studies relating to the implementation of an individual e-bus strategy, if needed,
- The examination of existing funding opportunities for the procurement of e-vehicles and the needed charging infrastructure.

Serfaus (AUT) – Introduction of a subway in small community

Figure 14: Map view of Serfaus

1. Project Description

	Subway in Serfaus
Description and problem statement:	The Austrian municipality of Serfaus has 1,151 inhabitants (2020) and, together with the neighbouring villages of Fiss and Ladis, it offers 15,400 overnight accommodations. As early as the 1980s, Serfaus experienced an increase in tourism and associated with this, a strong seasonal increase in traffic. In 1972, following the example of some Swiss communities, a so-called "traffic relief concept" was adopted. According to the said concept, winter sports enthusiasts were to be driven to the ski resorts exclusively by collective buses. When this concept also reached its limits in the small community because of the further increase in the number of visitors, alternative transport solutions were sought to guarantee the accessibility of the valley station of the cable cars and ski lifts. In this context, the following requirements had to be met: The means of transport should be able to be operated (almost) silently and the preservation of the village image had to be ensured.[40] After having examined several potential solutions, in 1983, the local council decided to build an underground, driverless, cable-driven aerial tramway financed by the municipality. Even if the said construction required the tearing-up as well as the tunnelling under the main street of the village and an additional partially shoring-up of the foundations of the adjacent houses, this technology was chosen because it was quiet and generated a low level of vibrations which meant that the impact on local residents during operation could be kept as low as possible. When the operations started in 1986, a driving ban was additionally imposed on the community of Serfaus. Since then, guests have been allowed to drive their private cars to the accommodation on their day of arrival. However, their use in the town during their stay was forbidden. In 2016, the existing system had to be renewed after 30 years without restricting operations in the summer and winter seasons. In the

[40] Cf. (Serfaus-Fiss-Ladis Marketing GmbH 2019) .

	context of the said renewal, the system capacity should be increased as well.
Project Content:	Renewal and expansion of the existing rail system and procurement of new rolling stock with the aim of increasing the number of transported passengers by reaching a better-quality level.
Measures:	Refurbishment and modernisation of all stations (including the barrier-free access still missing in two stations) as well as the line infrastructure. Construction of an additional station. Additional procurement of new vehicles, by increasing the passenger capacity to 3,000 passengers per hour.
Technologies / innovations:	Driverless hovertrain equipped with cable drive.
Sustainability aspects:	• Emissions: The hovertrain equipped with cable drive runs electrically. Assuming the use of green electricity, climate-neutral operation is feasible. • Energy consumption: The railway has a fully automatic electrical operation. • Land use: The railway was built underground along the main road. Consequently, it runs independently of above-ground traffic. No further sealing of areas has taken place. • Travel time / quality: The underground hovertrain has a high modal shift effect, which is further enhanced by the car-free city concept. The renewal of the entire system as well as the vehicles results in a positive travel-time balance (a reduction in terms of waiting time from 10 to 9 minutes until the next train could be achieved) and in an improved travel quality due to more comfortable vehicles.
Speaker:	Andrea Koolen, Tourism Association Tourismusverband Serfaus-Fiss-Ladis.

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- The community made a holistic decision early on (1980) for low-emission and sustainable traffic design and relief.
- The costs were borne by the municipality, and the local inhabitants involved in this decision.[41]
- To keep the impact as low as possible, a (low-noise and underground) technology meeting the local requirement was used.
- Well-balanced project management during the construction in 1984 / 85 and the refurbishment / renewal in 2016: All measures took place during the seasonal breaks so to keep the restrictions for tourists as low as possible during the peak periods.

[41] Cf. (Serfaus-Fiss-Ladis Marketing GmbH 2019) .

The resulting weaknesses seem to be the following:

- The construction and operation of subways is very costly. For this reason, it is not always readily available within small communities.

Alpine specificity:

- Preservation of the tourist region: preservation of the image and landscape of the village. Use of underground vehicles offering the option of transporting a large number of passengers. Without the development of the railway, the further development of tourism would hardly have been achieved.
- Reduction of CO_2 emissions by the use of emission-free technology as well as by the avoidance of car traffic.

3. Potential Analysis of the Project:

The subway project in Serfaus seems to represent a successful example of low-emission and sustainable traffic design and relief within small communities exposed to a strong tourism-related influence. Nevertheless, the transferability of the subway technology to other municipalities in the Alpine region is likely to be limited due to the high investment costs involved.

4. Recommendations for Action:

The following is recommended to the promoters:

- The conduct of research and commission studies open to all technologies and taking into account existing examples so to find the adequate mobility solutions for the specific local conditions by making use of the suitable technologies.
- Conduct of citizen surveys and participations to incorporate the concerns and wishes of the resident population into the project selection procedure.

5.3 PRESENTATIONS OF PROJECTS RELATING TO TRANSIT TRAFFIC

LinkingAlps (AUT) - passenger information systems for the improvement of cross-border traffic

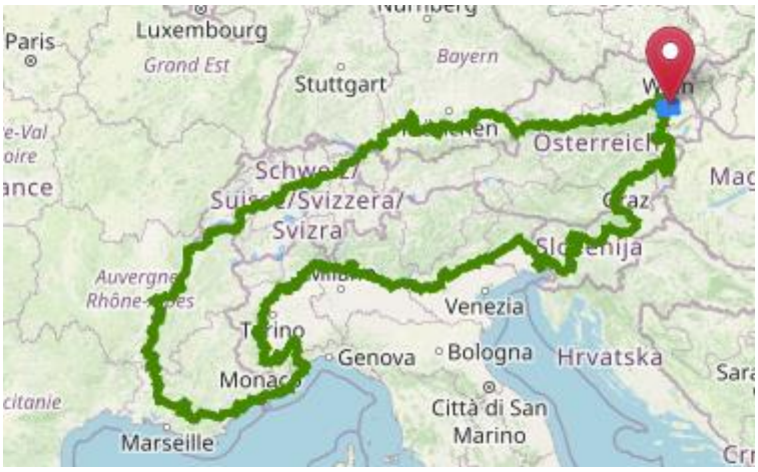


Figure 15: Map view of the project LinkingAlps

1. Project Description:

	LinkingAlps
Description and problem statement:	In the field of the cross-border public passenger transport, there is often the problem of inconsistent availability of passenger information which is due to the fact that each regional or national transport association and each country uses its own data platforms. Consequently, the planning of a cross-border as well as cross-operator and cross-modal connection is often not easily possible for travellers. The problem of the missing data access from other information systems for travel chains in the Alpine region is addressed by the project LinkingAlps funded by the Interreg[42] Alpine region funding program from October 2019 to June 2022. 14 partners (travel information service providers, regional transport associations, research organisations as well as consulting companies) located in six Alpine countries (AUT, CHE, ITA, DEU, FRA, SVN) are involved in this project. To permit the access from existing traveller information services to information from other systems, the regional and/or national travel information services need to be interconnected. For this purpose, the project partners have agreed to make their routing results available to each other via an open standardised Application Programming Interface (API). For the technical implementation of this interface, it was agreed that each provider would apply a unified API based on the CEN standard for distributed routing (CEN / TS 177118: 2018), allowing the connection of different decentralised systems without the integration of the respective data into a centralised database.

[42] The Interreg programs are part of the European structural and investment policy and promote cross-border cooperation between regions and cities in fields like transport, labour market, and environmental protection. Cf. (Ahlke, Kurnol and Thul 2021) .

Objective:	The aim of LinkingAlps is to build a standardised programming interface linking the traveller information of the participating project partners. Furthermore, the creation of a publicly accessible manual as a decision-making aid for future users will be needed. This should ensure the know-how transfer by consequently contributing to the further application of such approaches.
Measures:	Ex-ante analysis (including application cases and system architecture); development, implementation, and assessment of a standardised programming interface; development of a framework concept (including the operator model); transfer to future users (including the creation of a decision support manual).
Technologies / innovations:	Linking of various offers via API services.
Sustainability aspects:	• Emissions: No direct impact on emissions. However, if a shift from private transport to rail can be achieved through improved passenger information, the emission reductions may be possible. • Energy consumption: No direct impact on energy consumption. However, if shift effects can be achieved through improved passenger information, the energy consumption can be reduced. • Land use: The existing transport infrastructure will be used. • Travel time / quality: Improvement of travel quality through integrated information systems; better planning options in terms of route selection and travel times.
Speaker:	Katharina Leeb, AustriaTech - Gesellschaft des Bundes für technologiepolitische Maßnahmen GmbH (Federal Company for Technology Policy Measures)

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- Use of a uniform European standard.
- Connection of routing results from existing operators instead of the development and publication of a new mobile app.
- The project team is aware of the requirements for what concerns traveller information. Furthermore, the country-specific data is available.
- For travellers, an improved information system can be expected, while suppliers can expect the improvement as well as the expansion of their own traveller information system.

The resulting weaknesses seem to be the following:

- A potentially elevated need for coordination due to the involvement of a large number of partners.

- If the regional or national passenger information systems currently in use need an improvement, for example in terms of reliability and quality of passenger information, this will be reflected in the entire system.

Alpine specificity:

- Protection of the tourist region: reduction of CO_2 emissions, if needed, provided that there is a more intensive use of public transport. The service can also be used for the promotion of sustainable tourism, as in future there will be the option to plan journeys in a traveller information system written in the traveller's own language.

3. Potential Analysis of the Project:

The project holds great potential for the improvement of cross-border traveller information systems in the Alpine region. Thanks to the use of an open standardised program interface, the extension of the application to other countries in the Alpine region and beyond should be “rather simple”. However, the quality and reliability of the information still depends on the respective regional and national providers. The taking-up of project results and their transferability to other European regions is already being taken into account in the context of the project, for example through the production of a decision support manual.

4. Recommendations for Action:

The following is recommended to future providers:

- The verification via studies whether there is a demand for cross-border connections.
- The building-up of digital solutions on a uniform standard.

BrennerLEC (ITA) - Technologies for the reduction of emissions in transit traffic

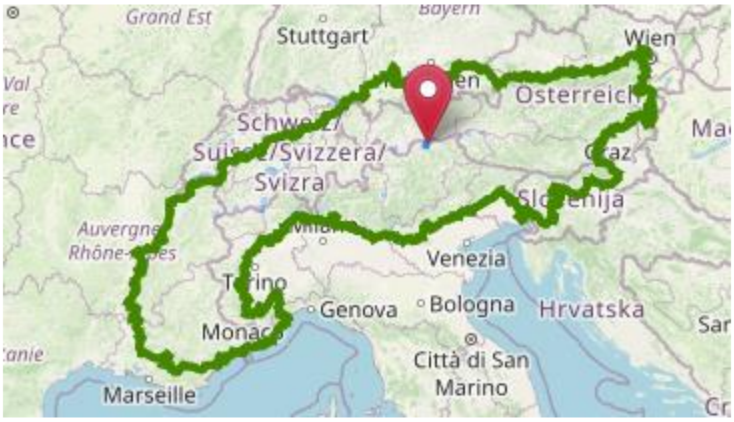


Figure 16: Map view of the Brenner motorway

1. Project Description:

	Brenner Low Emissions Corridor - BrennerLEC: Low-emission transport corridor along the Italian Brenner motorway
Description and problem statement:	The 314 km long Italian motorway A 22, also called Brenner motorway, connects the Austrian Brenner motorway A 13 with the Italian motorway A 1 near the Italian city of Moderna. For both passenger and freight traffic, the A 22 is one of the central trans-Alpine transport axes located between Germany and Italy. Between 2016 and 2021, the BrennerLEC (Low Emissions Corridor)[43] pilot project is investigating the potential management measures applicable when and where to guarantee the maximum environmental and transport efficiency. For this purpose, on a pilot test site[44] on the A 22, various measures (such as speed limits[45] were tested and assessed.[46]
Objective:	The objective consists of the test measures and the establishment of a low-emission corridor along the Brenner motorway in the Italian provinces of Trentino and South Tyrol. Furthermore, recommendations for the application of the measures to the Brenner / Kufstein-Affi corridor will be developed.

[43] The overall project coordinator is the company Brennerautobahn AG. Project participants include the Provincial Agencies for Environmental Protection of the Provinces of Trento and Bolzano and the University of Trento. The project is co-financed by the EU Commission within the framework of the European LIFE programme *(L'Instrument Financier pour l'Environnement*), a financial instrument of the EU aiming at the promotion of environmental and climate protection measures. Further information can be found at: https://cinea.ec.europa.eu/life_de.

[44] The pilot sections are the following: BLEC-ENV (road section from Bolzano North to Rovereto South, approx. 90km); BLEC-AQ (road section from Egna/Neumarkt to San Michele, approx. 20 km); BLEC-LEZ (road sections between the northern and southern entrance gates of the cities of Bolzano, Trento and Rovereto).

[45] In Italy, there is currently no provision in the road traffic regulations concerning the introduction of speed reductions for environmental purposes - this was made possible for the pilot sections for the duration of the project.

[46] For example, after the start of the project in September 2016, in the first application phase from April 2017 to March 2018, tests have taken place in the Egna/Neumarkt - San Michele motorway section, testing the impact of speed limits for environmental purposes. During the second phase of the project, from July 2018 to September 2019, further tests were carried out by displaying the situation-adapted speed limits on digital display panels along the carriageway by using various methods.

Measures:

The test included the measures listed here in the following:

- Dynamic road capacity management (***BLEC-ENV***), which aims at the adjustment of speed limits according to traffic volumes by temporarily opening an additional third lane ("breakdown lane clearance") when traffic conditions are close to saturation - objective: increase of the motorway capacity[47];
- Dynamic speed limit management through "intelligent traffic signs" (***BLEC-AQ***) applied in function of current and predicted air pollution levels - objective: improvement of the air quality[48];
- Dynamic integrated traffic management (***BLEC-LEZ***), which aims at the improvement of the coordination of travel information channels in order to direct traffic via recommended routes. The information to road users is provided via a mobile application (app) - objective: provision of an incentive to use alternative routes.[49]

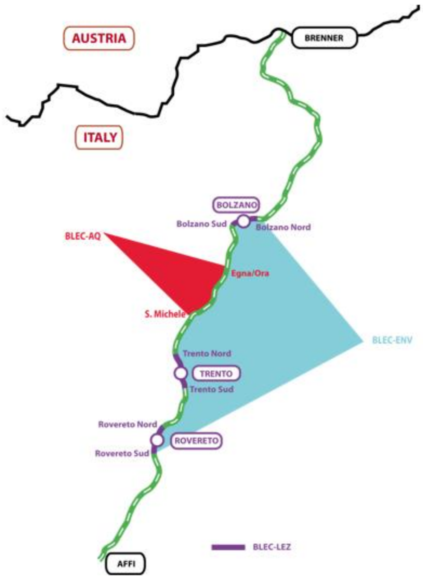


Figure 17: Areas of application of the measures

Technologies / innovations:

Use of multiple dynamic measurement systems for road capacity and speed limit management as well as integrated traffic management including an end user interface (mobile application).

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[47] By means of a dynamic road capacity management (*BLEC-ENV*), the project participants expect CO_2 emission reductions of up to 40% for cars and up to 60% for trucks.

[48] The dynamic speed limit management (***BLEC-AQ***) is expected to achieve an emission reduction relating to passenger vehicles by up to 25% for NO_x and 20% for CO_2. The reduction in total emissions by approx. 8% for NO_x and 6.4% for CO_2 with a reduction in average of the NO_2 concentrations in Arien by approx. 5% and the reduction of noise level by 1-2 dB are expected.

[49] The expected reductions resulting from the dynamic integrated traffic management (***BLEC-LEZ***) are of the same magnitude order as for the introduction of the dynamic road capacity management.

Sustainability aspects:	• Emissions: By means of the above-mentioned measures, it is possible to react to the respective traffic volume in order to achieve a reduction in terms of emissions. • Land use: The existing infrastructure is used in a more efficient manner. The traffic situation is measured by making use of a suitable sensor technology along the route. • Travel time / quality: The implemented traffic management measures can result in increases in terms of travel time.
Speaker:	Ilaria De Biasi, Autostrada del Brennero S.p.A. / Brennerautobahn AG

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- Application of a holistic approach to the problem by combining different approaches to achieve the maximum environmental and transport efficiency with the least possible inconvenience for road users.
- The model character of the project permits its transferability to other areas after its successful implementation.
- The comprehensive database generated by the project can also be used for future decision-making.

The resulting weaknesses seem to be the following:

- The obligation of road users to download a mobile app onto a terminal device (smartphone) to use the alternative route guidance.

Alpine specificity:

- Protection of the tourist region: reduction of CO_2 emissions, reduction of noise pollution, increase / maintenance of the landscape-related attractiveness.

3. Potential Analysis of the Project:

The project shows a great potential for what concerns the optimisation of the environmental and transport efficiency on the Brenner motorway. The project includes the examination of the transferability to other Alpine corridors. For this purpose, recommendations for action are to be developed. In addition, the project shows that, despite increasing social acceptance for environmental protection measures, the use of an appropriate communication will be needed in order to convey the benefits of concrete implementations to potential users, for example for what concerns the environmentally related speed limits or the use of digital applications for traffic control (app for suggestions on traffic route changes).

4. Recommendations for Action:

The following is recommended to users:

- The regular evaluation of speed reduction measures with a view to the actually achieved emission reduction by also including the improvement of traffic flow.

- The promotion of digital-based measures in order to encourage the use of alternative routes depending on traffic. In this context, the user requirements are to be considered as well.

The following is recommended to the countries of the Alpine Convention:

- The examination of the extent to which the legal basis for imposing speed limits needs an adaptation for environmental reasons.

Gotthard Base Tunnel (CHE) - Infrastructure project supporting the shift of traffic from road to rail

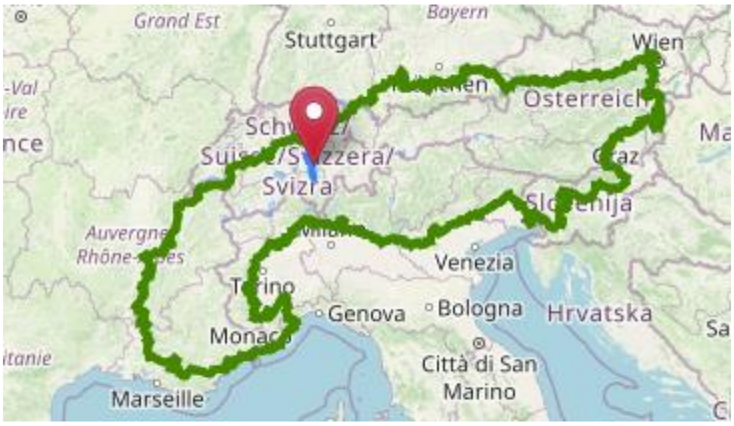

Figure 18: Map view of the Gotthard Base Tunnel

1. Project Description:

	Promotion of a modal shift to rail: The Gotthard Base Tunnel
Description and problem statement:	The existing railway infrastructure located on the north-south axis of the Alps was already under increasing strain in the 1980s due to the high volume of traffic as well as the further increase in demand for reliable and fast rail connections. Consequently, there was the need for a solution for both rail and road traffic. The referendum of 1992 laid the foundations for the construction of the two axes at the Lötschberg and Gotthard as well as the southern feeder road of the Gotthard Base Tunnel, the Ceneri Base Tunnel. With this “expansion” of the rail network “which seems to be giant for Swiss standards”, the majority of transalpine freight traffic through Switzerland was to be shifted from road to rail. Furthermore, the travel times between northern and southern Switzerland were to be subjected to a massive reduction. The Gotthard Base Tunnel was finally commissioned in 2016, after seventeen years of construction. With its length of 57.1 kilometres, it is currently the longest railway tunnel all over the world. Together with the Lötschberg Base Tunnel (34.6 kilometres, commissioned in 2007) and the Ceneri Base Tunnel (15.4 kilometres, commissioned in September 2020), the Gotthard Base Tunnel belongs to the so-called “New Transalpine Rail Link (NEAT) transport concept covering the entire Swiss territory.

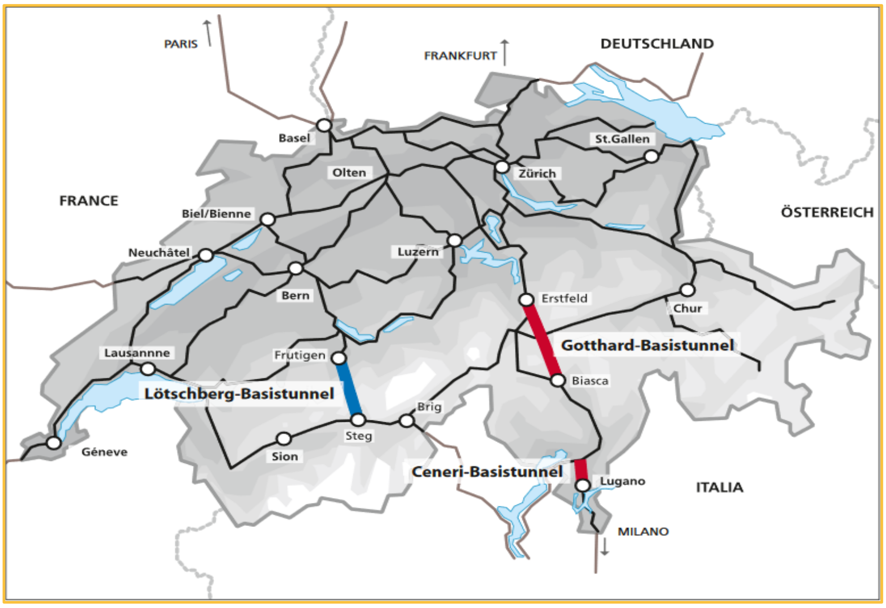

Figure 19: Overview of the base tunnel locations[50]

Objective:

The main objective consists of the improvement of the rail transit traffic in order to achieve a greater shift of road freight traffic to the railways (the upper limit of 650,000 trucks per year on the roads is to be adhered to). Furthermore, the SBB expects a growth in demand in passenger transport (from 9,000 in 2015 to approximately 18,000 daily travellers in 2025 [51]).

Measures:

Tunnel construction embedded in a comprehensive overall traffic concept.

Technologies/ innovations:

Tunnel construction works and implementation of a top-level safety concept over a tunnel length of 57 km.

Sustainability aspects:

- Emissions: The hoped-for shift in road freight transport should result in a noticeable reduction in emissions. Provided that individual transport is also shifted to the railways, an additional reduction can be achieved.
- Energy consumption: In the case of a significant modal shift, a reduction in the consumption of fossil fuels in road transport can be achieved.
- Travel time / quality: In the area of passenger transport, travel times have been reduced by around one hour in comparison with the previous rail connections. In freight traffic, the time savings on the Zurich / Basel / Lucerne - Lugano and Zurich - Milan routes, for example, amount to around 50 minutes in each case.

Speaker:

Hans-Peter Vetsch, Vetsch Rail Consulting GmbH

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[50] Cf. (Federal Office of Transport FOT 2019, p. 1) .

[51] Cf. (Mandour 2016, p. 1) .

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- The planning offices (10 companies) commissioned by the Swiss government developed a holistic transport concept. For this purpose, among other things, several transport axes and transhipment hubs in different countries were analysed. The said analysis was accompanied by the development of approaches to connect the axes one with another and by the implementation of measures for freight and passenger transport.
- Government funding and grants ensured the financing of the project from the beginning.
- Regulatory measures (for example night and weekend driving bans, limits on the number of 40 t lorries per year on the roads) are increasingly putting economic pressure on hauliers to use Switzerland's railways internally.

The resulting weaknesses seem to be the following:

- Due to its cost-intensity, the construction of tunnels is only feasible if high financial resources are made available.
- Only after completion of the feeder lines outside Switzerland, the Gotthard Base Tunnel will be able to implement all the positive modal shift effects.

Alpine specificity:

- Protection of the Alpine region: reduction of the CO_2emissions by shifting traffic to rail.
- Preservation of the tourist region: preservation of the landscape through the use of underground routes (tunnels).

3. Potential Analysis of the Project:

As an integral part of the NEAT project, the Gotthard Base Tunnel is a positive example of long-term and sustainable thinking, and likewise of the feasibility and financial viability of large-scale infrastructure projects following successful involvement of the population. After the completion of the feeder lines, the Gotthard Base Tunnel will be able to develop its full potential in the Swiss Alpine region in the context of the European TEN core network.

4. Recommendations for Action:

The following is recommended to state project sponsors:

- Conduct of public participations to incorporate the concerns and wishes of the resident population into the project planning at an early stage.
- Reflections concerning the long-term (freight) modal shift in an overall geographical context.

5.4 AUTONOMOUS DRIVING

Bad Birnbach (DEU) - Autonomous driving as part of the local public transport system

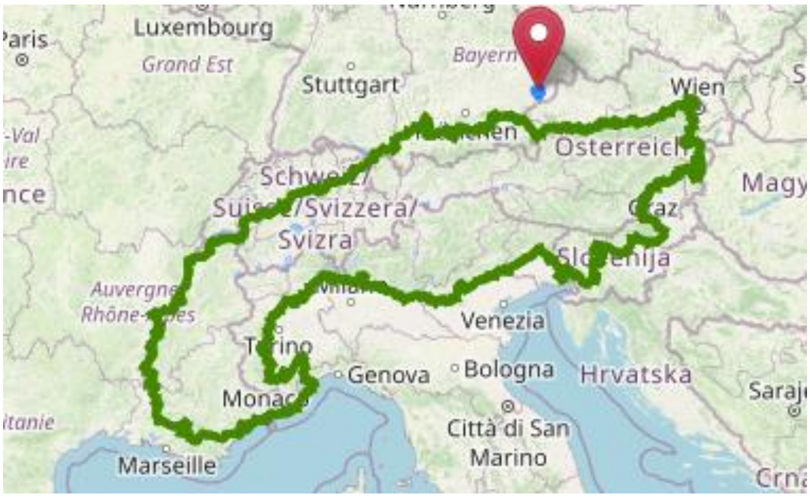

Figure 20: Map view of Bad Birnbach

1. Project Description:

	Autonomous driving in Bad Birnbach
Description and problem statement:	In Bad Birnbach, a Marktgemeinde (market town) located in the Lower Bavarian district of Rottal-Inn with a population of around 5,800[52], the use of an autonomous bus (hereinafter referred to as “shuttle”) in the local public transport was tested for the first time in 2017. The project differs from comparable projects implemented in Germany which are usually located in an urban environment, due to the fact that it is being used in a rural area. During its first pilot phase, the project was limited to a 700 m long route in the centre of Bad Birnbach. Due to high demand, the route was then extended from the centre to the train station (2.1 km in total) starting in 2019. Furthermore, autonomous shuttles of a newer design were used. In 2020,[53] the shuttle ran every 20 minutes from 8:00 a.m. to 6:00 p.m. and carried approximately 90 daily passengers, who were offered a free-of-charge use of the service. During each journey, an attendant is on board[54] if any intervention is needed during the journey.

[52] The exact number of inhabitants is 5,841 (as of 31 March 2021), cf. (Bavarian State Ministry for Digital Affairs 2021) .

[53] Due to the Corona pandemic, the shuttle had to stop its operation in November 2020, as the necessary distances as well as hygiene concepts could not be complied with in the bus with 6 seats. The service was then resumed in the end of May and/or at the beginning of June 2021. During the suspension period, the route was served by a bus with conventional drive, cf. (Pehl 2021) .

[54] In Germany, it is currently mandatory that a driving attendant must be present during the journey: Gesetz zum autonomen Fahren, German Act on Autonomous Driving § 1 et seq. (2), cf. (Brandt, et al. 2019, p. 4ff) .

Objective:	Knowledge production concerning the benefits of autonomous shuttles in the public space, deduction of experiences relating to the operation and technology and consideration of the option of integrating autonomously driving shuttles into the existing local public transport system.
Measures:	Procurement of driverless and electric minibuses of the type EZ10 from the French start-up EasyMile; adaptation of local conditions to guarantee the safe operation of the minibus (including the construction of a lockable, heated parking area equipped with charging columns, widening of the carriageway on two sections of the route, installation of appropriate signage along the route and of three speed bumps to achieve the speed reduction of the surrounding traffic[55]).
Technologies / innovations:	Autonomously driving battery electric vehicle; adaptation of road and environmental conditions for safe operation.
Sustainability aspects:	• Emissions: Use of a battery-electric, autonomously driving vehicle operating with zero local emissions. • Energy consumption: The energy consumption is estimated to be low overall due to the vehicle size and its low speed. • Land use: The shuttle uses the existing road infrastructure. • Travel time / quality: With a speed of up to 20km / h, fast travel is not possible. However, the shuttle makes a new technology tangible and can make its contribution to the creation of new, innovative transport services.
Speaker:	Stefan Kretzschmar, DB Regio

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- The project shows that autonomously driving shuttles can be used beneficially in the context of the local public transport system even in smaller communities.
- Possible frictions were counteracted by the gradual implementation, which promoted acceptance - a test and learning phase was first completed by involving the resident population before the extension of the service area.[56]
- Potential stakeholders were informed about the project and involved, for example, through accompanying research[57].

[55] Cf. topic “The road”, (DB Regio Bus Bayern GmbH 2021) .

[56] Cf. (Brandt, et al. 2019, p. 9) .

[57] Cf. (Brandt, et al. 2019, p. 15) .

The resulting weaknesses seem to be the following:

- The regular operation of autonomous vehicles is not yet conceivable at present, since traffic-challenging situations cannot yet be overcome without taking any accompanying measures.
- In case of climatic conditions which are not ideal (for example heavy rain, snowfall), the autonomous operation by replacing it by a bus with conventional drive.

3. Potential Analysis of the Project:

The project implemented in Bad Birnbach shows the positive results of the gradual introduction of a new technology to complement local public transport services in rural areas: acceptance and consequently use by the local population and tourists is steadily increasing. Generally speaking, its transferability to rural municipalities in the Alpine region[58] seems conceivable. However, as it is the case for any transport measure, an intensive analysis of the individual initial situation must be carried out and, in particular, the cost / benefit ratio must be part of the decision-making process. Furthermore, a realisation does not seem feasible without public or private start-up financing.

4. Recommendations for Action:

The following is recommended to future providers of such services:

- The detailed determination of the demand potential of the envisaged connections and the development of scalable entry models which may be operated only during peak tourist periods, if needed.
- The securing of the financing basis by involving public or private sector stakeholders (for example municipalities, accommodation providers).
- The examination of existing funding opportunities, for example for the procurement of the necessary charging infrastructure.

The following is recommended to municipalities:

- Active involvement of local mobility service providers from the beginning in order to counteract any competitive situations between existing (public transport and taxi) providers together with the active promotion of the cooperative interaction between all relevant stakeholders.
- Active support of the use of the service through advertising, discounts, etc. - especially at the beginning as this can result in the reduction of the acceptance threshold in the resident population.
- Provision of a sufficient timeframe for the new service to take root and design of the duration of public support services accordingly.

[58] The autonomous shuttle project implemented in Bad Birnbach is not geographically located in the area covered by the Alpine Convention. Consequently, the point of Alpine specificity does not apply in this context. Nevertheless, the potential analysis of the project should explain the reason why a project of this kind may also be useful for the Alpine region.

ECOTRAIN (FRA) - Autonomous driving on rail in rural areas

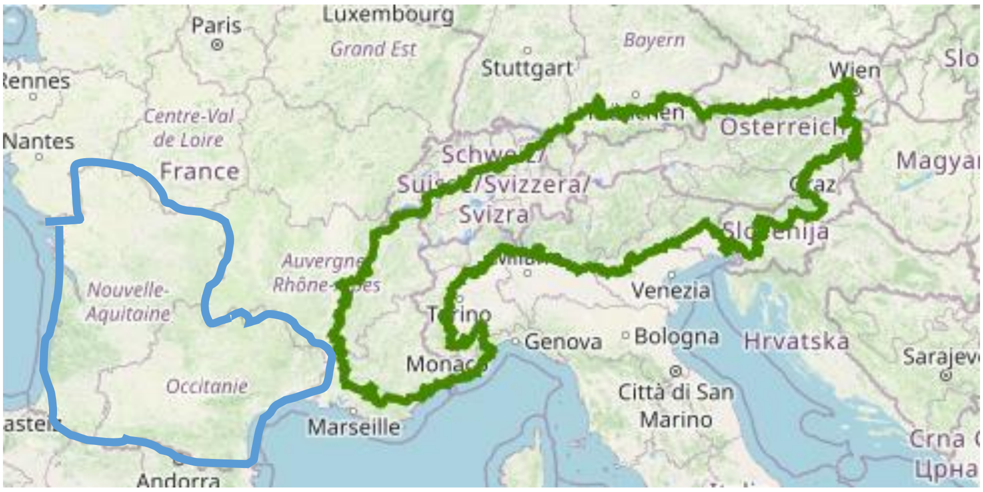

Figure 21: Map view of the regions of New Aquitaine and Occitania

1. Project Description:

	ECOTRAIN
Description and problem statement:	Many railway lines serving rural areas were closed in the past due to cost-related reasons. Against the background of the mobility turnaround and the need to connect rural areas, there is an increasing number of approaches aimed at the examination of the reactivation of the said lines. With the objective of operating an autonomous and battery-electric shuttle train for local public transport passengers and freight by 2026, a consortium made of five local providers is currently identifying the potential of route reactivation in the French regions of Occitania and New Aquitaine through preliminary studies. Against this background, the consortium is planning a preliminary prototyping on a test track from 2022 to 2023. The prototype construction and testing on a pilot track with 6 shuttles will then take place by 2025. The commercial sale of the shuttles and the commissioning in regional local public transport is planned, starting from 2026.
Objective:	The objective of the project ECOTRAIN consists of the reactivation of disused routes in rural areas and of the transport of passengers (up to 32) and goods (load of 5t) on these routes by making use of autonomously operating shuttle trains.
Measures:	Reactivation of disused railway lines, development, and production of shuttle trains[59] and programming of a new software for the autonomous operation of the shuttle trains.

[59] Since the shuttle infrastructure is to be independent of the mainline rail network, less complex train control technology will be required.

Technologies / innovations:	Autonomously driving shuttle trains powered by lithium-ion batteries for passenger and freight transport.
Sustainability aspects:	• Emissions: The battery-electric shuttle is said to have very low emissions. The consortium states 2g CO_2/km per passenger. • Energy consumption: The consortium states that due to the lightweight construction, a lower energy consumption may be expected in comparison with diesel vehicles. Furthermore, the batteries are to be charged largely by solar panels. • Land use: The existing infrastructure is used.
Speaker:	Philippe Bourguignon, Designer ECOTRAIN

2. Project Assessment:

The resulting strengths and/or success factors seem to be the following:

- Identification of currently unused potentials in the railway network.
- Examination of the reactivation and use of the existing infrastructure.
- Elaboration of approaches relating to the linking of passenger and freight transport.

The resulting weaknesses seem to be the following:

- Higher costs for the novel software development for autonomous operation as well as the novel vehicle technology (for example traction batteries and charging infrastructure) in comparison with the use of conventional (diesel / electric) types of drive.
- In France, the legal basis for the regular operation of autonomous rail vehicles must still be created.

3. Potential Analysis of the Project:

The project ECONTRAIN pursues an innovative approach to the development of a local public transport service in rural areas based on the existing infrastructure. The acceptance and consequently the use by the local resident population and economy still has to be tested in the context of a test operation. If this is successful, generally speaking, the transferability to other rural areas in the Alpine region seems[60] conceivable. However, as it is the case for any transport measure, an intensive analysis of the individual initial situation must be carried out and, in particular, the cost / benefit ratio must be included in the decision-making procedure.

[60] The project ECOTRAIN is not located in the Alpine Convention area, so the Alpine specificity point does not apply in this context and can consequently be omitted.

4. Recommendations for Action:

The following is recommended to the providers of such services:

- The detailed determination of the demand potential of the envisaged connections and the execution of a demand analysis permitting the identification of the potential railway lines for reactivation, if needed.
- The examination existing funding opportunities, for example, for the procurement of the needed charging infrastructure.

6 GENERAL RECOMMENDATIONS FOR ACTION

There is something like a "general rule": In order to achieve the reduction of CO_2 emissions caused by transport operations, technologies can contribute about three quarters, while the remaining quarter is to be achieved through changes in terms of behaviour. [61]

The objective of the project consists of the identification of technologies for the promotion of sustainable passenger transport in the Alpine region, of their assessment by defined Alpine-specific sustainability indicators and of the deduction of the respective recommendations for action. This should support the wider diffusion of promising solutions, especially in the Alpine Convention area, and the consequent promotion of the further development of sustainable passenger transport in the region.

The scope and diversity of the researched projects clearly shows that numerous initiatives have already been undertaken or are planned in the Alpine region as well, in order to design sustainable mobility taking into account ecological, economic and social demands in a balanced manner. In this respect, the Alpine region fits seamlessly into a broad panorama of innovative transport and climate policy approaches to the transformation of mobility in Europe. In many cases, the said projects are pilot projects which dues to their local character have a regionally limited impact. Although "more projects" basically mean "more sustainability", their overall impact may be further enhanced through an increasing networking and a broad exchange of experience, as promoted, among others, by the Alpine Convention.

The selection of best practice projects, examined in detail during the workshop, can consequently only reflect a minor selection of the variety of projects and ideas. However, it can highlight important aspects of sustainable, climate and environmentally friendly mobility design representing the focus of the present research project. At the same time, all the researched projects offer a fund of ideas by providing suggestions for further local, regional, and supra-regional initiatives, also located beyond the Alpine region.

In this context, it is not just about the transformation of drive technologies, digitalisation, and automation, but also about climate-friendly mobility behaviour. The objective is to achieve a more environmentally friendly choice of mobility forms in all fields, from transit and commuter to tourism and leisure traffic.

As a result of an overall assessment, the following success factors (recommend-dations for action) emerge in particular:

Networking, cooperation, and integration: The projects going beyond a system framework (be it an economic sector, a transport purpose, an organisational or administrative boundary) proved to be particularly successful. Generally speaking, the resulting synergy effects outweigh a higher complexity-related additional effort. In this context, the following examples can be mentioned:

- Ensuring of a demand-oriented local public transport supply by combining passenger and goods transport,

[61] Prof. Dr. Lenz (Deutsche Zentrum für Luft- und Raumfahrt e.V. (DLR), of the Humboldt University of Berlin, Institute of Geography) made this fundamental statement during the workshop in her conference entitled "Looking ahead: The future of mobility".

- Individual support for the creation of attractive public infrastructure permitting the improvement of the competitive position of the local tourism industry as a whole,
- The pilot use of innovative propulsion technologies to generate technical, application-oriented knowledge, particularly with a view to the efficient coupling of the transport and (hydro)energy sectors.
- The cross-border cooperation of stakeholders in the field of public transport in the provision of timetable information to permit the creation of a comprehensive, non-discriminatory, inter- and multimodal and networked public transport service in the Alpine region.

Creation of framework conditions: The creation of a suitable regulatory and funding policy framework is a crucial aspect permitting the successful establishment of forward-looking, climate and environment-tally friendly technologies. This applies both to the conversion of vehicle fleets to alternative drive systems and to the provision of an efficient digital environment, which is essential for efficient mobility design and the introduction of new IT-supported mobility technologies. The linking of services and data does not just enable a reduction in terms of emissions, but also an effective implementation of modal shift potentials.

The examples include:

- The smart linking of different transport modes, for example through a cross-provider tariff and distribution system and automatic ticketing,
- The development of traffic relief concepts to avoid tourism-related car traffic as far as possible,
- The granting of tariff advantages to increase the acceptance of new mobility platforms,
- The creation of transport incentives to increase the use of rail-based public transport.

Communication and transparency: The new mobility offers must be communicated and smartly marketed so to bring about changes in terms of mobility behaviour. In this context, communication and cooperation go hand in hand. Examples of this aspect are:

- The tourism marketing of innovative, location-specific transport solutions, which can range from the use of horse-drawn carts to metro systems,
- The implementation of information campaigns to increase awareness of digital applications, for example, for traffic-guiding alternative routing,
- The involvement of local public transport providers and taxi companies in the development of regional mobility concepts.

Targeted investments both in rail transport and charging infrastructure for alternative drives: The conversion of vehicle drives, especially to battery-electric and hydrogen-based systems, is also visibly gaining momentum throughout the Alpine region. This is the reason why a key focus must be on expanding the needed refuelling and charging infrastructure.

Furthermore, an increase in the share of rail in the transport volume needs the expansion of the rail infrastructure which is usually very cost-intensive and time-consuming and therefore requires a careful forecasting of demand and project planning with the early involvement of all stakeholders, as well as the development of a viable financing concept. Despite these challenges, rail transport is one of the most energy-efficient transport methods.

The examples of investments in transport infrastructure include the following:

- The Serfaus underground railway, the Gotthard Base Tunnel and the Zillertalbahn,
- The establishment of rental stations for electric vehicles and the associated expansion of the charging infrastructure,
- The electrification of local public transport vehicle fleets.

Overall, it was noticeable that comparatively few of the projects identified and discussed in the study explicitly address or are determined by Alpine specificities (such as, for example, topographical conditions, tourism). However, this does not represent a disadvantage since it rather indicates that the full range of innovative approaches to the further development of efficient, climate-friendly, and sustainable mobility can be applied to face the various transport challenges existing in the Alpine region - regardless of the project-specific regional context. Consequently, it goes without saying that local experiences and findings are regularly adapted to the local - Alpine - conditions and to the mobility requirements of the local resident population in a meaningful way. In this sense, it expands the scope of the projects and initiatives presented on the one hand by showing at the same time that innovative mobility solutions developed outside the Alpine region may also be usefully adopted in this region.

At the same time, this aspect shows a potential starting point for further research by reversing the line of vision: the Europe-wide or even international analysis of successful solutions to the issues of a smart, sustainable, and future-oriented transformation of mobility with a view to their transferability to the Alpine region.

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