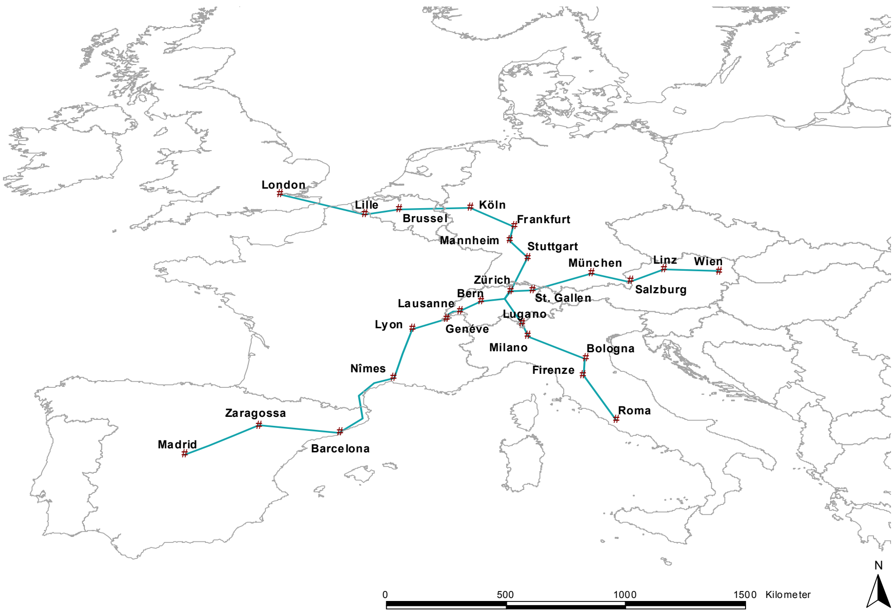


Energy and Environmental Assessment of a Eurometro

DEMAND and NETWORK – Influential Factors

Daniel Schöbi

Energy Department, University of Applied Sciences, Bern
Institute for Transport Planning and Traffic Engineering, Vienna University of Technology
schoebi.schwizer@gmx.net

Abstract

A Eurometro-system based on Swissmetro technology could provide an ecological alternative to aviation. Ongoing research evaluates on how a Eurometro-system should be implemented, interconnected with the local, regional and international public transport system, as well as integrated into existing and future High-Speed-Traffic (HST) -infrastructures and finally integrate Switzerland in a European HST-network. In a first step we will look back to the development of HST, overview the influential factors and then focus on trends and estimated demand and network.

Topic number:

1 MAGLEV – world wide high speed industrial development and projects

1.3 Social, environmental and ecological Aspects – Eco Balances
1.4 Comparison: Evaluations Of High Speed Systems (MAGLEV versus TGV, Air Traffic)

Key words:

demand – Eurometro – high speed traffic – network – trends

Content

1 Introduction

1.1 Network: definitions and synergies

Diversity has traditionally been the trademark of European countries. However, at present, Europe is rapidly evolving from an aggregation of strongly fragmented market areas into an undivided and uniform market with unprecedented scope [Commission of the European Communities, 1999] (1). At the same time, steps are being taken within the EU to remove any obstacles to effective competition that prevailing national borders may represent. The significance of transport networks in the EU is growing. In the transport of people, goods, services and information, there is a crucial need for well-functioning infrastructure networks.

We define a network as a collection of nodes (actors, cities) connected by facilities (links, arcs, relationships, waves) through which entities (such as goods, cars, passengers, services, power) pass. Facilities in physical networks can be roads, rails, pipes.

The word synergy literally means syn + ergos = work together for joint benefits or, better, "co-operation of various factors or organs with a common goal or performance". Usually it is known under the rule "1+1 = 3", that is the total exceeds the sum of individuals. Applied to infrastructural networks, Nijkamp (2) describe it "as a situation of positive user externalities through (spatial) interactions between various operators (actors and users) of a network as a result of an efficient interconnectivity of the network concerned (in terms of connectivity between nodes, accessibility of centers, or intermodality) which generates value added from scale advantages – and hence increasing marginal benefits (or decreasing marginal costs) for all users involved".

Networks are a recurring theme in the description, analysis and representation of events involving interaction between actors. These are performed by a variety of disciplines, from economics to social sciences and from geography to engineering.

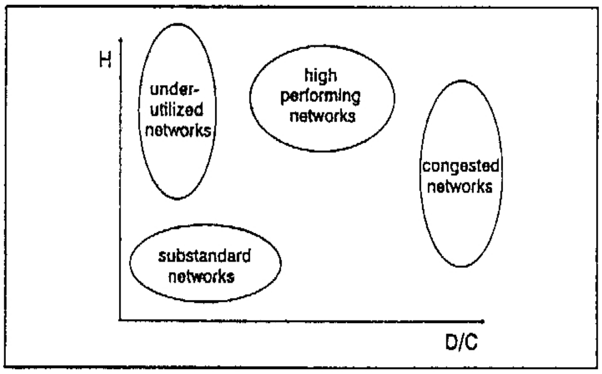


Fig. 1: Characterization of networks [P. Nijkamp, 1994] (3)

D/C use-capacity ratio
H cohesiveness of a network (intermodality, interconnectivity and interoperability)

1.2. Perspective: Sustainable Transport through New Technologies?

The potential of today's technical and political measures in the area of high-speed-transport (HST) are most likely not be sufficient to achieve the goals of climate and environment protection, as presented in the paper on air and high speed traffic (4). Therefore it is necessary to investigate and thoroughly evaluate new approaches and innovative solutions concerning the development of new technologies to improve eco-efficiency on the supply side as well as new measures to control mobility on the demand side. Trans-European-Networks (TEN) currently built up represent an important pillar of EU policies, but do not integrate Switzerland with its difficult topographic conditions.(5)

Recent history shows that the introduction of new technologies like the wide spread and use of the modern car in western societies or the decreasing air travel fares following liberalisation of the market led to big increases in mobility. From 1960 to 1990 the motorized mobility from the world population has risen by a factor higher than four. Demand will most probably continue to rise. Before the introduction of further new technologies and means of transport, the following questions should be investigated: What will be the effects of the introduction of a new technology in the future? Can its technical potential at least offset the additional environmental impact of the induced mobility or will it result in an further critical impact on the environment?

Therefore one question also must become a center piece of future research looking at a Swiss-or Eurometro-system: Can a new technology like the Swiss-/ Eurometro (an underground Maglev-system in Europe) (6,7) really provide significant long-term increase in ecological efficiency and thereby help to make Mobility in Europe more sustainable?

To answer above question research has to include scenarios of further development of HST-demand, the modal-split between air traffic, Eurometro and other high speed train systems. It has further to evaluate how a Eurometro-system could be implemented step-by-step, interconnected with the local, regional and international public transport system and integrated into existing and future HST-infrastructures. It should also show how regions with difficult topographical conditions like Switzerland can be integrated into a European HST- network. The underground tracks and energy-efficient technologies of a Eurometro-system could result in noticeable ecological gains compared to today's means of transport in the areas of energy and climate protection and also reduce negative impacts to the landscape and noise pollution.

1.3 Proceeding

The research presented aims at optimizing the European HST-system by introducing a Eurometro-System which could shift the modal split between high speed trains and air traffic a well as car traffic and thereby significantly reduce the environment impact of high speed and car traffic. As an indicators of its environmental performance the research will focus at energy demand and CO_2-emissions.

Transport infrastructures are connected with well-developed spatial patterns. Suitable regional differentiation is therefore very important for useful analysis of these interactions.

The main questions to investigate are:

- What effects regarding energy demand and CO_2 emissions will result from the introduction of a new technology into the European high speed traffic system such as a Eurometro system?
- Which additional control measures have to be introduced to successfully launch a Eurometro as a convincing alternative to short-haul air traffic and other means of transport within the distance range of around 1000 kilometers (600 miles) to achieve significant gains compared to today's means of transport in the areas of energy consumption and climate protection?

Step 1 describes today's and the past situation of the European High speed traffic-system and its characteristics (e.g. travel time budget, acceleration, purpose of travel, etc.). In addition, the effects of the HST-system on the sustainability of transport will be studied.

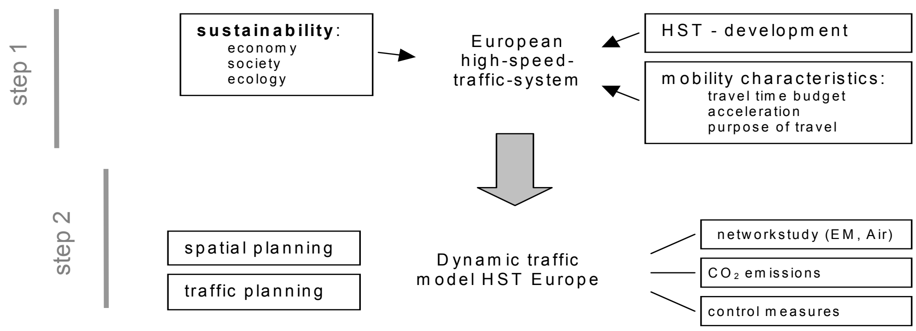


Fig. 2: The project structure consists of 2 steps

Focus of **step 2** will be a dynamic traffic model as a tool for strategic planning. It is planned to expand and calibrate an existing intermodal traffic model for the use in the research . The proposed approach is the extension of the basic dynamic analysis to the long time horizon by allowing the origin-destination (O/D) -matrices to depend on the exogenously given spatial distribution of business and human activities. This method will be an attempt to describe a large network, that could be used as an aggregated reduced form for the evaluation of transportation policies (e.g. impact of induced demand, introduction of a new technology, capacity limits, pricing, etc.). Important factors in the development of the demand of HST-systems are travel fares, travel speed, the level of comfort and the integration into the existing transport network.

1.3 The current situation: demand and network

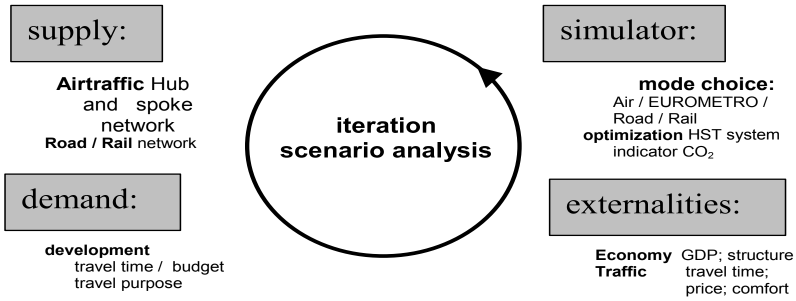


Fig. 3: European High – Speed – Traffic (HST) Simulation

The ongoing research in this area has proved to be very demanding and complex. It shows that hardly any basic data and calculation models on a Europe-wide high-speed transport system are available that could be directly used in an applied scientific approach. Furthermore, with today's simulation models, the demand for a new transport carrier on a European level with such different characteristics cannot be demonstrated. Work initiated during the final phase of the project F6 "Energy- and Eco-Balance" during the Swiss National Research Programme 41 (NFP 41) (7) in 2000 provided important results for the research work with regard to basic data and the application of different model approaches. The work carried out so far has only provided approximate simulation results and needs to be validated in research work by means of better data on actual traffic volumes. The existing results of the initial and greatly simplified models show, for example, a lower demand than determined by in-depth research within the NFP 41 project F1: "Nachfrageabschätzung für Swissmetro" (demand estimates for Swissmetro) [Abay, 1999] (6). Further aspects are also shown in the report "Ökobilanz der Swissmetro" NFP 41 project M29 (8).

Consolidation and investigations indicated that:

- Forecasts extrapolated up to the year 2020 for the increase of traffic volumes to be expected, the development of traveling costs and the impact of migration between transport carriers as well as the induced new transport systems, suffer from major uncertainties.
- In addition to important technical aspects such as network development, integration into existing networks, traveling speed and comfort, non-technical factors such as economic development, political decisions (e.g. concerning climate and noise protection) and the consideration of so-called "external costs" can be expected to become highly relevant.

Further research needs to provide better understanding of the future demand depending on mode shift from car- and train- traffic and additional mobility generated and its impact on the ecological performance of the system. The project will thus critically examine the impact of quantitative and qualitative arguments to address different time and different types of uncertainty. We look forward to present first results in September 2002 at MAGLEV 2002.

2 Historical Perspectives of HST

2.1 Ground-Transportation

The Definition of “High Speed” transportation is relative to the transportation technology of a time period. Thus it might be argued that high speed transportation began early in the 19th century when British engineers developed the first effective steam railroad locomotives, a technology which spread rapidly. The railroads pursued varying technologies in seeking higher ground transportation speeds; maximum speeds in excess of 160 km/h were attained early in the 20th century with steam propulsion and of 200 km/h would be attained by diesel-electric, electric and jet propulsion. The result of these changing technologies was to provide incremental improvements in speed and scheduling, but average speeds would remain less than 140 km/h. It was not until the 1960s and thereafter that serious efforts began to make high speed passenger systems to double and triple previously ground speeds. In 1965 the Japanese inaugurated the first regularly scheduled train service with an average speed over 160 km/h. Since then much international effort has been expended to improve and expand HST systems, now defined as those systems with speeds in excess of 200 km/h.

Away from the machine driven trains there were also a lot of experiments: Perhaps the most interesting high speed experiment early in the railroad era of the 1840s was the planning and construction of several “atmospheric” propulsion systems in England and France. The idea of using atmospheric pressure to provide a propulsuive force was similar to the physical concepts used in some nineteenth century steam engines. The physical concept for transportation systems was proposed a century later and was very simple. Place a piston (or passenger / cargo car) within a tube and create a partial vacuum in front of the piston (or car), while admitting atmospheric pressure behind it. Large pumping engines would be needed to create the vacuum. For the piston-in-cylinder concept, the net differential pressure would push the piston which would be attached to a lead propulsion car on rails. The concept of having an external power source would not be used again until the advent of electric traction systems in the 20th century. It is interesting to note, that the atmospheric propulsion would survive into today as the high speed pneumatic tube message systems for use in banks and commercial applications.

It is also of interest to note that in the 1960s when there was increasing interest in high speed ground systems, a Gravity-Vacuum Transit (GVT) (9) system was proposed as an urban passenger transportation system. Cars would move in fully enclosed deep tunnels using a combination of atmospheric propulsion and acceleration due to gravity so as to attain predicted speeds in excess of 250 km/h. Much technical work was done for the initial proposals and the advantages of low land use, minimal environmental impact, min. noise pollution, high speed, safety..were cited, but no demonstrations or trial systems were ever p

In the 1960s U.S. and French engineers experimented with jet propulsion and the famous “l’aerotrain” reached a maximum speed of 380 km/h in 1967. (10)

Fig. 4: The French “l’aerotrain”, 1974

Trans-Europe-Express (TEE) Concept

At the beginning of the century, the private railways were nationalized and changed into national railway companies because of its monopoly character in transportation and a difficult economic situation. This nationalization resulted in the first possibility to transport passenger and goods at low and nationally guaranteed prices on a complete railway network. After the second world War Europe began to develop international long-distance connections. The former luxury-train concept was not continued anymore by the railway companies, because they were more interested in gaining more quantitative and faster traffic. In the 1950s, the railways began building-up a new 200km/h speed network (the first train was operated between Milan and Florence) which should have been a competitor to civil aviation.

With the TEE-Concept the national railway companies tried to change the trend back from road and air to rail. The TEE-Concept contained a first-class comfort and a commercial speed of more than 100 km/h and a top speed of approximately 200 km/h – the passport-control was always done in the train. The concept was improved by a permanent increasing supply, but it did not achieve the desired success in railway traffic. On one hand the attraction of flying was higher, because of the permanent improvements (speed, frequencies, comfort and supply of other services), and the road-traffic was becoming faster and cheaper than rail, on the other hand the TEE-Concept had not a real continuity in the schedule operation an improving equipment. The TEE-Concept ended in the 70s followed by the national Inter- and Eurocity concept, which also contained a 2-class system and a typical design of each national railway company. Shortly after the introduction of national long-distance trains in 1981, the first real national high-speed project in Europe with a separate infrastructure began in France with the “Train à Grande Vitesse” (TGV) on a new built track between Paris and Lyon. This Project was the beginning of the high-speed transport by rail in Europe.

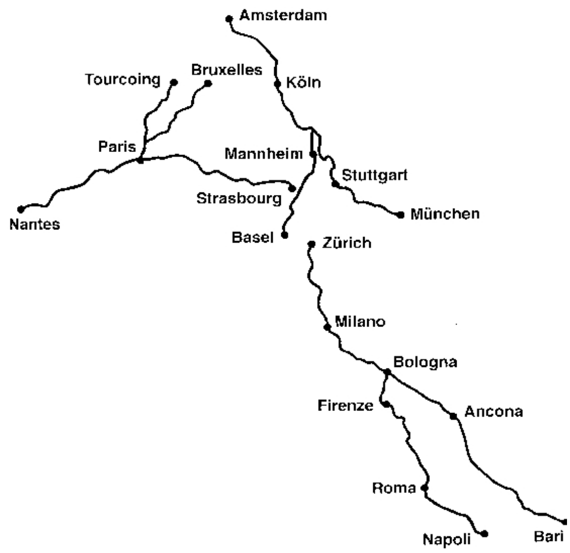


Fig. 5: The TEE-network during the last Schedule Period 1986 / 1987 [Cost 318] (11)

2.2 Air-Transportation

The brothers Otto and Gustav Lilienthal succeeded in the first gliding flight in summer 1891 and the Wright brothers in the first motor flight in 1905. In 1909 the first “long distance” flight across the channel was successful. After the First World War, the pioneering time of international aviation started with air mail transport. In 1919, the International Air Traffic Association (today IATA) was founded in The Hague with the task of coordination and representation of interests between members and national institutions.

The most often operating types of aircraft were in general characterized by a small capacity of about 10-20 passengers, low speed, up to 250 km/h, and a short flying range. The aircraft were used in most cases by the upper classes only and the number of flights was limited.

Besides the conventional propeller-driven aircraft airships, were able to offer a huge air passenger volume capacity with few infrastructure problems, but they were rather slow. During the Second World War, the aviation, e.g. the development of the air jets and the operation of big aircraft for military purposes, were forced strongly. Civil aviation and the work of a still small IATA almost ceased during that time.

Immediately after the Second World War a change happened in the use of aircraft and pilots. So, on the one hand, jet planes, on the other hand middle and large aircraft were used for the first time in civil aviation. Furthermore navigation systems and air services were improved enormously thanks technical innovations during the war. (11)

Development of modern civil aviation

Commercial aviation began its most important development in the 1950s with the North Atlantic flights as its masterpiece (with technical stops in Ireland and Newfoundland at the beginning, later non-stop). At first, national airlines began with national flights on longer distances (500 to 1000 km). So they only indirectly came in competition with road and rail which concentrated their supply on short distances up to approximate 500 km and air traffic could increase by high rates. Through the still continuing progress in aviation technology at the end of the 50s - the first long-distance jets Boeing 707 and DC-8 were introduced at the beg (nonstop) – intercontinental aviation began to expand. With the technical innovation and the increasing transport supply, competition pressure on the producers market increased. Moreover still newer, bigger and more secure technical facilities were built and put into operations, in order to accelerate the flight dispatch. In 1976, Air France and British Airways were authorized to operate the Concorde on a commercial base at twice the sound-speed, but over waters only. However, costs, high fares and load factors led to a network reduction of scheduled flights to the only destination of New York, still operating. (11)

Trying to cope with aircraft overcapacities, the airlines offered cheaper, discounted fares. The airline traffic increased at a steady-growing rate of 5-10% every year because of the purchasing power of passengers. This trend continued until the 90s. Besides the scheduled flights, the regional and the charter airlines developed. As a "counter offensive" from the air to the Trans-Europe-Express and because of the wide-spread success in America, the European regional air network developed. It allowed flexible connections between regions and large airports (hubs) and resulted in a direct competition with rail. Small turboprop aircraft with a seating capacity of about 18 to 50 places were used from the beginning. These aircraft have a short take-off and landing capability and are also economical in operation with a relative small passenger volume.

3 Trends and Potentials

3.1 Global trends

A century ago railroads reached their zenith. Automobiles were an infant technology. However, they were free from the limitations of a dedicated right-of-way and as a result, cars would alter individual travel worldwide. Who expected at this time the development from simple dirt pathways to highways or all the improvements in car technology?

Not to have a too technical perspective is important when research of this kind is conducted. Air and HSR are certainly technical systems, but the field involves a great number of social issues, including politics. On the one hand it is obvious that the potential development of the systems in question are very much dependent on the development in the world around. Research in the field has to involve considerations of the evolution in corresponding sectors. A number of factors has influenced and will influence the future progress. It includes areas like economic growth, the increasingly internationalized trade and business, new information technology applications, traffic as well as environmental policy, public administration, etc.

On the other hand the technical systems in question also have an impact on the world around. Does the development have potential positive side effects that the society can take advantage of?

Historically we have seen a co-variation between economic growth and transport volumes. Transport volumes even have tended to grow faster than GNP. For international journeys this relationship has been particularly pronounced. There is a common believe that western (and other) economies in general will continue to grow. If so, will the economic growth coincide with increasing travel volumes in the future, too? Private households traveling is closely linked to growth in disposable income and to the over all economic development. Humans in general tend to have a basic desire for certain journeys. Leisure travel is highly appreciated. The lust for new experiences and change is fundamental. Consequently it is natural to expect that certain kinds of traveling will be given priority and increase when household economies grow. Tourism is a growing sector. On the other hand, there are trips people do not want to carry through. To the extent that circumstances admits people will strive to substitute such journeys. The overall development in the field tends to be a decrease in trips that people find undesirable, but an increase in desirable trips. An expected growth in the economy combined with decreased travel costs point towards increased over all private travel.

Internationalization of the trade and business sectors has been a basic trend during the last decades. The free mobility of goods, services, humans and capital are cornerstones in EU policy.

Therefore transport policy has been an important focus in the union. Nationally developed transport systems, with national priorities and solutions have proved to involve some obstacles for transportation.

A decade ago there was quite a widespread apprehension that modern forms of information technologies (IT) would have considerable effects in terms of travel substitution. According to this vision video-conferencing, telecommuting, teleshopping, etc. would decrease the need for traveling. At an individual level travel substitution has been recorded. The development has proven, that IT also has counteracting effects. Trips are also generated. For instance, IT contributes to widen people's contact nets, which in turn leads to additional traveling. IT results in time savings, setting time free for activities like desirable traveling. So far we have seen a simultaneous growth of IT-communication and traveling. Physical movements and IT communication are complementary. The generating effects of IT tend to outweigh the substitutional effects at an aggregated level.

In the current debate arguments are raised for constraining travel due to environmental concerns. Up to now environmental problems basically have been met by technical measures. Cleaner fuels and emission control equipment has led to considerable reductions of emissions of air pollution. Noise barriers along roads and railways have limited noise disturbance. Purification plants have been built to overcome problems with water pollution. Up to now direct and indirect measures to influence transport patterns have rarely been implemented, but such instruments have been discussed. Such measures also bear on the fast growing congestion problems, especially in road traffic, but more and more even in air traffic. Problems that up to now, to a very limited degree, have been fought by other measures than building additional infrastructure. A change of focus has occurred. Financial constraints also have contributed to this development. Further interventions, due to environmental impacts are to come. Global climate change, implementation of external costs, taxes on kerosene, .. will influence individual motorized and long-distance traffic in the future. (11)

3.2 Trends in Air and Rail traffic

Historically, the characteristics of air and rail traffic have been very different. Throughout the western countries state-owned national railway companies are dominating. During the early development of airline systems most nations felt a need for national air companies. Ownership or partnership was a way to control and guarantee "satisfactory" supply of traffic. In parallel to those airlines, charter and currently low-cost companies developed. They have typically been run as pure private companies. Railway companies have come to be run as public administrations, but airline companies rather as businesses. International competition has demanded businesslike management.

During the last decades certain forms of deregulation or liberalization have been seen in a number of European countries. The ambition is to increase traffic systems efficiency and service through increased competition. In the railway sector however, the development has just started. There has also been a trend towards privatization and an endeavour to run both the air an rail traffic in question in a businesslike fashion. The changes have probably been most marked for some state railway companies. However, the transformation has also been obvious for a number of airlines. Large scale cooperation is a current trend in aviation. The present view seems to be that global competition demands more or less global collaboration.

Environmental concerns such as noise and air pollution, lack of land are moderating factors for further expansion of airports and other high-speed system. Current Development has strengthened the elements of competition as means to achieve efficient transport systems. At the same time it is obvious that complementarity also has a potential to improve over-all efficiency. This potential may appear most apparent when air and rail traffic are seen from travelers perspective. For instance, combined tickets allow them to choose one mode or another. It could also make long and medium distance rail transport to an airport more affordable. From the society's view complementarity could be a way to use scarce resources in a better way. To have both air and rail services at lines with limited travel demand is not necessarily the best solution. From the perspective of the traffic companies cooperation provide better prerequisites for competing with road traffic.

High-Speed-Ground-Transportation reduces travel times considerably, at the same time as airlines have problems to cut travel times. Figure 6 shows the Stockholm – Gothenburg relation to exemplify the development in a railway distance of 460 km (travel times from city center to city center with different mode). What we can see is that travel time with air planes still is at the 1968-year level. Travel time improvements due to the introduction of jet planes were counteracted by a relocation of the Gothenburg airport to a peripherical location. In the end of the 1980s the Swedish state railways introduced "city-express" – it was a classical direct train, that was given priority in the rail system. As indicated by the figure, the travel time was cut considerably for those departures. The introduction of the high-speed rail concept X 2000 cut railway travel times by about an hour compared to regular trains. The graph illustrates a future potential to cut travel times by the introduction of an improved HSR-Concept.

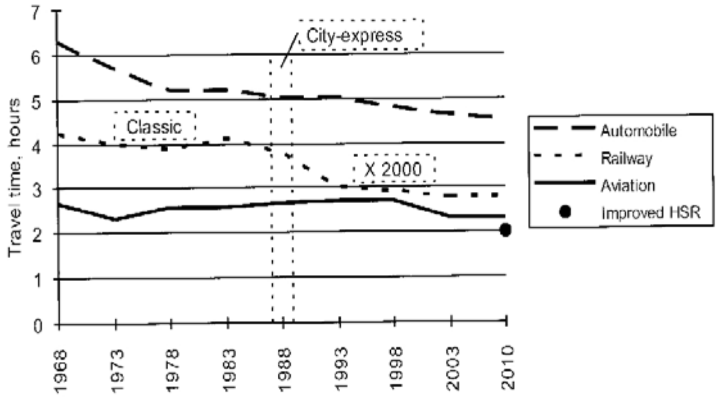


Fig. 6: Travel times between the city centres of Stockholm and Gothenburg with different modes – development and forecast. [Cost 318] (11)

3.3 Trends in Total Mobility

Travel Time Budget (TTB)

Ongoing research done by Andreas Schäfer and David Victor (12) shows out of historical data throughout the world that personal income and traffic volume grow in quite a parallel way. As the average income increases, the annual distance traveled per capita by car, bus, train or aircraft rises by roughly the same proportion. In search for patterns of how modes of transportation compete, Schäfter and Victor started with the well-known rule that on average people devote a constant fraction of their daily time to traveling – called the Travel time budget (TTB). All the reliable surveys they found support this hypothesis: the TTB is typically between 1.0 and 1.5 hours per person a day in a wide variety of economic, social and geographic settings.

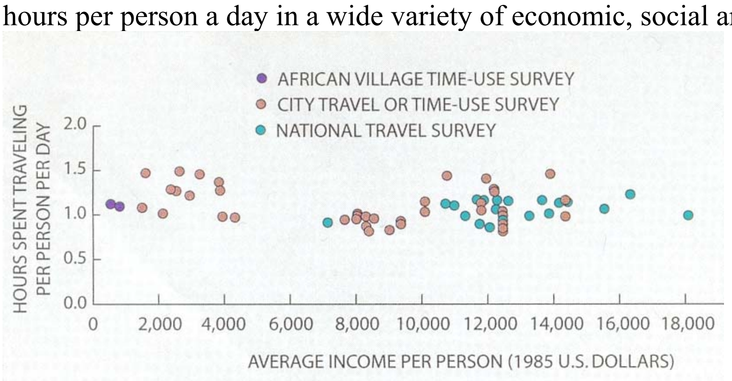


Fig. 7: Travel time budget
The amount of time that people spend on travel is consistent. [Schafer A. and Victor D.] (12)

Travel Money Budget

After housing, food and health, transportation expenses typically represent the third major household expenditure item, accounting for 3 to 5% for zero-car households and stabilizing at 10 to 15% of disposable income for households with at least one automobile, as suggested by

Zahavi (13) and actually reported as 10% of the income of an average Swiss household on the Swiss Federal Statistical Office (SFSO) webpage.

If people keep their time for traveling constant but also demand more mobility as their income rises, they must select faster modes of transport to cover a longer distance in the same time. At low incomes (below $5000 per capita), motorized travelling is dominated by buses and low-speed trains that, on average, move station-to-station 30 to 40 kilometres per hour. As people's income rises, slower public transport modes are replaced by automobiles, which typically operate door-to-door at 30 to 55 km/h and offer greater flexibility. These average speeds, which vary by region, are of course lower than the posted speed limits because of congestion and other inefficiencies. The share of traffic volume supplied by cars peaks at around $ 10 000 per capita. At higher incomes, aircrafts and other "expensive" high-speed transport modes supplant slower modes.

In addition, the availability of infrastructure (e.g. roads, rails, airports) constrains the transport choices. Because transport infrastructures are expensive and long-lived, it typically takes decades to eliminate them or to make new ones.

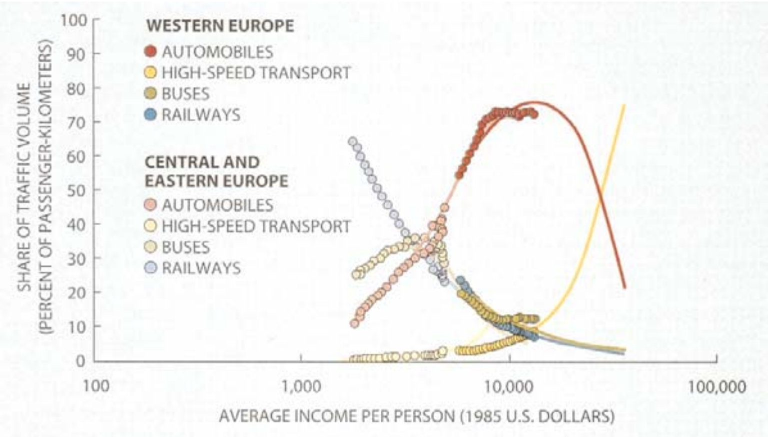


Fig. 8: Travel money budget
The modal split depends on income. [Schafer A. and Victor D.] (12)

Further informations about the impact on environment and projections of high speed traffic demand are presented in another conference paper "High Speed Transport and Climate Change – a new challenge" from W. Ernst, R. Heuberger, D. Imboden and M. Jenny.

Situation in Switzerland

In 2000 the population traveled a total distance of approximately 125 billion kilometers in Switzerland and abroad. This is revealed by the scientific survey of the population's travel behaviour conducted by the Swiss Federal for Spatial Development (ARE) and the Swiss Federal Statistical Office (SFSO) (Mikrozensus Schweiz - travel behaviour microcensus) (14).

The proportion of mobile persons is high; 90% of the population make at least one journey a day. Each person aged 6 and over travels an average of 17 400 km a year – 10 000 km of them by car, 2 000 by train, 630 km on foot, 520 km by tram or bus, 350 km by bicycle, 300 km on coaches and 1 000 km using other modes of transport. 3 800 km of the total is accounted for by journeys outside Switzerland. Fig. 8 illustrates the average amount of travelling per person and day without / with foreign travel. It shows the considerable gap in distance including the foreign travels (through the fast air-transportations).

	excl. foreign travel	with foreign travel
Distance [km]	37	48
Travelling Time [min]	85	89
No. of journeys	3.6	3.6

Fig. 8 Average amount of travel per person per day

Modes of transport: The car is used for 67% of the daily distance travelled within Switzerland. 34% of car journeys are even 3 km or less and occupancy averages 1.6 people.

	time spent traveling [min]	distance traveled per day [km]
foot / bicycle	34	3
car	35	25
train / bus	10	7
other	5	2
TOTAL	84	37

Fig. 9 Key figures on the modal split

Long Travels: As long travels count in the travel behaviour microcensus journeys with an overnight stay abroad. With the target-date-method it is impossible to get reliable date so in the microcensus 2000 for the first time there were questions about season, frequency, distance and mode choice. The average distance from a domestic journey is 293 km and to foreign countries 2130 km. Also the coherence between income and frequency is obvious as Fig. 10 shows:

	last journey…			
income	never	more than one year ago	last year	no. in the last 3 months
< 4000 SFr.	6.8	17.9	75.3	1.1
4000 – 8000 SFr.	1.5	8.9	89.5	1.4
8000 – 12 000 SFr.	0.4	4.1	95.5	2.0
> 12 000 SFr.	0.4	3.2	96.4	2.5
TOTAL	2.7	9.4	87.9	1.6

Fig. 10 Frequency of journeys and income

4 European High Speed system

4.1 Network

Initially, HST has mainly been seen as a new technology, evaluated according to the technical performance , especially in terms of maximum speed. It is quite significant, to this respect, that when the idea of a new link between Paris and Lyon first arose, the hypothesis of a high-speed rail line was considered just at the same level as other ones related to major advanced technology projects, such as the aérotrain (with magnetic sustention) or planes with short or vertical take-off. It is only thanks to the commercial success of this first experience that the interest turned to the economic performance of High-speed rail, beyond the contribution to the energy independence that influenced the decision taken in the context of the first oil crisis. On the one hand, this new mode was demonstrating its ability to divert a significant share of air-passenger-market on the basis of door–to–door traveling time, and to generate a much higher increase of total than expected from the forecasting models. On the other hand, it was possible to expand its efficiency far beyond the cities served by the new line, because of its compatibility with conventional tracks. In the context of the crisis of rail facing the competition of road transport, both on the passenger and freight sides, and the commercial dynamism of domestic air travel, this appeared as an exceptional opportunity to give to rail transport some kind of a new start. It consequently came to the building up of two new HSR lines (Atlantic and North corridors), and to the launching of projects in a number of European countries, including the adoption of long term national schemes for HSR infrastructure. The development of such projects, some of them allowing for an interconnection, led to the idea that HSR could do more than serving important corridors and constitute a network of its own. From that moment, it was becoming possible to think of it in bigger terms at the scale of the European territory.

Fig. 11: European High-Speed-Rail Systems, 2000

As shown in Fig. 5 and in the upper graph the European HST–system is until today a national-based story and in the center are the connections from north to south. Furthermore the speed limits in this transport network are quite distinctive and quite often the modern trains are using the old tracks that do not allow them to run fast. The barrier of the Alps for example is still an obstacle and does not allow speeds in the real HST–dimension, also the Swiss NEAT (under construction) will not be a real high-speed-track and will also be used for cargo transport further limiting the average speed level passengers trains. Only an additional high speed system in Center Europe as presented on the title page of this paper could fully integrate Switzerland into a European high speed network. It was developed in the framework of NFP 41 project F6: Energy and Environmental Assessment of a Eurometro (7).

4.2 TGV Sud-Est - a brief Case Study

The ability of HSR to compete with air transport has been clearly evidenced from the first experience of the Paris-Lyon corridor after the introduction of TGV Sud-Est in 1981. The competition by the TGV resulted in a strong reduction of demand for air travel from Paris to Lyon between 1980 and 1985, followed by a stagnation between 1990 and 1995. Since then demand for the TGV Sud-Est is growing again, as shown in Fig. 12.

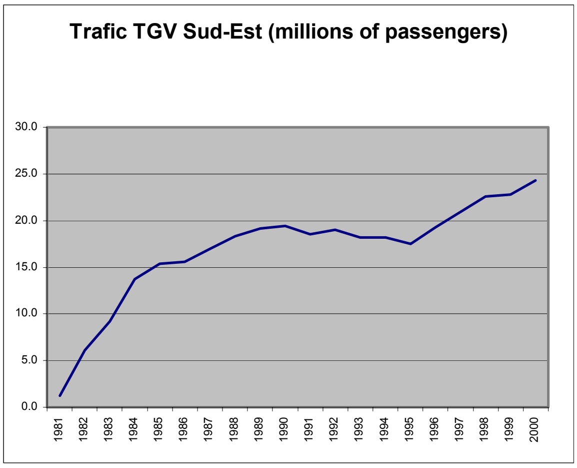
The development of domestic air traffic in France (see Fig. 13) shows that the new high-speed train had a considerable impact on the modal split, increasing the rail share from 40% to 72% between Paris and Lyon within four years. However, after 1984 this process came to a halt. Since then the modal split between air and HSR transport (TGV) has remained almost constant and now both modes of transport further develop side by side.

However, the extension of the high-speed train to Marseilles, resulting in a travel time of more than 4 hours does not seem to offer an interesting alternative to most air travelers. The data in

Fig. 13 clearly show that the number of air passengers on that link has continuously grown since 1980.

This fact clearly indicates that travel time is a very important guiding factor for the modal split between air traffic and HSR. A Maglev System, High-Speed-Rail or Air transport will be competitors, but often also complementing partners, depending on the travel time. Each of them has particular advantages and disadvantages and operates on specific markets.

The development of total high speed travel (HST) between Paris and Marseilles also indicates that introducing a new high-speed travel supply may result in a strong increase of total mobility.



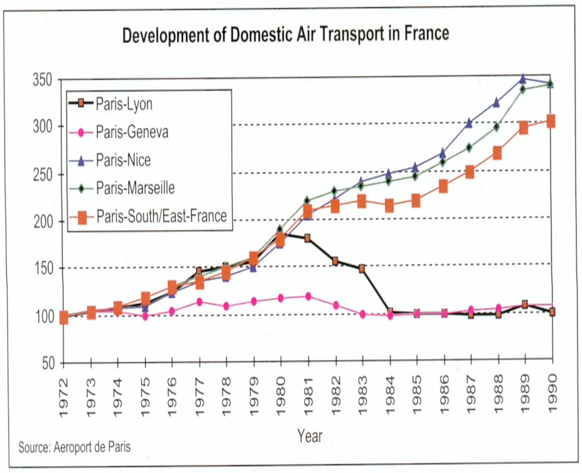


Fig. 12: Trafic TGV Sud – Est
Development of passenger flow.
[source: SNCF, 2002]

Fig. 13: Development of domestic air transport in France. [Source: aeroport de Paris]

The case study clearly shows that the modal split between air traffic and high-speed trains can be strongly influenced by modern high-speed train links. To make HSR–transport able to compete successfully with air traffic, travel time and frequency appear to be the two key elements to focus on during an analysis of desirable improvements of the overall service. One big advantage of the airline business is the possibility to react immediately to new transport demand situations, has a high degree of flexibility in adapting the supply to demand and creating new service. High-Speed-Ground-Transportation is not able to increase the accessibility of regions within a short period of time and needs a high level of demand since, on the one hand, it requires a special infrastructure and, on the other hand, the routes may only consist of a few stations, otherwise the travel time will increase.

	1981 in %	1984 in %
plane	31	7
train (TGV)	40	72
car and bus	29	21
TOTAL	100	100

Fig. 14 Distribution of mode of transport before and after the introduction of TGV Paris-Lyon. (11)

A further element to recognize is that, as usual for "new technologies", the question of adjustment between supply and demand for high speed transport has to be addressed in a dynamic way. This is not only relevant for a high-speed train system because of the significant proportion of creation of traffic that has occurred in most cases as compared with the situation ex ante. This is also true for the development of air transport considered apart, the progressive extension of the network, increase in frequencies and reduction of fares having generated new needs that could not be satisfied before. Considering that perspective, high-speed rail is nothing more than a step, although quite a substantial one, in the life cycle of the product "high speed", which may approach the turn from initial to growth. This last criterion introduces an additional dimension of complexity of the problem. Probably the trend of a new high-speed travel system is to increase total mobility to limit by additional control measures. All these aspects must be considered in the evaluation of the future demand.

5. Ongoing research work

5.1 Research Concept

As stated in Section 1, research should evaluate under which conditions modern highspeed ground transportation systems could lead to a more sustainable highspeed transport system. All three aspects of sustainable development (society, economy and ecology) shall be included as far as possible. The concept sets different "sustainable" goals for energy use and CO_2-emissions for total mobility. This goal shall be achieved by using the back casting method.

Back casting method

It can be said that back casting studies begin with a vision of a desirable future (in terms of fulfilling certain environmental restrictions) and one or more forecasts. In the following step, the forecasts are compared with the desired vision. In cases where change is needed, current trends must be broken perhaps through additional measures. This process requires an analysis of the changes that must occur, the decisions that are required, the restrictions that would be implied, and so on. Back casting has an obvious normative side since we ask what future is desired. Back casting is put forward as a more promising approach, especially for situations where great change is needed. However, it is possible that back casting and different forecasting approaches are complementary. The argument is that back casting is mainly appropriate where current trends are leading towards an unfavorable state. Therefore, forecasting methods are necessary because they inform the back caster when back casting is really required.

Scenarios have the potential of being a less rigorous and more open method of exploring the future. Perhaps they are the only method to identify "corridors" of relevant and feasible futures within a universe of possible ones …

5.2 Evaluation of influential factors

Because of the complexity it is essential to overview the different factors and evaluate the most relevant ones for a meaningful result. This process needs to be done very carefully as the potential impact of all main factors have to be considered in the ongoing research work. However, the development of the final model needs a stepwise process of simplifications and the use of key factors on the input and output side (e.g. energy or CO_2).

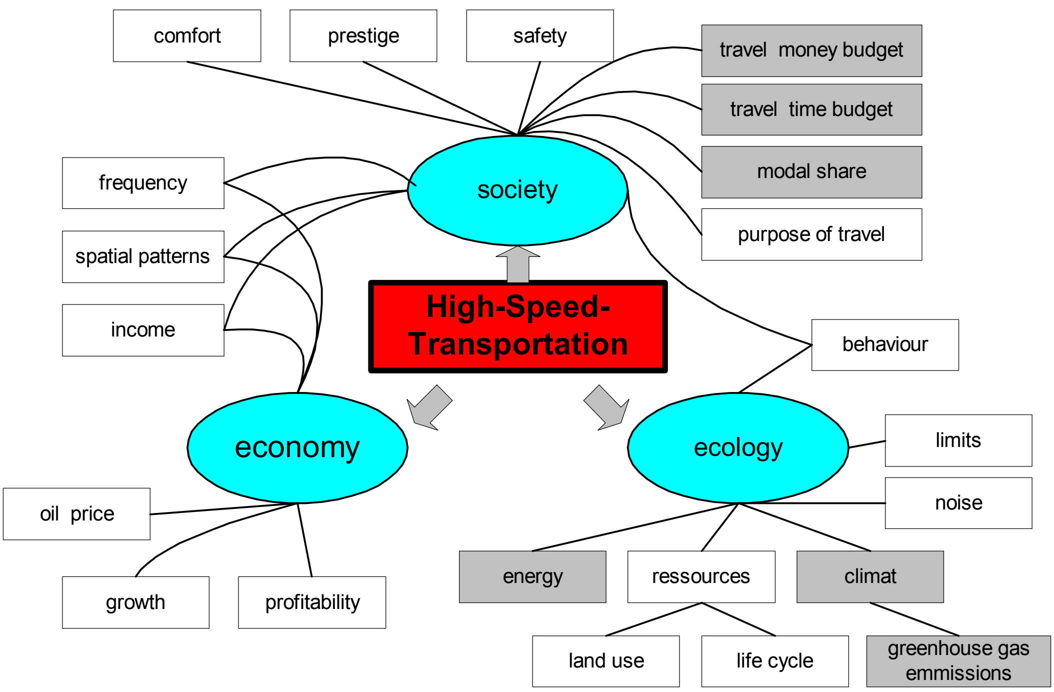


Fig. 15 Overview of influential factors

5.3 Key factor: CO_2 and Greenhouse Gas (GHG) emissions

Based on the concept of a more or less fixed travel time budget (TTB) per person and in consideration of the different travel one can estimate the Global Warming Potential (GWP) of the different modes per time unit. From this point of view, the climate effect of air traffic compared to the others is enormous. Lack of data the greenhousegas emissions from foot and bicycle are assumed zero. The CO_2 equivalents and average speeds used in figure 16 are based on the report “Ecoinventory transport, 1999”(15), the “Greenhouse Gases Inventory of Switzerland”(16) and own declarations.

The graph shows the resulting GWP of different travel modes, assigning factor 2 to the total impact of all climate relevant flight emissions as proposed in reference (4). The result is quite alarming: air trips might result in up to 20 times higher GWP than car and fast train systems per unit of time.

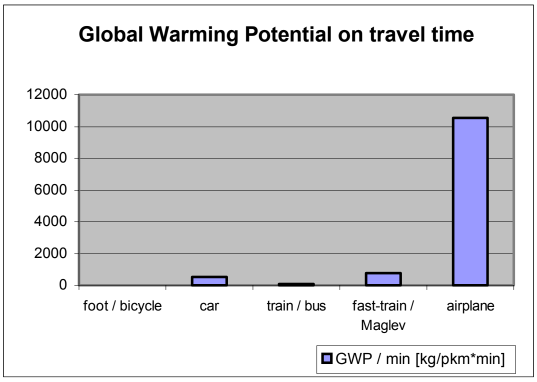
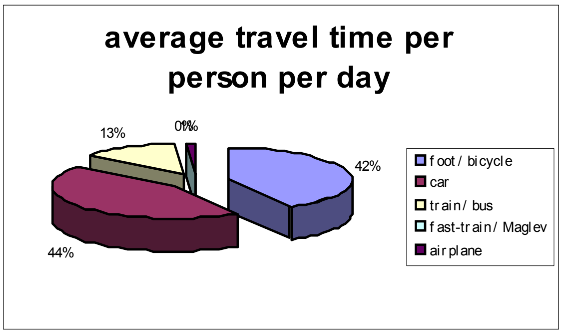


Fig. 16: Global warming potential (GWP) of different travel modes dependent on travel time.

Interesting is the following comparison of the percentage of the “average travel time per person and day” (Fig. 9 Key figures on the modal split) and the percentage of the „average GWP per mode per day“ – originate from multiply by the „GWP from different travel modes dependent on travel time“ (Fig. 16) and the average travel time of a person per day.
It shows that almost two thirds of the GWP per person and day are caused by car and another third of the 2% average travel time per air-transportation. Due to the electrification of trains and capacity public transport produces during the 13% of the average travel time only 3% of the GWP.



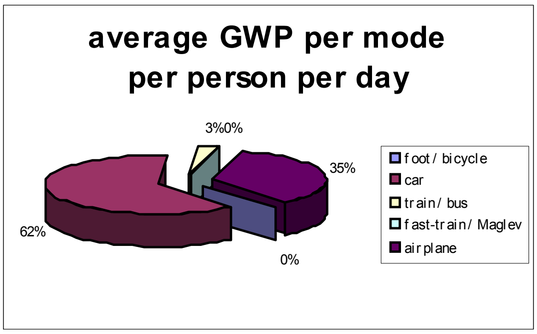


Fig. 17 comparison of average travel time and GWP per mode, person and day

Supposing that the average share of air transport will grow continuously within minutes – as the model of A. Schaefer (12) shows in a dramatic way because of the strong tendency to shift from slower to faster transport modes, the GWP from transport sector will grow significantly.

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