# Swissmetro: economic viability of the Basle-Zurich pilot line

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#### Basle-Zurich line, Economic evaluation, Pilot line, Swissmetro, Traffic analysis

#### Abstract

In the past two years, the management of the Swissmetro project has analysed the technical and economic feasibility of a high-speed connection between the centres of the Swiss cities Basle and Zurich. This 89.1 km long line, which could be in operation in 2020, will be ensured by a Swissmetro vehicle in only 15 minutes.

In order to put out the economic viability of this connection, a traffic analysis has been conducted, yielding passenger estimates for the years 2020 to 2040. This analysis, based on four forecasting scenarios, showed that between 19,000 and 30,000 daily passengers would be conveyed on this line in 2020 and up to 85,600 by 2040.

These traffic estimates have been used to determine the direct economic viability of the Basle-Zurich Swissmetro link. The connection will be profitable yielding a realistic internal rate of return ranging from 3.6% to 6.4%, depending on both the traffic scenario and the ticket price; this profitability would be largely increased if the Swissmetro line would also connect both Basle and Zurich airports, as well as other Swiss or European cities.

### **1** Introduction

As already shown by several existing experiments with high-speed trains, implementing an efficient and fast transport system is an important issue for the development and inter-linkage of urban centres. The increasing demand for mobility and its related growing environmental problems requires that new transport technologies be studied, and already planned new mobility corridors be evaluated. The development of robust methodologies for assessing such projects is therefore of utmost importance. The head of the Swissmetro project is aiming towards this goal by analysing various concrete high-speed lines (such as Lyon-Geneva, Geneva-Lausanne, Bern-Zurich or Basle-Zurich) and corridors (in particular Lyon-Munich-Vienna). The main objective is not only to stress the environmental advantages of the Swissmetro, but also to show the great economic and socio-economic benefits that these new high-speed lines can generate at small and large scale for all the regions under concern.

Swissmetro is a high-speed transport system based on magnetic levitation. It is considered today as one of the most innovative solutions for the 21<sup>st</sup> century, so far as passenger transportation is concerned [1, 2]. Entirely underground, it resembles at the same time a train without wheels and a plane without wings, enabling passengers' transportation at more than 500 km/h. The combination of different modern technologies aims at providing an environmentally friendly answer (in particular with respect to noise, landscape protection and attractive ecobalance) to the increasing demand for mobility. Past and current studies, which have been carried out in the past 10 years, showed the potential of this transport system for distances between stations ranging from 50 to 300 km and over.

## 2 Basle-Zurich line

The Swissmetro transport system, which shall be seen as a complement to the existing high-speed rail network, represents an additional stage in the evolution of ground transportation, which will then comprise 3 levels: a basic railway network, a high-speed network and a third layer of very high-speed services. This long-term prospect (2020 to 2050) comprising the Swissmetro system, will offer a very efficient but nevertheless environment-sensitive alternative to short- and middle-haul flights.

In this prospect, a link between the city-centres of Basle and Zurich could represent a first step towards a very high-speed corridor connecting Lyon to Vienna via Switzerland. This corridor would advantageously complement the outlined plan for a European high-speed train network by implementing an essential east-west connection, thus creating a better access to Eastern Europe, which would consequently link important economic poles by reinforcing the network of European cities.

The 89.1 km long Swissmetro connection between the city-centres of Basle and Zurich is thus a good potential candidate to become the Swissmetro pilot line. These two cities already possess an important commuting traffic, which represents an intrinsic economic advantage for this high-speed connection to reveal profitable without being connected to a wider Swissmetro network.



Figure 1 – The Swissmetro pilot line between the city-centres of Basle and Zurich, with the possible extension to the respective airports.

Thanks to the Swissmetro technology, which enables to reach commercial speed of over 500 km/h, the connection between Basle and Zurich would place these cities at 15 minutes from each other, thus creating a new synergy between their economic basins.

# 3 Traffic analysis

Depending on the political context surrounding the realisation of the Basle-Zurich Swissmetro connection, various analysis techniques have been used to estimate the traffic demand and growth rate from 2020 (operational start-up) until 2040. Four different forecasting scenarios have been retained depending on the type of environment and accompanying measures prevailing [3, 4].

- > The "minimal" scenario: Swissmetro is in direct competition with the other transport means, and no accompanying measures are foreseen.
- The "moderate-pessimistic" scenario: small additional passenger potential can be added to the minimal scenario due to a relatively weak Swissmetro impacts in the first period and altogether with a lower-end yearly increase rate (as compared with history record of TGV good lines, for instance).

- ➤ The "moderate-realistic" scenario: thanks to an adequate integrated mobility policy, some potential of the Swissmetro impacts is clearly visible in the first period. A reasonable yearly increase of 10% is foreseen during the three best years of growth, before saturation effects of various kinds exert their effect to slow down the increase pace.
- > The "optimistic" scenario: a strong high-speed effect is considered, based upon what happened in some of the well-known TGV cases. But as a consequence: 1) peak hours become quickly problematical and have to be handled with higher frequency trains during the daily rush hours; 2) the overall saturation effect can be felt quite early, with a ceiling already inescapable after 10 years of activity.

The analysis of these four scenarios yielded the results presented in Table 1 and Figure 2. According to the minimal scenario, Swissmetro will transport 19,000 daily passengers (total of both directions) in 2020 and only 23,500 in 2040 (see [3] for a discussion of such unrealistic evolution), while according to the optimistic scenario, it will transport 30,000 daily passengers in 2020 and 85,600 in 2040.



**Figure 2** – Traffic evolution (total of both directions) between 2020 and 2040 for the Swissmetro link Basle-Zurich Economic evaluation

	Scenarios			
Demand	Minimal	Moderate- pessimistic	Moderate- realistic	Optimistic
Daily passenger in 2020	19,000	26,000	26,000	30,000
Daily passenger in 2040	23,500	48,000	70,100	85,600

 Table 1 – Traffic evolution (total of both directions) as a function of four development scenarios.

#### 3.1 Assumptions

The preliminary economic evaluation of the Swissmetro link Basle-Zurich is based on the following assumptions:

- > The operational start-up of the 89.1 km long pilot line is foreseen in 2020;
- Four scenarios (minimal, moderate-pessimistic, moderate-realistic and optimistic) have been considered for the evaluation of the passengers' traffic between 2020 and 2040 (see previous section);

- The average one-way fare shall be CHF 20.- (today Swiss Franks), which corresponds to a price of CHF 0.22 per kilometre. In comparison, the current Basle-Zurich full SBB-fare is CHF 30.- in second class and CHF 50.- in first class (these prices are 50% lower for the passengers having the SBB half-price pass);
- ➤ The Basle-City station will be situated underneath the SBB-central station, whereas the Zurich-City station is foreseen underneath the Central place;
- The underground stations will be 130 metre long and thus have a capacity for a 400 passenger train;
- The traffic density during the 6 daily rush hours will be of 10 vehicles per hour and per direction in the first 3 above mentioned scenarios, and 15 vehicles per hour in the fourth case. During the 12 non-rush hours, these figures would be reduced to 6 vehicles per hour and per direction in all four scenarios;
- The travel time will be 15 minutes, non-including the 3 minutes for embarking / disembarking;
- > The estimated investment and operational costs, as well as the operational income, are computed in 2002 CHF.

#### **3.2** Investment costs

The investment costs necessary for the realisation of the Swissmetro inter-city line have been computed using data from the Swissmetro main study [2] and taking into account the characteristics of the line such as length, geology, number of passengers, traffic evolution, etc. These estimated costs can be considered as realistic, as they were calculated by companies bearing long-term expertise in tunnel digging and underground infrastructure building.

The estimated costs, which are summarised in Table 2, have been calculated for a vehicle capacity of 400 passengers, although the length of the vehicles does not affect the investment costs significantly.

Investments	Costs [mio CHF]	Life time [years]
Analyses of pilot line, licensing, fund raising	40	
Civil engineering	4,606	100
Electromechanical equipment	800	20
Mechanical equipment and vehicles	368	20
Approval, staff training, operational start-up	56	
Contribution to the industrial development	100	
Total	5,970	

 Table 2 – Investment costs and life time of the equipment for the Basle-Zurich line.

Analyses of pilot line, licensing, fund raising. An amount of 40 million CHF has been estimated for the analyses related to the pilot line (traffic, town and country planning, environmental impacts, safety, mode of operation, geology, etc.), as well as for the filing of a license application (detailed economic and financial studies, drawing-up of a business plan, final report) and for the fund raising necessary to finance the construction of the line.

**Civil engineering.** The civil engineering costs cover the 89.1 km double-tunnel line (including the 500 million CHF allocated to construction of the test line), the Basle and Zurich Swissmetro stations, and 5 operational posts (or intermediate shafts) used for digging the tunnels and housing the electrical

and mechanical equipment necessary for operating the line (electrical substations, vacuum pumps, repressurisation device, etc.).

**Electromechanical equipment.** The electromechanical equipment includes the propulsion, guidance, levitation and energy transfer systems for the vehicles, as well as all electromechanical equipment at the operational posts and stations.

**Mechanical equipment and vehicles.** The mechanical equipment covers the equipment in the stations, such as the airlocks, barrels and lifts, as well as the vacuum pumps, repressurisation devices, vehicles, etc.

**Approval, staff training, operational start-up**. The costs related to the preparation of the operational start-up have been estimated at 56 million CHF. These include the approval costs of the Swissmetro as a passenger public transport system, the staff training costs, as well as all the costs related to the actual operational start-up, such as final tests, promotion, opening, etc.

**Contribution to the industrial development**. The industrial development of the Swissmetro technology, including the construction of a 20 km long test line, has been estimated to about 1,850 million CHF. For the economical analysis of the Basle-Zurich line, a contribution to the industrial development and tests in situ of 100 million CHF has been taken into account..

#### **3.3 Operating costs**

**Assumptions.** The yearly operating costs, which are computed for 264 daily trips distributed over 18 operational hours, are summarised in Table 3.

Operating costs	Costs [MCHF] 400 passengers
Operating staff	15
Energy	14
Infrastructure maintenance	20
Equipment and vehicle maintenance	23
General costs	7
Total	79

Table 3 – Operating costs for the Basle-Zurich line.

**Operating staff.** It is assumed that the operating staff is composed of 150 persons having an average annual wage of 100,000.- CHF.

**Energy.** The energy costs correspond to a yearly consumption estimated at about 120 million kWh at the price of 0.10 CHF per kWh.

Maintenance and general costs. The operating costs related to the maintenance of the tunnel infrastructure, equipment and vehicles, as well as the general costs, have been estimated in [5] based on existing transport systems.

### 3.4 Internal Rate of Return

**Terminology.** The direct profitability of the project over a given period is expressed here in terms of the Internal Rate of Return (IRR) over 40 years. Computation of the IRR is based on the Net Present Value (NPV) of the project, expressed as the difference between the discounted amount of the

operational income and the discounted amount of the investment and operating costs. The Internal Rate of Return then corresponds to the discount rate, yielding a zero NPV.

**Internal Rate of Return (IRR).** The Swissmetro link between Zurich and Basle city centres produces, under the assumptions previously defined, the Internal Rates of Return (IRR) given in Table 4.

	Scenarios				
Assumptions	Minimal	Moderate- pessimistic	Moderate- realistic	Optimistic	
Operational start-up	2020	2020	2020	2020	
Vehicle capacity	200 seats	300 seats	400 seats	400 seats	
One-way fare (in 2000 CHF)	CHF 20	CHF 20	CHF 20	CHF 20	
Daily passengers (in 2020)	19,000	26,000	26,000	30,000	
Daily passengers (in 2040)	23,500	48,000	70,100	85,600	
Investment costs [MCHF]	5,740	5,780	5,970	6,050	
Operating costs [MCHF/Year]	64	72	79	83	
IRR	0.0%	2.5%	3.6%	4.4%	

 Table 4 –. Internal Rate of Return (IRR) for the Basle-Zurich line.

This IRR value corresponds to the profitability of the Swissmetro link for a commercial company, which would have to pay the global investment and operating costs. This value is attractive when compared with the profitability rate of railway lines, where the infrastructure costs are very often paid by the community, and not taken into account in the calculation of the IRR.

### 3.5 Analysis of sensibility

The Internal Rate of Return varies in a more or less important way when the initial assumptions are changed. These variations are shown in the following analysis of sensibility.

**Variation of the investment costs.** The estimated costs of the civil engineering and equipment (without vehicles) represent by themselves nearly 90% of the total investments. It is of prime interest to understand how the IRR varies with changes in the investment costs. Four scenarios have been considered in Table 5: (1) investment cost not included (this is often the case for the IRR calculation of railway lines); (2) 20% reduction in the investment cost, (3) investment costs as previously calculated; (4) 20% increase in the investment costs.

IRR (investment costs / Traffic scenario)	Scenarios			
Infrastructure and Equipment Investment Costs (IEIC)	Minimal	Pessimistic	Realistic	Optimisti c
IEIC not included	17.2%	22.8%	23.8%	25.7%
IEIC - 20%	0.6%	3.3%	4.4%	5.2%
IEIC	0.0%	2.5%	3.6%	4.4%
IEIC + 20%	-0.5%	2.0%	3.0%	3.8%

 Table 5 – Influence of the investment costs on the IRR.
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This analysis demonstrates the relatively low influence of investment costs on the IRR, as a 20% change in the investment costs generates IRR variations lower than 1%. Obviously, the IRR becomes extremely attractive for investors, would the investment costs not be included in its calculation.

**Influence of the operational income.** Variation of the ticket price has, however, a marked influence on the IRR, as shown in Table 6.

IRR (Ticket price / Traffic scenario)	Scenarios				
One-way fare	Minimal	Pessimistic	Realistic	Optimistic	
15 CHF	-1.4%	1.3%	2.4%	3.1%	
20 CHF	0.0%	2.5%	3.6%	4.4%	
25 CHF	1.0%	3.5%	4.6%	5.5%	
30 CHF	1.7%	4.4%	5.6%	6.4%	
<b>Table 6</b> – Influence of the operational income on the IRR.					

Besides the ticket price, the operational income also directly depends on the number of passengers. The comparison of the four scenarios considered reveals that this factor is of great influence on the IRR as seen in the Tables 4, 5 and 6.

### 4 Conclusion

The Swissmetro line between Basle and Zurich city-centres is thus economically attractive, as it provides in itself an important number of passengers without necessarily requiring connection with a wider (national or even European) Swissmetro network. A preliminary study indicates that this line is not only economically viable, but also financially interesting for the private and public sponsors.

The economic evaluation has indeed demonstrated that this line is not only attractive to passengers, but also in terms of profitability. Realistic though cautious hypotheses yields an Internal Rate of Return (IRR) of 3.6% over 40 years for a commercial company, which would assume the global investment and operating costs. A sensibility analysis has shown that variations in the investment cost only affect the IRR in a limited way, whereas the influence of the operational incomes on the IRR, namely demand and ticket price, is clearly significant.

Furthermore, the profitability of the Basle-Zurich connection could be significantly increased, would the line be part of a Swissmetro or Eurometro network or would it be extended to both Zurich-Kloten and Basle-Mulhouse airports, thus creating a single huge airport with the Swissmetro becoming a shuttle, or an "express moving walkway", between the two terminals.

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