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Materialienband M29

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Ökobilanz der Swissmetro

Umweltwirkungen durch Bau und Betrieb (Teil 1) und durch induzierte Aktivitäten (Teil 2)

Das Nationale Forschungsprogramm "Verkehr und Umwelt - Wechselwirkungen Schweiz- Europa" (NFP 41) will eine Denkfabrik für eine nachhaltige Verkehrspolitik werden. Es sucht Lösungsbeiträge aus allen Fachdisziplinen zu einer effizienten und nachhaltigen Befriedigung der Mobilitätsbedürfnisse.

Das Forschungsprogramm wird im Auftrag des Bundesrates vom Schweizerischen Nationalfonds zur Förderung der wissenschaftlichen Forschung durchgeführt. Es wurde 1996 lanciert und wird voraussichtlich bis zum Jahr 2000 dauern.

Le programme national de recherche "transport et environnement - interactions Suisse - Europe" (PNR 41) contribuera à formuler des actions originales et spécifiques à la Suisse, aptes à préserver la compétitivité internationale et la dynamique économique et culturelle du pays, grâce à un système de transport efficace, rationnel et respectueux de l'environnement naturel et construit.

Le programme est exécuté par le Fonds national suisse de la recherche scientifique sur mandat du Conseil fédéral. Il a été lancé en 1996 et durera probablement jusqu'à l'an 2000.

The National Research Programme "Transport and Environment - Interactions Switzerland/Europe" (NRP 41) intends to become a think-tank for sustainable transport policy. It shall supply contributions from all relevant disciplines towards the efficient and sustainable satisfaction of mobility needs.

The Swiss Science Foundation was given the task by the Federal Council of carrying out this programme. It started in 1996 and will probably last until 2000.

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Summary

The Projects and their Context

This volume contains two life-cycle assessments (ecobalances) of Swissmetro that provide answers to two different but intertwined questions: (i) the environmental impacts due to the construction and operation of Swissmetro and (ii) those due to the activities induced by the operation of Swissmetro.

The LCA of the direct environmental impacts contained in Part I has been motivated originally by the observation that, from the perspective of environmental impact assessment (EIA), Swissmetro appeared to be the environmentally most benign means of transportation to satisfy the long-term increase in mobility forecasted for Switzerland. The mobility is expected to double again over the next twenty years. The question was, therefore, if the same conclusion could be drawn on the basis of an environmental assessment on the basis of an LCA that defines different system boundaries and considers other types of environmental impacts as well.

This initial investigation was undertaken by ESU (Energy-Materials-Environment) within the ETH project Swissmetro. The resultant LCA report of 1997 had been based on Swissmetro specifications defined in early 1996. The concession demand of October 1997 for a pilot stretch Geneva-Lausanne used different specifications, in part made in response to the insights gained through this LCA of 1997.

NRP 41 made it possible for *Natural and Social Science Interface (UNS)* to update the earlier LCA of the direct impacts by using the specifications of the concession demand. The results of this updated. Ecobalance are presented in the first Part of this report.

This accounting for the environmental impacts of Swissmetro lies in the border zone of the environmental accounting for products or services and the one for a new transportation system (or technology). One basic assumption is here that the general societal conditions remain unchanged. A second life cycle assessment of Swissmetro has been initiated at *UNS* in order to correct for this limitation. In this case the changes likely to be induced by the coming of Swissmetro as well as other changes in society that can be expected in the future were to be considered through a scenario development. The decision was made to limit the analysis in a first step to the induced transportation and construction activities. This environmental assessment too has benefited from the financial assistance by the Swissmetro project of ETH and the NRP 41.

The two ecobalances described in this report concern therefore the proposed pilot stretch from Lausanne to Geneva, for one, and, as a second, the whole network planned at one time for Swissmetro (including the branches to Chur and Sion). There are other differences in the assumptions on which the two analyses are based. They concern some aspects of tunnel construction, of the utilisation of the excavated materials, and of Swissmetro technology. This explains why this report is made up of two distinct although related parts.

Ecobalance of Swissmetro – Environmental Impacts Due to Construction and Operation (Part 1)

Goal, Procedure and Assumptions

The accounting for the environmental impacts due to the construction and operation of Swissmetro had two goals. One was to identify the potential for an ecological optimisation of Swissmetro (eco-design). The other was the ambition to lay the foundation for an ecological comparison of Swissmetro with other means of transportation (ecological optimisation for the purpose of managing the predicted increase in mobility).

It was for these two purposes that the environmental impacts were to be determined through a Life Cycle Assessment (LCA). The requirement for non-renewable energetic resources was to be used as the main indicator for the judgement of environmental impact. Additionally we have used the CML categories to determine other environmental impacts. The impacts of the other transportation systems have been determined with the help of the environmental impact database available in Switzerland, the „Ökoinventar Transporte". The functional unit used for the ecological optimisation is the *vehicle kilometre* (vkm) because the energy required for driving the vehicles is almost independent on the number of passengers transported. The functional unit for the comparison of Swissmetro with the other means of transportation is the *passenger kilometre* (pkm) as the load factor of the vehicles, that is the best utilisation of existing capacity, determines the judgement about the relative ecological merits of a means of transportation.

The structure of the system Swissmetro to be accounted for has been chosen in light of the questions and needs of the ecological optimisation and of the comparison with the other means of transportation. The data given in the concession demand for the pilot stretch Geneva – Lausanne have been used as the basis for the accounting.

Results

Table 1 contains the results for the energy requirements for the different elements of the system Swissmetro, both for the original specifications of 1996 as well as for those from the concession demand. The calculation is based on a use phase of the Swissmetro infrastructures of 100 years. The net reduction in the energy requirement of almost 20% is the result of an even larger reduction in the energy requirement due to the operation of the infrastructure and a few small increases in the energy requirements for system elements.

The significant reduction in the energy requirement for the operation of infrastructure is above all due to the introduction of elevators with energy recuperation. This design change occurred as a reaction to the result of the ecobalance of 1997, which had shown that the operation of the infrastructure was responsible for a surprisingly high amount of total energy use identified.

Activities (Processes)	Updated Ecobalance		Ecobalance 1997		Difference
	TJ/a (2)	% (3)	TJ/a (4)	% (5)	TJ/a (6)
Underground constructions (Tunnel, Access pits, Stations)	71	9	70	7	0.3
Disposal of excavated material	31	4	25	2.6	6
Electro-mechanical & mechanical installations in the tunnels	52	6.6	52	5.3	0.2
Production & maintenance of vehicles	11	1.4	11	1.1	–
Operation of infrastructure	102	13	291	30	-189
Operation (vehicles)	523	66	522	54	1
Total system (sum)	*789*	*100*	*971*	*100*	*–182*

Table 3 The requirement of non-renewable energetic resources for the pilot stretch of Swissmetro from Geneva to Lausanne based on the updated ecobalance (2000) in comparison to the ecobalance of 1997 (UCPTE electricity mix, use phase 100 years).

The energy requirement for the operation of the vehicles does not change in the absolute. However its part in the total energy requirement increases from 54% to 66%, the automatic result of the absolute reduction in the energy required for the system as a whole. The implication of this change is that the specifications for the dimensions of the tunnels (diameter, aerodynamic vortexes) become more determinant for the overall sensitivity of the energy required per passenger kilometre (pkm), the usual indicator for judging the (environmental) quality of transport services.

The preferred passenger scenario with 29‘400 passengers a day (in both directions together) implies a load factor of 61% and goes together with an energy requirement in the updated ecobalance of 1.29 MJ/pkm. The passenger scenario used in the original ecobalance of 1997 with a load factor (of 54%) that is most similar to these 61% went together with an energy requirement of 1.81 MJ/pkm. This improvement of 28% in the energy efficiency is the net result of a 20% improvement in the energy efficiency of the total system (see Table 1) and of the increase in the assumed number of passengers transported (in the scenario favoured today) by 14%.

The easiest way of comparing the energy efficiency of Swissmetro with those of other means of transportation is to use the numbers contained in the Swiss database “Ökoinventar Transporte”. In that case Swissmetro compares favourably the energy requirement of 1.40 MJ/Pkm for the rapid trains of the Swiss railway company (SBB) (calculated with the UCPTE electricity, which is environmentally worse than the own mix of SBB) and a load factor of 31%. The performance of Swissmetro is about equal to the 1.26 MJ/pkm by the German high-speed trains (ICE) (with a load factor of 55%). Passenger transportation by car has the worst energy efficiency with 3 MJ/pkm and an assumed load factor of 34%. Here Swissmetro is clearly at an advantage (as is the case with other train types too.)

This comparison with the rapid trains of SBB has to be interpreted with care. The most modern trains used by SBB today require already significantly less energy than the rapid trains used in the database. And it is quite probable that additional gains will be realised in the coming 50 years. Additionally, the load factor achieved on the main east-west trunk line by SBB is certainly higher than 31%.

Ecobalance of Swissmetro Environmental Impacts due to Induced Activities (Part 2)

Goal and Assumptions

The main goal of this investigation was the determination and evaluation of the environmental impacts of the activities induced by the acceleration of mobility through Swissmetro. The induced activities to be considered foremost were the additional traffic and construction activities generated. The specific aims of the investigation can be formulated thus:

- To determine in a prototypical manner the ecobalance of a system that has far-reaching implications.
- To contribute to knowledge about the consequences of different constraints on future mobility developments and their environmental impacts.
- To provide an estimate of the environmental impacts of Swissmetro that includes an assessment of the induced effects with respect to mobility and the use of land.

We attempt a judgement on the importance of the environmental impacts of the induced activities relative to those of the construction and the operation of Swissmetro despite the high uncertainty in the determination of the volume of induced activities. Our hypothesis is that the latter might be less significant than the former.

The starting point for the analysis is the observation that on average the population uses 85 minutes every day to satisfy its mobility needs. Accelerating a part of this mobility will therefore presumably be used to travel farther within this constant time budget. One reason to do so is in order to reach new places in the countryside for the purpose of living there.

We have chosen the full Swissmetro system as a basis for our model. We assumed that the number and geographic location of the Swissmetro stations (Geneva, Lausanne, Bern, Lucerne, Zurich, St. Gall, Basle, Bellinzona, Chur, and Sion) would be those corresponding to the maximum variant of Swissmetro known to the public at the time of our research.

The technical details for Swissmetro (e.g., speed) were taken from the concession demand for the pilot stretch from Geneva to Lausanne.

Procedure

The conditions determining future mobility cannot be forecasted with any precision. We therefore developed four scenarios. This way of proceeding is attractive because Swissmetro will not be operational before 20 to 30 years. Additionally, the consequences of a new transportation system, its induced activities, will not be realised before the system has been in use for some time. Each scenario has been modelled in two ways: a variant without and one with Swissmetro. The difference between the environmental impacts of the two variants is the impact that is due to the construction and the operation of Swissmetro. Swissmetro is therefore made responsible only for those impacts that occur in addition to those that would occur over time anyway in a world without Swissmetro. This approach to environmental accounting in which the system analysed changes with the variant chosen is still methodologically virgin territory and is currently discussed as a *marginal ecobalance*.

The planning horizons considered are:

- The time when the full system is completed and in operation. (Our assumption is 2020.)
- The time when the induced activities have been realised. We think this will be around the midlife of the Swissmetro system and therefore assume this horizon to be 2050).

We model both of these horizons independently of each other, starting each time with the present situation. This means that 2050 is not simply the prolongation of a development that will have occurred until 2020.

We have made use for the development of our scenarios of a procedure developed by Rico Maggi. The development of transportation is determined in this approach by five influence factors: Ecological conscience, state regulation, public financing, and the transportation software and hardware in future use. The scenarios we have developed on this basis differ mostly in terms of the assumed prevalence of an ecological conscience among the population and the extent to which the state makes use of regulatory means and of public monies.

The scenario “*Bekannt*“ («known») corresponds to a world formed by the trends and planning orientations already dominant today. It is the presence of an ecological conscience in the population at large that in the scenario “*Grün*“ («green») provides the basis for an adequate environmental behaviour. However, this conscience is not necessarily translated into action under the conditions prevalent in this scenario. The development of the urban agglomerations and of the transportation systems is strongly controlled in the scenario “*Reguliert*“ («regulated»). In the scenario “*Umfassend*“ («all inclusive») we have both a highly developed ecological conscience among the population and a system of strict state regulation.

We have determined the development of the future mobility for each of these four scenarios with a rough GIS-based transportation model of Switzerland. It is above all the links between the different transportation system, which are modelled in a rough and ready way because the territory of each municipality is represented as a gravitation point in our model space. We have attempted to compensate for this weakness by adjusting the average speeds of our means of transportation until we were able to reproduce in a satisfactory manner both the available trend forecast for the future mobility in Switzerland and the modal split assumed to occur in the future.

The ecobalance for the different means of transportation (the functional unit is passenger kilometres (pkm)), for the required additional buildings (the functional unit is square metres of gross floor surface), and for the additional use of agricultural lands (the functional unit is square metres of built-up land) has been calculated with the software ECOINVENT.

Results

Of all the activities induced by Swissmetro, we have investigated more closely only the additional mobility and construction of new buildings and calculated their environmental impacts. The induced extension of the area that is built-up has here not been included in the ecobalance. But it affects the evaluation of future mobility nonetheless through the prolongation of travel distances that are required to reach the new housing and office developments.

Mobility

Our estimate of the total mobility in 2050 for a world with Swissmetro varies for the four scenarios between 60 billion passenger kilometres in the scenario „Umfassend" («all inclusive») und 130 billion passenger kilometres in the scenario „Bekannt" («known»). However, if the increase in mobility calculated for 2020 had continued until 2050, we would be confronted with an additional mobility of 50 billion passenger kilometres more than we experience today. But even though the mobility in 2050 is not quite as large as one could expect given the situation in 2020, we still find an increase of 40% compared to the level occurring today.

The mobility in 2050 is in both the scenarios „Grün" («green») and „Reguliert" («regulated») above what we experience today, although this increase is minimal in case of the second of these scenarios. The mobility in the scenario „Umfassend" («all inclusive»), however, is with minus 37% significantly below what we have today.

Figure 1 shows the induced changes in the performance of the different means of transportation for the four scenarios with horizon 2050. Swissmetro acquires in all four cases a significant part of the passengers of traditional rail and induces an increase in car transportation. Car transportation is reduced only in the scenario „Reguliert" («regulated»), a development that is re-enforced by the introduction of Swissmetro.

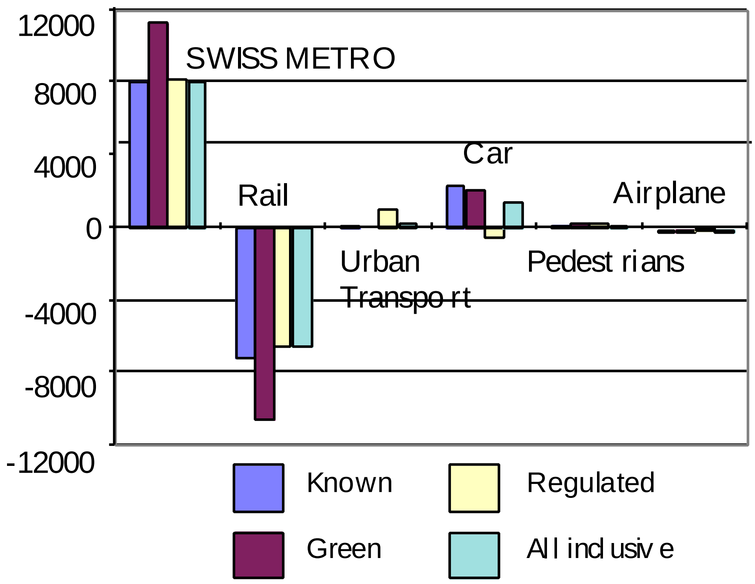

Figure 2 **Changes in the performance of the different means of transportation in a comparison of the situations without and with Swissmetro; planning horizon is 2050; in millions of passenger kilometres in 2050.**

As a conclusion we can say that Swissmetro will generate additional traffic due to its higher speed and the gains in time this makes possible. This conclusion is likely to hold for many situations defined by widely different conditions. This additional traffic is not just a consequence of the implementation of a policy to use or not to use urban areas in a denser manner. This can be seen by comparing the scenario „Grün“ («green”) with its pronounced policy to build more densely in urban areas with the scenario „Umfassend“ («all inclusive») in which a similar policy is pursued, albeit to a lesser degree. The former scenario has the second smallest amount of induced transportation while the latter one has the second highest.

If these hypothetical changes in the performance of the different means of transportation have a negative or a positive effect on the ecobalance of the induced activities depends of course on the relative size of the environmental impacts generated by them (see below).

Gross floor surface

In all four scenarios Swissmetro induces the construction of additional gross floor space compared to a situation without it. These results are summarised in Table 2. The additional need in 2050 is significantly higher than in 2020, up to four times so in the scenario „Bekannt“ («known»), for example. It is about twice as large in the other scenarios. However, this need for additional floor space will be satisfied in both the scenarios „Reguliert“ («regulated») and „Umfassend“ («all inclusive») within the inhabited areas of today, in large part thanks to the policy of densification pursued by the state in these two scenarios.

		Bekannt («known»)	**Grün («green»)**	**Reguliert («regulated»)**	**Umfassend («all incl.»)**
Gross floor surface – needed for					
Living	Mio. m^2	69	37	9	15
Working	Mio. m^2	40	20	5	7
Shopping	Mio. m^2	8	4	1	2
Other activities	Mio. m^2	68	37	9	14
Total	Mio. m^2	185	97	23	38
% of increase realised outside of today’s urban areas		114%	18%	0%	2%

Table 4 Need for additional gross floor surface for different activities; planning horizon is 2050. The numbers represent for each scenario the difference between the situation without and with Swissmetro.

The Ecobalance of the Induced Activities

The ecobalance of the activities induced by Swissmetro is built on two elements. A first element consists of the determination of the volume of the induced activities. Four scenarios have been developed for this purpose. We do not make forecasts of how many activities Swissmetro will induce and of the environmental impacts caused by them. We only indicate the additional environmental impacts with which one might have to reckon if one of these scenarios correctly represents the future situation.

The second element is the ecobalance of the two induced activities, *transportation* and *construction*. With it are determined the environmental impacts due to one additional square metre of usable gross floor surface and due to one passenger that is transported an additional kilometre. There exists a number of variants for undertaking this accounting. One variant differentiates between the use of construction materials that are used today, and tomorrow as well, and between a situation where the construction materials used in the future differ from those known today. Another variation concerns the lifetime for Swissmetro. Its extremes are defined by the assumed length of life of the tunnels (100 years) and a lifetime defined by the life of the vehicles and the equipment in the tunnels (30 years). The environmental impacts can be evaluated with the method of EcoIndicator95+, the environmental impact point method (UBP) and the need for non-renewable energetic resources.

The scenario „Reguliert“ («regulated») is best for the environment. Its induced activities have environmental impacts that are just one fourth as important as those in the other extreme case, the scenario „Bekannt“ («known»).

The uncertainties behind the calculations of these environmental impacts can be gauged, for example, by looking at the variants of one scenario. The difference between an assumed lifetime of Swissmetro of 30 or 100 years is in the scenario „Reguliert“ («regulated») environmental impacts that are multiplied by a factor of two (when measured in EcoIndicator95+ points). A change in the use of materials for construction leads to a smaller change in environmental impacts. The difference between the extreme values of the environmental impacts of all possible variants in the scenario „Bekannt“ («known») is 60% of the lowest value. This difference is larger when measured in absolute terms than the environmental impacts of the variant of scenario „Reguliert“ («regulated») with the upper extreme value. This is to say that the differences between the environmental impacts of the variants of one scenario are relatively large. However, one can still discriminate between the four scenarios despite the uncertainties identified here.

The conditions determining the development of mobility that have been operationalised with the four scenarios seem to have a decisive influence on this development. We conclude from these considerations that the size of the environmental impacts caused by the future mobility can be influenced by the choice of the appropriate constraints. Which of them – that is which of the hypotheses we have formulated for the evaluation of the induced activities – will turn out to be the decisive ones, awaits an appropriate sensitivity analysis that we have not undertaken so far.

For the planning horizon of 2050, the environmental impacts of the mobility induced by Swissmetro correspond to the performances of the different means of transportation (see the section on *mobility* above). Swissmetro substitutes in all scenarios for a significant amount of traditional rail traffic. This leads to a corresponding reduction of the environmental impacts. The impacts from urban transportation induced by Swissmetro are small. On the one hand, this is the consequence of the low environmental impacts associated with this means of transportation. But they are also low because Swissmetro induces only little additional urban transportation, at least in our model. It is finally noteworthy that Swissmetro induces additional car traffic in all scenarios bar one, the scenario „Reguliert“ («regulated»).

The environmental impacts of the induced activities “construction” correspond to the size of these activities. This is not surprising in view of the fact that we have not differentiated between the material requirements of the different building types needed to satisfy these activities. However, the construction activity both within the existing urban areas as well as (and especially) outside of them is severely limited in both the scenarios „Reguliert“ («regulated») and „Umfassend“ («all inclusive»). The consequence of this policy is low environmental impacts. There is quite a bit of induced construction in the scenario „Grün“ («green»). But this occurs mainly within today’s urban areas. The scenario „Bekannt“ («known») has the largest environmental impacts due to induced construction activities. Construction within today’s urban areas falls but the scenario nonetheless shows the largest volume of construction activities overall.

Discussion of the Results

The determination of the induced activities of Swissmetro, especially for a distant planning horizon, and their evaluation with an ecobalance requires a simulation and valuation model that is intuitively comprehensible. We have constructed a relatively simple model in a rather pragmatic manner in order to be able to work with rather robust data. This model abstracts, e.g., from all economic factors. In this way it was possible to describe with four scenarios hypothetical constraints to the future environmental impacts of mobility. We also managed with this model to evaluate in a robust manner the far-reaching consequences that Swissmetro might have and to account for their environmental impacts in a prototypical ecobalance.

The direct environmental impacts of Swissmetro have been calculated based on an actualised ecobalances making use of the definitions of Swissmetro provided in the concession demand (in Part 1). Those definitions relate to the pilot stretch between Geneva and Lausanne and cannot necessarily be used to evaluate the impacts of the whole Swissmetro system. The accounting for the induced activities of Swissmetro (Part 2) includes the direct environmental impacts of the different means of transportation, hence also of Swissmetro. But it has been adjusted in Part 2 for the constraints proper to the whole system.

The approach chosen for the construction of the scenarios has been inspired by the approach used by Maggi. It impresses through its parsimony, using just the two influence factors of “state regulation and public financing” and of “ecological conscience”. However, the operationalisation of these two factors, i.e., their translation into input data that can be used in the accounting model, leaves room for a lot of interpretation. The results presented here show that the model used, the input data chosen, and the scenario results are all consistent with each other.

Nonetheless they represent just subjective images of the future. They are not forecasts. They incorporate just those aspects that seem to be necessary to permit an environmental accounting. However, the possible images of the future developed here provide a basis for a more precise evaluation of the complex interplay between three elements of the modelling: the constraints on the future mobility that have to be determined, the assumptions about future developments that are for the moment still required, and the desired system of transportation and the evaluation of its environmental impacts. The reader is explicitly asked to analyse the scenarios developed here and to judge them intuitively. If she or he is able to derive options for actions to be taken today, we will have achieved the goal of a scenario analysis.

The basic assumptions used in the model are based on:

- The technical specifications of Swissmetro that have been and that probably will continue to be subject to significant modifications.
- An average daily travel time of 85 minutes for each inhabitant of Switzerland. Its past constancy seems to be accepted; its future constancy can be questioned.
- An international mobility that has been assumed to be constant for our modelling purposes.

Only the induced mobility and the induced construction activities are modelled in the scenarios. They therefore model only a small part of all the induced activities that one might want to analyse. The extension of the analysis to the “consumption” of agricultural land for building purposes has been prepared but has not yet been undertaken. The induced mobility in its totality can be influenced by a large number of factors, e.g., the emergence of new behaviours in response to the introduction of a new transportation system. Swissmetro might induce people in Bern to visit the opera in Zurich. Public investments to make public transportation more attractive might generate an increase in mobility. Developments such as these can only be based on speculation at this time. They therefore have been left out of our model.

Worsening environmental problems in the future, or their weakening, would have to be recognised in ecobalancing by recognising them and by adjusting the impact weights accordingly. The consequence would be a change in the weighted environmental impacts of Swissmetro in comparison with the other means of transportation with which it competes or which it would replace. Forecasts about the severity of environmental problems are not very reliable if they are available at all. We have therefore accounted for the environmental impacts of the induced activities by assuming that the today’s environmental situation is maintained into the future.

We have tried to reflect the development of new materials and of new production technologies for them by introducing a correction factor as one variant in our analysis. However, neither these materials nor these production processes are contained in the environmental inventories that are currently available. It is therefore impossible to determine if the introduction of such materials will have impacts that are overall beneficial or harmful for the environment. This is one question that should be investigated with a sensitivity analysis in the future.

To account for the environmental impacts of the induced activities we have made use of the functional units that are commonly used in ecobalancing. These are the passenger kilometre (pkm) for transportation and the square metre (m^2) of gross floor surface for the construction activities. This assumes that all the activities within the same category are the same. However, a trip on Swissmetro is most likely to be different than a trip on today's rapid trains of SBB. The higher speed of Swissmetro is producing a greater "utility" due to the time gained thanks to it. This benefit might be compensated for some persons by the loss of a view onto the passing landscape that comes inherently with this new transportation system. It is possible that the inclusion of such qualities in the determination of the functional unit might change our conclusion that Swissmetro will create an increase in the environmental impacts of the transportation system as a whole.

Conclusions

The sum of the individual results presented here can be summarised in the following manner:

1. The transport of passengers is unlikely to be made sustainable by only introducing new means of transportation with a lower specific impact on the environment. The environmental impacts of the induced activities (such as the extension of inhabited areas and an increase in construction activities) can contribute a significant part to the total of all the environmental impacts.
2. Accounting for the indirect environmental impacts of Swissmetro suggests that the total impact will increase under a wide range of scenario conditions. The better environmental performance of Swissmetro is not enough to compensate the increase in the environmental impacts of the additional traffic that is to be expected with the introduction of Swissmetro.
3. Passenger transportation will require a higher need of non-renewable energetic resources in all of our scenarios. Here too the lower energy requirement of Swissmetro is insufficient to compensate the energy required for the additional traffic generated by Swissmetro.
4. The environmental efficiency of Swissmetro is better in comparison to other means of transportation if the optimistic assumptions about the load factor that will be achieved can be realised. However, there exists a potential to increase load factors for the other means of transportation too.
5. The environmental impacts of the activities induced by Swissmetro are not only due to the production of additional traffic. The impacts of the induced construction activities make up a significant part of the overall impacts, depending on the scenario of between 10% and 35%.
6. We cannot decide on the basis of our model if the use of new materials in the construction sector would lead to a lower impact from the induced construction activities. We have modelled this possibility by using a rough correction factor. But its assumed size is reflected directly in the results, which makes us suspicious of the quality of this correction.
7. The goal for a future means of sustainable transportation must be to achieve a long lifetime. Assuming a short life instead of a long one increases the environmental impacts of Swissmetro by between 40% and 60%.

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