Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office for Spatial Development ARE

Costs and benefits of transport

Transport and mobility give rise to various costs and benefits. A number of these are noticed directly by transport users: the cost of petrol or of a train ticket, or the ability to travel in comfort to their place of work by car or train. By paying for their petrol or train ticket, they assume a portion of the costs they are generating. These directly assumed costs are referred to as internal or private costs.

In addition, however, mobility gives rise to a number of costs that are not reflected in the aforementioned costs. Traffic noise, for example, impairs the quality of life and health of people living near railways, roads or airports. This may cause the people affected to incur treatment or hospitalisation costs. Such costs are not reflected in the price of mobility, however, and are thus referred to as external costs.

External benefits are the counterpart to these external costs: Specific travel habits result in benefits that go beyond those enjoyed by the particular person travelling. In the case of pedestrians and cyclists, physical exercise generates health benefits that have positive effects on society as a whole: less illness means more productive employees and hence lower healthcare and social insurance costs.

To ensure that resources in an economy are properly deployed, the external costs or benefits should be internalised. In other words, they should be debited or credited to the people that generate them. Switzerland's heavy goods vehicle charge (LSVA) is a shining example. Since it was introduced, heavy goods vehicles have been helping significantly to internalise their external costs.

Externe Kosten und Nutzen des Verkehrs in der Schweiz
(1) German
Valid from 30.06.2014 | Size: 1205 kb | Type: PDF

External Effects of Transport 2010
(2) Monetising Environmental, Accident and Health-Related Effects (english abstract and summarised version).
Valid from 18.06.2014 | Size: 6939 kb | Type: PDF

External Effects of Transport 2010 - Summarised Version
(3) Monetising Environmental, Accident and Health-Related Effects
Valid from 18.06.2014 | Size: 344 kb | Type: PDF

External Effects of Transport 2010

Monetising Environmental, Accident and Health-Related Effects

Summarised Version

18 June 2014

for the Federal Office for Spatial Development

ECOPLAN Forschung und Beratung in Wirtschaft und Politik

INFRAS Forschung und Beratung

Publication Details

Recommended citation format

Author:	Ecoplan / Infras
Title:	External Effects of Transport 2010
Subheading:	Monetising Environmental, Accident and Health-Related Effects Summarised Version
Commissioned by:	Federal Office for Spatial Development
Location:	Bern, Zurich and Altdorf
Date:	18 June 2014
Available from:	www.ecoplan.ch

Committee

Christina Hürzeler (ARE, Chair)
Franziska Borer Blindenbacher (ARE)
Iris Maria Oberauner (FOE)
Manfred Zbinden (FEDRO)
Roman Rosenfellner (FEDRO)
Christoph Schreyer (FOT)
Alexandra Quandt (SFSO)
Theo Rindlisbacher (FOCA)

Project Team

Heini Sommer (Ecoplan, Project Manager)
Christoph Lieb (Ecoplan)
Matthias Amacher (Ecoplan)
Markus Maibach (Infras, Dep. Project Manager)
Daniel Sutter (Infras)
Cuno Bieler (Infras)
Remo Zandonella (Infras)
Jürg Heldstab (Infras)
Martin Röösli (Swiss TPH)
Danielle Vienneau (Swiss TPH)
Laura Perez (Swiss TPH)
Hans Buser (nateco)
Thomas Künzle (Meteotest)

Ecoplan AG

Forschung und Beratung
in Wirtschaft und Politik

www.ecoplan.ch

Monbijoustrasse 14
CH - 3011 Bern
Tel +41 31 356 61 61
bern@ecoplan.ch

Schützengasse 1
Postfach
CH - 6460 Altdorf
Tel +41 41 870 90 60
altdorf@ecoplan.ch

Infras AG

Forschung und Beratung

www.infras.ch

Binzstrasse 23
Postfach
CH-8045 Zürich
Tel: ++41 44 205 95 95
Fax: ++41 44 205 95 99
zuerich@infras.ch

Abstract

The study calculates the external and social (national economic) environmental, accident and health-related effects of transport in Switzerland in 2010. In doing so, previous calculations relating to road and rail transport are subject to a methodological review, and recalculated for 2010 using fully updated data sources for the following 12 cost areas: air pollution-related damage to health, damage to buildings, crop shortfalls, forest degradation, loss of biodiversity, noise, climate change, nature and the landscape, soil degradation, upstream and downstream processes, accidents, and additional costs in urban areas. In these cost categories, the external costs of air and waterborne transport in Switzerland are calculated for the first time, and the road transport section of the study has been extended to include non-motorised transport (pedestrian and cycle traffic). The positive effects on health of the physical exercise involved in non-motorised transport are also quantified.

Aggregated across the four modes of transport, total external costs come to over CHF 9,400 million for 2010. At CHF 5,500 million, private motorised road transport is the main originator of these external costs, followed by road freight transport at CHF 1,00 million (a share of the HVF has been factored in as an internalisation measure), and by public road transport, with a contribution of CHF 190 million. Air transport resulted in external costs of CHF 920 million, while rail transport accounts for CHF 740 million. Waterborne transport generated external costs of CHF 57 million. In addition to external costs of CHF 900 million, non-motorised transport generates external health benefits worth CHF 1,300 million. The significant differences in distances travelled using the individual modes of transport must be remembered when comparing these absolute figures. Considerably more person and tonne kilometres are travelled by road than by other modes of transport, while figures for waterborne transport are much lower.

Summarised Version

Background and Objective

The Swiss Federal Statistical Office (SFSO) and the Federal Office for Spatial Development (ARE) have produced a Transport Account for traffic in Switzerland. This Account updates the previous study, conducted in 2005 (SFSO 2009). In addition to road and rail transport, it covers air transport and some aspects of waterborne transport for the first time.

As the input for this overall Account, the present report concentrates on establishing the external costs ("negative externalities") caused by these modes of transport in 2010. Compared with previous studies, "road" as a mode of transport now includes non-motorised transport (pedestrian and cycle traffic), with both its external costs and its external benefits, in the form of positive effects on health.

Methodology

Calculations of external costs concentrate on **environmental, accident and health-related effects**. They are based on the following framework:

a) Definitions and price basis

Both social and external costs have been calculated.

- The **social** (in terms of the national economy) **costs** of transport comprise the costs to society that are caused by transport activity. They comprise internal and external costs.
- **Internal costs** are those which transport users pay themselves, such as premiums for motor vehicle liability insurance.
- **External costs** refer to that part of social costs which is not paid by the originators of transport activity. A typical example here is the noise caused by that transport activity, which is not reflected in the price of the journey.

The results are calculated at **factor prices** as at 2010, i.e. indirect taxes such as VAT are not included or have been factored out.

b) External costs from differing perspectives

External effects can be determined from a number of different perspectives:

- **Mode of transport** perspective: The entire mode of transport (road, rail, air or water) is viewed together as a unit. Within the mode of transport, all of the costs borne by its users are deemed to be internal, such as accident-related costs caused to a cyclist by a passenger vehicle. With this perspective, external costs exist only if they are incurred outside of the particular mode of transport. With the mode of transport perspective, the issue is which mode of transport causes which costs, and the extent to which these costs are cov-

ered within the mode of transport itself (the cost coverage ratio). The mode of transport perspective provides the basis of the Transport Account, and forms the core of this report.

- **Transport type** perspective **– heavy vehicles**: This perspective was determined by the Swiss Federal Supreme Court for the calculation of the heavy vehicle fee (HVF) for coaches, light goods vehicles (LGV) and heavy goods vehicles (HGV). With this perspective, all costs which are not incurred within the heavy vehicle segment are deemed to be external. In contrast to the mode of transport perspective, the costs that a truck causes to a car are thus regarded as external.
- **Transport user** perspective: The third perspective considered in the report is that of the transport user. This perspective is not included in the summarised version (however, see section 16.3). When distinguishing between internal and external costs, the starting point is the individual transport user. All costs that the originator of a transport activity does not pay for themselves are regarded as external. The transport user perspective centres on the efficient use of the transport infrastructure from the point of view of the national economy. The cost rates that have been determined serve as an input in the calculation of internalisation charges.

c) Distinction between modes of transport, scope of study

The definitions used in the Transport Account were also used to **distinguish** the modes of transport included in the study.

- Road transport includes all traffic (including non-motorised traffic) on thoroughfares from motorways down to third-class roads.
- Rail transport covers all traffic on the entire rail network (excluding cog-wheel railways and cable cars).
- Air transport considers all flights to and from international and regional airports. It excludes airfields, heliports and military aviation.
- Waterborne transport includes the Rhine river ports in Basel, as well as moorings for public passenger boats and freight transport.

Where **road and rail transport** are concerned, costs are essentially calculated using the **territorial principle**. This covers those costs which are caused by traffic in Switzerland. By contrast, the **shared route principle** is applied to **air and waterborne transport.** In other words, all journeys are allocated 50:50 to their place of origin and their destination. Consequently, internal journeys are covered in full, while journeys to / from other countries are covered for the second half of the route into Switzerland, or the first half of the route out of the country. The shared route principle is used to delimit international transport (by air and along the River Rhine).

d) Cost and benefit categories covered, methods of calculation

This study concentrates on calculating the external costs of transport in 12 selected categories. The table below shows the key methodological elements applied to each cost type.

Figure S-1: Methods for calculating external costs, by cost type

Cost type	Method
Health costs as a result of air pollution	Medical treatment costs, net lost output, replacement recruitment costs, intangible costs owing to shorter life expectancy and illness (all damage cost approach)
Building damage as a result of air pollution	a. costs of additional renovations (locations exposed to traffic); b. shorter life of building facade (locations not exposed to traffic); c. additional cleaning costs (all damage cost approach)
Crop shortfalls as a result of air pollution	Reduction in agricultural income as a result of high ozone levels (damage costs)
Forest degradation as a result of air pollution	a. Lower income from timber harvests as a result of high ozone levels; b. lower income from timber harvests as a result of soil acidification; c. costs of higher levels of windthrow as a result of soil acidification (all damage cost approach)
Loss of biodiversity as a result of air pollution	Costs of (virtual) measures to restore biodiverse ecosystems (replacement cost approach)
Noise	Nuisance (falling housing prices) and health costs (similar to the health costs caused by air pollution – all damage costs)
Climate change	Costs of avoidance measures to achieve long-term global climate targets (avoidance cost approach)
Nature and the landscape	Replacement cost approach: a. Loss of habitats: costs of the (virtual) restoration of lost biotopes or defined ecosystems (habitats); b. Habitat fragmentation: costs of the (virtual) creation of defragmentation infrastructure
Soil degradation from toxic substances	Costs of the (virtual) clean-up of toxic substances from contaminated soil (repair cost approach)
Costs of upstream and downstream processes	Climate change and air pollution costs associated with the manufacture, maintenance and disposal of vehicles (means of transport), energy sources (fuels, electricity) and infrastructures
Accidents	Medical treatment costs, net lost output, replacement recruitment costs, intangible costs, administrative costs, property damage, police and subsequent legal costs (all damage cost approach)
Additional costs in urban areas	a. Time-related costs for non-motorised transport owing to geographical separation (damage costs); b. impairment of local character and appeal: costs of upgrading heavily used local thoroughfares (repair cost approach)

The benefits of transport, which are certainly considerable and largely internal, fall outside of the scope of the present study – with one exception. The internal and external benefits of non-motorised transport in Switzerland have been included for the first time. These benefits include longer life-expectancy and fewer hospital stays as a result of physical activity. They are determined using the same method applied to damage to health caused by air pollution, as shown in figure S-1. In accordance with its brief, this study does not examine other benefit categories and their potential external share (see discussion in section 2.2).

e) Treatment of internalisation charges

Internalisation charges which can be allocated directly to a specific cost category (e.g. noise-related aircraft landing fees, the "climate cent" levy) are deducted directly from the re-

lated costs. However, the Heavy Vehicle Fee, HVF – which was designed to internalise the external costs of heavy road traffic – is compared with the external costs of heavy vehicle traffic in a separate concluding analysis. By contrast, the mineral oil tax is not treated as an internalisation charge, because it is already factored in to the Infrastructure Account.

f) Treatment of uncertainty

It is impossible to calculate externalities without making assumptions or simplifications. This report deals as follows with these **uncertainties**: where a scientifically-founded **"best guess"** is available, it has been used. Otherwise, the calculation is based on a **prudent estimate** (the "**at least approach"**). In other words, where assumptions and simplifications have been made, they are "**as realistic as possible, but conservative in the event of doubt"**. In practical terms, this means that uncertainties are subject to cautious assumptions, which tend to result in the actual costs and benefits being understated rather than overstated.

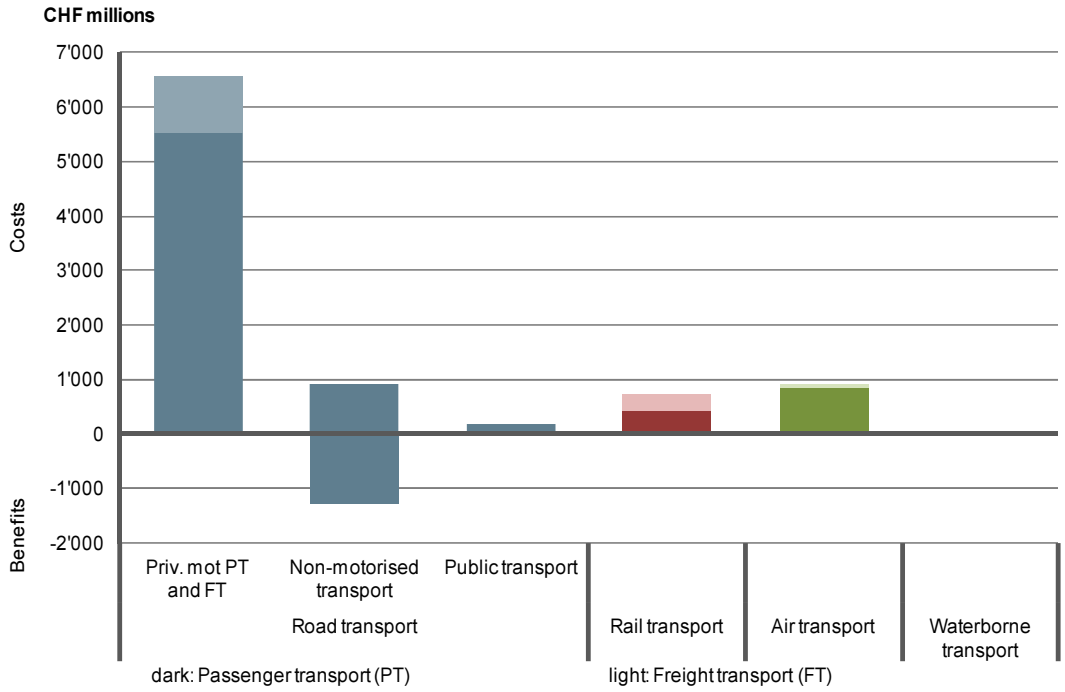
Findings on External Effects

a) External effects of transport as a whole

Figure S–2 and figure S–3 show that, from the mode of transport perspective, transport generated external costs totalling CHF 9,400 million in 2010. Most of these costs – some 82%, or CHF 7,700 million – were caused by road transport. Of this, private motorised passenger transport accounted for CHF 5,500 million, freight transport CHF 1,000 million (a portion of the HVF has been set off as an internalisation measure), non-motorised transport CHF 900 million, and public road transport CHF 190 million). Second place is taken by air transport, which accounts for 10%, or CHF 920 million. Rail transport generated costs of CHF 730 million, or 8% of the total. Waterborne transport resulted in external costs of CHF 57 million or 0.6%. In total, 84% of external costs are caused by passenger transport, and 16% by freight transport. In addition to its costs, non-motorised transport generates external health benefits of CHF 1,300 million. It must be remembered, however, that the distances covered using the individual modes of transport differ widely. Considerably more person and tonne kilometres are travelled by road than by other modes of transport, while figures for waterborne transport are much lower.

The analysis shows that four cost categories have a significant effect on the total: climate change, accidents, noise, and air pollution-related damage to health each account for costs of between CHF 1,750 million and CHF 2,000 million. Upstream and downstream processes, as well as nature and the landscape, generate further costs of approx. CHF 900 million each. Damage to buildings accounts for a further CHF 350 million or so, while all other cost categories contribute CHF 150 million or less each. Over CHF 700 million in HVF revenues must be deducted from these costs. This HVF revenue is not distributed across the individual cost categories. In addition, non-motorised transport generates external health benefits of CHF 1,300 million.

Figure S–2: Overview of external effects from the mode of transport perspective, 2010
Road/rail transport: territorial principle*, air/waterborne transport: shared route principle**



* Territorial principle: traffic within Swiss borders
** Shared route principle: traffic within Swiss borders and half of flight/shipping routes from Switzerland to foreign destinations, and vice-versa (see section 2.3.2).

Figure S-3: Overview of external effects from the mode of transport perspective, 2010
Road/rail transport: territorial principle, air/waterborne transport: shared route principle

CHF millions	Road transport			Rail transport	Air transport	Water-borne transport	Total
	Priv. mot. PT and FT	Non-mot. transport	Public transport				
Air-related health	1'444	-	60	185	37	29	**1'756**
Air-related building	297	-	12	38	8	6	**362**
Air-related crop shortfall	52	-	4	1	2	1	**59**
Air-related forest degradation	45	-	3	1	1	1	**51**
Air-related biodiversity loss	134	-	7	2	3	3	**148**
Noise	1'427	-	37	269	66	-	**1'799**
Climate change	1'234	-	26	4	686	8	**1'959**
Nature and the landscape	750	10	10	119	6	5	**900**
Soil degradation	113	-	5	24	-	-	**142**
Upstream and downstream processes	704	34	20	48	108	3	**917**
Accidents	980	856	7	4	2	0	**1'850**
Urban areas	109	-	3	32	-	-	**144**
Deduction of HVF share	-720	-	-	-	-	-	**-720**
Total	**6'570**	**900**	**194**	**727**	**919**	**57**	**9'367**
Health bens - non-mot. transport	**-**	**-1'281**	**-**	**-**	**-**	**-**	**-1'281**

Rounding differences may result in slight deviations from the stated totals in this and all subsequent figures.

b) External effects of road transport

In road transport, passenger vehicles are responsible for the lion's share (63%) of external costs (see figure S–4). Motorcycles and light goods vehicles each contribute 7.3% to the total, while heavy goods vehicles and articulated lorries together account for 6.1%, with a portion of the HVF already factored in as an internalisation measure. Pedestrian traffic resulted in net external benefits of a just over CHF 500 million, because the health benefits of CHF 890 million are far higher than the accident costs of CHF 360 million caused by non-motorised transport. Other external costs for this transport category are also very low, as are those of trolley buses and trams.

Figure S-4: External effects of road transport from the mode of transport perspective, 2010, by cost component and vehicle category, as well as costs per pkm and tkm

External costs	Passenger transport										Freight transport				Overall
Road transport	Private motorised transport				Non-motorised transport			Public passenger transport							total
CHF millions	Car	Coach	M-cycle	Moped	Cycle	VLD	Pedest.	Bus	Trolley	Tram	LGV	HGV	Artic.	Tr/Mach.	
Air-related health	1'019.2	22.7	8.3	0.6	-	-	-	60.2	n.a.	n.a.	129.3	169.4	94.9	n.a.	**1'504.6**
Air-related building	209.8	4.7	1.7	0.1	-	-	-	12.4	n.a.	n.a.	26.6	34.9	19.5	n.a.	**309.7**
Air-related crop shortfall	27.0	1.2	0.6	0.0	-	-	-	3.7	-	-	6.1	10.0	6.9	n.a.	**55.5**
Air-related forest degradation	25.0	1.0	0.5	0.0	-	-	-	2.9	-	-	4.9	8.0	5.5	n.a.	**47.9**
Air-related biodiversity loss	86.5	2.3	1.1	0.0	-	-	-	6.8	-	-	12.3	18.8	13.0	n.a.	**140.8**
Noise	644.1	17.2	249.7	1.7	-	-	-	35.4	0.3	1.1	142.6	233.6	137.8	n.a.	**1'463.5**
Climate change	956.2	9.5	17.9	0.8	-	-	-	26.1	-	-	86.5	94.8	68.6	n.a.	**1'260.6**
Nature and the landscape	601.1	4.0	9.0	0.5	4.2	0.1	5.9	9.3	0.1	0.1	45.9	53.5	36.1	n.a.	**769.7**
Soil degradation	56.8	2.2	1.2	0.1	-	-	-	4.6	0.5	0.0	10.9	26.2	15.5	n.a.	**117.9**
Upstream and downstream processes	537.3	4.8	8.7	0.5	12.3	0.5	21.6	11.5	1.9	6.2	49.7	56.4	46.8	n.a.	**758.1**
Accidents	590.7	1.7	257.7	59.0	449.7	45.9	360.0	3.1	2.6	1.5	34.2	13.9	6.6	16.6	**1'843.3**
Urban areas	90.6	0.3	1.9	0.1	-	-	-	2.2	0.4	0.6	9.3	3.5	2.9	n.a.	**111.8**
Deduction of HVF share	-	-12.5	-	-	-	-	-	-	-	-	-	-375.1	-332.1	-	**-719.7**
Total	**4'844.2**	**58.9**	**558.1**	**63.6**	**466.2**	**46.5**	**387.5**	**178.2**	**5.8**	**9.5**	**558.3**	**348.0**	**122.2**	**16.6**	**7'663.8**
As % of overall total	63.2%	0.8%	7.3%	0.8%	6.1%	0.6%	5.1%	2.3%	0.1%	0.1%	7.3%	4.5%	1.6%	0.2%	**100.0%**
Total, transport type perspective		**64.0**										**372.2**	**136.7**		**572.9**
Health bens - non-mot. transport	-	-	-	-	**-388.5**	**n.a.**	**-892.2**	-	-	-	-	-	-	-	**-1'280.7**
Costs: cents/pkm (PT), cents/tkm (FT)	**5.3**	**2.3**	**23.8**	**47.9**	**3.7**	**40.9**	**-10.3**	**7.0**	**1.1**	**1.0**	**52.6**	**4.4**	**1.2**	**n.a.**	

M-cycle = motorcycle, VLD = vehicle-like device, Pedest. = pedestrian, LGV = light goods vehicle / delivery van, HGV = heavy goods vehicle, artic. = articulated lorry, Tr = tractor, mach = machinery, n.a. = not available

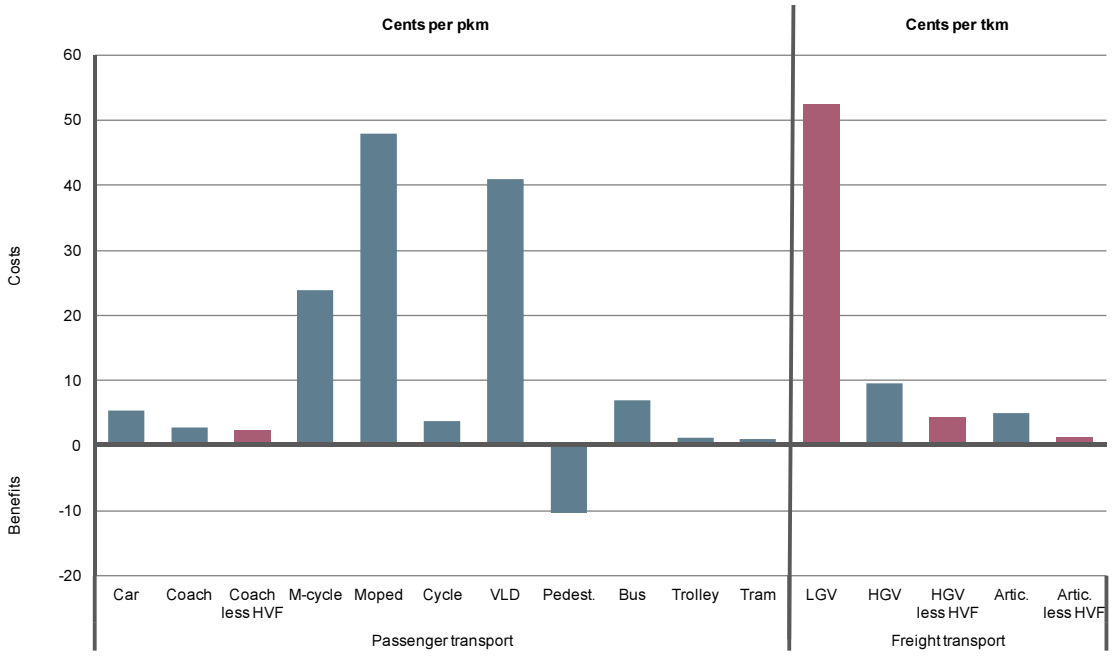
From the transport type perspective, the external costs of heavy vehicle transport are 8% higher than they are from the mode of transport perspective. Although a portion of HVF revenue is factored in as an internalisation measure, the aspects of heavy vehicle transport examined by this study still resulted in external costs of CHF 570 million in 2010. However, this amount does not allow any conclusions to be drawn on whether or not the HVF has been set at the right level to cover the costs of heavy vehicle traffic that are incurred by the general public. This question can only be answered by factoring in infrastructure costs, or the shortfall or surplus reported for heavy vehicle transport in the schedule of categories contained in the Road Account (see discussion in section 16.1.1).

In view of the high accident costs they cause, from the mode of transport perspective small-engined mopeds and vehicle-like devices (VLD, defined as human-powered wheeled devices such as roller skates, scooters/kickboards, etc.) generate the highest external costs per per-

son kilometre in the passenger transport segment. These costs are 48 and 41 cents respectively per pkm (please refer to the last line in figures S–4 and S–5). However, vehicle-like devices reach 41 cents/pkm only because their health benefits could not be determined. Motorcycles also result in costs of 24 cents / pkm, mainly because of high accident and noise costs, while the external costs of passenger vehicles come in at 5.3 cents / pkm. Public road transport generates an average of 4.8 cents / pkm in external costs. This is only slightly less than private passenger vehicles, because of the relatively high costs of air and noise pollution. The data do not permit a distinction to be drawn between urban buses and regional buses, although higher seat occupancy means that urban buses would perform better in any such comparison. Private passenger vehicles cause higher costs in towns and cities than they do on motorways, so taking the bus in town and city traffic thus results in significantly lower external costs per pkm than travelling by car. In addition, bus routes often perform a "feeder function", as a link in what may be a longer chain of journeys by public transport, with further sections travelled by train (2.3 cents / pkm). Pedestrian traffic generates external benefits of 10 cents / pkm. By contrast, the high accident costs caused by cyclists are greater than the benefits to health. This produces net costs of 4 cents / pkm.

Small loads mean that light goods vehicles (delivery vans) generate the highest costs per tonne kilometre, at 53 cents / tkm. Heavy goods vehicles and articulated lorries are responsible for costs of 4.4 and 1.2 cents / tkm respectively.

Figure S-5: External effects of road transport from the mode of transport perspective, 2010, per pkm and tkm



c) External effects of rail transport

Rail transport generates aggregate external costs of CHF 727 million. Passenger transport accounts for CHF 410 million of this (56%), while freight transport is responsible for CHF 317 million. Expressed in terms of distance travelled, this corresponds to 2.3 cents / pkm for passenger transport, and 2.8 cents / tkm for freight transport.

At 36%, noise costs are the highest component of the total for rail transport, followed by air pollution-related costs to health, at 25%, and nature and landscape costs, which account for 16%. The other individual cost categories contribute only 6% or less each to the total.

Figure S-6: External effects of rail transport from the mode of transport perspective, 2010, by cost component

External costs in CHF millions **Rail transport**	Passenger	Freight	**Total**
Air-related health	116.0	69.1	**185.0**
Air-related building	23.8	14.2	**38.0**
Air-related crop shortfall	0.1	0.7	**0.8**
Air-related forest degradation	0.1	0.6	**0.7**
Air-related biodiversity loss	0.2	1.3	**1.5**
Noise	101.0	168.1	**269.1**
Climate change	0.6	3.2	**3.8**
Nature and the landscape	87.9	31.1	**119.0**
Soil degradation	21.1	3.1	**24.3**
Upstream and downstream processes	29.2	18.8	**48.0**
Accidents	2.0	2.4	**4.4**
Urban areas	28.3	4.2	**32.5**
Total	**410.3**	**316.7**	**727.0**

d) External effects of air transport

The external costs of air transport total CHF 919 million, with 92% (CHF 842 million) caused by passenger transport, and the remaining CHF 77 million accounted for by freight transport (see figure S–7). This corresponds to 2.7 cents / pkm and 7.6 cents / tkm respectively. At 75% of the total, climate-related costs are the clearly dominant cost category in air transport. In addition, 12% of costs result from upstream and downstream processes, 7% from noise, and 4% from the costs to health of air pollution. The other cost categories contribute an aggregated 2.4% to the total, with no single category exceeding 1%. If minimum and maximum CO_2 cost rates are applied as a sensitivity analysis to climate-related costs and upstream and downstream processes, then the total costs of air transport vary between CHF 580 million and CHF 1,515 million.

Furthermore, 95% of these costs, or CHF 875 million, are caused by flights from and to international airports in Switzerland, while only 5%, or CHF 44 million, is accounted for by flights from and to regional airports. Airfields and heliports are not included in these figures. Scheduled and charter flights are responsible for 90% of the costs. This figure is divided equally between intercontinental and European scheduled and charter flights. Helicopters generate 0.3% of the costs, while other general aviation is responsible for the remaining 9%.

Figure S-7: External effects of air transport from the mode of transport perspective, 2010, by cost component

External costs in CHF millions **Air transport**	Passenger transport	Freight transport	**Total**
Air-related health	33.8	3.3	**37.1**
Air-related building	7.6	0.8	**8.4**
Air-related crop shortfall	1.4	0.1	**1.6**
Air-related forest degradation	1.2	0.1	**1.3**
Air-related biodiversity loss	2.7	0.3	**3.0**
Noise	62.4	3.8	**66.2**
Climate change	627.1	59.0	**686.1**
Nature and the landscape	5.4	0.5	**6.0**
Soil degradation	-	-	**-**
Upstream and downstream processes	98.3	9.3	**107.6**
Accidents	1.7	0.0	**1.8**
Urban areas	-	-	**-**
Total	**841.8**	**77.3**	**919.0**

e) External effects of waterborne transport

Waterborne transport results in aggregate external costs (from the mode of transport perspective) of CHF 57 million (see figure S–8). Of this, 53% (CHF 31 million) is accounted for by passenger transport on Swiss lakes, and 47% (CHF 27 million) by freight transport. Expressed in terms of distance travelled, this corresponds to 19 cents / pkm and 1.3 cents / tkm respectively. Where freight transport is concerned, there are nonetheless significant differences between shipping on the Rhine (below Basel in accordance with the shared route principle), and freight transport on Switzerland's lakes: below Basel, the costs come to just 0.5 cents / tkm, but they are 46 cents / tkm on lakes – 95 times higher. This is because of much smaller tonnages and shorter distances on the lakes, as well as higher pollutant emissions. We also believe that a relatively high level of uncertainty is attached to data on waterborne transport.

In this segment, PM10 (particulate matter) emissions result in the highest costs, specifically 51% in costs to health, and 11% in damage to buildings. Climate-related costs contribute 14% to the total, while nature and the landscape account for 9%. The other cost categories result in only 6% or less of costs in each case, and total 15% overall.

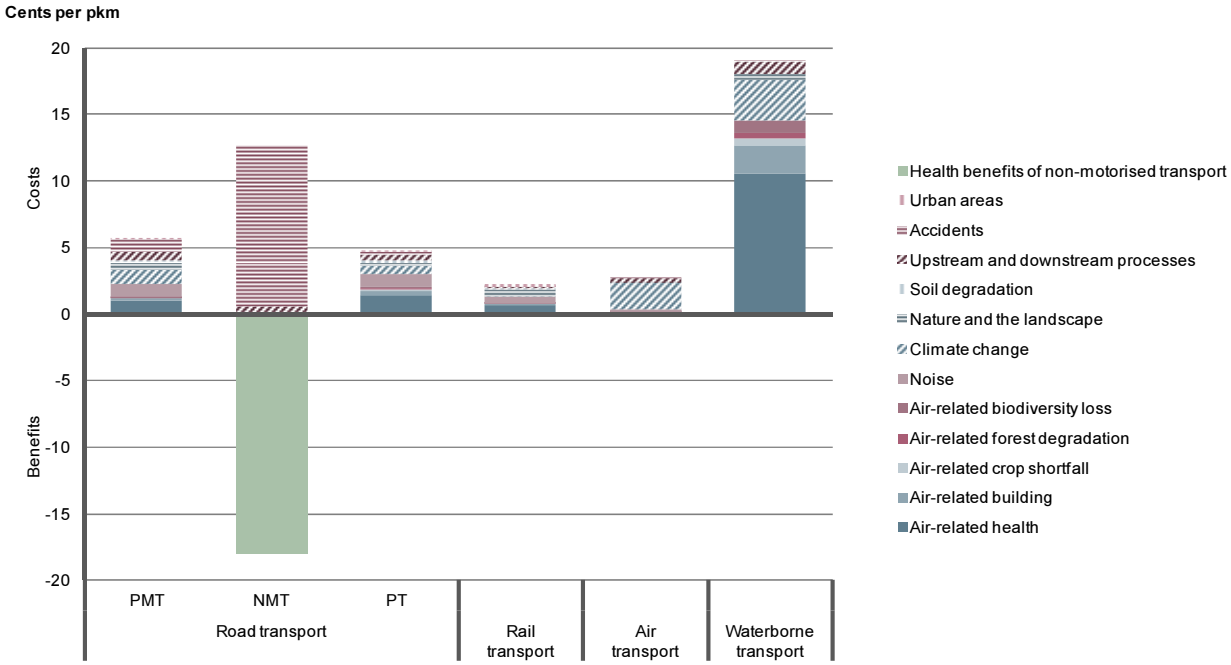
Figure S-8: External effects of waterborne transport from the mode of transport perspective, 2010, by cost component

External costs in CHF millions **Waterborne transport**	Passenger transport	Freight transport	**Total**
Air-related health	17.0	12.5	**29.4**
Air-related building	3.5	2.6	**6.1**
Air-related crop shortfall	0.8	0.6	**1.4**
Air-related forest degradation	0.7	0.5	**1.2**
Air-related biodiversity loss	1.6	1.1	**2.7**
Noise	-	-	**-**
Climate change	4.8	3.3	**8.1**
Nature and the landscape	0.8	4.2	**5.0**
Soil degradation	-	-	**-**
Upstream and downstream processes	1.5	1.9	**3.4**
Accidents	0.0	0.1	**0.1**
Urban areas	-	-	**-**
Total	**30.6**	**26.8**	**57.5**

f) Comparison of the external effects of the four modes of transport

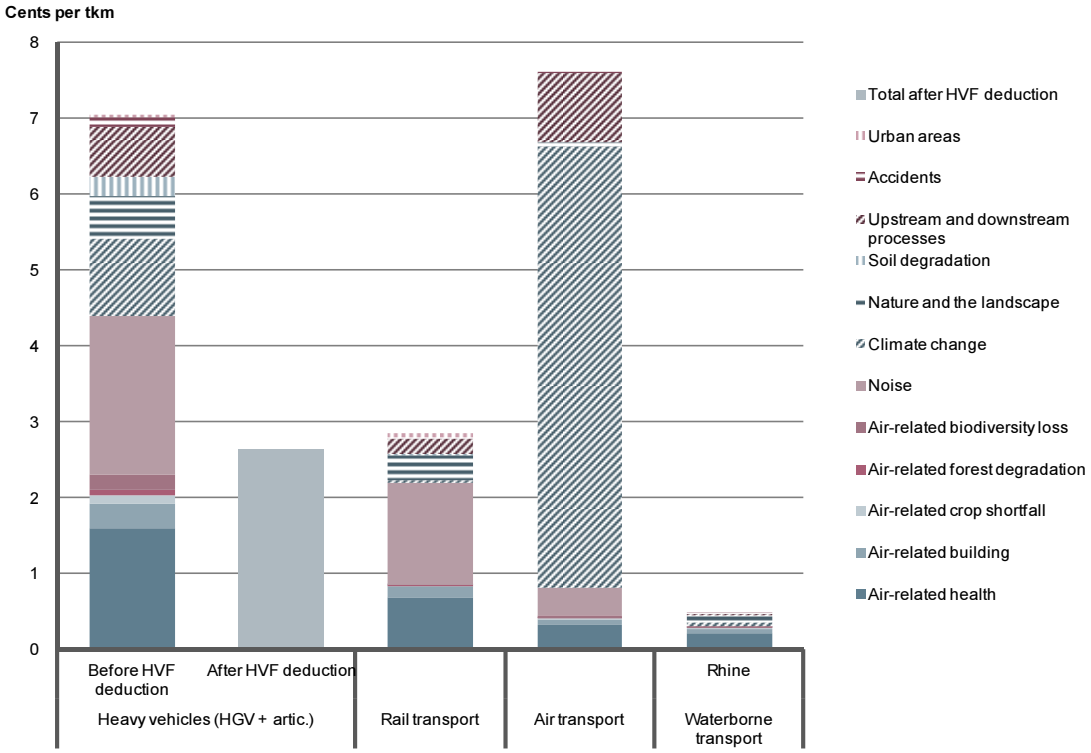
In the **passenger transport** segment, private motorised transport causes external costs of 5.7 cents / pkm, which is somewhat higher than public road transport, at 4.8 cents / pkm (see figure S–9). At 2.3 cents, rail transport generates the lowest costs per pkm. In view of the long distances travelled and high seat occupancy, air transport comes in at 2.7 cents / pkm. Waterborne transport is associated with the highest costs, of 19 cents / pkm, owing to its very high emissions of air pollutants and greenhouse gases. Non-motorised transport also generates high costs per pkm, primarily because of accident costs caused by the individuals themselves – but it is able to more than offset these with even higher external health benefits, resulting in net external benefits of 5.3 cents / pkm. It should be pointed out here, however, that the individual modes of transport and vehicle categories are comparable only up to a point, and that comparisons make the most sense for trips of similar distances, e.g. between different categories of urban vehicles, or comparisons between modes of transport for longer journeys.

Figure S-9: Comparison of transport modes for passenger transport, 2010: external costs per pkm (mode of transport perspective)
Road/rail transport: territorial principle, air/waterborne transport: shared route principle



In the **freight transport** segment, road transport results in costs of 7.1 cents / tkm (average of heavy goods vehicles and articulated lorries, see figure S–10). However, 4.4 cents / tkm of this is internalised with the HVF, meaning that only 2.6 cents / tkm actually remains in external costs. The net costs of road freight transport are lower than those of rail transport, at 2.8 cents / tkm. Air freight generates external costs of 7.6 cents / tkm, and freight shipping on the Rhine 0.5 cents / tkm. Freight transport on lakes, at 46 cents / tkm, is not shown in figure S–10, as lakes account for only 2% of tonne kilometres in waterborne freight transport. When comparing modes of transport, it must be remembered that the value of a given tonne of goods varies widely. Bulk goods are transported by ship, for example, while smaller, high-value goods are transported by air.

Figure S-10: Comparison of transport modes for freight transport, 2010: external costs per tkm (mode of transport perspective)
Road/rail transport: territorial principle, air/waterborne transport: shared route principle



g) Uncertainty

The calculations of external and social costs are subject to a degree of uncertainty, which may be considerable in some cases. These have been investigated in the form of sensitivity analyses. Here, changes were made to individual key assumptions, and the effect on the result then analysed. Figure S–11 summarises these findings and shows the margins of variance in external costs, aggregated for all four modes of transport for each cost category (mode of transport perspective). These variance margins vary, depending on the cost category, from +11% / +11% to +50% / +80%.

- **Air-related health**: Valuing the intangible costs of lost years of life using VLYL (value of life year lost) is inaccurate, because it can vary between -50% and +100%. This results in variance in health costs of between -35% and +71%.
- **Noise**: Although great efforts have been made to develop reliable models of noise, uncertainties in calculating noise result in a variance margin of -37% to +44%.
- **Climate change:** Uncertainty about the level of the CO_2 cost rate, in particular, produces variances of between –45% and +80%.
- **Nature and the landscape:** Here, uncertainty about the cost rate for habitat fragmentation results in variances of between -22% and +27%.

- **Accidents**: External accident costs can be calculated relatively accurately (±11%). The variance is attributable primarily to uncertain levels of transfer payments, and the proportion accounted for by compensation.
- **Health benefits of non-motorised transport**: Health benefits vary by only ±15%. However, it has not been possible to quantify the uncertainty in the connection between physical activity and benefit to health.

Figure S-11: Margins of variance in sensitivity analyses

CHF millions	Base result	Minimum	Maximum	Variance margin
Air-related health	1'756	1'133	3'002	-35% to +71%
Air-related building	362	272	453	-25% to +25%
Air-related crop shortfall	59	43	76	-27% to +29%
Air-related forest degradation	51	35	66	-32% to +30%
Air-related biodiversity loss	148	118	178	-20% to +20%
Noise	1'799	1'136	2'593	-37% to +44%
Climate change	1'959	1'069	3'528	-45% to +80%
Nature and the landscape	900	703	1'140	-22% to +27%
Soil degradation	142	71	213	-50% to +50%
Up/downstream processes	917	551	1'562	-40% to +70%
Accidents	1'850	1'649	2'056	-11% to +11%
Urban areas	144	116	256	-19% to +77%
Health bens - non-mot. transport	-1'281	-1'092	-1'446	-15% to +13%

However, many of these uncertainties are mutually interdependent, so that the variance margins will be reduced, or offset against each other to some degree, if they are aggregated across all cost areas. It should also be remembered that assumptions are made in a large number of individual decisions in a way that reported costs are underestimated.

h) Comparison of external effects with previous results

This section compares the new results for 2010 with the findings of the 2005 study (see Ecoplan, Infras, 2008). Since no official calculations were made for other modes of transport in the 2005 report, the present comparison is limited to road and rail transport.

Where **road transport** is concerned, the costs resulting from the latest 2010 calculations are almost exactly the same as in 2005. In the interests of comparability, non-motorised transport has been factored out of the 2010 calculations. A reduction can thus be observed in real terms, i.e. when adjusted for inflation. This constancy is the result of opposing effects in a number of cost areas, which almost cancel each other out.

- Health-related costs as a result of air pollution are CHF 330 million lower on the basis of new findings on the exposure-response relationship between air pollution and lost years of life.

- The accident cost factor has fallen by CHF 450 million, primarily because of a sharp fall in the frequency and severity of accidents.
- Meanwhile, noise costs are CHF 360 million higher as a result of rising prices, an expanding population, an increase in the number of homes, and lower noise thresholds when calculating health costs.
- Losses of biodiversity as a result of air pollution (CHF 140 million) were included for the first time in 2010.
- There was a CHF 130 million increase in the costs of upstream and downstream processes owing to the first-time inclusion of indirect air pollutant emissions (the study previously covered only greenhouse gases), and a higher climate change cost rate.
- There were also increases in several other cost categories, mainly as a result of rising prices.

Figure S-12: Comparison of calculations for 2005 and 2010 (external costs from the mode of transport perspective)

CHF millions	Road transport (excl. NMT)			Rail transport		
	2005	2010	Difference	2005	2010	Difference
Air-related health	1'834	1'505	-329	120	185	65
Air-related building	274	310	36	15	38	23
Air-related crop shortfall	63	55	-8	2	1	-1
Air-related forest degradation	64	48	-16	2	1	-1
Air-related biodiversity loss	n.a.	141	141	n.a.	2	2
Noise	1'101	1'463	363	74	269	195
Climate change	1'256	1'261	4	7	4	-3
Nature and the landscape	687	760	72	110	119	9
Soil degradation	107	118	11	33	24	-9
Up/downstream processes	593	724	131	41	48	7
Accidents	1'435	988	-447	4	4	0
Urban areas	78	112	34	20	32	12
Total	**7'492**	**7'483**	**-9**	**429**	**727**	**298**

The costs of **rail transport** rose by 69%, or CHF 298 million, between 2005 and 2010. As with road transport, approximately CHF 60 million of this figure is explained by price increases, population growth, etc. The rest is attributable primarily to noise. The first point here is that the effects of noise are now evaluated mainly on the basis of night-time noise, instead of daytime noise, as previously. For rail transport, night-time noise levels are only marginally lower than those for daytime noise. The second is that the thresholds above which the effects of noise are counted have been lowered. Higher PM10 particulate matter emissions are also an important factor, as they have resulted in higher health-related costs and more damage to buildings.

Findings on Social Effects

Figure S–13 shows aggregate social costs and benefits for the areas covered by the study. The following (internal) costs and benefits should be considered in addition to the external effects described above:

- **Health benefits of non-motorised transport**: The exercise taken in the form of non-motorised transport increases life-expectancy and reduces the number of hospital stays. In addition to the reported CHF 1,281 million in external benefits, internal willingness to pay for these intangible benefits (preventing suffering, pain, shock and an increase in general enjoyment of life) is approximately CHF 11,000 million.
- **Accident costs**: Internal accident costs come to CHF 10,300 million, CHF 10,200 million of which is accounted for by road transport. Again, some three quarters of the total figure consists of intangible costs. Property damage, which is paid for by those at fault for the accidents, or their liability insurers, also represents a significant block of costs.
- **Separation effects**: Waiting times in non-motorised transport that are caused by motorised transport (CHF 158 million) are contained within the "road" mode of transport.
- **Internalisation charges**: Internalisation charges were deducted when calculating external costs. These must be added back in when calculating social costs. They consist of HVF revenues (CHF 720 million), income from the "climate cent" levy (CHF 106 million, CHF 105 million of which originates from road transport), and noise and emission-related aircraft landing fees (CHF 34 million and CHF 4 million respectively).

Aggregate social effects therefore come to CHF 20,700 million in 2010. Road transport is responsible for 91% of these costs (CHF 18,800 million) because of the great distances travelled, and high accident costs, among other factors. A nuanced view must be taken of road transport, however. Private motorised transport causes social costs of CHF 11,700 million, freight transport CHF 2,400 million, and public road transport CHF 340 million. Non-motorised transport generates costs of CHF 4,400 million, on the one hand, and benefits of CHF 12,300 million on the other, resulting in net social benefits of CHF 8,000 million. Air transport results in social costs of CHF 985 million (5%), while the figure for rail transport is CHF 800 million (4%), and that for waterborne transport is just CHF 60 million (0.3%).

Figure S-13: Overview of social effects, 2010
Road/rail transport: territorial principle, air/waterborne transport: shared route principle

CHF millions	Priv. mot PT and FT	Non-mot. transport	Public transport	Rail transport	Air transport	Waterb. transport	Total
Air-related health	1'444	-	60	185	41	29	**1'760**
Air-related building	297	-	12	38	8	6	**362**
Air-related crop shortfall	52	-	4	1	2	1	**59**
Air-related forest degradation	45	-	3	1	1	1	**51**
Air-related biodiversity loss	134	-	7	2	3	3	**148**
Noise	1'427	-	37	269	100	-	**1'833**
Climate change	1'337	-	28	4	686	9	**2'064**
Nature and the landscape	750	10	10	119	6	5	**900**
Soil degradation	113	-	5	24	-	-	**142**
Upstream and downstream processes	704	34	20	48	108	3	**917**
Accidents	7'542	4'315	148	76	30	2	**12'113**
Urban areas	262	-	8	32	-	-	**302**
Total social costs	**14'107**	**4'359**	**341**	**799**	**985**	**60**	**20'651**
Health bens - non-mot. transport	**-**	**-12'314**	**-**	**-**	**-**	**-**	**-12'314**
External effects, mode of transport perspective							
Total external costs	6'570	900	194	727	919	57	**9'367**
Health bens - non-mot. transport	-	-1'281	-	-	-	-	**-1'281**
Difference between social and external effects							
Difference between social and external costs	7'537	3'459	148	72	66	2	**11'284**
Difference between social and external NMT health benefits	-	-11'034	-	-	-	-	**-11'034**

In total, 86% of social costs are caused by passenger transport, and 14% by freight transport. Passenger transport thus takes a slightly higher share of social costs than of external costs. This is because road traffic accident costs are caused mainly by passenger vehicles. The health benefits of non-motorised transport also accrue to passenger transport.

If the shares of each cost and benefit category are analysed, the two primary effects – accidents and the health benefits of non-motorised transport – strike the reader immediately, as they account for increases and reductions in costs respectively of over CHF 12 billion. Climate change costs, noise, and the health costs associated with air pollution each account for between CHF 1,750 million and CHF 2,000 million. Upstream and downstream processes, as well as nature and the landscape, generate further costs of approx. CHF 900 million each.