Years of life lost due to transportation noise and air pollution: a comparative risk assessment for Switzerland in 2010

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ABSTRACT

Background: The health impact of noise and air pollution from rail, aircraft and road traffic is needed to estimate external costs of transport-related pollution to help policy-makers adapt road taxation schemes in Switzerland.

Objective: To estimate life years lost due to transportation-related noise and air pollution in Switzerland.

Methods: Spatially resolved noise and air pollution models for the year 2010 were derived for road, rail and aircraft sources. Average day-evening-night sound level (Lden) and particulate matter (PM10) were selected as indicators, and population-weighted exposures derived by traffic source. Cause-specific exposure-response functions for mortality were derived from a meta-analysis for noise and literature review for PM10. Life years lost were calculated using life table methods.

Results: Burden was characterised using relative risk estimates of 1.046, 1.014 and 1.076 per 10dB increase in Lden for death from myocardial infarction, stroke and hypertension-related disease, respectively and for natural cause mortality using a relative risk estimate of 1.045 per 10 µg/m3 increase in PM10. Total transport-related burden in Switzerland in 2010 amounted to 17,682 years of life lost (69% air pollution; 31% noise). Stratified by source 14,464 (84%) years of life lost were due to road, 13% to rail and 3% to aircraft traffic.

Conclusions: Transport-related pollution and burden in Switzerland is dominated by air pollution from road traffic. Noise remains an important contributor to total burden.

INTRODUCTION

In recent years, there has been substantial growth in the body of evidence for the effects of transportation-related noise pollution. The negative health impact from noise due to transportation is linked to annoyance and other non-auditory health effects (Basner et al. 2013). Of particular importance are new studies that show an association between chronic exposure to transport-related noise sources and cardiovascular outcomes, such as Ischemic Heart Disease (IHD), blood pressure disorders, stroke and diabetes, independently of the effects of air pollution (Sørensen et al. 2011, WHO 2011, van Kempen et al. 2012, Sørensen et al. 2013). The impact of noise from transportation was thus most likely only partially accounted in past cost evaluations.

Together with air pollution, noise is the largest environmental exposure for urban populations in Europe and elsewhere. A substantial part of the noise and air pollution exposure originates from road, railway and aircraft traffic. For policy-making it is

important to have reliable estimates of the independent contribution of the different transport sources of noise and air pollution to total health burden beyond cost estimations.

In Switzerland, the political consensus is that road transportation must cover the entirety of the costs it generates, including the cost arising from construction and maintenance work and from damage to environment and health. Road taxation schemes to cover these costs are thus derived in part on calculation of external costs of noise and air pollution revised every 5 years. Based on the noise and air pollution exposure in Switzerland, and on systematic review of epidemiological literature, the external costs in 2005 of road and rail traffic were an estimated 1,954 million Swiss Francs (CHF) for air pollution and 1,174 million CHF for noise exposure (ARE 2005).

This study estimates the years of life lost (YLL) due to road, rail and aircraft traffic noise and air pollution in 2010 in the Swiss population as an input for the new revised external traffic cost estimates.

METHODS

We combined population exposure to noise and air pollution and exposure-response functions of the effects of noise and air pollution on mortality to obtain estimates of change in YLL, using the life tables approach.

Population exposure

Exposures to noise were derived from existing models for year 2010. For road and rail noise population exposures were derived from SonBase, the Swiss GIS-based noise model (Höin et al. 2009). SonBase models noise propagation from source to reception points, taking account of building height, first order reflections and noise barriers. Noise levels at source points are first calculated with CADNA-A and STL-86+ models using data from a detailed Swiss national traffic model (Federal Office for Spatial Development ARE 2010). SonBase calculates equivalent continuous noise level (Leq) at the most exposed façade of each building in Switzerland. Estimates of aircraft noise for the national airports of Zurich and Geneva come directly from the airport operators, which evaluate the airport-specific noise models annually. The data for Basel and other 62 small regional airports were derived from an older SonBase model developed by the Federal Office of Civil Aviation.

The noise metric used in our study was Lden, the average sound level over all 24 hour periods of a year, with a 5 dB and 10 dB penalty, respectively, in evening and night. Noise levels modeled at residential addresses were combined with population counts to determine total exposure in 1 dB steps from <40 – ≥80 dB. For subsequent burden calculations, a threshold of no effect of 48 dB was assumed based on the weighted-average of reference values of studies included in a meta-analysis to derive the exposure-response functions (Vienneau et al. 2014, in prep). We thus calculated the population-weighted exposure over this threshold for each noise source.

For air pollution, PM10 was used as the pollutant indicator to allow for comparability with past studies. Exposure levels for 2010 were obtained from 200x200 m dispersion models for PM2.5 and PM10 which accounted for primary particulates, secondary particle formation from precursor emissions (NO2, SO2 and VOC) and transboundary large-scale PM10. The dispersion model was run for total air pollution

and separately for each transport source. Population counts in each grid cell were combined with gridded PM2.5 levels to obtain a population-weighted concentration for the whole of Switzerland. Population exposure to PM10 was then derived by applying a population-weighted ratio PM2.5/PM10 of 0.73 derived from the exposure model. This ratio was further needed to convert the available risk function for PM2.5 into a comparable function for PM10. As done in previous evaluations in Switzerland, a level of 7.5 µg/m3 PM10 was used as natural background level for burden evaluation.

Derivation of exposure-response relationship

We conducted a literature review to derive or obtain exposure-response relationship reflecting the most current scientific evidence in the association between noise, particulate matter and mortality. Given recent new evidence for noise, a new meta-analysis was developed to derive an exposure-response function for myocardial infarction, stroke and hypertension-related mortality.

Calculation of YLL

We used the life table approach to calculate changes in YLL for a reference and an alternative scenario. In the reference scenario, life tables for the Swiss population were calculated extrapolating observed survival probabilities in the year 2010. For the alternative scenario, life tables were rerun with modified survival probabilities that assumed no one in the population was exposed to Lden >48 dB or PM10 >7.5 µg/m3 during 2010 (returning to previous levels after 2010). The difference between the reference and alternative scenario is interpreted as the YLLs attributed to noise or air pollution in year 2010 in Switzerland (Miller et al. 2003, Röösli et al. 2005). Since damages are less weighted in economics, a discount rate of 1 percent per year is applied to all future YYL.

RESULTS

Population exposure

Approximately 6.6 of the 7.8 million residents (84%) in Switzerland were found to be exposed to road noise in excess of 48 dB (Lden). The majority of these persons lived in areas with Lden noise levels between 48 and 60 dB (61%). On this basis, we computed the population-weighted excess exposure as 8.74 dB for road noise. Substantially fewer persons were exposed to rail (1.5 mil) and aircraft (0.58 mil) noise, respectively reflecting an excess exposure of 1.89 and 0.37 dB (Lden). The population-weighted exposure to total PM10 in 2010 was 19.4 µg/m3, with contributions of 4.4, 0.54, 0.12 µg/m3, respectively, for road, rail, and aircraft sources. These transportation sources accounted for 26.0% of the total PM10 load.

Exposure-response relationship

In the absence of updated exposure-function for noise and cardiovascular mortality, noise burden was characterised by developing new exposure-response functions after thorough literature review and meta-analysis (Vienneau et al, in prep). For MI, we identified 10 studies conducted since the mid-1990s, providing 13 relative risk

estimates (Babisch et al. 1994, Babisch et al. 1999, Babisch et al. 2005, Beelen et al. 2009, Selander et al. 2009, Huss et al. 2010, Gan et al. 2012, Sørensen et al. 2012, Correia et al. 2013, Hansell et al. 2013). Most were conducted in Europe for road noise; 3 investigated exposure to aircraft noise, two of which were in North America; and none were found for railway noise. Six studies were found for stroke, contributing a total of 8 relative risk estimates for meta-analysis split evenly between road and aircraft noise and including one estimate for noise from rail (Beelen et al. 2009, Huss et al. 2010, Sørensen et al. 2011, Gan et al. 2012, Correia et al. 2013, Hansell et al. 2013). For hypertension, we combined the two recent meta-analyses, van Kempen and Babisch (2012) on road and Babisch et al. (2009) for aircraft, to derive the exposure-response function. Relative risk estimates used in our evaluation are 1.046 (95% CI 1.015, 1.079), 1.014 (0.964, 1.066) and 1.076 (1.032, 1.121) per 10dB increase in Lden for death from myocardial infarction (MI), stroke and hypertension-related disease, respectively. For the calculation, confidence intervals including 1 were censored at 1 to prevent calculating beneficial effect of exposure.

We followed the recent review of the literature by the World Health Organization to select the exposure-response function for long-term exposure to PM10 and mortality (WHO 2013). WHO recommends that current cost-benefit analysis for estimation of impact of long term (annual average) exposure to all-cause (natural) mortality in adult populations (age 30+) be based on a recent meta-analysis of 13 cohort studies for PM2.5 that gives a linear relative risk of 1.062 (95% CI 1.040 – 1.083) per 10 µg/m3 (Hoek et al. 2013). We transformed this RR for PM10 using the population-weighted ratio of 0.73 observed between PM2.5 and PM10 in Switzerland from 2010 exposure modeling. The RR used in our estimation is 1.045 (1.029, 1.06) per 10 µg/m3 increase in PM10 for natural cause mortality.

YLLs

The results of the YLL in Switzerland due to transport noise and air pollution exposure, discounted to 2010 using a discount rate of 1% per year, are shown in Table 1.

The total transportation-related burden in Switzerland in 2010 amounted to 17,682 YLL (69% air pollution; 31% noise). By transportation source this equates to 84% YLL due to road, 13% to rail and 3% to aircraft traffic. In Switzerland, the largest contribution to the burden of air pollution is from road traffic (86%). While road traffic is also the major contributor to noise burden (79%), interestingly, the contribution of rail source to the YLL burden of noise is greater than that of air pollution (17% for noise versus 11% for air pollution).

Table 1: Years of life lost (YLL) due to air pollution and noise by transportation source

Outcome	Total transport		Road traffic		Rail traffic		Aircraft traffic	
	YLL	%	YLL	%	YLL	%	YLL	%
Air pollution: all non-accidental cause	12471** (8121, 16489)	69	10663 (6944, 14099	86	1311 (854, 1733)	11	289 (188, 382)	2
Noise: cardiovascular disease*	5540 (1849, 10277)	31	4404 (1470, 8169)	79	952 (318, 1765)	17	184 (62, 342)	3
Total	17682	100	14464	84	1920	13	311	3

* Myocardial infarction, stroke and blood pressure related diseases
** Total YLL for air pollution includes shipping transport
Numbers in brackets are based on lower and upper 95% CIs on the exposure-response functions

DISCUSSION

Exposure to road, rail and aircraft traffic in 2010 amounted to 52% of the total burden of noise and air pollution in Switzerland. Stratified by source, road traffic remains the largest single contributor (84%), however the noise generated by rail traffic is also considerably damaging in Switzerland. Aircraft traffic is a rather moderate burden contributor (3% total transport) at a Swiss-wide level. The contribution of this source of noise to the total source-specific burden, however, is proportionally very large (59%) compared to road (30%) or rail (50%). This indicates that policies that attempt to prevent concomitant exposures to transportation-related noise and air pollution will likely be beneficial.

YLL is only one part of the total costs from air pollution and noise exposure. For the total external cost calculation, we also considered morbidity effects (e.g. cardiorespiratory hospital days, bronchitis and asthma). Noise annoyance and noise induced sleep disturbances were also economically considered on the basis of the loss in renting costs in noise exposed areas. This information was derived from nationwide multivariable renting cost models which assume that these immediate consequences of noise exposure are reflected in the market by the willingness to pay for quiet homes (data not presented). This part of the noise costs is higher than the combined costs due to mortality and morbidity. As a consequence, total external costs of traffic noise exposure are relatively close to the total external costs of traffic related air pollution, although in terms of YLL air pollution is substantially more relevant.

Given that only a few noise studies exist by type of transport, we abstained from applying different exposure-response functions in our evaluation. Thus, the same exposure-response function was applied for all traffic noise sources. The type of source may be strongly related to outcome or characteristics of individuals. Using a single exposure-response for all sources may thus be problematic. The same applies for air pollution. We used the same exposure-response function for PM10 for all type of sources. In particular, with respect to long term effects on mortality relevant for YLL calculation, little research has been done on the different toxicity of source related particles. Particles from road traffic, for example, may have a different effect on long term mortality than particles from railway traffic which is primarily

mechanically generated from wear on the rail. PM10 is also a limited indicator for air pollution from aircrafts.

Nevertheless, assessment of total traffic related air pollution effects is expected to be less critical since a large contribution of total air pollution exposure is from road traffic. Estimated health effects of PM2.5 and PM10 from cohort studies thus largely reflects the effect of road traffic exposure.

CONCLUSIONS

Exposure to transport-related air pollution and noise exposure in Switzerland is widespread and contributes largely to the burden of these pollutants. While exposure assessments are becoming more precise with availability of source-specific exposure models, uncertainties about the exposure-response functions for different transport sources remain, especially regarding noise.

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