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Synthesis Report: Environmental problems

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1 OVERVIEW OF KEY FINDINGS

This synthesis has been written based on contributions from PROSPECTS, SCATTER, ISHTAR, PROPOLIS and CITYFREIGHT.

The principal environmental impacts of transport and land use that we considered here are atmospheric pollutants, greenhouse gases and noise.

There is a clear causal link between traffic and environmental problems. However, the link with urban sprawl, though theoretically realistic, is much more difficult to establish because of the lack of available data.

In this synthesis, we will focus on pollutants, greenhouse gases and noise, which were covered by the contributing studies.

There is no threshold under which **air pollution** is harmless. ISHTAR has focused on **particulate matters** (though other pollutants such as nitrogen oxides and secondary pollutant as ozone should be taken into account). Following the Directive 1999/30/EC, the concentration of PM_{10} in the air in 2005 should not exceed 40µg/m³ (annual average). Overall, each 10µg/m3 of PM_{10} increases the risks of mortality and illness linked to respiratory ailments by a few percents (for asthma, respiratory diseases etc) up to 30% (in the case of acute bronchitis).

Air pollution has an impact on **cultural heritage** too. Pollution accelerates the natural ageing of stone. In the most polluted cities, pollution can cause the loss of more than one millimetre of stone thickness in 10 years. The nature of the stone is of course an important factor, as is local climate. Reduction of sulphur oxides emissions has improved in the past, but nitrogen oxides could also be a source of corrosion.

For **global warming**, PROSPECTS proposes an additional tax of 50 €/tonne of CO_2 in 2010. This level should allow meeting the Kyoto target. This corresponds to about 0.12 €/litre of gasoline and 0.15 €/litre of diesel. PROSPECTS suggest a tax level 4 times higher by 2020, as additional reductions (further to Kyoto targets) will have to be met to tackle global warming.

There are a number of potential effects of **noise** on health, in domains such as annoyance, speech interference, concentration on tasks, mental health, hearing loss, stress or sleep disturbance. However, according to ISHTAR, there is no evidence of effects other than those based on **sleep disturbance** and annoyance. For noise, scientific evidence suggests thresholds below which it is unlikely that there is an impact on health, though this is not yet firmly established. Uncertainties remain large in this field.

2 WHAT THE THEORY TELLS US

The principal environmental and safety impacts of transport and land use are:

- Atmospheric pollutants and greenhouse gases
- Noise
- Severance of land
- Visual impact

The last two items are not readily quantified, and are not covered in the PLUME studies.

Atmospheric pollutants can be local, regional or global in their effect. Several different pollutants can be identified at the **local level**, including oxides of nitrogen (NOx), carbon monoxide (CO), volatile organic compounds (VOCs) and particulates of differing size. Lead and sulphur oxides (SO_x) are also generated, but have become less significant. Local air quality management surveys in the UK suggest that the pollutants of greatest concern at typical UK urban concentrations are NO_2 and particulates of less than 10 microns in diameter (PM_{10}s). Finer particulates ($PM_{2.5}$, or even smaller ones) are more harmful than PM_{10}, but harder to measures. It's only in the recent years that we have begun researching their impact.

Local pollutants are generated in different ways, and have different effects; however, the process for appraising them is reasonably similar.

The most important **regional** pollutant is ozone, which results from the more long-term (one to three days) photochemical reactions of primary pollutants, mostly NOx and VOCs. The highest concentrations of ozone can occur many miles from the sources of pollution, as primary pollutants are transported by winds before the photochemical reactions take place.

Carbon dioxide is different, in that it is a **global** pollutant, with no local impact. It only contributes to global warming. It can be assessed in aggregate for an urban area (or even for a wider region still).

Council Directive 1999/30/EC gives current limits on concentrations for the various pollutants.

PROSPECTS delivered some useful results on the cost of emissions. PROSPECTS first proposed some values for the cost of transport emissions of **pollutants**. These values were taken from a literature review.

Table 2.1: Costs in Euros per emitted kilo of pollutants from transport

	SO_2		NO_x		VOC		PM_{10}		
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Small town	Rural
Eyre	52	7	13	9	3	3	92		14
EUNET		1.7		4.5			185*		
ECMT			8	4	8	4			0
Eriksen	9	2	8	4	8	4	206	25	0
SIKA	27	2.3	10	6.8	8.5	3.4	864	216	0

* $PM_{2.5}$
Source: ¨PROSPECTS

PROPOLIS mentions two valuations of pollution externalities, one derived from the results of the European project ExternE, and one from a study made by INFRAS - IWW for the International railway Union (UIC).

The project ExternE has produced results for 13 different cases whose results are included in Table 2.2.

Table 2.2: Unit values of air pollution: results form ExternE project (Values in Euro/kg of pollutant)

ExternE Case	Country	Type	Population Density (inh/km^2)	PM $_{2,5}$	SO_2	COV	NOx	CO
Paris	France	Urban	22 300	2 553	46.4	2.6	21.7	0.025
Paris Lion	France	Extra-urban	105	173	13.3	1.1	22.4	0.002
Milan	Italy	Urban	7-21000	4 840	87.3	3.5	13.4	0.053
Amsterdam-Schiphol	Netherlands	Urban	6-7000	447	11.5	1.1	7.2	0.003
Amsterdam	Netherlands	Urban	6-7000	438	11.4	1.1	7.2	0.003
Rotterdam Nijmagen	Netherlands	Extra-urban	200-3000	336	10.7	1.1	7.2	0.002
Schiphol Rotterdam	Netherlands	Extra-urban	500-3000	424	11.4	1.1	7.2	0.003
Athens	Greece	Urban	1-50000	nq	13.3	4.5	6.7	0.013
Athens Thessaloniki	Greece	Extra-urban	81	506	9.4	1.6	6.9	0.004
Stuttgart	Germany	Urban	225	480	13.8	1.4	17.1	0.004
Stuttgart - Mannheim	Germany	Extra-urban	nd	268	11.7	1.4	19.0	0.003
London	U. Kingdom	Urban	nd	1 447	42.3	3.7	23.2	0.022
Barnsley	U. Kingdom	Urban	245	492	20.8	2.0	8.7	0.005

Source: ExternE project

The specific elaboration that was carried out by TRT on the base of the results from the INFRAS/IWW study and from the mentioned study from Amici della Terra are reported in Table 2.3.

Table 2.3: Unit values of air pollution: elaboration for Italian case (Euro/kg)

	Average value	Urban	Extra urban
SO_2	127	223	72
NO_x	8.2	14.9	4.8
PM_{10}	151	244	79
CO	1.0	1.2	0.4
COV	5.4	6.3	2.0

Source: Amici della Terra, *I costi ambientali e sociali della mobilità in Italia.*

Second, for **global warning**, PROSPECTS proposes an additional tax of 50 €/tonne of CO_2 in 2010. This level should allow the Kyoto target to be met, and is based on IPCC works (IPCC 2001). This corresponds to about 0.12 €/litre of gasoline and 0.15 €/litres of diesel.

On the other side, PROPOLIS mentions standard values fixed by the IPCC (Intergovernmental Panel on Climate Change) and the UNEP (United Nations Environment Programme), which range between 23 and 121 Euro/tonne of CO_2 (1995). This is consistent with the values proposed by PROSPECT.

For 2020, the objective is long term; to be on a path towards the stabilisation of CO_2 in the atmosphere. Stabilisation levels range in IPCC (2001) from 750 to 450 ppm (in volume). These levels are long term targets that can be reached more quickly or slowly, along different development paths. PROSPECTS suggest a level of tax of 200 €/tonne of CO_2 by 2020. This not based on hard facts, but on the evidence that for the long term, much larger reductions in CO_2 emissions than the Kyoto target will be needed.

Noise is a local pollutant. PROPOLIS mentions values for the cost of noise exceeding the threshold of 55 decibels at day time and 45 decibels at night time, which are the usual limits. These values are taken from an INFRAS/IWW study. These values are average and do not differentiate costs in urban areas from costs in small centres or other conditions. Anyhow, the cost of noise is mainly concentrated in urban areas and it should be calculated on the traffic flows relevant to urban zones. Moreover a further distinction of zones should be made, between for example industrial, residential, commercial zones.

Table 2.4: Average noise costs - 1995

	Passenger (Euro/1000 pkm)				**Freight (Euro/1000 tkm)**
Country	Car	Motorcycle	Bus	Railways	Trucks
Average EU17	5.7	17.0	1.3	3.9	6.7

Source: INFRAS-IWW, *External Effects of Transport*

3 WHAT MODEL RESULTS TELL US

4 WHAT EMPIRICAL EVIDENCE AND CASE STUDIES TELL US

4.1 Environmental Impact of Urban Freight Distribution

CITY FREIGHT reviewed problems related to freight delivery in urban areas. Harmful environmental impacts of urban goods transport (emissions, noise, safety risks, physical obstacles, vibration, and energy consumption) are a common problem in all of the cities. Efficient solutions to reduce environmental impacts are often expensive, both for local authorities, that must finance the implementation, and the private sectors, whose operating costs are often on the increase due to traffic restrictions for example.

Emissions are the most notable environmental impact. Cities try to lower emission levels by restricting traffic in the central areas, lowering speed limits and introducing access restrictions based on vehicles' environmental performance. The European Union regulates the emission levels with the Euro emissions standards. It is worth noting that the increase of emissions due to freight is actually an increase in car emissions because of increased congestion.

Traffic ***noise*** is an increasingly important topic in environmental concerns. The same level of noise from goods transports may be experienced in different ways depending on the location (city centre or suburb), time of the day (early morning, noon, night) or evenness of the noise (a steady flow of vehicles or sharp noises from unloading and loading).

To avoid delays caused by congestion, the transport sector increasingly uses night and off-peak deliveries. This increases noise impacts, as populations are more sensitive to noise during the quiet periods (typically at night). This, together with problems caused by congestion land use costs etc., can have strong impacts on the localisation decisions of new industrial and logistics activities.

Retail activities are concentrated in city centres with a great variety of stores, restaurants, offices, etc and the frequent delivery of small amounts of goods is required. Therefore distribution efficiency is low compared to hypermarkets and requires a large volume of traffic in comparison to the quantity of goods. Since recreational activities and pedestrian streets are concentrated in city centres, **aspirations to make city centres attractive** are in stark contrast to the needs of an efficient distribution of goods.

4.2 Environmental Impact of Urban Sprawl

The effects of urban sprawl, as presented by SCATTER, are one of the most hotly debated issues in the literature. One of the reasons is the lack of reliable empirical evidence to support the arguments made either for or against sprawl.

The summary provided by the Transportation Research Board (1998) and discussed in SCATTER lists some of the limitations of the current research on costs of sprawl. This report divides the effects of sprawl into five groups; public and private capital and operating costs, transportation and travel costs, land/natural habitat preservation, quality of life and social issues.

4.2.1 Land Consumption

"The use of land for urban development and transport in the EU continues to harm the environment through, for example, loss of high quality arable land, destruction of biotopes and fragmentation of eco-systems. "In some regions, there are increasing spatial conflicts between additional housing requirements, commercial developments, agricultural use and protection of open space" (European Commission, 1997).

There is conflicting evidence on land consumption for residential purposes. According to Orfeuil (2000) the amount of open space used by each inhabitant has increased in the last 20 years by two or three times. However this measurement of land consumption is not agreed upon. Camagni *et al* (2002) have calculated land consumption in urban development as the ratio of land area developed for residential and service use between 1981 and 1991 in each commune to the number of dwellings. "This indicator was preferred to the per capita consumption of land because the latter may increase in cases where the population of a commune declines, giving a false indication" (Camagni *et al* 2002). The results of their analysis proved that land consumption is actually declining rather than increasing.

But land consumption for residential use is not the only factor to be considered. Another factor to be borne in mind is the high consumption of land for road infrastructure: 25% of the total urban area in Europe and 30% in the United States. Research carried out in the Paris region showed that the private car, which accounts for 33% of total trips, consumes 94% of road space/hour; while the bus, with 19% of total trips consumes only 2.3%: in other words, a bus in movement consumes 24 times less space per passenger than a single car (Servant, 1996).

4.2.2 Energy Consumption

Energy consumption depends indirectly on the same variables as land consumption, via their linkage with mobility patterns: trip length and modal choice between private and public means. The level of petrol consumption can be used as a parameter of the level of car use. In these terms this level has been increasing constantly since the late '70s. Opinions on the risk of depleting this non-renewable energy source due to urban sprawl tend to differ. However both the United Nations and the European Union have moved in favour of the compact town model embracing the position, supported by research (Newman, Kenworthy, 1989), that more dense cities consume the least amount of energy for transport. The compact city model is also claimed to allow energy-saving opportunities for new technologies, such as combined heat and power systems (HM Govt, 1994; Elkin *et al*., 1991).

4.2.3 Atmospheric Pollution

It is hard to establish a direct connection between urban density by itself and the increase in the amount of atmospheric pollution. The level of pollution due to motorcar dependency can more easily be connected to population densities (Höjer, 2000). Studies have shown different results. Some support the hypothesis that more compact (and therefore dense) city models limit the number of journeys and the length of car travel and that dense areas can have up to three times less emissions than more sparsely populated urban areas. According to Burton (2000), it is possible that the compact city may present a health risk due to localised air pollution, particularly from traffic, but also from the closer proximity of residential and industrial uses. Increasing trends in air pollution over the past 40 years have been linked with increases in respiratory diseases such as asthma and lung cancer.

Despite these studies it cannot be inferred that density alone is a sufficient explanation for the level of pollution. This relationship between density level and pollution is arguable and should be further investigated to understand which activities should be more concentrated. If population and jobs however concentrated remain separated, little improvement is to be seen with regard to pollutant reduction.

4.3 Impact on Monuments

Materials exposed to the outdoor environment degrade because of the processes of natural ageing. Pollution increases the speed of the degradation process. Pollution can have the following impacts on stone monuments: corrosion, increase opacity, alteration of colour, decrease of mechanical resistance or increase of brittleness. The main impact considered in ISHTAR and discussed here is corrosion, which reduces the thickness of stone over time.

The impact of pollution on stone monuments, although certain, is very difficult to assess accurately. Sulphur dioxide is the primary pollutant that causes alterations. Uncertainties remain on the role of nitrogen oxides.

Overall, impact will depend on the pollutant compositions, on the kind of stones used and on climatic conditions (the quantity of rain).

There are currently no data on noise and vibration impact on monuments. These impacts are not considered in this report.

There is a natural ageing process of stones used in monuments, which will occur even in non-polluted area. It ranges from 0.2-0.5 mm/100 years in the case of very compact materials, with porosity inferior to 1%, to 3-10 mm/100 years in the case of materials with porosity, P>10%.

Average loss rate data for calcareous stones in urban environments range from about 5 µm to 140 µm of stone for each metre of rain. Most values are around 20 to 30 µm of stone per metre of rain. For the sake of modelling, one often takes an average of one metre of rain per year, which results in a range from 0.5mm/100 years to 14mm/100 years.

It is worth noting that damages described here do not address discontinuous and catastrophic phenomenon, such as the separation of superficial crusts, the fall of material totally deprived of cohesion or the opening of fractures. These can be frequent and they severely worsen the conservation of material and its durability. If these losses of material occur on engraved surfaces, or on surfaces with artistic and/or historical merit, it is evident that the impact of a similar damage is of great importance.

4.4 Impacts on Health

4.4.1 PM

ISHTAR has investigated the role of suspended particulate matter (PM) with regards to its short- and long-term effects on mortality and morbidity. Most of the scientific evidence available to date concerns PM10 and PM2.5 (particles less than 10 and 2.5 µm across), although the role of finer particles is of increasing interest. In the evaluations mentioned in ISHTAR, particulates have been used as a summary indicator of air quality, as emissions of most other pollutants are correlated to PM emissions.

In addition to PM air pollution, recent work in health impact assessment has taken ozone into consideration, which is not correlated to PM. Since there are not many examples of ozone health impact, it seems somewhat premature to incorporate ozone in a standard procedure, before a wide consensus has been reached, for example, on risk coefficients and requirements for concentration measurements. Therefore, only the case of PM pollution is discussed here.

Pollution impacts on health are short-term and long term. There is no threshold below which pollution is not harmful.

The relative risks for unit increase PM_{10} for all these adverse outcomes are usually of the order of few percent units increase for each $10\mu g/m^3$ increase in PM_{10} concentration. It is of about 30.6% for acute bronchitis (see Table 4.1). Please note that this table gives values for PM_{10} only. Values for finer particulates would be higher, though quantities emitted (in grams or micrograms) will be typically lower.

Table 4.1: Health endpoints used for PM health impact assessment.

Cause	Relative risk per $10\mu g/m^3$ PM_{10} (95% CI)
Mortality (Adults aged 30+, excluding accidental causes)	1.026 (1.009,1.043)
Hospital admissions for CVD causes	1.009 (1.006, 1.013)
Hospital admissions for respiratory disease	1.016 (1.013, 1.020)
Acute bronchitis (aged <15)	1.306 (1.135, 1.502)
Asthma exacerbation (aged <15)	1.051 (1.047, 1.055)
Asthma exacerbation (aged 15+)	1.004 (1.0, 1.008)
Restricted activity days (aged 20+)	1.094 (1.079, 1.109)
Occurrence of respiratory symptoms	1.07 (1.02, 1.11)

Source: ISHTAR

*1 (ref 22), guideline value is the value above which an observable effects might be expected
*2 (ref 21), guideline value is the value of the lowest exposure at which on average an effect has been observed in epidemiological studies
*3 (ref 23)
*4 (ref 24), value is based on reference 28 and indicates the value above which an effect is observed.

4.4.2 Noise

There are a number of potential effects of noise on health, in domains such as annoyance, speech interference, concentration on tasks, mental health, hearing loss, stress or sleep disturbance. However, according to ISHTAR, there is no evidence of effects other than those based on annoyance and sleep disturbance.

Although the scientific evidence suggested thresholds below which it is unlikely that there is an impact on health, the authors could not interpret these as definitive at this time. Table 4.2 provides the threshold values identified in the literature.

On the other hand, just because research has not definitely proved any causal linkage between environmental noise and long-term adverse health effects, this does not mean that such linkages do not exist. It remains inherently plausible that excessive noise might contribute to long-term adverse health effects, and because of this the whole area is increasingly becoming a matter of public concern.

Table 4.2: Guideline threshold noise exposure values below which reviews reports that an effect is unlikely to be observed

Effect	Guideline threshold value (dB(A))
Annoyance	40 ($L_{Aeq,24h}$: transportation noise) [*1] 42 (L_{dn}: outdoors) [*2] 55 (dB $L_{Aeq:}$ outdoors, few seriously annoyed below this value)
Speech communication	45-55 (dB L_{Aeq} : for elderly or impaired) [*4] 55-65 (dB L_{aeq}) [*4]
Sleep	30 (dB L_{amax} - for continuous noise to avoid serious effects) [*4] 45 (dB L_{amax} - for low background and non-continuous noise) [*4]
waking during the night	60 (SEL indoors) [*1] 60 (SEL indoors) [*2] 60 (dB L_{Amax}) [*4]
changes to sleep stages	35 (SEL indoors) [*2] 40-45 (dB L_{amax}) [*4]
subjective reports of sleep quality	40 ($L_{Aeq,\ night}$) [*1] 40 ($L_{Aeq,\ night}$:outdoors) [*2]
mood next day	60 ($L_{Aeq,\ night}$) [*1] 60 ($L_{Aeq,\ night}$:outdoors) [*2]
heart rate	40 (SEL indoors) [*2] 45 (dB L_{Amax}) [*4]
Stress related health effects	
general cardiovascular effects	65-75 (dB L_{Aeq}) [*4]
Hypertension	70 ($L_{Aeq,,\ 06\text{-}22h}$:outdoors for road and aircraft traffic noise in living environment) [*2]
Ischemic heart disease	70 ($L_{Aeq,}$:outdoors) [*1] 70 ($L_{Aeq,,\ 06\text{-}22h}$:outdoors for road and aircraft traffic noise in living environment) [*2]
Hearing loss	70 ($L_{Aeq,}$:indoors for living and recreational environment) [*1] 65-75 (dB L_{Aeq}: “negligible” risk for hearing loss for 8 hour exposure and 40 years age group) [*4]
Performance	55-65 (dB L_{Aeq}: for deteriorated reading acquisition in school children, people learning languages and the elderly) [*4]
performance by school children	65 ($L_{Aeq,\ school}$: outdoors) [*1] 70 ($L_{Aeq,\ school}$: outdoors) [*2]

Source: ISHTAR

[*1] (Noise ref 22), guideline value is the value above which an observable effects might be expected
[*2] (Noise ref 21), guideline value is the value of the lowest exposure at which on average an effect has been observed in epidemiological studies
[*3] (Noise ref 23)
[*4] (Noise ref 24), value is based on reference 28 and indicates the value above which an effect is observed.

Given current knowledge, it is not possible to establish health effect based assessment methods. Unresolved questions are among others:

- Exposure-response relationship cannot currently be accurately estimated,
- The share of the affected population is difficult to assess,
- Threshold levels cannot be established, although evidence suggests there is a threshold below which no effect occurs,

- There are uncertainties in assessing the overall impact of noise on health. These relate to the treatment of more than one effect, the role of modifiers, the cumulative exposure of different time periods, the handling of vulnerable or susceptible groups, and the role of other risk factors in assessing conditions of multi-factorial origin. These need to be better understood before effect-based assessment methods can be established.

5 TECHNICAL SUMMARY

There are a number of areas mentioned in PLUME studies where evidences are inconclusive or conflicting.

- The valuation of external costs of pollution is one of these. Results vary according to methodologies, which effects are included or not, and local circumstances. Development of standard methodologies at the European level should help in this regard.
- It is also difficult to establish the long term cost of global warming, because economic techniques of discounting are not made for such long term estimations (over at least a century). It is thus difficult to establish a unique value for this effect.
- The effects of urban sprawl are one of the most hotly debated issues in the literature. One of the reasons is the lack of reliable empirical evidence to support the arguments made either for or against sprawl. Issues such as the impact of urban density on the environment remain largely uncertain.
- More research is needed to understand the generation and the impacts of some pollutants by transport, in particular fine particulates (below 2.5 µm of diameter) and ozone. This is also true for some unregulated pollutants, such as PAHs.
- There are a lot of variations in the impacts of pollution on monuments, as stone quality, climate and the present pollutants is highly variable from on place to the other. This is thus an issue that is difficult to evaluate. In addition, these evaluations only account for proportional damages, not for discontinuous events such as fractures or the loss of engravings.
- For noise, there is no evidence of effects other than those based on sleep disturbance and annoyance. However, not enough is known to assess if excessive noise might contribute to long-term adverse health effects.

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