

9 ENVIRONMENT

9.1 INTRODUCTION

In this chapter we discuss the relation between urban road user charging and the environment.

However, “environment” is a multi-faceted concept which may refer to a wide range of aspects. In this chapter we focus on four types of central environmental qualities that all may be directly affected by the changes in traffic patterns that will follow from the introduction of road user charges :

- Climate change – CO₂ emissions
- Local air quality (NO_x and Particulate Matter) and its consequences for human health
- Noise
- Urban quality – townscape and liveability

We thereby exclude the aspect traffic safety.

In addition to these more or less direct effects, we briefly include also two types of more long term, indirect and general effects that an urban road user charging program may have on environment through

- Car fleet composition
- Demand for new infrastructure

The analysis is based on a standard survey of available literature, but with particular emphasis on publication in scientific journals, and experiences gained from the Stockholm trial.

9.2 WHAT IS THE IMPORTANCE OF THE THEME?

For the last decades transport policy on international, national and local level has been increasingly often linked to environmental aspects. Since the 1990's “sustainable transport” and “sustainable mobility” are key concepts in transport policy making, pointing at the need to integrate environmental concern with other aspects (social, economical) in all transport related decisions.

This development is based on an increased understanding of 1) that humanity is facing a number of environmental problems that are large and challenging, and 2) that the transport sector contributes substantially to many of these problems.

A few illustrative examples from the European Environmental Assessment reports EEA (2001, 2003, 2007) are presented as follows:

Global warming: Reaching the EU target of keeping the increase of global average temperature to 2 degrees Celsius above pre-industrial levels will require much larger reduction of global emissions of greenhouse gases by 2020 than what is given by the Kyoto agreement for 2010. Already through the Kyoto protocol, EU member states have committed themselves to an 8% reduction of such emissions from 1990 levels by 2008-2012. It is far from certain that EU member states will be able to meet those commitments, and much stronger policy efforts than those currently seen will be necessary to reach the necessary reductions in the next decade. Currently, transport contributes with approximately 20 % of EUs total emission of greenhouse gases, but this share is rapidly increasing due to fast rises in demand for transportation. A baseline scenario sees a 31 % rise in transport emissions above 2000 levels by 2030. Four-fifths of these expected emissions will come from road transport.

Local air quality and health: The health effects of pollutants can range in severity from death to minor illness or discomfort. Substantial variations in sensitivity to an exposure may occur between individuals, due to age, nutritional status, genetic predisposition and state of general health. For a number of pollutants, EU-directive COM (2005) 447 has set maximum levels of concentrations/exposure to protect human health. Despite the fact that these limits are legally binding, substantial parts of the population (in particular those living in urban areas) are still subject to concentrations over those levels. For **particulate matter (PM₁₀)** as well as ambient air **nitrogen dioxide (NO₂)** 23-45% of the urban population in EU was potentially exposed to concentrations in excess of the EU limit value in There was a slight downward trend for **NO₂** over the period, but no discernible trend for **PM₁₀**. Road transport contributes substantially to both **PM₁₀** and **NO₂** problems, and EEA concludes f ex that “...it remains likely that for some decades to come, many urban areas in the EU-25 will continue to have unsafe concentrations of particulates, largely because of the continued growth in road transport”.⁸

Noise: It is clear that environmental noise can affect people's health and quality of life. The exact magnitude of the problem is yet to be quantified. An important contribution to the understanding is expected from an ongoing WHO study, expected to be finalised in December 2008. Already the variety of end-points that will be addressed in the WHO study indicates the wide range of negative health effects that may arise from environmental noise: “...cardiovascular disease, cognitive impairment in children, hearing impairment due to leisure noise, tinnitus, annoyance, and sleep disturbance...”. In 1999 it was estimated that more than 30 % of EU citizens were exposed to road noise levels above 55 L_{dn} dB(A)⁹ (“highly annoyed”), and more than 15% to levels above 65 L_{dn} dB(A) (“detrimental to health”).

Further to the Commission proposal for a Directive relating to the assessment and management of Environmental noise (COM(2000)468), the European Parliament and Council have adopted Directive 2002/49/EC of 25 June 2002 whose main aim is to provide a common basis for tackling the noise problem across the EU.

Urban quality: Urban quality can heavily influence the attractiveness of an area or region. The ability to for example take a pleasant walk, with clean air, in a well managed urban environment increases residents quality of life.

From the above it should be clear that environmental issues will remain central to transport policy making for a long time. Urban road user charging (RUC) will not be an exception to this rule. Rather, the relation between urban road user charging and environmental issues is close and twofold. First, with an appropriate design, road user charging schemes can be used to help tackling several of those environmental problems that are caused by traffic (as will be shown in section 9.3 below). This should be acknowledged, also in those cases where charging is introduced primarily for congestion reasons. Calthrop and Proost (1998) point to the fact that any transport policy should consider all externalities (i.e., congestion and environment) *simultaneously*. But secondly also (and as will be shown in section 9.4), public environmental concern may increase the acceptability of road user charging generally. This is a very important aspect, since lack of acceptability is otherwise known to be the main stumbling block for practical implementation of theoretically sound charging policies.

9.3 WHAT DO WE KNOW ABOUT THE THEME?

9.3.1 Green-house gas reductions – Fossil carbon–dioxide.

Climate change is a global threat, and green-house gases are equally harmful irrespective of where they are emitted. Many (in particular economists) would therefore argue that *local* RUC has little relevance to CO₂ policy (Johansson-Stenman 2005). Never the less, there is reason

⁸ EEA (European Environment Agency) (2005) The European environment state and outlook 2005, page 99.

⁹ Noise levels vary considerably over the day, and noise is more disturbing during night time. L_{dn} is an aggregate descriptor, averaging over the whole day and night, but with an extra penalty for noise during night.

to include CO₂ in the discussion here since it is currently considered to be the most difficult and important future environmental threat from transport, and since general CO₂ arguments (“car traffic has to be reduced”) are commonly used to support RUC policy.

For any given fossil fuel, carbon-dioxide emissions will be proportional to fuel consumption. Any urban RUC scheme designed to reduce vehicle mileage in the charged area, will thus reduce fuel consumption and CO₂ emissions accordingly. On top of that driving behaviour will also change. In most cases, this reduction of mileage will contribute to a somewhat more-than-proportional effect in CO₂ emissions, since driving in congested stop-and-go conditions consumes more fuel than driving at even, self-selected, speed. Generally, traffic conditions are important determinants of emission factors. For example, fuel consumption factors may vary by a factor 2 between different street types (Ericsson and Brundell-Freij, 2001).

However, current empirical evidence seems to indicate that when aggregated, the effect RUC has on fuel consumption factors is almost negligible (compared to the first-order effect of reduced vehicle mileage). In the Stockholm trial, the overall reduction of vehicle mileage was estimated to be 14% within the charging cordon, and 3% on a regional level (county). A model that took these reductions into account, but also accounted for changed speed profiles (and consequently changing emission factors), estimated the corresponding reduction in CO₂ emissions to be 15% and 3%, respectively. The additional reduction due to more even speed profiles was thus not more than 1%. (Carlsson *et al*, 2006)

Without doubt, any policy that should contribute significantly to the required reductions in CO₂ emissions has to be applied on a national scale. Having said that, however, the reductions obtainable from local urban RUC are considerable compared to other potential local-regional policy measures. In the Stockholm case, the congestion charging contributed more to CO₂ reductions in the county than the top listed measure on the regional authority’s action plan for reduction of CO₂ emissions from transport.

9.3.2 Local air quality

There is a general consensus that local exhaust emissions from traffic are a serious threat to life and health of urban populations. As was shown above, concentrations of harmful substances (in particular particulate matter, PM) are often considerably higher than those maximum levels and targets for environmental quality that has been set by European law. As a consequence, local authorities in major cities are legally bound to take action to reduce these concentrations. In this chapter, immissions refers to the reception of material, such as pollutants, by the environment and from any source.

For health effects of local air quality, too, both those types of contributions that were discussed above for greenhouse gases (reduction in vehicle mileage and emission factors, respectively) apply¹⁰. But in addition to these, a third factor contributes to an overall disproportionate positive effect: With Urban RUC, reductions in immissions are typically larger than reductions in emission, since reductions appear where people are most exposed to them – that is in densely populated (day and/or night) city centers.

As was the case for CO₂, the effect from reduced mileage on local air quality seems to outweigh the effect of reduced emission factors. However, the effect of “efficiently” located emission reductions may be considerable. In Stockholm county as a whole the average *immissions* of exhaust-related PM₁₀ fell by 6% during the trial (that is, aggregating concentrations, and weighing them by the number of affected inhabitants). Thus, the fact that

¹⁰ For PM₁₀ and NO_x, the relation between speed profiles and emissions are more complex and vehicle-dependent than for CO₂. Beevers and Carslaw (2005) conducted emission simulations based on measured speed data from London central zone, before and after the introduction of congestion charging. For one vehicle types they even found that PM₁₀ emission factors increased somewhat (4%) when charging was introduced. For those vehicles, the increase in speed (leading to higher emissions), outweighed the positive effect of less speed variation. However, also in this case, the effect of reduced mileage dominated over the change in emission factors.

emissions were reduced where people were most exposed to them doubled the effect from what would have been achieved if the (3%) reduction in mileage had been evenly distributed in the county. (SLB analys 2006)

In London, total NO_x emissions were estimated to have decreased by 12% within the zone, while there was a corresponding increase on the inner ring road of 1,5%. There has been concern (dating as long back as Buchanan (1963)) that second-best charging scheme designs (i. e toll rings or zone-based systems), may divert traffic, and thereby re-allocate air quality problems without necessarily reducing them. In the typical case, however, population density will be higher in the area from which traffic is diverted, than around those ring roads where there will be an increase. This supports the hypothesis that air quality (as an average over the affected population) will improve. Never the less, there may be cases when the redistribution of traffic creates new environmental problems. Not least from an acceptability perspective, there may be reason to consider the potential regressive redistribution of welfare that may arise from relieving environmental pressure from (well-off) central districts, by moving those problems to less privileged suburban neighbourhoods. (Jones (1998)) Such effects can be compensated by a combination of measures in different package solutions.

It should be noted that for most locations where environmental quality targets are exceeded, RUC alone will not be able to solve the problem unless extreme charges are being implemented locally. Often, traffic volumes will have to be reduced by a factor 2 or more, since background levels of PM from other sources than traffic is considerable. However, already those reductions that may be achieved through RUC imply substantial health effects. In Stockholm it was estimated - based on a recent Norwegian study of dose-response relationships (Naftstad *et al*, 2004) - that 25-30 premature deaths per year could be avoided if the lower concentrations of PM10 implied by congestion charging would be maintained.

9.3.3 Noise

In principle, traffic volume reductions is the most efficient way to reduce traffic noise disturbance, since such a reduction affects all noise everywhere simultaneously (f ex both outdoors and indoors, in contrast to exchange of windows). However, there is a problem in that very large reductions in traffic are necessary for the noise reduction to be noticeable, due to the non-linear sensitivity of the ear. A doubling of traffic is experienced as a just-about-noticeable increase in noise.

But the degree to which people are disturbed by traffic noise is highly individual and varies with emotional state and situation. Thus, also reductions that are too small to be “observable” (on average) will cause some individuals to be less disturbed than they would otherwise have been.

There is an option that charging could be used with the aim to reduce noise, for example, by differentiating prices in sensitive areas and/or in sensitive periods of time such as night time.

The traffic reductions achieved in the Stockholm trial would be expected to lead to an average reduction in noise of approximately 1 dB(A) (Miljöförvaltningen 2006). This prediction was also confirmed by measurements.

9.3.4 Urban quality – Liveability and townscape

Urban streets are not only for (vehicle) travel but also for living and being, seeing and experiencing, walking and talking. Excessive car traffic is known to deteriorate the quality of all those activities.

In Stockholm, opinion polls show that inner city inhabitants were generally more positive to charging than people living elsewhere. (Winslott Hiselius *et al.*, 2007) (In Stockholm this was despite the fact that detailed analysis showed that inner city inhabitants paid more charges and gained less travel time than others). One possible explanation for the positive attitudes

among inner city inhabitants was the extra benefits in liveability gained by those that spend more time (outside their car) in the neighbourhoods where car traffic is reduced.

However the attempts to measure these qualities by objective criteria in Stockholm were less successful. Neither “objective” criteria evaluated by expert architects (Gehl architects, 2006), nor subjective assessment as reported in a postal survey (Transek, 2006a), gave clear indications that liveability qualities had improved overall.

Neither are there clear indications in the corresponding studies relating to the London scheme, that the public have perceived an improvement of liveability aspects. Both citizens living inside, and outside, the charging zone refer predominantly to “reduction of congestion” as the main personal benefit of the scheme, and none of the 5 most frequently given (unprompted) responses referred explicitly to liveability (MORI, 2004). However, it is possible that there was never the less a (hidden) difference in the hypothesised direction. “Reduced congestion” may be used synonymously to “lesser travel time” by people going into the zone, while the same response may mean “emptier, nicer streets” when given by someone who lives there.

Where liveability and urban quality is regarded as a central objective for charging, it would often be possible to further enhance those effects through reallocation of “freed” road space to pedestrians and bicycles. This could be achieved for example by pedestrianisation (concentrating vehicle traffic to some streets), or reducing the number of lanes open to vehicle traffic, and widen sidewalks and introduce bicycle lanes instead. With such policies, speed of vehicular traffic will not (or only to a lesser extent) be reduced, despite a reduction in motorised traffic. Instead, that benefit will be exchanged for an improvement of the urban qualities for non-motorised road users (May, 1975).

9.3.5 Car fleet transition

According to EU policy a substantial part of necessary reductions in greenhouse gas emissions are forecasted to arise from a transition of the car fleet - from fossil fuel based to bio fuel based, and from cars with high energy consumption to more fuel efficient models. For this transition to take place, however, governments have to rely on the purchases of private car owners. Therefore, many countries are looking for incentives that may increase consumers’ willingness to buy “greener” cars. In such policies, RUC may play a role. Allowing green cars to be exempted from paying the charge will reduce life-cycle costs of owning such a car considerably. In practical implementation green cars in Stockholm have been exempted from paying charge all together. However, price differentiation might be another option where “green cars” pay the “correct” price with respect to the specific targets and all others pay even more.

Although the Stockholm charging trial lasted only 7 months, there is anecdotic evidence that the fact that the scheme exempted green cars helped boosting the market. Also, this hypothesis is - if not confirmed - at least supported, by the fact that the share of “green” new cars on the market increased more in Stockholm than the Swedish average during the same period.

Modelled predictions of changes in the Swedish car fleet also indicate that other cost-reduction incentives of approximately the same total magnitude may have significant effect on the propensity to buy green cars, as well as car renewal rate for those affected. (Naturvårdsverket 2007) It has to be remembered, though, that it is typically only a small number of car drivers who will have much to gain by being exempted from charging. In a studied 2-week period during the Stockholm trial, less than 5% of the private cars registered in the county paid more than the equivalent to €25. (Transek 2006b)

The larger the part of the car fleet that is exempt from charges is, the smaller effect will charging have on vehicle mileage. Therefore, before adopting an exemption policy for green cars, the balance between beneficial effects on car fleet composition on one hand, and

detrimental effects on congestion relief, on the other, has to be carefully considered. The Swedish parliament's decision to introduce congestion charges on a permanent basis in Stockholm, included a time-limited exemption for green cars. For the first five years of charging (when the number of green cars in the fleet is forecasted to be relatively low, and incentives at the same time can be expected to be necessary to set off the market) green cars will be exempt from charges. After this period (when a non-negligible part of congestion will be due to green cars), this exemption will be explicitly reconsidered.

9.3.6 New infrastructure

In the intense debate on transport and the environment, one of the more overlooked negative effects is the intrusion into natural landscapes, recreational areas and ecosystems. EEA (2005) shows that from 1990 to 2000 "artificial land cover" – which is areas used for housing, industries, transport networks etc - increased by more than 10000 km² in Europe. The major part of this uptake is due to housing, commerce and industry, but transport infrastructure adds to the picture.

Although there is now a broad consensus among researchers that metropolitan congestion can generally not be built away (Goodwin, 1997), neither political actors nor the public seems willing to accept this fact. If there is congestion, there will be public opinion pressure that new infrastructure is "needed". Reversely, we would expect it to be simpler to protect natural landscapes from artificial intrusion if congestion is successfully tackled by other means, such as charging.

Theoretically, (from a normative transport economics perspective) it can be shown that congestion charging may either increase or decrease the overall social benefit of infrastructure investment (WSP Analys & Strategi, 2007), depending on the detailed function of the networks and activity systems involved. However when the effect of three real suggested investment programs in Stockholm were simulated with, and without congestion charging respectively, it turned out that the aforementioned expected gut reaction from the public was "right". For all three investment programs, aggregated benefits decreased substantially if congestion charging was first introduced. Thereby social profitability decreased and (theoretically) the political desirability of building new infrastructure.

The argument to introduce congestion charging to save ecosystems from exploitation is not only theoretical. The Swedish Society for Nature Conservation (www.snf.se) have for many years been very active in the political debate for congestion charging. Their main motive for being so is their conviction that only with RUC will it be possible to avoid new ring roads in the rural landscapes around Stockholm.

9.4 WHAT ARE THE POLICY IMPLICATIONS?

As was shown in Section 9.3, urban road traffic causes large environmental problems, and urban road user charging schemes may – if appropriately designed – improve urban environmental quality. There is therefore reason to consider RUC not only from a congestion perspective, but also based on environmental considerations. There may even be cases when, even though congestion problems are not large enough to motivate charging, environmental problems per se would make charging a reasonable policy option.

In setting the detailed design, however, policymakers will often have to balance optimality with respect to these two objectives, against each other. Some examples:

- A highly time-variable charge may be the most efficient for congestion reduction (giving incentives for departure time change for those car drivers that are unwilling to change mode). From an environmental perspective, however, it may be better to press harder for mode choice, through a more uniform charge over the day.
- From a noise perspective, the more traffic there is on a road the lower the marginal noise costs are. Hence, charging should be high in congested areas or times for

- reducing congestion, while prices should be high at nighttimes or in sensible areas for reducing noise.
- From a congestion perspective, it will often be desirable to divert car traffic to ring roads. This may sometimes increase overall mileage (adverse climate effects), and may increase local environmental problems in previously less problematic areas.
 - For the use of charging revenues, a policy maker aiming for congestion relief is likely to focus those investments that will further support that objective – such as investment in new road infrastructure. Increase in road capacity will increase the demand for vehicle traffic generally and therefore imply adverse climate effects. A policy maker who has, instead, her focus on environment would prefer to use the money for, for example, improving public transport.
 - If the charging scheme is to be used as an incentive for car fleet transition (exemption for green cars), this ambition has to be balanced against the detrimental effect such exemptions will have on congestion reduction.

When it comes to formulating and implementing a charging scheme in practice, however, there will in most cases be more synergy than conflicts between the two objectives “reducing congestion” and “improving environment”. Perhaps most importantly: a combination of the two objectives is likely to increase the number of citizens who agree that “*there is a problem (congestion or environment) that need to be solved*”. Obtaining agreement on this point has been shown to be one of the major determinants of public acceptance for charging (Schade, 2003). Of the two objectives – reducing congestion and improving environment – delivery versus the second may be the most important to find public support. Jaensirisak *et al* (2005) found that among the potential impacts of charging, “*an ability to achieve substantial environmental improvements*” was the single most important contributor to increased acceptability, followed by “*contributions to reducing delayed time for cars*”.

9.5 WHAT IMPLICATIONS DOES THIS THEME HAVE ON OTHER THEMES IN THE SOAR?

Based on the results and conclusions above, we find that there are many links between the environmental perspective on RUC, and themes discussed elsewhere in this report.

- **Objectives:** Environmental effects should be considered when objectives are formulated for a charging scheme.
- **Scheme Design:** Environmental ambitions should affect for the scheme design in terms of the *type* of scheme (toll ring, zone), *location* of cordon and control stations, level of *charges*, *variability* of charges, and potential *exemptions*.
- **Prediction:** *The prediction of environmental effect requires several additional models to those needed for the prediction of volume and congestion effects. To be able to assess a suggested charging scheme with respect to its environmental consequences, we should ideally be able to predict speed variation and noise as a function of volume, emission factors as a function of speed profiles, air quality (concentrations) as a function of emissions, immissions (affected population) as a function of air quality and noise, and health effects as a function of immissions.*
- **Evaluation and Appraisal:** Environmental effects should be considered as an integral part of a multi-criteria appraisal. Relevant values of health effects and other environmental consequences have not yet been researched to an extent as compared with elements traditionally regarded as important in appraisal such as the value of time. Also, it must be borne in mind that the appraisal of environmental effects is subject to fundamental uncertainty linked to the problems of how risks and (very) long-term effects should influence decision making.

- **Acceptability:** Finally, and as was pointed out in Section 9.4, the expected environmental effects plays an important role for public acceptability of a proposed charging scheme. Failing to analyse the environmental aspects of a charging policy, may well prohibit its implementation altogether, even if that policy is suggested and designed from a congestion perspective.

9.6 WHAT GAPS EXIST IN OUR KNOWLEDGE ABOUT THE THEME?

Based on the conducted literature study, we conclude that the primary target areas for future research on this topic should be the following:

Firstly, it is unclear as to the effect that congestion “in itself” (driving characteristics) has on emissions. There seems to be a general assumption among the public as well as “congested-oriented” traffic researchers, that reducing *congestion* (less stop-and-go, more “smooth” driving) is important to improve urban air quality. The limited research in this area seems less conclusive, and does anyway point clearly to the fact that reducing *volumes* is much more important than reducing *congestion* per se.

Secondly, there seems to be an opportunity for cross-disciplinary research centred on consensus-building for charging based on combinations of congestion and environment arguments. To which extent do these arguments appeal to the same segment of voters? To which extent are those arguments automatically conflicting through basic antipathy (so that, e.g. those that want to support an environmental policy, would be against if it turned out to reduce congestion).

Finally, there is a need to combine analyses of short term adaptation to charging, and long term decisions with respect to car ownership. Only on the basis of such a combined analysis would it be possible to identify reasonably “optimal” combined strategies with respect to charging exemptions (or reductions) for green cars, other types of economic incentives for car fleet transition, and charging effectiveness.