Air åpollution - Contolling dust in winter Oslo

Table of Content

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This is an excellent paper. Compared to ECN 375, it is longer than 20 pages, as the guidelines when this paper was written was aprx. 30 papges.

Abstract

The aim of this assignment is to analyze different ways of reducing suspended dust in Oslo, and to see how the different tools interact with each other. The introduction of taxes on vehicles driving with studded tires, raising the toll ring fare during rush hours and reducing speed on the main fare troughs is meant to reduce the occurrence of PM_{10}. The usage of salt is a presupposition for the effectiveness of the tax on studded tires. Our analysis shows that even though each of the measures yield a positive result alone, neither of them is effective enough to stand alone. Combined, however there can be a result closer to the optimum, and certainly good enough to reach the constraint. We also expect an even better result if there is a satisfactory public transport system in place.

1. Introduction

One of the main urban pollution problems is the occurrence of dust. Dust is particularly harmful to children and people with allergies and respiratory conditions, and is mainly caused by traffic and smoke from burning wood. Air pollution along the roads primarily consists of NO_x- gaseous and particulate matter (PM_{10}). The concentration of nitrogen-gaseous is affected by the volume of the traffic and weather conditions such as precipitation, temperature, wind-direction and strength.

In the Norwegian law on pollution the municipalities appear as the pollution authority. Each municipality is responsible to make sure that the provisions are abided. The regulation determines marginal values for different rates of concentration of for example dust caused by traffic. The principals, here: Oslo municipality, are responsible for implementing adequate efforts, to “make up” for the environmental abatement, e.g. by ensuring that the fine is so high that the agents choose to abide the law.

Air pollution can roughly be divided into two aspects; dust in suspension and chimney smoke. In this paper, we choose to isolate the traffic from chimney smoke, to shed light on the problems of dust from traffic in Oslo. Among many different policy instruments, we have chosen to examine four which are meant to reduce the suspension of dust; (1) increase the amount of non-studded tires, (2) using salt instead of gravel to improve road conditions in the winter time, (3) reducing speed, and (4) reduce the traffic volume.

As the largest city in Norway, Oslo has had dust problems compatible to those of metropolitans like Madrid and Paris (Statens veivesen A). We would thus like to examine the dust problem in Oslo with a box of environment-enhancing tools and shed light on the complexity of the problem. The municipality has carried out several initiatives related to the dust problem, to different degrees of success.

Our problem statement is as follows:

In which way will our chosen measures reduce the occurrence of dust in Oslo? Which strengths and weaknesses do these economic instruments have, and to what degree are these instruments effective in environmental and economic terms?

Increasing taxes and fees, traffic diversion, and information campaigns are amongst other things possible instruments to combat traffic pollution. These could cover several environmental problems, but with different transaction costs. Whether the occurrence of dust is an externalized or internalized effect, is a matter of how you view the different roles of the local government. Furthermore, incentive systems, monitoring and enforcement are important parts of the problem.

2. Background and History

In Oslo, the local air pollution is at it's highest on cold, dry and calm days. Traffic, smoke from wood burning and industry all contribute, but traffic is the main culprit. Particularly vehicles with studded tires cause dust, which traffic again whirls up. With no circulation in the air, the dust goes up and falls straight down, culminating in a local problem.

The dust concerned with in this paper is in terminology called PM_{10} - particulated matter (dust fragments) with diameter less than ten micro meter. The national limit of dust occurrence in Norway, which is also compatible with the EU's standard, is set to 50 µg /m^3 (50 micro grams per cubic metre of air). According to the binding limit which was introduced in 2005, this limit should not be exceeded more than seven days per year. Certain central areas of Oslo stand out, particularly the central east part of the city, lower parts of Groruddalen, in addition to the main fare through in and out of Oslo along E6 and E18.

Figure 1: Map of Oslo where the red areas indicate areas where the day middle value >50 µg/m^3 is exceeded more than the annual limit prior to 2005, namely 35 days (Source: Oslo kommune og Statens vegvesen region øst 2004*).*

Measures have been taken to reduce the amount of dust, particularly on cold days. Information campaigns, speed reductions, road cleaning, and taxes on the usage of studded tires have all been implemented to a larger or smaller degree and success. In 1997, Oslo municipality introduced the latter-mentioned tax as a mean of reducing the number of vehicles using studded tires. But as the goal of 80 % non-studded vehicles was within reach only after a few seasons, the tax was abolished. However, in 2004 it was again reintroduced as the previous positive trend did not continue.

2.1 Suggested Policies

In this paper, the following measures will be discussed as attempts to reducing the level of dust and will be seen in lieu of the use of studded and non-studded tires:

- Tax on studded tires
- Salt and gravel
- Reduced speed
- Traffic reduction

Salt has been used on the Norwegian road network since before 1970 and has gradually increased in popularity. However, there are environmental as well as health and safety aspects related to the use of salt. Speed reduction makes traffic float smoother with less acceleration and breaking. The downside is the feeling of lost time when road conditions allow for increased speed. Furthermore, taxes such as the tax on studded tires have previously proven successful, though the hot potato is the actual purpose of the tax. At what level should the tax be set and which externalities are environmentally, economically, morally, and legally relevant? There's no doubt that a total reduction of vehicles passing through Oslo will have a positive effect on the pollution level. However, forecasts tell of increased future needs for communication. How is it possible to combine these?

3. Status Quo and Optimality - A Bird's Perspective

In this paper, we assume that the situation is unregulated. This is obviously not correct, but an assumption we choose to work under in order to make the effects of our suggested tools clearer.

The rationale behind solving an environmental problem is that an environmental problem creates a net welfare loss. This induces another constraint to our analysis; the policies to solve these problems can not have unintended welfare losses that are greater than the increase in welfare they yield. In this chapter, we will view the indirect effects of our selected tools to decrease the amount of dust created by the traffic in Oslo.

Today's situation yields a welfare loss that is bigger than what the municipality is ready to accept. In the figure below, the welfare loss is indicated by the coloured area. The optimum however is marked by q*, but it is not likely to be achieved in the near future. One reason for this is that the total amount of traffic in Oslo area is expected to continue to grow with 10% within the next ten years (Statens vegvesen region øst 2004).

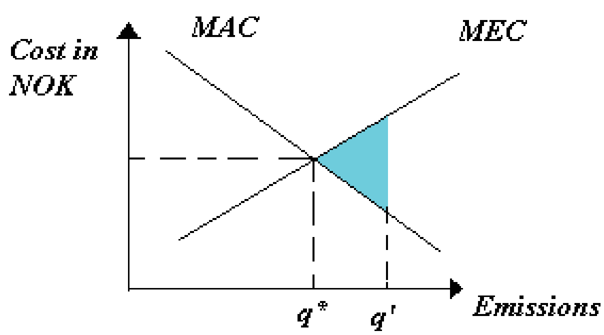


Figure 2: The initial situation q' and the optimum q*. The dead weight loss is indicated by the coloured area.

Oslo municipality has made a plan of action to reduce the occurrence of dust in the inner parts of the city. Oslo municipality introduced a constraint at to how much dust they can allow in a 24 hour period. This is to reduce the dead weigh loss (DWL), but at present they have no penalty mechanisms when the limit is breached. As a matter of fact they allow 7 breaches each year, as the grace factor.

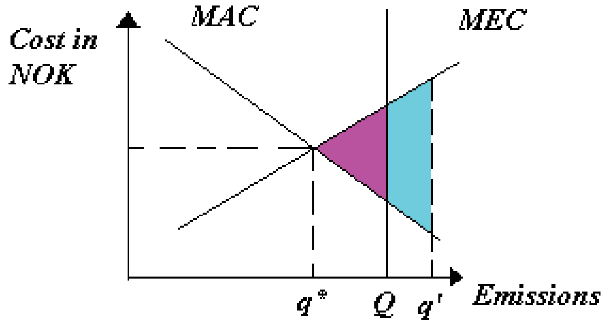


Figure 3 The current situation, including the municipalitys constraint and the reduction of DWL. q' indicates the initial level, Q the municiplalities chosen constraint, and q* optimum. The coloured area indicates the DWL.

As one can see from figure 3, the DWL is reduced if the constraint is met. The optimum represents the best combination of policies, but as we know the best solution is rarely available. Our goal in this paper is to present a mix of tool that takes us as close as possible this point. Each of the policies also includes some effects that yield some positive or negative change in welfare. We can not fully account for these effects, but we will try to show the outlines of these secondary effects.

We have tried to illustrate how the different policies will change people's welfare. By this we mean both the health gain people will have of lower concentration of dust, and also people's safety in terms of reduced risk of traffic accidents.

3.1 Salted roads

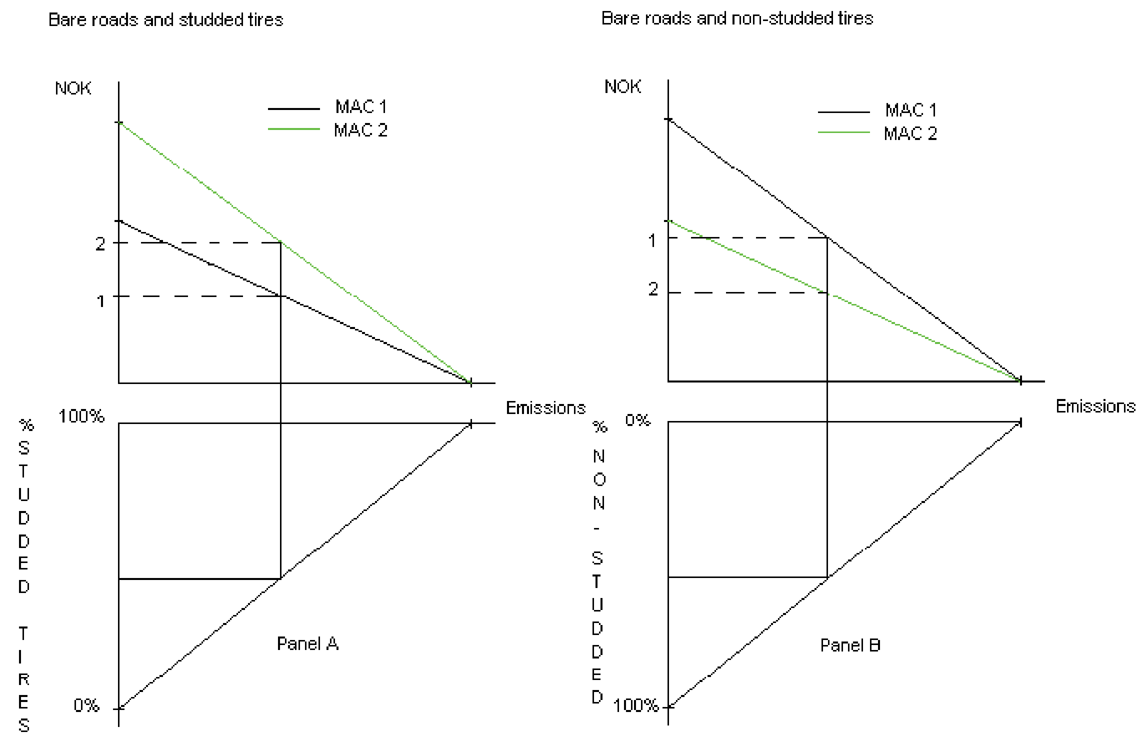


Figure 4 Panel A: Bare roads and studded tires. Panel B: Bare roads and non-studded tires. MAC 1 in the topmost graph represents the initial MAC curve. MAC 2 in the topmost graph represents the welfare gain/loss when you take traffic safety, clean air and health conditions into consideration.

Salt is used to de-ice roads in Norway. Studded tires are invented for snow and icy road conditions, so driving with studded tires on bare roads are in fact dangerous from a safety perspective.

Panel A above helps to illustrate that when driving with studded tires on bare roads, the MAC curve will shift out as a consequence of increased dust. The social costs in NOK for driving with studded tires increases from point 1 (initial) to point 2. This is a welfare loss, and therefore not an optimal solution.

Panel B above shows that if you drive on bare roads with non-studded tires, the MAC curve will shift inwards, and represent a welfare gain. The traffic safety is increased because you drive with the appropriate tires for this type of road condition. Driving with these types of tires will also make a difference in terms of local air pollution as these tires don’t tear and wear the asphalt to the same extent as studded tires, consequently producing less dust. We then have a situation where the costs per unit of social welfare will shift down from point 1 (initial) to point 2.

3.2 Snow-covered roads

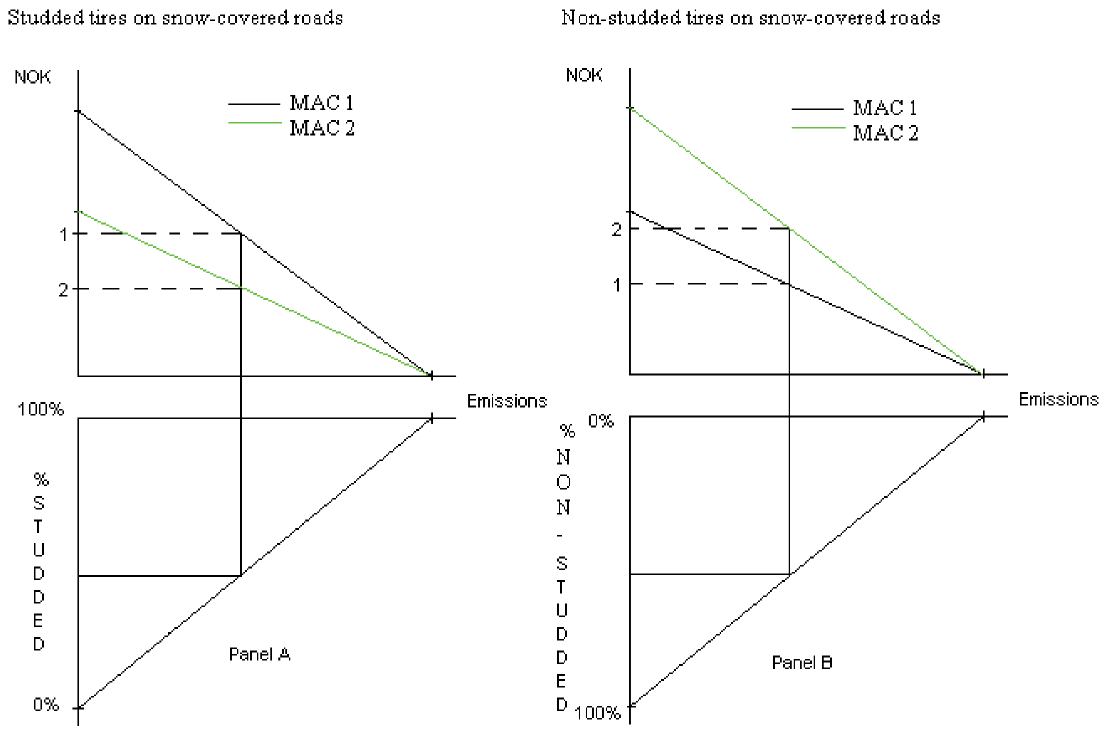


Figure 5: Panel A: Studded tires on snow-covered roads. Panel B: Non-studded tires on snow-covered roads. MAC 2 in the topmost graph represents the initial MAC curve. MAC 2 in the topmost graph represents the welfare gain/loss when you take traffic safety, clean air and health conditions into consideration.

Studded tires are considered the best option if you drive on roads that are covered with snow and ice. In the left graph above figure 5, panel A, (driving with studded tires on snow-covered roads), we will have a welfare gain in terms of safety and thus a health related gain. Although dust is barely produced under these terms, the traffic safety is increased as studded tires are considered safer under these conditions. On the other hand, driving with non-studded tires does not produce dust on snow and ice, but they are not that safe under these types of conditions. That’s why the graphs emphasize that driving with studded tires is the best solution in this case.

3.3 Speed and traffic volume

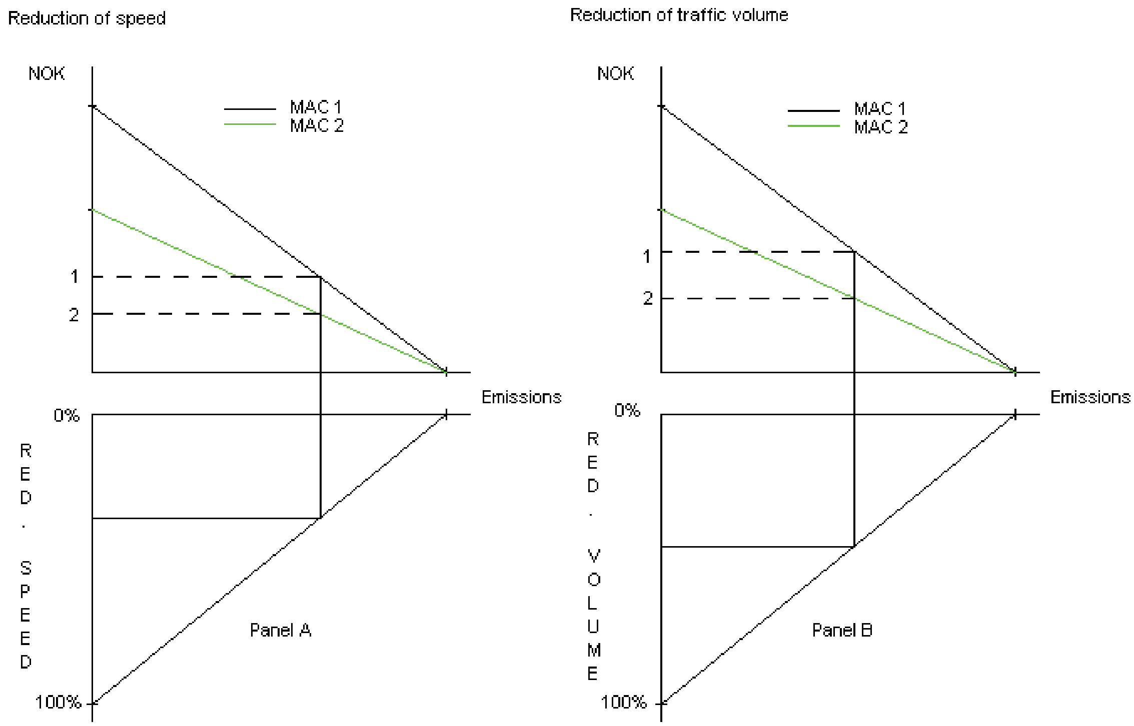


Figure 6: Panel A: Reduction of speed. Panel B: Reduction of traffic volume. MAC 1 in the topmost graph represents the initial MAC curve. MAC 2 in the topmost graph represents the welfare gain/loss when you take traffic safety, clean air and health conditions into consideration.

Figure 6 shows the two last policies we are going to discuss. Panel A shows the reduction of speed, and panel B pictures reduction of traffic volume.

Reduction of speed will make the traffic run smoother, and you will not have the negative effect of stopping and starting the car all the time. This will be positive in terms of the production of dust. By reducing the speed, you also get a positive effect on traffic safety. Research shows that by reducing the speed limit, you will get a positive effect in terms of fewer sewer accidents; hence fewer people get injured or worse, killed (Ragnøy 2004: IV). We see that a reduction in speed will have a net welfare gain, and moving the costs from 1 down to 2.

Reducing the traffic volume will also have many positive effects. Fewer cars in the city centre will make the traffic flow easier. This will have a positive effect both health related, traffic safety (both for other drivers as well as pedestrians – less chance of being run over by a car when there are fewer cars) and environmentally. Again, we see that the costs will shift from point 1 down to point 2.

4. Measures

To view the problem regarding PM_{10} as a purely economic problem is not possible. In this case we need to see the connection between the physical environment and the economy. The polluted air is a part of the biosphere. The biosphere in turn influences the economic possibilities the society has (Vatn 2005: 247). The biosphere has a capacity to neutralize a certain amount of emissions, but when that capacity is reached, both the physical and economic environment is degraded. PM_{10} occurs naturally and in small concentrations it is not harmful. The challenge is to find the optimal amount of emission (Vatn 2005: 371).

4.1 Tax on Studded Tires

Studded tires are the safest option on snowy and icy roads, but can be dangerous on bare roads. They don't give enough grip on asphalt, but are clearly better under harsh winter conditions like snow and ice. Studded tires produce up to 100 times more dust than non-studded tires on bare roads (Statens vegvesen B:42). That's why Oslo City council now has re-implemented tax on studded tires and they hope that this will reduce the number of studded tires in Oslo. During the time period 1998 – 2001, the percentage of cars using non-studded tires went from 50 % to 80 %, and there was also a significant decline in the concentration of PM_{10} (Müllerström et al. 2004). The tax was taken away in spring 2001, due to the target being met. However, figure 9 shows that there was a steady increase of PM_{10} after the removal. This can be a result of both weather conditions and the fact that the tax was taken away. The Oslo City council saw this development, and in 2004 they decided that the tax should be re-implemented and has been so ever since (Müllerström et al. 2004).

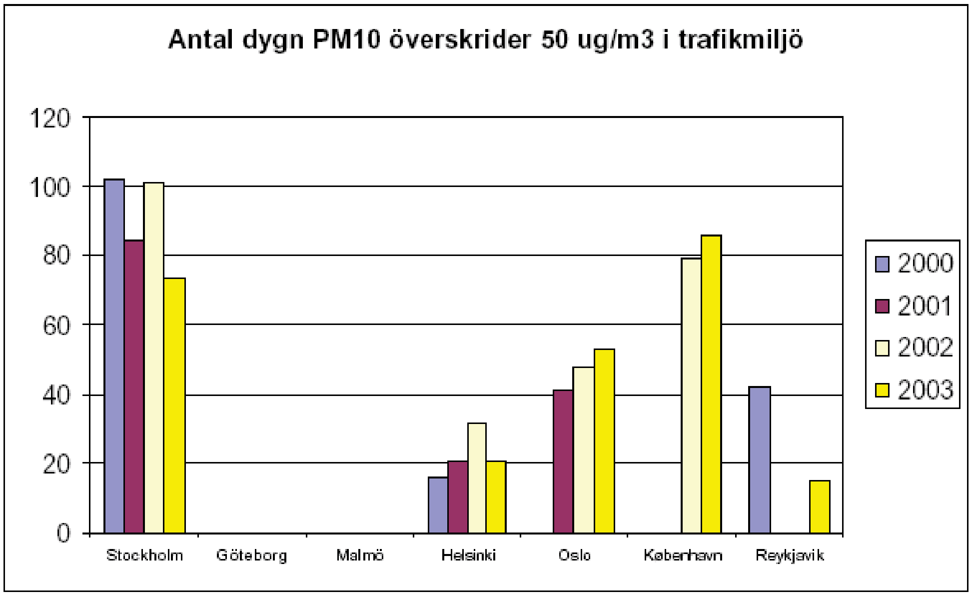


Figure 9: Number of days when PM_{10} exceed allowed value (Müllerström et al. 2004).

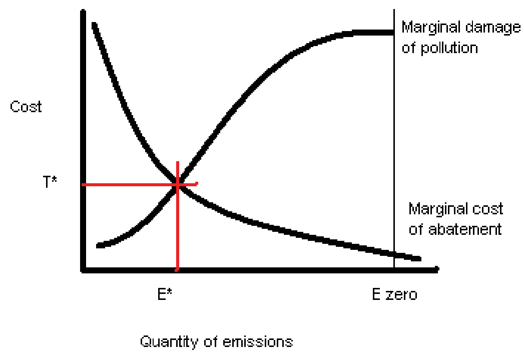
To have permission to drive in Oslo with studded tires, the car owner/car driver has to buy a token. You can choose between day pass, month pass or season pass. The prices are as follows:

Table 1: Fees on studded tires (Source:Oslo kommune, Samferdselsetaten 2007)

	Day pass	Month pass	Season pass
Small car (under 3,5 tons)	30	400	1 200
Big car (over 3,5 tons)	60	800	2 400

Trucks and larger vehicles have to pay a fee that is double of what smaller cars have to pay. The reason for this is that they produce more dust, and also contribute to spread and whirl up more dust than smaller cars.

A Pigovian tax can be defined as a tax on a firm or persons who pollute the environment or create negative externalities. One of the main reasons of this tax is to discourage activity that has negative externalities or can be harmful to the environment and/or society. A Pigovian tax has to be set equal to marginal (social) damages, but these costs are difficult to measure. The graph below illustrates this.



Figur 7: Pigovian tax. T* = optimal tax or fee; E* = optimal emissions level; E zero = current or initial emissions (Source: Sterner 2003:72).

Initial emissions are at E zero. This level of emission is not preferable, and we want to reduce it. A Pigovian tax is set at the level T*, where the marginal damage cost equals the MAC.

A Pigovian tax is a way of internalizing the externalities by a tax equal to the marginal cost of the environmental damage caused by for example driving with studded tires. As we know, driving with these tires, we produce dust that is harmful to people and pollutive. Setting a tax that is equal to the cost of driving with studded tires can motivate people to choose other kinds of tires. This result is the desired one when using a policy instrument (Sterner 2003: 71-72).

Since Oslo is a city in south-east Norway, the winters are relatively short and dry. But outside of Oslo, where there is more snow, commuters to Oslo might prefer studded tires because the conditions are more suitable for driving with these types of tires there. But when they drive too and in Oslo city centre, studded tires are superfluous and can also be dangerous in terms of road safety. Information is thus needed, so that people are aware of the problem and maybe change tires or find another way of commuting to work in the city.

The MAC curves that illustrate the costs per units of abatement, looks different when you use studded tires and non-studded tires. The different types of tires represent different types of driving conditions, and when you drive on the wrong kind of tires, it can be dangerous. The MAC curve will shift out and in according to which type of conditions you drive on. The optimal place for the MAC curve is less steep than the initial MAC curve. This represents a lower cost per unit social welfare.

4.2 Salt and Gravel

Warm mid-winter months mean slippery conditions and, consequently, an abundant use of salt. At first, salting of roads was used to reduce the risk of accidents during rough driving-conditions. A report done by SINTEF proves that the road accident rate has decreased in the five year period the report deals with. It shows that accidents caused by driving are reduced by 20 % on salted conditions in the winter time (SINTEF 1995: 7).

When we have precipitation and ice, the salt makes the freezing point go down. In other words, the salt prevents the snow to pack so it will be easier to clear the road. Another good thing about salt is that it is preventive against the forming of ice layers, and even if an ice layer has already formed, the salt will melt this. However, the temperature is crucial. The optimal salting temperature is between +0.5 to -8 ºC but under special conditions salting might take place below -8 ºC.

Gravel causes more dust both on snow-covered and on bare roads in conjunction with studded tires. It is however often used where and when it is too cold to use salt and/or where the traffic volume is too low for salt to work effectively. Costs of using gravel on roads are much lower than usage of salt for de-icing but causes more dust than salting does. So we assume that salt is preferred above gravel, and keeps a focus here on only salting as a tool.

When driving with studded tires on snow-covered roads, there will be a low amount of dust in suspension, and the gripping power is manageable. But when it comes to traffic volume and driving in urban areas such as Oslo, it does not take long before the snow melts. Road salting is thus only needed in areas where the roads are bare but still slippery.

If the driver uses non-studded tires on bare, salted roads in the winter, he/she will get a better grip and a feeling of assurance compared to studded tires. If we take a closer look at this situation; driving on slippery bare roads with studded tires, we will get a MAC-curve which lies *higher* than the initial one seen from an environmental perspective. However, by using non-studded tires the amount of PM_{10} produced is less than with studs, and will therefore pull the MAC curve in the opposite direction.

One important factor which needs to be taken into account here is the traffic safety. A vehicle with non-studded tires on bare and salted roads has a higher traffic safety than a vehicle which drives with studded tires on the same driving conditions. The traffic safety will decline if the bare road has not been salted. This culminates in the question “What is more harmful to humans?” Respiratory problems caused by traffic dust have to be evaluated against road accidents. Let us assume that traffic accidents are less preferable than allergies and asthma etc. This means that salting is necessary on winter roads in urban areas.

So what impacts on the environment does the use of salt have? Salting can pollute groundwater and have emergent and acute effects on animal lives. It has also a documented negative effect on the vegetation close to the road. The rate of salt application is positively correlated with salt concentrations found in roadside soils (PH Jones et al. 1992). Any chemical de-icer used to clear roadways in winter will eventually be present at detectable levels in the environment. Much of the salt used will infiltrate the groundwater aquifer.

The costs of using salt and gravel have both an environmental and a socio-economic aspect. The use of salt for de-icing roads results in significant private and social cost - that including the costs of maintenance and road repair, vehicle corrosion costs and loss in recreation and aesthetic value through roadside vegetation damages. The amount of corrosion on cars gives the vehicles a lower lifetime. The social costs are greater than the private costs because of the great damages added to the environment. Social costs like pollution, run-off to groundwater aquifers, and accumulation of salts to the adjacent soil and vegetation, and emergent impacts on animal life are more acute than car-corrosion. It is here important to remember the environment on one hand with an intrinsic value, and on the other hand, the health-effects on human beings.

4.3 Reduced Speed

It is scientifically proven that driving at high speed with studded tires on bare asphalt creates more dust than driving at the same speed with non-studded tires. ”In lab-run tests, non-studded tires hardly produce PM_{10}, whereas studded tires produce a lot, and the production increases with increased speed” (Rosland 2005: 3). Figure 7 below shows how the amount of dust created by studded and non-studded tires at different speed.

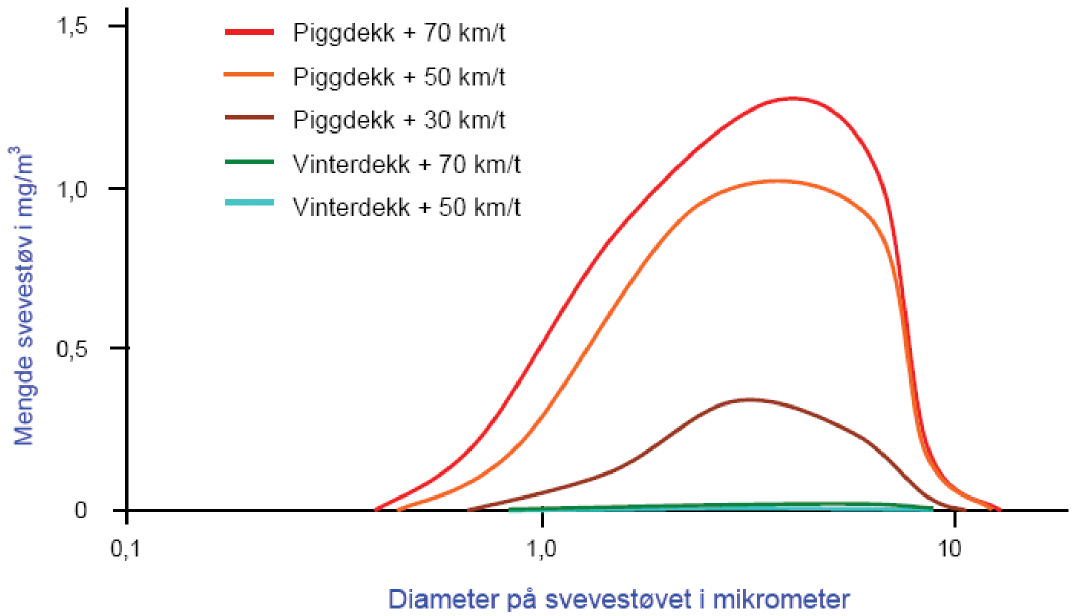


Figure 7 The figure shows the amount of dust with diameter less that 10 micro meter generated by studded and non-studded winter tires. The laboratory tests were run at 30, 50 and 70 km/h. "Piggdekk" is Norwegian for winter tires with studs, and "vinterdekk" means winter tires without studs (Source: Rosland 2005).

One can from this conclude that as long as there are cars driving with studded tires, there are environmental gains from reducing the speed. Similarly, there seem to be no point in reducing the speed if driving with winter tires without studs as these hardly produces any dust. However, one must have in mind these test were run in a lab. In real life there might be more dust on the roads that are being whirled up by traffic.

An interesting finding from the pollution boots scattered around Oslo states the following (Oslo kommune og Statens vegvesen region øst 2004: 28):

1) By main roads and in a distance up to 50-100 metres from road with speed limit above 70-80 km/h, the occurrence of PM_{10} (…) is normally in the interval of 60-90 µg /m^3.
2) In badly affected areas with wood burning and roads with speed limit 50-60 km/h, the occurrence of PM_{10} is normally in the interval of 10-30 µg /m^3.

By reducing the speed, one is thus capable of reducing emissions, meeting and in this example even exceeding the limit value. Converting the facts into a figure and also adding a graph which shows the MAC curves, we get a picture similar to figure 8.

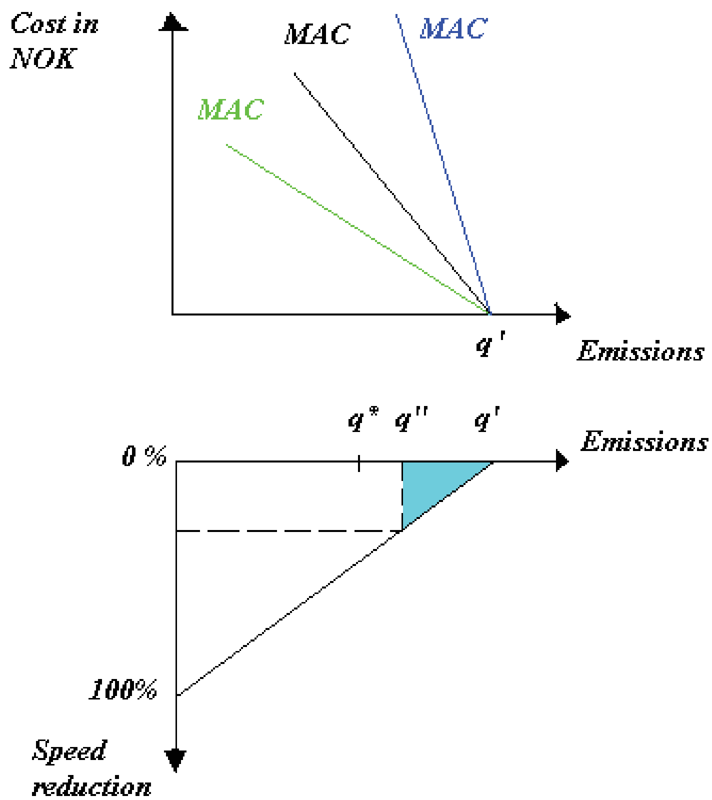


Figure 8 Top: Fluctuating MAC-curves. Bottom: Speed and emission reductions. q' indicates today's emission level, q'' is the obtained value with decreased speed, and q* symbols the desired emission level.

The bottom graph shows how a percentage reduction of speed reduces emisson. With maintaining today's speed limit, the emission level is at ***q'***. With a certain reduction, say 30 %, one can reach ***q''***.

The top graph pictures possible MAC-curves. It is beyond this assignment to discover the real slopes of these, but below follows a discussion of the MAC-curves relative slope.

Estimates Oslo municipality has carried out show that total investment costs of installing digital road signs will be NOK 6 mill (Oslo kommune og Statens vegvesen region øst 2004: 65).[1] This number excludes installation costs and energy needed for the batteries that run the signs. These signs are more costly to introduce but are cheaper and easier to monitor.

[1] The estimates are based on 236 signs on the projected roads of which the speed limit is above 60 km/h. All signs are to be replaced by new ones, each to the price of NOK 37 200. The new signs are run on batteries that are being charged on the existing road lights. For every 20th sign, there need to be a regulation device which costs NOK 42 000. Projected roads are Ring 3 from Lysaker to Ryenkrysset (in total ca 19 km one way), E18 from Lysaker to Bispelokket/Sørenga (in total ca 10 km one way), and Rv4 Sinsen to Kaldbakken/Grorud (in total ca 8 km one way).

From findings and experience from already implemented temporary speed limits in Oslo, 60 km/h seem to be an ideal speed for obtaining the optimal limit value of dust which is 50 μg /m^3. However, 6 mill NOK is a significant cost to 38 km of road (Oslo kommune og Statens vegvesen region øst 2004: 65).

Social costs with reduced speed are the regulation and implementation costs. Furthermore, private costs include lost time. The absolute costs of the latter can be debated as a felt time loss and valuation of time is individual. Moreover, in rush hour traffic, the speed limit and the actual speed of traffic are not equal. A lower speed limit might thus not make real difference in time spent getting from A to B.

To summarize, reduced speed creates a win-win situation from an eco-social perspective no matter studded/ non-studded tires or snow-covered roads/ bare asphalt. Lower speed reduces the whirling of dust, saves lives, creates less pollution with a smoother flow of traffic etc. Presuming the MAC_1 curve in figure 8 is the starting point, higher cost due to implementation may make the total costs move in the direction of the MAC_2 curve. However, the more benefits, the less real costs, and hence a decline in the MAC_3 curve as indicated by the green curve in the graph.

4.4 Traffic Reduction

Traffic above the optimal level causes several environmental and social costs. Therefore reducing the total volume of traffic could be beneficial. In theory road pricing could be implemented as the only Pigovian tax regarding motorized vehicles. Technologies also allow this, which make a record of where and how much you drive. A general knowledge as to how much different types of cars pollute pr driven km combined with this very precise km measurement, allows the principal to account for all damage caused by each car. The principal can therefore include all the social and environmental costs to the tax. If the principal, in this case Oslo municipality, had had this information they could easily tax cars accordingly. This works in theory, but would have tremendous costs, both connected to the transaction and monitoring costs. You would also have an ethical aspect, regarding privacy.

Instead of this, a more manageable solution is to differentiate the pricing of the toll ring, which is currently surrounding the central parts of Oslo. Today there already exists a differentiated pricing system. The price depends on how heavy your car is. A standard car[2] is half the price as a heavy car. Another possibility is to implement a time differentiated toll.

Three cities have already implemented road pricing. Trondheim and Stockholm have a quite similar approach to the pricing scheme, while London has opted for a more dramatic change. Trondheim and Stockholm have higher fees for entering the city by car during the morning rush, and cheaper or free after work hours.

In Trondheim there was a 10 % reduction of cars during the rush hour (Sterner, 2003, ch. 20), but somewhat increased outside of rush hours. In order to get this effect one needs to give the users of the road system a substitute. Most of the traffic in and out of the toll ring in Oslo is related to necessary daily activities like getting back and forth from work. Considered in terms of micro economy this is to be viewed as a necessity and without satisfactory substitutes the demand curve for these goods is vertical. At the moment there are no substitutes that are up to these measures, and therefore one can not expect a behavioural change, as the change in driving cost would imply.

In the case of reducing PM_{10} caused by traffic in Oslo the initial monitoring cost could be fairly low as there already is a toll ring in place. If for example, the tax during the morning rush was to be increased from 20 NOK to 50 NOK per passing and a driver passes one time every Monday – Friday, 48 weeks of a year that would give an increased cost of each driver 7200 NOK per year. This indicates that it is not cheaper to enter the city by car, and gives incentives to either car pooling or to use other means of doing your daily commuting.

In both Stockholm and London are parts of the revenue from the tax is invested in better public transportation. This would also be necessary to do in Oslo, as the capacity on the most heavily trafficked lines is already full. It is reasonable to think that the results in Oslo would resemble the results from Trondheim.

[2] Standard car weighs less than 3,5tons, a heavy car defined as more than 3,5tons

London has introduced a day pass system. This pass is rather expensive (£8 a day) for cars fuelled by petrol or diesel. To simplify monitoring, all cars in the city centre of London must have a pass, even though they may be excepted form paying.

In both London and Stockholm are there made incentives to drive more environmentally friendly cars, as they are exempt from the paying the fee. London is however the only one of these three cities that has graded the tax reduction as to how "clean" your car is. This provides a strong incentive to buy a car with low emissions.

As shown in chapter 3, if the volume of the traffic drops, the slope if the MAC curve is going to be less steep, because of the net increased welfare. Road pricing is a well known economic tool which is used to implement the polluters pay principle in accordance with traffic, and to reduce the volume of vehicles in an area. The idea is that with increased costs of entering an area by car, the number of people doing so will go down.

Today 74 % of all travelling in the Oslo area is done by car (Statens vegvesen region øst 2004) and the competitive situation is in favour of driving your own car, both when it comes to costs and regarding efficient time spending. There is expected to be a decrease of 12 % of the total amount of travels done by public transportation from 2001, if the relative costs are held constant and the toll ring is abolished by the end of 2007 as planned, even if the Oslopakke 2 is implemented (Statens vegvesen region øst 2004). However if the road pricing is implemented one expects an increase of 13 % in public transportation towards 2015. This transfer comes from private transport (cars) to public transport which gives a yearly reduction of environmental costs and costs related to accidents of 35 million NOK (Statens vegvesen region øst 2004).

5. Discussion

5.1 Rights

According to Coase, one should assign rights to the party with the highest welfare losses as the optimal solution then will be reached, at the least cost. In this case, if the motorists are in their right to pollute, the residents should be taxed or take the costs of moving. Similarly, if people have the right to breathe clean air wherever they decide to settle, the motorists should bear the economic burden. The government is responsible for road planning and the drivers are thus only users of the good, not culprits. At the same time, it's the local government that is responsible for tax collection and the civilians' welfare. Hypothetically, reduced speed in combination with, say a road tax which is spent on welfare enhancing measures in the local area, may make more people move into the area as the "bribe" is considered profitable. The tax is again not optimal according to the Coasian position as there are clear limits in which the state can intervene, especially when there are transaction costs.

Pigou's position is that the state can and should act on behalf of the population and thus reduce TC. In cases where the state works against itself and its own responsibilities, it is the right structure, normative and ethical issues that determine the outcome. However, these change with the different political stands that take office and their views on whose interests that should be protected.

Earmarking of revenues is often used and popular from a fairness perspective. This is contrary to economic theory which states that money should be spent where the gain is the highest. Returning money to where they come from seems fair, but investing in better roads or driving conditions will never be a profitable project. However, if one broadens the view a bit and returns the revenues to infrastructure in general, one can invest in more profitable projects to lower social and environmental costs.

5.2 Costs and Benefits

High levels of dust can cause respiratory problems that again might lead to worsened heart conditions for the most fragile part of the population. An environmental plan for Oslo states that about 2000 people in Oslo live in areas where the day middle value frequently is exceeded. Note that this is *only* the residents. In addition to these, you have the workers, commuters and so fort that are also exposed on a daily basis. On top of this, an increase in traffic up to 40 % during the next decade in certain areas of Oslo is expected due to an increase in population and an expanding need for mobility (Oslo kommune og Statens vegvesen region øst 2004: 8).

The social costs by *not* using salt on the roads in winter time can be tremendous from a health and human life perspective. As earlier mentioned (ch.4.1), reports prove that driving accidents are reduced (20 %) on salted roads. Traffic accidents where people are badly injured can cost the society a lot of money. But the social costs by salting can also have terrible effects when it comes to conserving the environment. We have already pointed out that run-off and accumulation of salts can pollute both groundwater and the adjacent soil. This will in time degrade the nearby ecosystem, and have unwanted and acute effects on animal life.

Furthermore, social costs with reduced speed are the regulation and implementation costs. Private costs include lost time. The absolute costs of the latter can be debated as a felt time loss and valuation of time are individual.

5.3 Monitoring and Enforcement

The purpose of monitoring and enforcement is to deliver the desired level of compliance at the least social cost (Romstad 2007). In this situation, the efforts made to reaching the target level should not exceed the gains from fulfilling the goal. In other words, one should not spend more resources on monitoring the traffic than it is financially sound in order to get the drivers to comply with the speed regulations. Moreover, if one is certain that standard limits are not exceeded, one can more easily handle the estimated future growth in traffic.

The policy instruments can be divided in direct regulation and indirect regulation. When we are to assess which types of instruments to implement, there are especially two matters one need to take into account; control-effectiveness and cost-effectiveness

By control-effectiveness one means how close to the target one can get, by the use of a chosen environmental policy. For instance, if the government has decided an upper value for emissions, the instruments used that keeps the emissions under this value will be control-effective. But environmental policy can be expensive. Thus it is also necessary to look into the cost-effectiveness, which means finding those policy instruments which are feasible so one can fulfil discharge legislation on the most inexpensive way.

Reduced speed might be more acceptable for people living in the affected areas who also drive cars. Information and attitude campaigns, like the national "wear safety belts campaign" from the two previous summers, are thus pivotal in reminding people of the problem and appeal to their conscience. However, one must keep in mind that different regions have different marginal economic costs, and if the "law of one price" is applied to all areas, we will experience welfare losses as one has reduced speed in areas where it is strictly not necessary both from an economic or environmental point of view.

The TC's of both the congestion charge and the tax on studded tires are considered somewhat similar in terms of implementation costs. Both the toll ring and the tax system for studded tires are already up and running, so it's quite easy to implement a higher tax. The operating costs of these two policies are e.g. issuing fines and operating monitoring cameras. The equipment needed for monitoring the rush hour tax is already in place. This will make it less expensive compared to the other policies presented earlier. The monitoring costs connected to controlling the tax on studded tires, are however higher. There is a need to hire control staff that checks the cars parked in the city. Administration costs include the wages to employees working directly or indirectly with the policies.

These costs are expected to be lower than the gains from the reduced traffic volume and therefore this is, from an economic point of view, a useful tool and combined with others to optimize the level of dust created by traffic in Oslo.

5.4 Optimality

An overall reduction of the traffic volume in Oslo, and on the main roads leading into the city, will reduce the amount of dust dramatically. A car creates considerably more dust when it accelerates or brakes, and as the time spent in queues decreases and the speed evens out, overall friction is reduced. Another aspect of reducing queues is that the cost of spending more time going back and forth to work is reduced. These additional costs of travel include, among other things, costs related to travel time, and more directly fuel costs.

Both road pricing and a tax on studded tires appeal to a fairness principle, as the polluter compensates for the damage he causes. As a policy we expect road pricing to be an unpopular suggestion as it increases the costs of continuing with the current way of doing things.

Previous experiences have shown that the optimal rate of cars with studded tires in Oslo (20 %) is attainable by a tax on studded tires alone (Müllerström et al. 2004). Moreover, the positive effect did not last when the tax was removed. Additionally, the pollution target was not satisfactorily met as the constraint was exceeded. This suggests that other measures also are needed for a more sustainable solution.

Today's emission level needs to be reduced by x in order to reach the constraint of 50 $\mu g/m^3$ which is not to be exceeded more than seven days per year. In technical terms, this can be written as

$$\mathbf{1 - x \leq 50\ \mu g/m^3} \qquad \textbf{[1]}$$

x can be written as

$$\mathbf{x = \alpha_1 a + \alpha_2 b + \alpha_3 c} \qquad \textbf{[2]}$$

In this paper, x consists of road taxation (a), tax on studded tires (b), and reduction of speed (c). Each of these instruments needs to take a percentage of the reduction, here indicated by the alpha. It is beyond this assignment to find empirical evidence of the real values of the alphas, but we will attempt to explain *how* the chosen instruments interact and thereby supplement each other.

Salt and non-studded tires complement each other in reducing dust. Salt allows for an increased usage of non-studded tires, which are optimal on bare winter roads. Salt does cause dust, which is whirled by traffic, but non-studded tires produce less compared to cars with studded tires. When all externalities are taken into consideration, the reduction of PM_{10} as a consequence of usage of non-studded tires needs to outweigh the former mentioned down sides by the increased use of salt - this in order to be an efficient instrument.

The effect of reduced speed and increased road tax are reciprocal and they both contribute to making driving less attractive. An increased tax to enter the city provides incentives for driving less. Less congestion enhances traffic safety and improves air quality. However, with fewer cars in traffic, the benefits from reduced speed may decrease as the traffic flows better with fewer accelerations and retardations. For those with stronger preferences for private transportation, either due to time preferences or cost by public transportation, a temporarily binding constraint is generally accepted as long as the agents have understanding for the perspectives and trust the time limit. Public choice theory therefore argues that such measures never will last as the authorities are dependent upon the public's consent.

Less harsh alternatives to reduce traffic volume might be less optimal. If we for a moment pretend that there were defined ownership rights to the air, the transaction costs of negotiating a solution would be so huge that it would by far outweigh the benefits of the reduction. Another way is to give positive incentives not to drive. Instead of taxing those how drive, reward those who don't. This requires a substitute which both has the capacity and the efficiency to make the compensation worth while. In time, a punishing legislation may also lead to a change in attitudes towards the problem (Nyborg, 2003). One related example of this is found in London. Previous to the implementation of the congestion charge, the public was generally negative to the tax on cars in the city centre. Recent studies show the policy has grown more and more popular as the effects have taken place (Transport for London, 2003). All this considered, the TC's of a governmentally dictated policy are considered to be lower than the softer options.

Benefits from reducing the occurrence of dust are trivial, yet extensive and cost-saving. The suggested measures in this paper would single-handedly contribute to solving at least one side of the dust problem, but it is beyond doubt that these measures combined would strengthen the outcome. Additionally, if all the welfare enhancing measures from an environmental perspective were backed up by improved public communication, this would even further stress the importance of joint implementation.

6. Conclusion

We see that reduced speed, road taxation and tax on studded tires are effective instruments for reducing the levels of $PM_{10.}$ The amount of traffic decreases as both the time and monetary expenses of driving and owning a car increase. Less private transportation enhances air quality, i.e. reduces the amount of suspended dust. Additionally, it lowers overall social costs in terms of frequency of accidents, road maintenance, environmental degradation and other health-related matters.

Salt is a necessary presupposition in order for non-studded tires to work optimally, but causes damage to road-side vegetation, ground water and will also contribute to an increased level of PM_{10}. Reduced speed means reduced whirling of dust, but involves a time cost. Taxes work accordingly to the Polluter Pays Principle and have a direct effect on users of studded tires and the road network, but there are costs involved in implementing, monitoring and enforcing these instruments. Ideally, a combination of instruments should be initiated as the different measures come at different costs and involve different externalities.

Health-related costs would be cut dramatically if e.g. both speed reduction and taxes were jointly implemented. This would ideally lead to less traffic, less congestion, less pollution, less environmental and social cost, etc. Improved salting of roads would also reduce the need for studded tires, whereas taxes on top would motivate people to change type of tires.

If you introduce one policy i.e. increased tax on either tires or rush hour traffic, the decrease in speed might be redundant. Fewer cars with non-studded tires in the city centre will make the traffic float smoother, and consequently produce less dust. The target may be reached in this way without reducing speed. If however implemented, this will add further environmental gains.

For a more effective implementation, a cheaper and more efficient substitute to commuting by car is needed. Improved public communication would strengthen the effects of the suggested measures, in addition to improved infrastructure for alternative, environmentally friendly means of transportation.

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