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Effects Comparison of Tools to Control the Traffic Demand as an Instrument of Urban Environmental and Climate Policy

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1 ABSTRACT

The Clean Air Directive did not aim to traffic emissions only, but one of the consequences were more than 160 Low Emission Zones throughout Europe, regulating the traffic from polluter cars in urban areas. Most of the Low Emission Zones are drive bans for vehicles with high PM emissions, some are charged zones. Both variants proved to be in a position to change traveler behaviour, though charged zones tend to be more flexible than drive ban zones as people have more time to adopt, more people can be affected, the zones can be substantially larger and the scheme can be tightened more sensitive. Assuming that the instrument of Low Emission Zones might be applied to carbon emissions as well leaves nearly no option but charged zones due to these reasons. As a consequence, the charging scheme is crucial in order to help reducing carbon emissions. Basically two different charging principles are discussed in Europe: conventional cordon prizing and mileage based pricing. With cordon pricing, the charge gets due when passing the zone boundaries, while with mileage based pricing, the charge increases with the distance traveled. So obviously, mileage based pricing is more suitable as it follows the polluter-pays-principle while cordon pricing seems to be insensitive to this. By applying traffic models and demand elasticity models it is possible to determine the achievable benefit of both; comparing this benefit to the system cost leads to the cost-benefit-analysis of both principles. An example is given in this paper.

2 BACKGROUND

The citizens' request for healthy and livable city centers as well as legal regulations like the EU Ambient Air Quality directive [1] effect communalities to take action in order to reduce air pollutants immissions. This directive fixes the threshold values for important pollutants like SO2, NOX, particle matter, etc. Any European citizen can claim for proper measures to be taken by the regional government. Communalities are reacting; in Europe some 160 low emission zones were set up, more will follow.

3 INTRODUCING LOW EMISSION ZONES

According to the Low Emissions Zones Network [2], Low Emission Zones (LEZs) are areas where polluting vehicles are restricted from entering. This means that polluter vehicles are banned or have to pay a charge. The emissions that are aimed to be reduced by LEZs are mainly particle matter and sometimes nitrogen dioxide.

The existing ~160 European LEZs can be classified into the following categories:

	Drive ban	***Charge***
All Vehicles	e.g. German LEZ	Milan Ecopass
Heavy Goods Vehicles (HGV)	e.g. Netherland LEZ	e.g. London LEZ

Table 1: Categories of Low Emission Zones

The experience on these categories can be summed up as follows:

- All vehicles drive bans: The ban affects the whole vehicle fleet (private + commercial) by pollution class sensitively excluding from entering the zone.
- HGV Drive bans: Commercial vehicles are pollution class sensitively excluded from entering the zone.
- HGV charge: Commercial vehicles have to pay a charge according to the pollution class when entering the zone.
- All vehicles charge: All vehicles are subject to a pollution sensitive charge when entering the zone

3.1 Effects of Drive Bans

Drive bans are immediately effective from the first day on; hence this is the fastest way to reduce traffic pollution - if the driver's compliance is enforced.

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However, drive bans make necessary a sudden behavioral change like using public transport instead of the private cars or investing into modern or green cars. Frequently, due to the financial burden, certain sections of the population are disadvantaged in adopting properly; such are low income groups, families with many children, economically inactive households, handicapped people and small scale enterprises. A typical vehicle distribution according to the pollution class is shown in Fig. 1.

As vehicles that fail the access criteria become practically worthless, debates are regularly picked up about governmental overriding of private rights. These debates completely overlay the debate about the ecological reasons and the necessity for behavioral changes. In addition, exemptions from the drive ban as well as long transitional periods are set to smooth the deployment, indeed compromising the fact of a rapid pollution reduction, counting on the natural renewal of the vehicle fleet. Applied to the general public, driving bans are very likely to miss the target of sustainably setting minds and changing mobility habits; although applied to the commercial segment (HGV), pollution reductions are achievable: Being electronically enforced, the HGV specific LEZs in The Netherlands caused a significant higher share of less polluting Euro-4 and Euro-5 vehicles within the zone than outside, resulting in a concentration reduction of -0.2 ... -1.1 µg/m³ for NO2 and -0.1 ... -0.6 µg/m³ for PM10 [2].

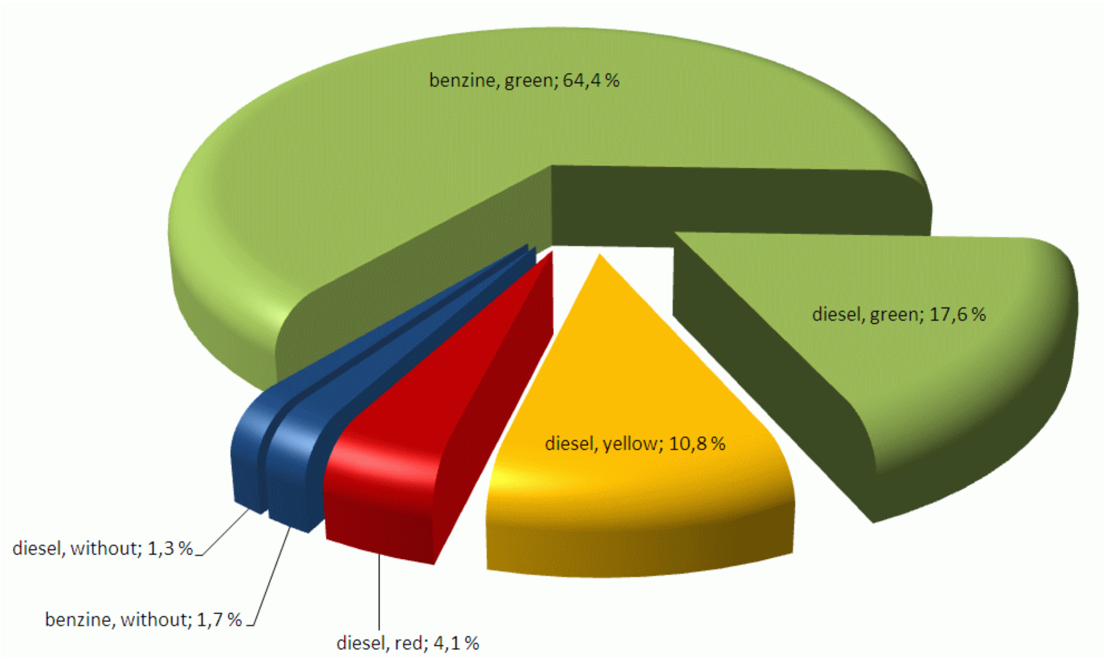

Fig. 1: Typical distribution of passenger cars in a city of ~100.000 inhabitants that is categorizing vehicles according to the PM10 pollution class; the class is depicted with coloured stickers (green for less polluting vehicles, yellow for the mid range, red for heavily polluting vehicles, no sticker in case the vehicle is too old for categorizing); vehicles are excluded from entering the zone according to the sticker color (name of the city is known to the author, source: web-based vehicle registration statistics of the city).

It is noteworthy that the driving bans are static, i.e. 7 x 24, during working hours, etc. Though, particle matter and other emissions and immissions heavily depend on dynamic influence factors like the weather situation or the traffic situation, particularly congestion [5]. Most of all, PM immissions vary seasonally. During summer, the near-ground air gets heated up and rises; wind distributes the particle matter over a larger area, consequentially the pollution in the city is reduced. During winter though, the near-ground air stays where it is and particle matter concentrates with on-going traffic. Additional PM sources are house fires and winter road sand. If precipitation stays out, the air is not cleaned. The immissions thresholds may be exceeded even without any traffic contribution. At the other hand, if the weather is favorable, traffic eventually does not lead to an exceeding of the thresholds. In the first case the driving ban is reasonable, in the second case the driving ban comes to nothing. Particularly the second argument is taken up by lobby groups and gets part of the public discussion, knowing that there are other traffic related emissions like CO2 that are not covered by the driving ban.

3.2 Effects of Charged Low Emission Zones

Charging at the other hand promises a smoother but more sustainable behavioral change as the affected population is not completely excluded from entering the city; people may adopt according to the individual capabilities and needs. The London LEZ for instance with its nearly 1500 km² aims at the commercial segment [11]; namely HGV have to pay a day pass ticket of 200£ (100£ for vans and minibuses) depending on their pollution class. The result was that fleets were reorganized; in the meantime, a near 100% compliance with the appointed minimum emission class is recognized. Concerning CO2, there may be some small benefits through newer and more fuel-efficient vehicles being introduced into the fleet as a result of the scheme, but the zone does not specifically target CO2 emissions.

On the other hand, charging can be applied to private cars as well: With the "Ecopass" program, the Italian city of Milan charges according to a Euro emission class model [7]. Vehicles with the worst pollution class have to pay a day pass ticket for 10€, other, less polluting vehicles have to pay 2€ or 5€; the most modern vehicles including GPL fuelled vehicles have free access to the zone. The polluter cars were reduced by -56.7% in the first year of operation. Pollution could be reduced quickly; the effects are measurable even outside the zone. Finally, CO2 was reduced by 9% [8]. Secondary effects like reduced congestion and less parking pressure were measurable.

3.3 From LEZ to L-GHG

LEZ with drive bans are hardly an option to be used as a Low Greenhouse Gas Zone because drive bans are digital: Vehicles are excluded or they may enter. Long transition periods would be needed, the political consensus would end up with transition phases that are close to the natural fleet renewal, probably foiling the Commission's White Paper on Transport target of halving the GHG emissions from private car use in cities until 2030 [3]. Considering the experience with conventional LEZ, charged schemes obviously seem to be the better choice.

By analyzing the existing charged LEZs, a traffic cut can be observed; hence GHG is reduced accordingly as shown above. On the long run LEZs produce a shift from old cars to new – compliant – cars. Concerning CO2, there are some small benefits through newer and more fuel-efficient vehicles being introduced into the fleet as a result of the scheme, but no zone specifically targets CO2 emissions. Consequentially, the CO2 reduction first of all comes from the fleet renewal but will increase again according to general traffic increases. This can be demonstrated in the city of Milan, where the daily traffic volume in the zone was cut from 98 thousand to 87 thousand vehicles (see Fig. 2). The scheme encourages the usage of less polluting modern vehicles – and they are entering; People change from older cars to newer ones, but they do not sustainably change their behavior. The vehicles have less polluting engines, though the scheme helps less with congestion [4], bringing the well known increased fuel consumption due to stop-and-go operation and particle matter emissions due to tire and break abrasion – being emitted even by electric vehicles. At the same time, the revenues collected diminish, threatening the ability to keep the system in operation.

Though, is there a hint that a conventional charged LEZ can be turned into a Low GHG zone? By analyzing the time period shortly after introducing the scheme, two behavioral changes are recognizable [6]:

(1) The polluter cars were reduced by -56.7% in the first year of operation. This was a less sustainable achievement as many of those cars are being substituted by less polluting Euro 4&5 vehicles that are not subject to charging.

(2) Car traffic dropped by 5 million vehicles in the first year of operation – at the same time, 35 million additional rides took place in public transport. The local public transport operator increased the rolling stock capacity prior to the introduction.

The lessons learned from the Ecopass program are the following:

The paying for pollution principle is in a position to encourage behavioral changes. people use more public transport instead of (polluting) private cars or renew the fleet in a significant dimension;

The sustainability of behavioral changes depends on the applied scheme; Making GHG emissions part of the scheme allows selectively decarbonising cities;

A prerequisite of introducing such a scheme is the consensual decision making as well as the public consultancy in order to generate knowledge and acceptance.

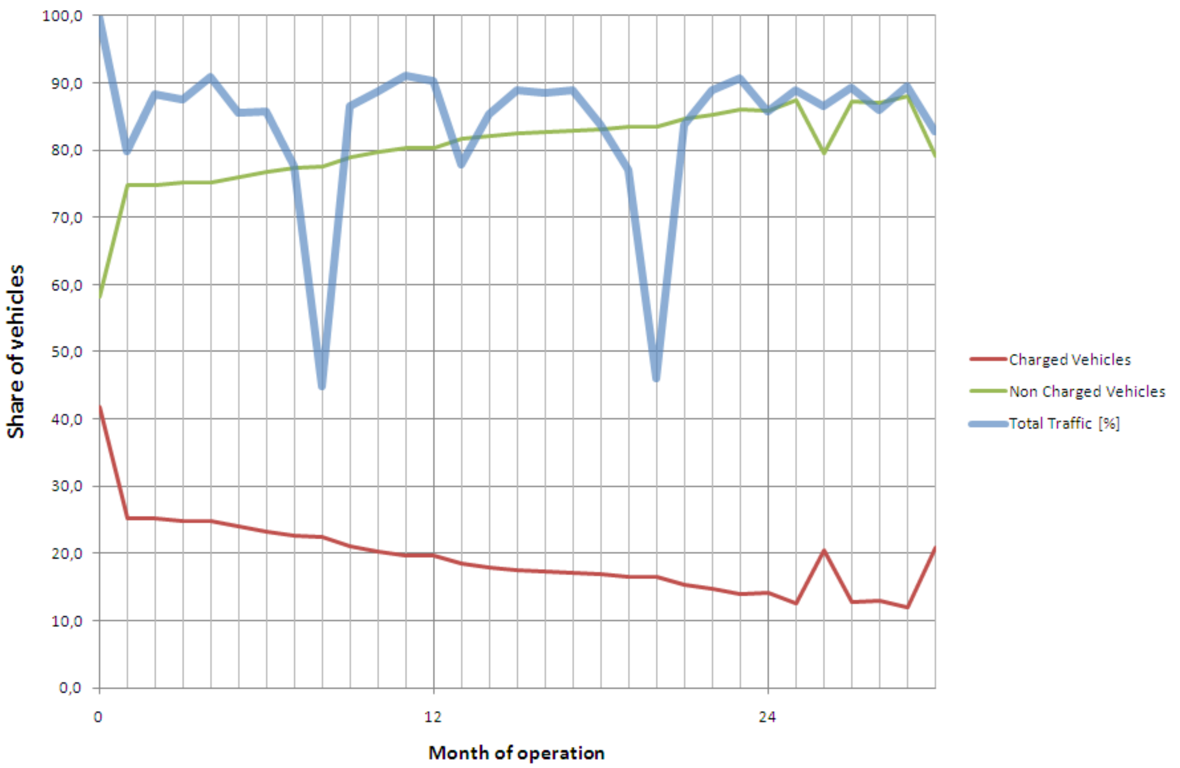

Fig. 2: Monthly traffic development within the Ecopass area since the introduction in January 2008 until June 2010 ("0" is the reference data); Total traffic references to the pre-Ecopass numbers; the share of charged and non-charged vehicles reference to the total traffic. Source: [6]

4 COMPARING CORDON CHARGING TO MILEAGE-BASED CHARGING

Access regulation turns out to be a strong instrument to change traveler behaviour towards a smaller footprint. Applying driving bans for not complying vehicles is simply not feasible, as too many people would be excluded; apart of that, the zones need to be large in order to achieve a substantial effect. So the remaining option is charged zones, accompanied by information & education and a balanced mix of complementary measures. The decision making process of charged zones though covers two crucial questions:

Which measure or scheme can achieve the desired effect while polluter-pays-principle is kept in a fair and transparent way?

Is the cost-benefit-ratio positive?

4.1 Effects comparison of cordon pricing and mileage-based pricing

With cordon pricing, a flat fee is charged when accessing the zone. In contrary, a mileage based charge is up to the distance driven within the zone. How can the two schemes be compared?

The cost model of Prof. Rémy Prod'homme [9] from the University Paris XII offers a possibility to assess the effects of such measures. His model can be applied to any given area; the road usage q can be measured in vehicle*km. It considers the demand for the use of the roads as a function of the unit cost of using the road. The most important element of this unit cost is the cost of the time needed to drive one km. Furthermore it considers the individual cost i(q), which could be considered a supply curve; this is the per-km cost borne by a motorist. And finally he considers the social cost s(q) created by a vehicle as a function road usage. This social cost is equal to the individual cost plus the cost of the additional time spent by all other vehicles because one extra vehicle is on the road. It is given by $s(q) = i(q) + i'(q)*q$. According to the model, the individual optimum is where the individual cost curve intersects with the demand curve; the social optimum is where the social cost curve intersects with the demand curve. A congestion charge increases the individual cost and shifts the intersection points towards less traffic.

Table 2 shows the model parameters that are used for comparing a cordon pricing to a mileage pricing, the model represents a city of 500,000 – 700.000 inhabitants:

Traffic category	Share [%]	Daily traffic count	Average km in the zone	1000 veh*km in the zone
Traffic within the zone	10	41,894	4	168
Short distance traffic with origin/destination in the zone	40	167,577	4	670
Long distance traffic with origin/destination in the zone	40	167,577	4	670
Through traffic	10	41,894	4	168

Table 2: Synthetic traffic model for assessing the effects of urban road user charge

It is worth mentioning, that the above numbers highly influence the shape of the cost curves in Fig. 3. For instance, if the average km in the zone increases, the cost curves get more flat because the same traffic is distributed on longer stretches of road ("less congestion"); if the charges are increased, the cost curves go up. Two charge variants are set:

A cordon charge of € 1,00 for every access/exit

A mileage charge of € 0,15 per km.

The demand curve is typical and is taken from the London Congestion Charge [10]. The effects of these variants are shown in the figure below.

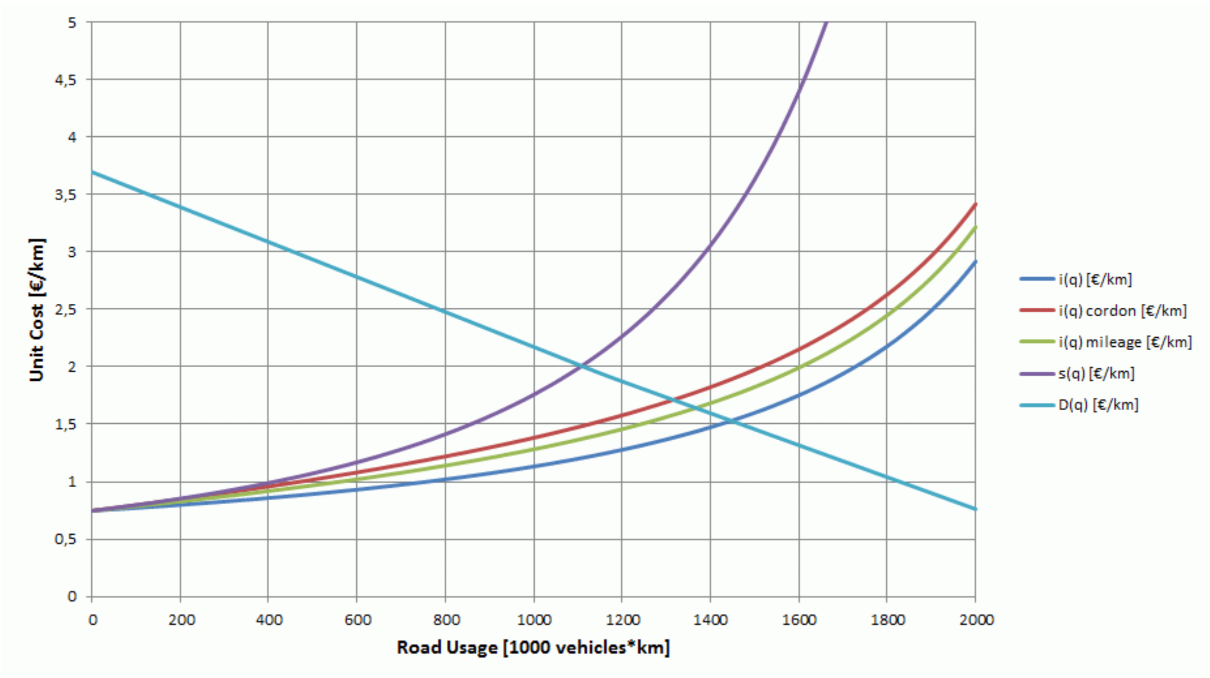

Fig. 3: Effects of urban road user charging on the traffic; individual cost rise with increasing traffic due to higher travel times, consequentially the demand declines with higher traffic; i(q) … individual cost; i(q) cordon … individual cost with cordon charging; i(q) mileage … individual cost with mileage based charging; s(q) … social cost; D(q) … demand curve; Lw … social loss due to congestion without any measure; Lm … social loss due to congestion with mileage based charging; Lc … social loss due to congestion with cordon pricing.

The social loss due to congestion without the charge is Lw; in this example this loss is € 573 mn per year. This loss can be reduced due to the charge variants to Lm (€ 370 mn per year) or Lc (€ 339 mn per year) respectively. The social gain due to the measure is Lw-Lm in the case of mileage based charging (€ 203 mn per year) or Lw-Lc. In the case of cordon charging (€ 233 mn per year). By increasing the charges, the intersection points of the respective individual cost curves (i(q) cordon and i(q) mileage) with the demand curve D(q) would move left towards the social optimum, showing the traffic reducing effects of the charge.

4.2 Cost benefit comparison

In addition to the above parameters, 100 access sites and 700.000 registered users are assumed; in the cordon variant, each access site registers every vehicle passage; for simplicity, in the mileage based charging variant, each access site serves as an enforcement site, verifying that the obliged vehicles carry a working on-board unit. On the basis of state-of-the-art industry cost, the following comparison is given in Table 3:

	Cordon pricing	***Mileage pricing***
Technology	DSRC on-board units for frequent drivers (30%); standard ANPR registering	GNSS on-board units for all vehicles; GPRS communication to central
Capital expenditures [€]	27 mn.	123 mn.
operating expenditures [€/y]	9 mn.	93 mn.
Social gain [€/y]	233 mn.	203 mn.

Table 3: Synthetic traffic model for assessing the effects of urban road user charge

The most significant reason for the high capital expenditures with mileage pricing is the significant higher GNSS on-board unit price for all registered users. The reason for the high operating expenditures with mileage based pricing is the communication cost for all GNSS on-board units.

5 CONCLUSION

In Europe, Low Emission Zones were the response to the Clean Air Directive that limits the maximum threshold levels of air pollutants immissions. Most of the European Low Emission Zones are pure driving ban zones aiming on PM10 emissions only. Some Low Emission Zones are charged zones, which turn out to be a little more flexible. When bringing carbon emissions into the access criterion, there is nearly no choice than deploying charged zones, but still the open question is to apply a simple cordon scheme or a mileage based pricing that follows the polluter-pays-principle at best.

By applyin demand elasticity models, the proper scheme and charge can be determined in order to achieve the desired traffic reduction and carbon reduction. The outcome of this assessment is the social benefit of the measure. This benefit is facing the deployment and operating cost for the scheme, giving a decision support for choosing the right measure.

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