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Low emission zones in Europe: their impact on sustainability and logistics.

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Low emission zones in Europe: their impact on sustainability and logistics.

Abstract

- Local and regional environmental externalities: congestion, air quality, etc.
- A paper will be submitted and presented.

The enhancement of air quality in urban areas is a challenge which gets increasing attention in Europe. The European policy level, national bodies, local governments, cities as well as companies have been developing goals and policies. Consequently, different European cities created 'Low Emission Zones' to tackle increasing emission levels of road traffic. This is certainly in line with the latest European White Paper on this matter, published in 2011, and foreseeing to create a Single Transport Area by 2050. The aim is to streamline the transfers between different types of transport, and also to cut carbon emissions by 60% by stopping the use of conventional-engine vehicles in cities.

A Low Emission Zone is mostly a zone or corridor in an urban area, where an authority puts in place restrictions on emission levels by road traffic. The goal is to decrease emissions at the most populated parts of the country. The vehicles entering the zone are having newer, cleaner engines. The zones are implemented and restrictions are sometimes increased or some evolved to traffic free zones. In the present paper, the implementation phases of LEZ's are looked at. An overview is given of LEZ's put in place, and their resulting impacts.

Flanders, a region in Belgium, is thinking about the implementation of LEZ's to decrease emissions. As Belgium is not meeting EU air quality goals, action is necessary and urgent. The EU Commission decided to refer among others Belgium to the EU Court of Justice when not meeting directive 2008/50/EG concerning Air Quality.

This paper will build further on research conducted to simulate LEZ implementation and impact in Belgium. A study was commissioned by the region of Flanders to see how an emission zone can be put in place, and the effects an LEZ will result into. A reference scenario is calculated to compare the different outcomes with the scenario where no policy change takes place. One can see that different scenarios result in different outcomes.

Next to an overview of European best practices, the present paper simulates the implementation of LEZ's and their impact at the level of Flanders. To do this, a limited cost-benefit analysis was made. More specifically, a reference scenario is calculated to compare the different outcomes with the scenario where no policy change takes place. The findings suggest that little impact is expected if a LEZ is only implemented for freight flows

Keywords

LOW EMISSION ZONES, URBAN LOGISTICS, CITY DISTRIBUTION

INTRODUCTION

The enhancement of air quality in urban areas is a challenge which receives increasing attention in Europe. The European policy level, national bodies, local governments, regions, cities and of course companies have been setting goals and developing policies. Belgium, and the region of Flanders, have been developing policies on transport aiming at reducing transport emission levels. A decreasing trend is seen but the European goals are difficult to achieve. Flanders is struggling more in particular with two policies, on the one hand the emissions of new vehicles and on the other hand PM_{10} emissions (PM_{10} is the fraction of fine particles with an aerodynamic diameter smaller than 10 μm). Two issues occur: the new sold cars' CO_2 emissions and the European fine particle criteria are exceeded.

Long term focus

The focus on emissions in urban areas is certainly in line with the 2011 European White Paper *Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system*, foreseeing to create a Single Transport Area by 2050. The aim is to streamline the transfers between different types of transport and also to cut carbon emissions by 60% by stopping the use of conventional-engine vehicles in cities. Sustainable commuting trips[1] are seen as an important topic. According to the European Commission (EC) (2011), urban mobility is responsible for 25% of road-related CO_2 emissions. Therefore, a constant decrease of fossil fuel use has to lead to a replacement of the conventional engines in parallel lowering the fossil fuel dependence, greenhouse gas emissions, local emissions and noise problems. (European Commission, 2011)

The White Paper (2011) followed the publication of a Green Paper *Towards a new culture for urban mobility*, published by the EC in 2007. Experience in the CIVITAS[2] project and the communication on the "citizens' network" (1995) was taken into account. The main conclusion was that Europe needs one integrated policy on different aspects of urban mobility. Passenger- as well as freight transport were mentioned. A better integration of freight and passenger flows on the network is seen as a basis for a better urban mobility culture. Less congested traffic in European cities is the priority as this downturn of mobility has important economic, social and environmental consequences. The second priority lies in limiting emissions. The EC sees potential in the integration of external costs by the road users. The growth in emissions by road traffic will be tackled. The introduction of Intelligent Transport systems (ITS) is the third priority. (European Commission, 2007)

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[1] Point 2.4, White paper, *Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system,* EC, 28 March 2011.

[2] The CIVITAS network helps European cities organizing more sustainable, clean and energy efficient urban transport.

Other European developments are worthwhile highlighting. In January 2008, the EC came with a groundbreaking climate action plan. A decrease in energy use is put forward so that the EU would be less dependent on energy imports. The EC wants Europe to be the center of the fight against global warming. More concrete goals were set. These ambitious goals are a decrease of 20% of energy use by 2020 (compared to 1990 levels), a decrease of harmful greenhouse gases by the same 20% and an increase of renewable energy use by 20%. Therefore, the decision is often referred to as the PACT 2020. Efforts are shared by the different member states. Goals were set nationally. (Ryckevelde, 2011; European Commission, 2011)

Policies regarding new vehicles

Now, let us go more concrete. A European framework was developed, in which emission goals were set for vehicles that should be met at specific years. This policy, referred to as the *Euronorms,* decreased vehicle emissions significantly. The goals for different allowed emissions for trucks are shown in Table 1. Truck manufacturers need to comply with the criteria. Year on year, these norms became stricter. The trucks meeting the most recent norm (Euro 5) are emitting significantly less than ten years ago. According to Table 1, a Euro 5 truck emits 66% less CO and 97% less PM than a Euro 1.

Table 1 : Emission standards for new trucks, diesel g/kWh (smoke in m^{-1})

	Date	CO	HC	NO_X	PM
Euro I	1992, < 85 kW	4.5	1.1	8.0	0.612
	1992, > 85 kW	4.5	1.1	8.0	0.36
Euro II	1996.10	4.0	1.1	7.0	0.25
	1998.10	4.0	1.1	7.0	0.15
Euro III	1999.10, Only EEV's[3]	1.5	0.25	2.0	0.02
	2000.10	2.1	0.66	5.0	0.10/0.13 (gas)
Euro IV	2005.10	1.5	0.46	3.5	0.02
Euro V	2008.10	1.5	0.46	2.0	0.02
Euro VI	2013.01	1.5	0.13	0.4	0.01

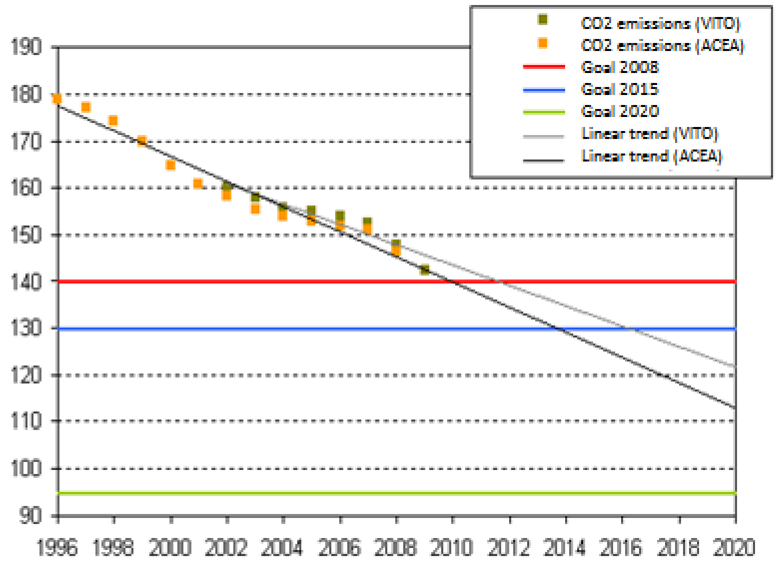
Source : Dieselnet.com, 2010

For cars, a different policy scheme was developed. The newly built vehicles need to comply with *Euronorms* as well. But concerning the emissions, CO_2 is looked at in more detail. The EC agreed with

[3] EEV is the EU term for clean vehicles. These emit less than 0.25 g/kWh CO, 0.02 g/kWh NO_x and 0.15 g/kWh PM.

the manufacturers to decrease CO_2 emissions of new cars. In Belgium, the average CO_2 emissions for the 2008 fleet of newly produced cars was 148 g/km (data from VITO, Flemish Institute for Technological Research), exceeding the agreed common EU goals with almost 6%. The petrol cars prove to have a more drastic decrease compared to diesel cars, being the majority of Belgian passenger cars. In 2009, 60% of Belgian cars were diesels. Much more than in the neighbouring countries Germany and the Netherlands where this share is only 25.9% and 16.9% (Fierens, 2008). In 2009, the average CO_2 emissions for the fleet dropped to 143 g/km. For new diesel cars, this was 142 g/km compared to a 146 g/km for petrol cars (Mira, 2010). Figure 1 gives a decreasing trend, although not as much as necessary to meet EU goals. The linear trend drawn by VITO and ACEA (European Automobile Manufacturers' Association) does not result in the needed decrease. The graph gives the 2008, 2015 as well as 2020 objectives. Belgium is struggling to meet the goals. The emission levels are not decreasing fast enough, which is a first emission problem Flanders is coping with. (Mira, 2011)

Figure 1 : CO_2 emissions of the fleet of new sold European and Belgian cars (g/km)



Source : Mira, 2011

Policies regarding all vehicles in use

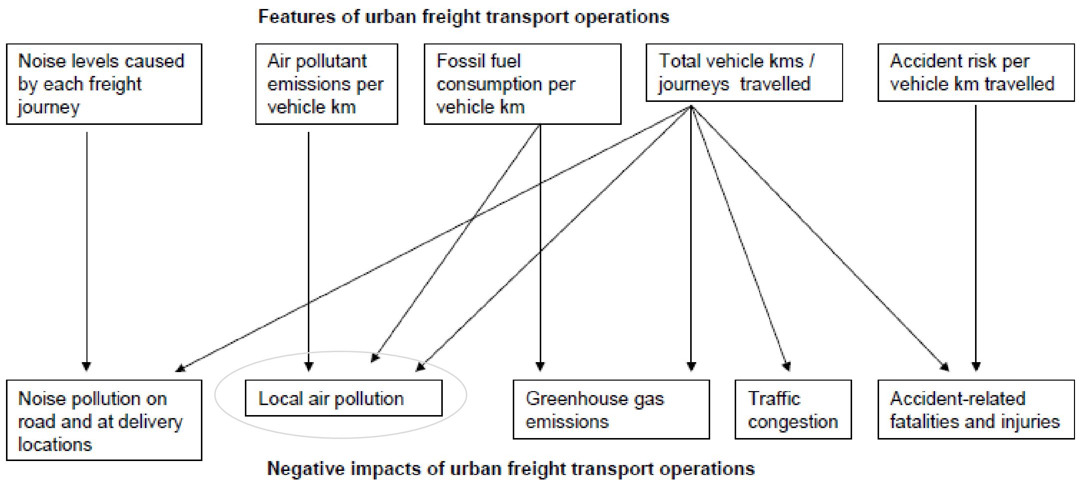
Directive 2008/50/EG[4] concerning Air Quality is obliging countries to take action to limit EU citizens' exposure to emissions. As such, not only newly produced but also current fleets are under influence of European policies. The final responsibility for meeting the goals set for every member state lies with the national, regional and local governments. As Belgium is not meeting these EU air quality

[4] Directive 2008/50/EG bundles all previous EU directives on air quality and sets norms for $PM_{2.5}$. A 20% reduction of $PM_{2.5}$ by 2020 was put forward by 2020 (compared to 2010). Flexibility is allowed on PM_{10} and NO_2 norms in difficult areas. For 35 times a year, the 50 microgram PM_{10} per m^3 norm can be exceeded on certain locations. (VMM, 2011)

goals, action is necessary and urgent. The EC even decided in April 2011 to refer among others Belgium to the EU Court of Justice because of not meeting PM_{10} emission criteria. By April 2010, the EU PM_{10} emission criteria – on selected hotspots in Flanders – were exceeded more than 35 times. This is a second striking example of Flanders not meeting the agreed criteria. PM_{10} emissions are decreasing in Flanders. But gains are mainly seen in the industry and agriculture, less in transport which is still responsible for 26% of the total (Mira, 2010; Mira, 2011).

In the past, many policies concentrated on newly built vehicles, which proved to be an efficient but slow moving process. Older vehicles stay on the market till the end of their life span and are less influenced. Hence, short term gains might be possible when concentrating on the use of the actual fleet. This possibility seems to be underestimated. Therefore, the present paper focuses upon measures on the actual fleet. Browne *et al.* (2011) summarized the negative impacts of urban transport and the relation with some of its typical features. Local emissions are to be decreased by lowering the emissions/vkm, the fossil fuel consumption/vkm and vehicle use. A measure like Low Emission Zone's (LEZ), being a zone or corridor in an urban area where an authority puts in place restrictions on emission levels by road traffic, is fitting in his framework. The goal is to decrease emissions at the most populated regions. Vehicles entering the zone need to comply with a scheme putting in place emission and/or age restrictions. As a consequence, vehicles in de zone are having newer, cleaner engines compared to the average. The zones are implemented and afterwards the restrictions are made more rigorous or some even evolved to traffic free zones.

Figure 1 : Relation between features and negative impacts of urban freight transport



Source : Browne, Allan *et al.,* 2011

Literature on traffic emissions is mainly looking at using more efficiently the actual fleet, where vehicle routing research is an example. A research gap is clearly available as little is written on banning a part of the fleet in specific zones. A LEZ is a policy development where in certain geographical regions not all vehicles are allowed. This is a different situation where operators need to not only to adapt their operations but also their fleet. The measure could be a policy helping to solve the emission problems Flanders is coping with. Former research simulating a LEZ implementation in Belgium (Yperman, Vanhove, Voogt, 2011) is the basis for this paper. As research did hardly look at any results the LEZ might have on the logistics organization, this study looked at this impact as well. The paper adds value to the research field by looking at the impacts of LEZ on freight movements, the increased advantages of low emission vehicles and the increased viability of non-conventional logistics. Desk research is providing an overview of European LEZ's and gives a mainly qualitative cost-benefit analysis.

The motivation to write this paper is to evaluate LEZ's on their impact on emissions and logistics. Can foreign examples influence Flanders in making a decision on implementing these zones? To be able to draw conclusions, some sub-research questions were formulated. Firstly, what are LEZ's and how are these implemented? Secondly, what are the effects on emissions and fleet characteristics? Are only trucks or all traffic zones equally effective? Thirdly, what are the possible effects of Flemish LEZ's? Last, what socio-economic effects can be expected in the logistics sector?

The remainder of the paper is structured as follows. The first section gives an overview of European LEZ's, with a specific interest in Germany and the Netherlands. This focus will further be elaborated where effects of the zones on emission levels in these two countries will be researched. Germany decided to set emission criteria on all traffic, the Netherlands only demands Dutch truck owners to comply with the restrictions. The second section is incorporating foregoing conclusions in a simulation on possible effects of LEZ's in three Flemish cities. The third and last section will be looking at socio-economic effects and influences on the logistics organizations. Conclusions will follow.

1. European Low Emission Zones

LEZ's, can be interpreted in different ways. The focus can be very big or very local. For example, a LEZ can be seen as a wide spread area where activities related to traffic, housing and industries have to meet certain (emission) criteria. On the other hand, a road with speed limitations can already be seen as a small environmental zone. The second option is mostly put in practice for traffic safety reasons, while it has an effect on road transport emissions as well (Hoogma, van de Laar, Motshagen, 2003). With the implementation of LEZ's policy the makers focus mainly on emissions, after congestion the second most important external cost of transport. (Blauwens, De Baere, Van de Voorde, 2008)

First, a LEZ should be defined. A definition used by Novem, the Dutch Body for Energy and Environment, can be found in the 4th Dutch National Environmental Plan. (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2010; Hoogma et.al., 2003)

> An Environmental Zone (LEZ) is seen as an area where, for reasons of liveability (like air quality) and congestion, a selective restriction policy is implemented on road vehicles.

The European TRENDSETTER project, founded to support sustainable urban mobility, proposes several concrete actions like restrictions on traffic (banning heavy trucks), advanced mobility (supporting multimodality, bicycle use and car sharing), public transport (separate bus lanes and increased services), organizing logistics flows more efficiently (increasing barge and rail transport for example) and increasing the use of sustainable vehicles and fuels. The TRENDSETTER project had another definition. Five TRENDSETTER cities (Stockholm, Graz, Lille, Praag en Pecs) have 1600 test vehicles using biogas or electricity in operation. In 2002, a document was published supporting the policy possibilities on LEZ's. The following definition was used in the research. (Feychting *et al.*, 2002, p. 6)

> The expression "environmental zones" used in this project means a geographical zone within which special regulations and restrictions for car and heavy vehicle traffic apply aimed at reducing air pollution.

Following the foregoing introduction on the subject, here, an LEZ is defined as a geographical zone where for reasons of liveability local governments, preferably within a national framework, put in place a restrictive policy on road transport users with the goal of limiting road transport's negative impact within this zone (for example emissions and noise).

Different European countries have implemented LEZ's years ago, which gave the authors the opportunity to look at effects and success factors. Table 2 gives insight in emission criteria that vehicles need to comply with, which are made more rigorous in time. Differentiations based on different criteria, besides emissions, are widely spread. The policymakers set differentiated criteria based on time (day and night), vehicle categories (cars or trucks, trucks -3.5 tons or trucks +3.5 tons), location (criteria differing for shopping streets) or finally based on nationality (vehicles registered in the country implementing LEZ's and foreign vehicles). Different law enforcing possibilities exist as well, from manual control of the compliance till automatic registration of number plates by smart cameras.

Table 2 : Low emission zones in Europe

	Vehicle			Details	Emission-norm	Location	Enforcement	Comments
	C	T	F					
DK		X	X	+3.5 ton	Euro 4, Older vehicles need a particle filter	Parts of: Aalborg, Aarhus, Copenhagen, Frederiksberg en Odense.	Unknown	• Copenhagen: Max 18 tons. Parking restrictions for +3,5tons vehicles during night. • LEZ sticker is needed.
DE	x	X	X	All traffic	Specific per city		Mobile police	• From 1ste of March 07. • Emission criteria per city. • Nationally organized.
UK		X		+1.2 ton	+3,5 ton = Euro 3 Jan 2012 = Euro 4		Fixed and mobile camera's	• London from 4th of Feb. 2008. • London + Greater London. • From 1/12 : Vans 1, 2 - 3,5 ton. • Registration at Transport for London >> No toll. • If vehicle does not comply >> 200 GBP toll per day.
IT		X	X		No Euro 0, 1, 2	Regions Lombardia, Trentino - South Tirol, Piemonte, Tuscany and Sicily Mont Blanc Tunnel, FR/IT	Unknown	• Mont Blanc tunnel minimum Euro 1. • Time differentiation exists. • Some regions only know LEZ's in the winter.
NL		X		+3,5 ton	Min Euro 3 + particle filter (< 8 years) Euro 4 and 5 free entrance	Amsterdam, Breda, Rotterdam, Delft, Den Bosch, Den Haag, Eindhoven, Leiden Utrecht, Maastricht en Tilburg	Unknown	• From 1st of July 2007 in 12 cities. • Nationally organized. • Covenants between national and local governments. • Passenger cars in consideration.
AT					Euro 2 / 3	A12	Unknown	
SE		X	X	+ 3.5 ton	Age + emission norms	Mölndals, Göteborg, Stockholm, Lund, Helsingborg, Malmö	Unknown	• Trucks allowed 6 years from first registration (Euro 2 + 3 max 8 years old). • Euro 3 till 2014 (First registered in 2006). • Euro 4 till 2016. • Euro 5 and EEV-vehicles allowed till 2020.
CZ					Euro 2	Centre Prague	Unknown	
FR							Unknown	Future project in 8 cities from 2012.

C = Cars, T= Trucks, F = Foreign registration
Source: Own compilation based on Transport en Logistiek Vlaanderen, 2010

A LEZ can be structured in different ways. Table 2 states that countries mainly introduce emission criteria on trucks. Car traffic is hardly affected by the measure. A different motivation is expected for cities and countries choosing to restrict trucks and cars in contrast with the ones only restricting trucks. The authors expect different emission problems or emission goals to lie at the basis of this difference. The city of Stockholm (Sweden) as pioneer, started to implement LEZ's in 1996. Since then, others followed this example, but changed criteria and exceptions. Germany and the Netherlands were identified as two good examples to further look at. Both have a national framework, where many cities followed the national guidelines when implementing the measure locally. The clear difference is that Germany decided to include all road traffic in the scheme, whereas the Netherlands is only strict on Dutch trucks above 3.5 tons loading capacity. Both have interrelated measures on public transport fleets, city-owned vehicles and other emission sources like heating and industrial activities. Germany is having the biggest number of cities implementing the measure, 38 in total, whereas The Netherlands has introduced LEZ's in 12 cities. The enforcement is mainly organized manually, although Amsterdam (NL) invested in camera's with number tag recognition. (Van den Brinck, *et al*., 2008; Umweltzone.net, 2011)

1.1. LEZ's in the Netherlands

The Netherlands has experience with LEZ's since some years. A national framework was set up in which cities can find their possibilities in implementing a LEZ locally. The city needs to sign a convenant, a charter, with the national authorities when implementing a LEZ. In 2006, the covenant *Stimulating clean freight vehicles and environmental zones* was signed for the first time. It is signed between the Ministry of Housing, Spatial Planning and the Environment (VROM), the Ministry of public works (V&W), EVO (the shippers council), TLN (transport organization) and KNV (transport workers) and the city concerned. The convenant has put forward steps when implementing a LEZ for freight vehicles, so that a coordinated implementation is possible. Passenger cars are not taken into account yet, although some cities are thinking about a LEZ implementation for these vehicles. The covenant has more actions incorporated besides the LEZ implementation. Actions like clean public transport, a clean urban vehicle fleet and stimulating efficient urban distribution is put forward. The Dutch LEZ's apply uniform criteria where freight vehicles need to comply with (Table 3). (Logistiek.nl, 2008)

Table 3 : Emission criteria in Dutch LEZ's

Till the 1st of January 2010	- Euro 0 and Euro 1 freight vehicles are banned. - Euro 2 and Euro 3 freight vehicles are only allowed if equipped with a fine particle filter, installed five months from market release. - Freight vehicles complying with Euro 4 on any other way are allowed in the LEZ.
Between the 1st of January 2010 and the 1st of July 2013	- A Euro 3 freight vehicle is allowed after January 2010 if maximum 8 years old, equipped with a fine particle filter (except when not being available on the market). - Euro 4 freight vehicles and cleaner (Euro 5, Euro 6 and EEV) are allowed.

From the 1st of July 2013	- Only Euro 4 freight vehicles and cleaner are allowed. Some listed types of vehicles, like the LPG and CNG powered fleet, are exempt for the LEZ scheme till the age of 13 years old. - A local exemption is possible for max 12 times a year if the vehicle owner has a motivation not to comply with the LEZ. The exemption are given by the city council.

Source : Nieman *et al*., 2010

The above-mentioned national framework creates uniformity. All vehicles +3.5 ton need to comply with Table 3' criteria. LEZ's exist in Amsterdam, Breda, Rotterdam, Delft, Den Bosch, Den Haag - Rijswijk, Eindhoven, Leiden, Utrecht, Maastricht en Tilburg and are indicated by standard road signs. Enforcement happens on the basis of the number tags. These are checked manually by civil servants, or by automatic number plate recognition technology. The LEZ's in the Netherlands are to be evaluated yearly. The most recent report by Nieman *et al*., (2010) studied the impact, the strengths and the weaknesses. In addition, the study incorporates the excepted impact for the years 2013 and 2015. Uniformity allows comparing the results of the cities involved. Some insights are listed below.

1. <u>The LEZ is effective on certain locations</u>

   For roads where the EU PM_{10} emission criteria are not met, the effect is significant (lowering emission concentrations by 0.15 to 0.25 µg/m^3). Both the 2013 and 2015 predictions show similar effects. On roads where the 2015 criteria for NO_2 concentrations would not be met (40 µg/m^3), the effect can result in an extra decrease of 0.3 µg/m^3.
2. <u>The LEZ decreases the share of transport in the total PM_{10} emissions</u>

   Transport is playing a big role in in the negative effects by fine particles like PM_{10}. By implementing a LEZ, the traffic share on total PM_{10} concentrations in 2010 decreased by 2 to 7%. These concentrations, alongside roads in the LEZ, are in 2010 on average 0.02 – 0.08 µg/m^3 lower compared to the scenario without an LEZ.
3. <u>The LEZ leads to a decrease in NO_2-concentrations from 2013</u>

   Remarkable is that the 2010 NO_2 concentrations are not lower than in the scenario without LEZ's, due to the fact that the newest combustion engines emit hardly less NO_X and the negative effects of fine particle filters on NO_2 concentrations. From 2013, a decrease of between 0.02 to 0.09 µg/m^3 is possible. The intensity of transport has declined by 1 to 2%. In 2015, the effects will be comparable to these in 2013.
4. <u>Effects are not like in the original simulations</u>

   When comparing the effects simulated before 2007 with the actual 2010 effects, LEZ's prove to be less effective. Three reasons were found. First, the new trucks are less clean than predicted; Second, the policy on installing particle filters helped reducing the PM_{10} emissions but not the

NO_2 concentrations, as the latter went up. Last, the predicted effects were calculated on the basis of optimal conditions, without exemptions and with full compliance.

5. The percentage of trucks not meeting the criteria halves

   The percentage of trucks not meeting the criteria in the convenant, i.e. trucks with exemptions or contraveners, was on average 25% in 2010. Without the LEZ, this would have been 48%. The number of banned trucks, not meeting the criteria, is on average between 20 en 30%.

6. Big differences between compliance in different cities

   In Amsterdam, 5% of all tucks are violating the criteria, whereas in ‘s-Hertogenbosch, Eindhoven and Breda this is 20 to 25%. Amsterdam is equipped with automatic number tag registration cameras. This will be a strong law enforcement factor.

7. Better enforcement leads to a bigger compliance

   Comparing Amsterdam with other cities proves that compliance is better when enforcement is more fierce, although the trucks not being banned are on average not cleaner than in other cities. To have a *level playing field* between cities and transporters, compliance should be similar in all cities.

8. The pressure of the LEZ’s on the truck replacement policies is decreasing

   The fleet is gradually getting cleaner, as all new trucks are cleaner. One cannot buy a *dirty* truck anymore.

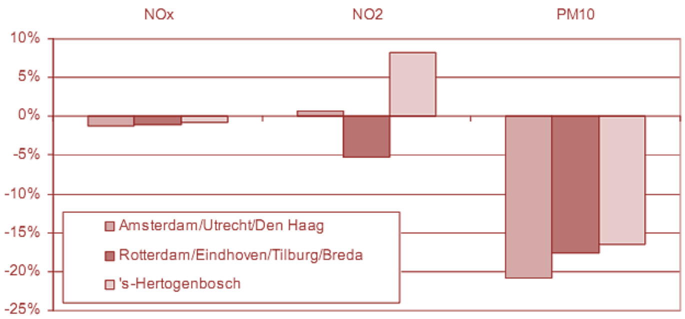
9. Cities renew their fleets and public transport is getting cleaner as well

   Of the 10 LEZ publishing more details on their fleet, six (Utrecht, Breda, Delft, Rotterdam, ‘s-Hertogenbosch en Leiden) have a big part of their fleet not meeting the criteria (> 15%). The other four cities (Amsterdam, Eindhoven, Den Haag en Tilburg) have almost 100% of their vehicles meeting the criteria. Utrecht replaces in 2011 the majority of the fleet.

10. LEZ’s fuel urban distribution actions

    Many LEZ’s have made different actions possible focusing on urban distribution. New innovative concepts (Cargohopper, binnenstadsservice.nl, beer boat etc.) arose and are still in operation. (Nieman *et al*., 2010)

Figure 2 : Effects of LEZ’s on NO_X, NO_2 an PM_{10} in the Netherlands



Source : Nieman *et al.*, 2010

On locations where day exceedings of PM_{10} emissions exist, the LEZ's have a positive impact of 0.15 to 0.25 µg/m^3, although due to fleet replacements the LEZ's loose impact on the fleets. The effect on the concentration of NO_2 is 0.3 µg/m³. The share of traffic in PM_{10} emissions lowered by 2 to 7%, being a decrease of 0.02 to 0.08 µg/m^3. NO_2 is not affected that much, only a reduction of 0.02 to 0.09 µg/m^3 is expected. For PM_{10}, a -21% decrease is observed in Amsterdam/Utrecht/Den Haag next to -16% or better in the other cities, shown in Figure 2. (Nieman *et. al.*, 2010)

1.2. LEZ's in Germany

German LEZ's, called Umweltzones, are having as well a national framework but cities have the freedom to allow locally criteria to be more strict than in other German cities. All vehicles driving in the German LEZ's need to have a sticker on the windscreen. These are green, yellow and red, symbolizing the emission class of the vehicle, like shown in Table 4. All traffic is included in the scheme, making Germany a unique example.

Table 4 : Criteria in German LEZ's

Euro norm	First day on the market passenger cars	First day on the market trucks and busses	
	Diesel	**Diesel**	
Euro 1 or worse	Before 01.01.1997	Before 01.10.1996	No sticker
Euro 2 or Euro 1 with filter	Before 01.01.1997 to 31.12.2000	Before 01.10.1996 to 30.09.2001	
Euro 3 or Euro 2 with filter	Before 01.01.2001 to 31.12.2005	Before 01.10.2001 to 30.09.2006	
Euro 4 or Euro 3 with filter	Before 01.01.2006	Before 01.10.2006	
	Petrol / Gas	**Petrol / Gas**	
Euro 1 or worse	Before 01.01.1993	Before 01.01.1993	No Sticker
Euro 1 and better	Before 01.01.1993	Before 01.01.1993	

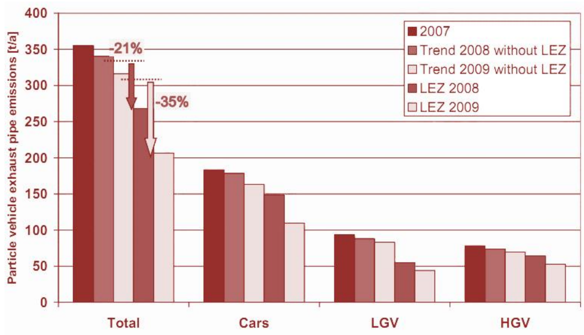
Source : Umweltzone.net, 2011

Signs at the boundaries of the LEZ indicate whether red, yellow and green vehicles are allowed. All colors are allowed in the first phase. Later on, red and yellow are banned. In Frankfurt for example, from January 2010 yellow and green-stickered vehicles are allowed, whereas yellow ones are already banned in Berlin. The impact is huge. Only in Berlin, the zone is almost 38 on 34 km big. Therefore, Berlin's results in particular are included in the paper. (Milieusticker.eu, 2011; Rauterberg-Wulff, 2010, The climate company, 2011)

The impact of Berlin's fleet is significant. In 2008, at start-up, not less than 21,000 diesel passenger cars (pre-Euro 2), 29,000 diesel vans (pre-Euro 2) and 29,000 petrol-powered cars were influenced, being 7% of the 1.26 million vehicles in Berlin. From 2010 on, almost 22,000 diesel cars were banned.

Figure 3 gives an insight in the LEZ results on PM_{10}, a decrease of 31% on the trend by 2009. Vehicle replacement policies were affected. Not less than 90% were Euro 4 vehicles, compared to the national average of 49%. For trucks in particular this is 75% compared to 25-30%. Also a reduction of 10 to 15 day exceedings on PM_{10} (> 50 µg/m³ for PM_{10}) was achieved. (Rauterberg-Wulff, 2010)

Figure 3 : Diesel PM_{10} emissions in Berlin' LEZ



Source : Rauterberg-Wulff, 2010

Given the above insights regarding PM_{10}, a 2-7% 2010 reduction in the Netherlands and a -35% 2009 reduction in Germany - section two simulates the implementation of a LEZ in three Belgian cities: Antwerp, Mechelen and Leuven (Yperman, Vanhove & Voogt, 2010). First, an overview is given of the actual trend without policy changes. Secondly, analyzing LEZ's with different characteristics is giving more insight in the concrete savings on emissions that could be achieved.

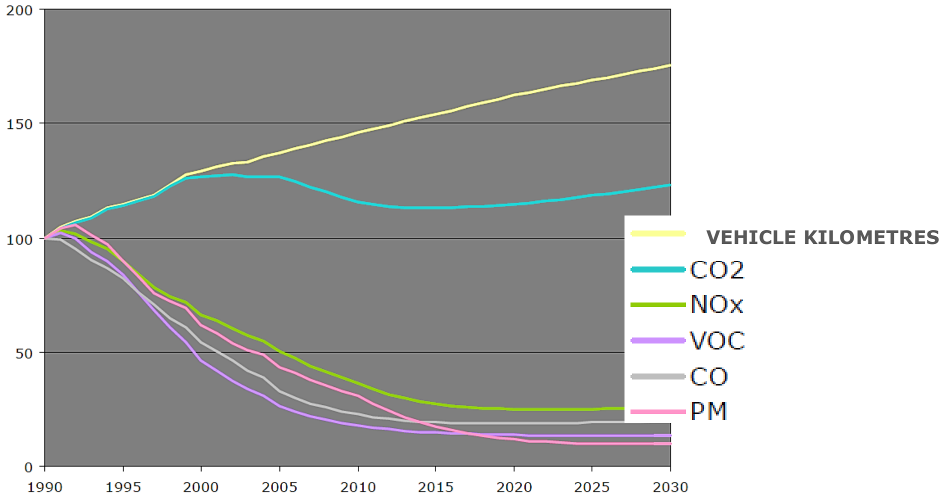
2. Simulation results for Belgium and Flanders

Yperman, Vanhove & Voogt (2010) looked at the opportunities of implementing LEZ's in Flanders. A base scenario simulation gives insight in the future developments on emissions, without any policy changes. A potential impact on 740,123 vehicles is expected if the Dutch example (limitations only on Dutch trucks +3.5 tons and busses) would be followed. The German scenario consists of taking into account all motorized vehicles entering the zone. In that situation, the measure might be concerning 5,932,689 vehicles (specialized vehicles and tractors exempted). These numbers only concern Belgian-registered vehicles. (Statbel, 2009)

The autonomous changes are going in the good direction. Yperman *et al.* (2010, p. 39) state that all emission levels besides NO_2 will decrease. NO_2 levels will increase by 2015 due to the introduction of

Euro 5 engines but will afterwards go down by 2020. Figure 4 illustrates this evolution (Transport and Mobility Leuven, 2006). Road transport is increasing and is predicted to increase further, so emission decreases are fully related to the new engine technologies fueled by the Euro norms. In Belgium, just as in other Western-European countries, a strong increase in transport is expected: 30% for passenger cars between 2005 and 2030, and 60% of tonkm for freight vehicles. (Planbureau, 2009)

Figure 4 : Expected evolution of Belgian road transport related emissions, 1990 = 100



Source : Transport and Mobility Leuven, 2006

The Belgian cities of Antwerp (485,000 inhabitants), Leuven (98,000 inhabitants) and Mechelen (63,000 inhabitants) were looked at in more detail. Data of the Flemish traffic centre was used, however, due to data problems, not taking into account data on busses. Differentiated emission factors were applied to the traffic predictions, based on types of vehicles, fuel (petrol or diesel), emission classes in the fleet, engine- and non-engine related emissions and three types of roads. These predicted autonomous evolutions show a significant decrease of emissions. All percentages are comparing 2015 and 2020 predictions with the 2010 levels. Reductions for Antwerp are: -45% and -41% on Elementary Carbon and $PM_{2.5}$ by 2015 and respectively -72% and -64% by 2020. As Also NO_X is expected to decrease by 2020 by 49%. Moreover NO_2 is decreasing by 25% by 2020. For Mechelen, -36% and -60% on respectively Carbon and $PM_{2.5}$ is expected. Moreover, a 41% reduction on NO_X is possible, next to a 14% reduction in NO_2. (Yperman *et al.*, 2010)

First, in the case of Antwerp, two simulation zones were defined : one compromising the historic centre and a 7 times larger zone bounded by the ring road. For Leuven and Mechelen only one zone was defined, being within the ring road. The basis scenario tested is with a Euro 4 norm by 2015 and Euro 5 norm by 2020. In the case of Leuven, a second simulation took place with criteria: Euro 5 by 2015 for diesel vehicles and Euro 6 by 2020. Petrol vehicles should meet Euro 1 by 2015 and Euro 2 by 2020 in the basz scenario, or Euro 2 and Euro 4 in the more strict scenario. The scenario does not simulate a shift to vehicles falling out the scope of the zone (light trucks). Only through-passing vehicles are expected to go around the zone.

The simulations gave a significant decrease in emissions, for some scenarios. Therefore, the results per zone are discussed. The Antwerp scenario including all traffic gave some significant decreases in emissions. For all emissions, the 2020 results are compared to the base scenario. This scenario gives decreases of -66%, -43% on $PM_{2.5}$, -26% on NO_X and -15% on NO_2. The small and big zone give an effect, correlated with the vehicle intensity in the zone. So, a 7 times bigger zone gives a 7 times bigger emission decrease. The scenario with only trucks gives less promising results. The decreases go from 1 to 2% in the base scenario. Secondly, the Leuven results for all traffic give -65% on Carbon, -43% on $PM_{2.5,}$ -26% on NO_X and -15% on NO_2 by 2020. These results are similar to the Antwerp results. The base scenario with only trucks give a decrease of 2-6% compared to the reference scenario. The second scenario for Leuven, with the more strict criteria, give an extra decrease. These are -64% on Carbon, -44 for $PM_{2.5}$, -41% on NO_X and -35% on NO_2 (by 2020). Thirdly, a scenario with all traffic gave in Mechelen a decrease of -66% on Carbon, -44% on $PM_{2.5}$, -24% on NO_X and -14% on NO_2. Those results are almost identical to the Antwerp and Leuven results. The scenario's with only trucks give a small decrease of only 0.3% (compared to the reference scenario).

On the basis of these results, one can conclude that regarding emission decreases, LEZ's can prove useful in meeting emission goals. The results show, however, that not only trucks need to be taken into account, as these scenarios give no extra decreases compared to the reference scenario's. A second observation is that the bigger the zone is, the bigger the effects are, straightforward as the traffic intensities are higher in a bigger zone, so are the emissions.

3. The economic and logistics effects

Next to the effects on emissions, researchers in transport economics wonder about the possible effects on the logistics operations. In any LEZ, trucks are partly banned, whereas cars are almost never focused on. Only London and Germany are having different policies, focusing on all traffic. Very little studies are taking into account these effects. Therefore, it is useful to incorporate these findings. Parallels with Belgian logistics are expected.

3.1. Economic costs and benefits

Buck Consultants International en Goudappel Coffeng BV made a study in 2009 looking at the effects the Dutch LEZ's are having. A number of cost-benefit conclusions were possible, as some cities had already implemented the zones according to the convenant mentioned above. Thus the costs for cities were based on the real costs made by the cities. According to Buck Consultants International &

Goudappel Coffeng BV (2009), the costs are dividable in three categories : First the research and process costs which occur before implementation, second the implementation costs, third the operational costs. In section 3.1.4., the benefits are looked at.

3.1.1. Research and process costs

When implementing an LEZ, cities are obliged to sign the Dutch covenant including a stepwise plan. The effects on (local) air quality have to be simulated before implementing the LEZ scheme. Often outsourced research partners are doing this step, so a cost estimation is straightforward. In many cities, the research phase is used to simulate also the logistics activities within the city so that the decision makers have a clear view on the flows of goods, characteristics and type of transport lorries used. On the basis of this research, many cities took measures to change logistics activities to a more efficient use of the limited road capacity. The costs for this first phase are mainly related to the size of the city, and therefore considerably. A number tag database composition is estimated to cost 15,000 EUR. To have a clear view on the flows of goods, characteristics and type of transport lorries used in the concerned city some research on logistics in the city is needed : estimated cost is 30,000 EUR. A simulation on emissions is estimated at 10,000 EUR and as last the economic effects study would cost 10,000 EUR. A 0.5 FTE is needed to safeguard the process. Buck Consultants International and Goudappel Coffeng BV (2009) estimate this phase to cost 100,000 EUR. (Buck Consultants International en Goudappel Coffeng BV, 2009)

3.1.2. Implementation costs

If a city is choosing to implement an LZE, based on the research taking place in phase one, extra costs do occur. The infrastructure will need some adaptation meaning small road works and putting in place new signing. After the decision an intense communication campaign is necessary to inform the citizens and logistics operators about the implementation and criteria that the latter ones do need to comply with. The infrastructural costs related to the enforcement policy need to be taken in to account as well. These costs add up, and are off course interrelated to the number of entries to the LEZ, and the communication strategy used. Communication and signing would cost 40,000 EUR. A basic law enforcement infrastructure would cost 40,000 EUR as well. (Buck Consultants International en Goudappel Coffeng BV, 2009)

If an automated enforcement system is used, these costs will be bigger in the investment phase. But operationally, the costs will by lower compared to a pure manual mechanism. Buck Consultants International and Goudappel Coffeng BV (2009) estimate these costs being 80,000 EUR.

3.1.3. Operational costs

As last cost category one can distinguish is that of operational costs. When the zone is implemented, strict enforcement is necessary. A big operational cost difference is seen between the fully automated control and pure manual enforcement. Next to this category, some administration will be needed. If stickers are needed, the administrative costs go up but preferably these will be covered by an administrative charge. The majority of the operational costs will be related to law enforcement. Buck Consultants International and Goudappel Coffeng BV (2009) estimate this to 75,000 EUR per year.

3.1.4. Benefits

Next to the cost, a LEZ has benefits as well. According to Buck Consultants International and Goudappel Coffeng BV (2009), these are four. First: cleaner air in the city making the city more attractive for companies, offices and inhabitants. On the other hand this positive effect can be overshadowed by extra logistics difficulties. Second benefit is that the LEZ's in the Netherlands prove that an incentive is given to companies to innovate. New concepts for urban logistics flourish in cities where trucks are banned. A third benefit: health effects. Cleaner air will have a positive impact on the health of all living, working, passing the zone and even to a certain extent around it. Especially, the last one is difficult to quantify. (Buck Consultants International and Goudappel Coffeng BV, 2009)

A last benefit that needs to be added is that LEZ's can help EU member states to comply with European emission maxima that were agreed. Some countries were recently referred to court for not meeting the criteria. (European press release IP/11/435, 2011) No decision was made, but when a monetary penalty would be given, this is an indirect cost effect not having a LEZ scheme. This penalty could be weighed against the direct costs described in 3.1.1. to 3.1.3.

3.2. Logistics effects

Effects on the logistics sector will be expected. Fleets will need to be renewed faster than planned. Strangely, this impact is hardly taken into account by governments as well as in research. Only one academic publication was found (Browne *et al*., 2004). For the Netherlands, some basic calculations were made. For Amsterdam, economic effects on the logistics were estimated to lie between 5 and 8 million EUR. In total, for 8 LEZ's, the replacement of trucks and investments in filters was estimated at between 20 and 25 million EUR. Extra yearly depreciation costs would be between 2.5 and 3.1 million EUR per year. All is related to the implementation speed, and emission criteria. A slow implementation gives the industry time to react whereas a quick decision lets the transporters no choice to change their fleets. Even when only a part of the fleet needs to be renewed, costs occur. Non-compliant vehicles can be used outside the zones, but this limits the flexibility of transport companies. Efficiency is lost. On the other hand, The Netherlands proves that LEZ's among other measures fuel urban logistics innovations which can lower the costs. A 1.5 to 3 million EUR savings on operational cost could be realized when innovating. (Buck Consultants International en Goudappel Coffeng BV, 2009)

Browne *et al.* (2004) prepared a research project looking at logistics effects of a LEZ in London. Interviews and survey results were combined: 55 answers were received from logistics companies. Only a small number of transporters would choose a route around the LEZ. The majority wants to comply to the criteria, and changing to a fleet not in the scheme (small vans) was not seen as an option. Hardly any transport company would drive into the zone without complying. What was seen was that many, especially the biggest companies, would reorganize their fleets so that the oldest ones would drive around the zones. This has a positive effect on air quality within the zones, but on a national level this could result in an opposite effect. (Browne *et al.*, 2004) A problem could occur if these policy decisions are mainly favorable to the big companies. When looking at the Belgian fleet, 3,479 transport companies own only one truck. The majority of 75% on 8,703 companies has 5 vehicles or less. These are in a very weak position as these small companies cannot shift fleets easily. (Febetra, 2011) A similar survey was undertaken pointing out that 48% of the respondents are indifferent to a LEZ implementation in Flanders. 34% even found it a good measure. This research mainly looked at the shippers which stated that 87% expects a negative influence on flexibility and load factors. On the other hand, the research pointed out that environmental parameters are more and more included in the bidding process for new transport agreements. (Maes, Sys, Vanelslander, 2011)

When reflecting on the cost benefits balance, one cannot make a detailed conclusion because of a lack of research on the costs for the economy, the qualitative nature of liveability of cities and the high dependence of local situations (types of zones, type of vehicle included, big versus small cities etc.). The economic cost benefit balance seems to be negative. A big effort is asked from the logistics sector where the benefits like air quality improvements are difficult to quantify.

CONCLUSIONS

In this paper, the policy measure of Low Emission Zones was analyzed in detail. Whereas European policies (eg. Euronorms etc.) are mainly looking at the new produced vehicles, the implementation of an LEZ is a measure looking entirely at older/available vehicles. These vehicles can be passenger cars or trucks. The paper consisted of desk research which resulted in an overview of European examples, an analysis of the Dutch and German cases and a cost benefit analysis.

Directives like 2008/50/EG concerning Air Quality are obliging countries to take action to limit EU citizens' exposure to emissions. The 2008 average CO_2 of new produced cars was in Flanders 148 g/km, exceeding the agreed common EU goals by almost 6%. In 2009, the average CO_2 emissions for the fleet dropped to 143 g/km. A decreasing trend is seen, although not as much as necessary to meet EU goals. Belgium is struggling to meet the goals. The emissions not fast enough decreasing, which is a first emission problem Flanders is coping with. As Belgium is not meeting EU these air quality goals, action is necessary and urgent. The EC even decided to refer among others Belgium to the EU Court of Justice because of not meeting PM_{10} emission criteria. The EU PM_{10} emission criteria were in Flanders exceeded more than 35 times. This is a second striking example of Flanders not meeting the agreed criteria. Therefore research into LEZ's is adding value.

The Netherlands set up a convenant structure structuring the implementation in 12 cities. The results is a 2-7% decrease on the 2010 PM_{10} emissions. When looking at European countries, one can conclude that Germany, with LEZ's for all traffic, is really the exception. All others are only banning national trucks not complying with the criteria put in place. The results in both cases are significant, whereas the German example has made possible a drastic cut on emissions within the city boundaries. Not less than 35% of PM_{10} emissions was saved on the trend in 2009. Of which speaking is very positive for emission intensities. Without any policy change, even taking into account a major European traffic increase, emission levels go down. Bringing us to the long term effects of the policies of the European Union.

The latest evaluation study of the Dutch LEZ's gave us the comment that the influence of LEZ's is diminishing, as fleets get cleaner and cleaner. Next, the simulation of Yperman, Vanhove, & Voogt (2010) and the German example showed a better effect of LEZ's on all traffic. Therefore, the conclusion is that, to be effective and if implemented, an LEZ should be implemented on all traffic. Only influencing trucks will have little impact on emissions on the other hand forcing the logistics sector to change fleets faster than planned.

Because the costs and benefits are difficult to quantify, a concrete conclusion is not possible. The research gave insight in the height costs for the transport industry, intermediate costs for the bodies implementing the LEZ and a uncertain unquantifiable impact on liveability of cities and the monetary benefits of cleaner air.

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