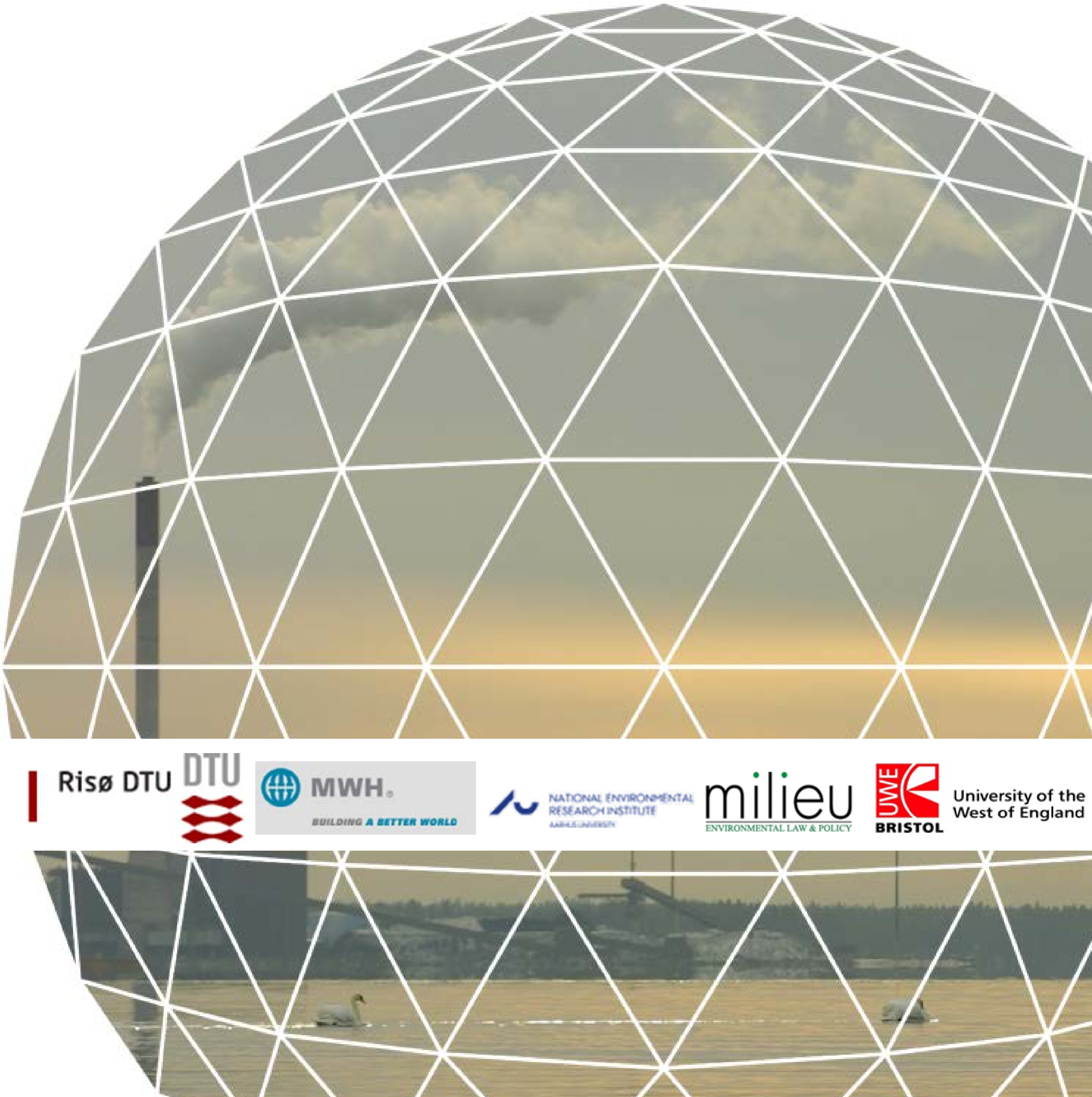
Project implemented by consortium partner:

FEASIBILITY STUDY: EUROPEAN CITY PASS FOR LOW EMISSION ZONES

Final Report

Client: DG Environment



FEASIBILITY STUDY: EUROPEAN CITY PASS FOR LOW EMISSION ZONES

Final Report

Client: DG Environment

Rotterdam, 30 January 2014

ECORYS

About Ecorys

At Ecorys we aim to deliver real benefit to society through the work we do. We offer research, consultancy and project management, specialising in economic, social and spatial development. Focusing on complex market, policy and management issues we provide our clients in the public, private and not-for-profit sectors worldwide with a unique perspective and high-value solutions. Ecorys' remarkable history spans more than 80 years. Our expertise covers economy and competitiveness; regions, cities and real estate; energy and water; transport and mobility; social policy, education, health and governance. We value our independence, integrity and partnerships. Our staff comprises dedicated experts from academia and consultancy, who share best practices both within our company and with our partners internationally.

Ecorys Netherlands has an active CSR policy and is ISO14001 certified (the international standard for environmental management systems). Our sustainability goals translate into our company policy and practical measures for people, planet and profit, such as using a 100% green electricity tariff, purchasing carbon offsets for all our flights, incentivising staff to use public transport and printing on FSC or PEFC certified paper. Our actions have reduced our carbon footprint by an estimated 80% since 2007.

ECORYS Nederland BV
Watermanweg 44
3067 GG Rotterdam

P.O. Box 4175
3006 AD Rotterdam
The Netherlands

T +31 (0)10 453 88 00
F +31 (0)10 453 07 68
E netherlands@ecorys.com
Registration no. 24316726

W www.ecorys.nl

Preface

This Final Report has been prepared by the Ecorys Consortium under Specific Agreement 6 of Framework Contract ENV.C.3/FRA/2011/08. The project has been carried out by consortium members MWH, Milieu, Ecorys and Aarhus University, under MWH leadership.

The project team and authors of this report are:
Douglas Clark (team leader)
Rob Jeuring
Willem Spit
Oskars Beikulis
Valts Vilnitis
Vladislav Bizek
Matthew Williams
Agnieszka Markowska
Niall Lawlor
Guillermo Hernandez
Lucy Sadler
Chetan Lad
Sarah Strickland

Table of contents

List of Tables

List of Figures

Abbreviations, Acronyms and Symbols

24/7	continuous operation 24 hours a day, 7 days a week
AEI	Automatic equipment identification
ANPR	Automatic Number Plate Recognition system
AQG	WHO Air Quality Guidelines
ARM	Access Regulation Measure
ARS	Access Restriction Scheme
AVI	Automatic vehicle identification
BaP	Benzo(a)pyrene
BC	Black carbon
BEV	Battery Electric Vehicle
CDR	Central data repository, at EEA
CLRTAP	UNECE Convention on Long-range Transboundary Air Pollution
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
DG ENV	European Commission Directorate-General for Environment
DG MOVE	European Commission Directorate-General for Mobility and Transport
DOC	diesel oxidation catalyst
DPF	Diesel particulate filter
DPF	diesel particle filter
DSRC	dedicated short-range communications
EEA	European Environment Agency
EGR	Exhaust gas recirculation
EMEP	European Monitoring and Evaluation Programme (under CLRTAP)
ETC/ACM	European Topic Centre / Air Quality and Climate Change Mitigation
EU	European Union
EU13	“New” Member States of the EU
EU15	“Old” Member States of the EU
EU27	Member States of the EU prior up to 30 June 2013.
EU28	Member States of the EU since 1 July 2013 (including Croatia).
EUCARIS	EUropean CAR and driving license Information System
FCREV	Fuel-cell Range Extender Vehicle
FFV	Flexi-fuel Vehicle
GRPE	Working Party on Pollution and Energy of the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29)
HEV	Hybrid Electric Vehicle
HFCV	Hydrogen Fuel Cell Vehicle
ICE	Internal Combustion Engine
IIASA	International Institute for Applied Systems Analysis
ITS	Intelligent Transport System
Lden	Day-evening-night noise indicator
LEC	low emission certificate
LEZ	Low Emission Zone
LNG	Liquefied natural gas
Lnight	Night time noise indicator

LPG	Liquefied petroleum gas
mg	milligram
NFR	UNECE Nomenclature for reporting
ng	nanogram
NMVOC	Non-methane volatile organic compounds
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides (NO and NO_2)
NRMM	non-road mobile machinery
O_3	Ozone
OBE	on-board equipment (toll payment device)
OBU	on board unit (toll payment device)
Pb	Lead
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate matter
PM_{10}	Particulate matter smaller than 10 µm in diameter. Technical definition for monitoring: Particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at an aerodynamic diameter of 10 µm
$PM_{2.5}$	Particulate matter smaller than 2.5 µm, also known as fine particles. Technical definition for monitoring: Particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at an aerodynamic diameter of 2.5 µm
REC	retrofit emission control device
REEV	Range Extender Electric Vehicle
RPC	reduced pollution certificate
RSU	road side unit (toll collection device)
SCR	Selective Catalytic Reduction
SCR	selective catalytic reduction
SMART	specific, measurable, attainable, relevant and time-bound
SO_2	Sulphur dioxide
SUMP	Sustainable Urban Mobility Plan
SWOT	Strengths, Weaknesses, Opportunities, and Threats. A structured planning method.
TSAP	Thematic Strategy on Air Pollution
UMP	Urban Mobility Package
UNECE	United Nations Economic Commission for Europe
VOC	Volatile organic compounds
WHO	World Health Organization
µg	microgram
µm	micrometer

1 Introduction

1.1 Introduction

This Final Report, together with Annex A, is the fourth deliverable of the project. It presents the results of the two tasks of the project: 1) literature review supported by relevant cases and 2) the assessment of the potential for a European city pass.

1.2 Background

Air quality is a problem in many European cities. In many European cities, PM_{10} and NO_2 concentrations still exceed EU air quality limit value set in 1999, which were to be met by 2005 or 2010. The newer $PM_{2.5}$ limit value will be challenging to meet by 2015. The WHO (2013) has reconfirmed and strengthened the documentation of serious health impacts of urban air pollution and recommends revision of limit values to the even lower WHO guideline levels. As a result, many cities have introduced low emission zones (LEZ) to improve air quality and to meet the limit values. There is increasing evidence that LEZs can have significant benefits to human health, even though the reduction of PM_{10} levels may be modest (Cyrys et al, in press).

There are no uniform regulations or standards for LEZs in the Member States, although a few (Germany, Denmark, Sweden, Netherlands, Czech Republic) have adopted national LEZ regulations. Even within the Member States with national LEZ regulations, each city may be free to implement LEZ with local conditions and administration, creating a patchwork of restrictions and procedures that can be a burden for intercity and international drivers and road transport operators.

The guidance and proposed voluntary standards in this document are intended to assist Member States and municipalities to implement harmonised LEZ that minimize the social and economic impacts of LEZ, while maximizing the air quality, noise and health benefits.

1.3 Project tasks and structure of this report

Task 1

Task 1 sought to identify results of existing studies (case studies) and literature that can be synthesised into general guidance for cities implementing LEZ, to be carried out in Task 2. Five subtasks have been carried out under Task 1.

Task 1.1 *Identify cities with existing air quality problems that may benefit from a LEZ*. The results were first presented in the Interim Report, and are presented here in Chapter 2. An addendum to the previously reported work is included in section 2.4, regarding the breakdown of exceedances and LEZ by exceedance type.

Task 1.2 *Summarize the air quality and health benefits of LEZ reported in recent literature*. The results of this literature review were first presented in the Initial Report, and are presented here in Chapter 3.

Task 1.3 *Summarize the noise benefits of LEZ reported in recent literature*. The results were presented in the Initial Report, and are presented here in Chapter 4.

Task 1.4 Summarize the costs and social and commercial impacts associated with implementation of LEZ. The results of this task were presented in the Initial Report. They are combined with the results of Task 2.4 and presented in Chapter 8.

Task 1.5 *Identify innovative approaches to LEZ.* There results of this task are presented in Chapter 5. This chapter has not been presented before.

Task 2

The overall objective of Task 2 is to assess the barriers and risks, and costs and benefits of propose standards and guidance for European City Pass system of harmonised LEZ. The following six subtasks have been carried out.

Task 2.1 *Identify aspects of LEZ that could be standardized at the EU level*. The results of this task are combined with Task 2.2 and presented in Chapter 6. Both of these tasks were presented in the Interim Report.

Task 2.2 *Identify the possible scope of a European City Pass system*. The results presented in Chapter 6 combine the results of Task 2.1 and 2.2, which were previously presented in the Interim Report.

Task 2.3 Assessment of potentials and risks. Presented in Chapter 7. Previously presented in the Interim Report.

Task 2.4 *Cost benefit analysis*. The results of Task 2.4 are presented in Chapter 8. This combines the results of Task 1.4, which has been previously reported in The Initial Report.

Task 2.5 *Guidance and requirements document for the European City Pass system*. The result of Task 2.5 is the report "Standards and Guidance for European Low Emission Zones", which is Annex A to this report.

Task 2.6 *Final conclusions and recommendations*. Conclusions and recommendations of the project are given in Chapter 9.

2 Limit Value Exceedances and Low Emission Zones

2.1 Introduction

This chapter focuses on two questions that were not quantitatively addressed in the 2010 study of access restriction schemes (ISIS & pwc 2010):

1. How many cities with exceedances of air quality limit values for NO_2 or PM_{10} have included a low emission zone among the measures to achieve compliance?

and the inverse question:

2. Do all cities with low emission zones have exceedances of air quality limit values?

The first question should reveal the extent to which LEZ is viewed as an effective and politically and social acceptable air quality improvement measure. Differences in LEZ adoption rates between Member States may be indicative of differences in strategies, differences in vehicle fleets and political priorities for compliance with air quality standards.

The second question should reveal if LEZ are being implemented in cities that meet the air quality limit values. Implementation of LEZ where air quality criteria are already met would raise the question of whether such a measure is justified. An industrial stakeholder (AECA, 2013) has expressed concern that LEZ schemes should only be implemented in cities that would not comply with EU air quality legislation.

In the process of answering these questions, limitations of the available data have been encountered, which are also discussed.

2.2 Data and methodology

Cities with exceedances of NO_2 or PM_{10} limit values

Information on exceedances of air quality limit values in EU cities is available in several ways:

1. Member States submit annual air quality assessment reports to the European Commission under the Air Quality Framework Directives[1], known as the *Air Quality Questionnaire*[2]. The questionnaires include statistical data for all monitoring stations used for compliance checking, for each air quality zone in the Member State. The questionnaires are submitted to the EEA and are accessible online via EEA's Central Data Repository (CDR[3]). The most recent questionnaires are for 2011;
2. Member States annually submit validated monitoring data to EEA under the Exchange of Information Directive[4]. These submitted data are also accessible online via CDR;

[1] Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe, which replaced the former Air Quality Framework Directive 96/62/EC.

[2] Commission Decision 2004/461/EC laying down a questionnaire to be used for annual reporting on ambient air quality assessment.

[3] http://cdr.eionet.europa.eu/.

[4] Council Decision (97/101/EC) of 27 January 1997 establishing a reciprocal exchange of information and data from networks and individual stations measuring ambient air pollution within the Member States.

3. EEA compiles statistical data at each monitoring location from the submitted monitoring data, which is available as AirBase datasets on monitoring stations, measurement parameters, and statistics[5]. The most recent statistics are available for 2011;
4. The European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM) compiles an annual overview of the submitted Air Quality Questionnaires for the European Commission[6]. This includes a spreadsheet list of air quality zones with compliance status for all air quality limit values. The most recently available list is for 2010[7].

For this task, the first and third data options were used. A list of all NO_2 and PM_{10} monitoring stations with reported exceedances of NO_2 (hourly or annual) or PM_{10} (daily or annual) limit values was taken from the country questionnaires for 2011 on the EEA Central Data Repository. These were matched to monitoring site descriptions taken from the Airbase list of monitoring stations[8]. The list of zones with exceedances in item 4 above was not readily usable for this task, because the air quality zone names do not correspond to city names, except for the largest cities (agglomerations).

Of the total 8413 monitoring stations, 1043 measured exceedances of either NO_2 (hourly or annual) or PM_{10} (daily or annual) limit values, or both in 2011. These included 518 traffic stations, 447 background stations, 70 industrial stations and 8 with unspecified station type.

The monitoring stations with NO_2 or PM_{10} exceedances were extracted to a separate spreadsheet. Each city could have more than one monitor measuring an exceedance, so a pivot table was used to identify cities with exceedances; 752 cities were identified as having exceedances of either NO_2 or PM_{10} in 2011. Norway and Switzerland were not included in the search.

The number of cities in 2011 that exceeded the annual limit value for NO_2 (40 µg/m^3) was 291. These ranged from 41 µg/m^3 in 15 cities up to 103 µg/m^3 in Florence, Italy.

A total of 32 cities in 2011 exceeded the hourly limit value for NO_2 (200 µg/m^3) more than 18 times. All but four of these cities also exceeded the annual limit value. The hourly exceedances ranged from 19 hours above the limit value in two cities to 269 hours above in Stuttgart, Germany.

The annual limit value for PM_{10} (40 µg/m^3) was exceeded in 154 cities in 2011, ranging from 41 µg/m^3 in 18 cities up to 87 µg/m^3 in Pernik, Bulgaria. All but three of these cities also exceeded the daily limit value for PM_{10}.

The daily limit value for PM_{10} (50 µg/m^3) was exceeded on more than 35 days in 569 cities in 2011. The number of days of exceedance ranged from 36 days in 17 cities up to 219 days in Pernik, Bulgaria.

Cities with LEZ or ARS

Two existing lists of cities with access restrictions and/or low emission zones have been used to identify cities with LEZ:

- A list of cities from the 2010 study on access restriction schemes "ARS 2010" (ISIS & pwc, 2010). The ARS 2010 list contains 340 cities, with an addition 41 city-LEZ entries where there

[5] AirBase - The European air quality database. http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-7.

[6] Jimmink et al. (2011), Jimmink et al. (2012).

[7] http://acm.eionet.europa.eu/docs/AQQlist_of_Zones_2010_ETC_ACM_TP_2012_7.xls.

[8] http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-7/AirBase_v7interim_stations.zip.

are distinct ARS and LEZ for the same city. The ARS 2010 list includes information on the type and objective of each scheme, vehicle types restricted, enforcement approach, and charging;
- The Low Emission Zones in Europe website (www.lowemissionzones.eu) "LEZ list", which includes 204 different cities, as of August 2013.

The combined list of ARS and LEZ cities totals 386 cities, with 158 cities appearing on both the LEZ website list and ARS 2010 lists.

2.3 Results of combining lists

For each of the 752 cities with measured exceedances, the city name was looked up in the lists of ARS and LEZ cities. Of cities with exceedances, 183 (24%) appear on either the ARS or LEZ lists, while 569 cities with exceedances (76%) do not appear in either the ARS or LEZ lists. There are 203 cities from the ARS and LEZ lists (53%) that are not in the list of cities with exceedances. The combined list contains 954 cities.

Table 2.1 presents a summary of the numbers of cities on the three lists by country.

Table 2.1 Distribution by country of 923 cities from the combined lists of cities with exceedances and cities in the ARS 2010 list and LEZ website list. Note that exceedances were not identified for Norway (NO) and Switzerland (CH)

Country code	Cities with exceedances in 2011	Cities in ARS 2010 list	Cities in LEZ list
AT	37	2	3
BE	18	10	1
BG	26		
CH		2	
CY	1	1	
CZ	50	4	1
DE	122	56	68
DK	1	5	5
EE		2	
ES	31	12	
FI	1	1	
FR	73	18	
GB	8	36	3
GR	7	1	
HU	13	4	1
IE		2	
IS		1	
IT	170	113	97
LU	1	1	
LV	1	3	
MT	1	1	
NL	8	25	13
NO		4	3
PL	118	4	

Country code	Cities with exceedances in 2011	Cities in ARS 2010 list	Cities in LEZ list
PT	12	5	1
RO	6	17	
SE	6	7	8
SI	10	3	
SK	25		
Total	**746**	**340**	**204**

A total of 125 (60%) of the LEZ website cities have exceedances of NO_2 or PM_{10} reported in the air quality questionnaires for 2011. Some of the LEZ cities not appearing in the list of cities with exceedances may be part of regional low emission zones or zones associated with major urban areas which do have exceedances. However, there are a significant number (79) of cities with LEZ that do not appear to exceed the NO_2 or PM_{10} limit values in 2011. This simple analysis does not take into consideration the implementation date for the LEZ nor prior history of exceedances, so it is possible that some LEZ cities without exceedances may have achieved their purpose by 2011.

Table 2.2 presents the distribution of number of cities with and without LEZ (defined by presence in the LEZ website list), by occurrence of exceedances of the NO_2 or PM_{10} limit values in 2011.

Table 2.2 Distribution of cities with and without LEZ, by occurrence of exceedances of NO_2 or PM_{10} in 2011

	with exceedance			no exceedance			
Country	**with LEZ**	**no LEZ**	**subtotal**	**with LEZ**	**no LEZ**	**subtotal**	**Total**
AT	1	36	37	2		2	39
BE	1	17	18		7	7	25
BG		26	26				26
CH					2	2	2
CY		1	1				1
CZ	1	49	50				50
DE	60	62	122	8	6	14	136
DK	1		1	4		4	5
EE					2	2	2
ES		31	31		8	8	39
FI		1	1				1
FR		79	79		4	4	83
GB	2	6	8	1	28	29	37
GR		7	7				7
HU	1	12	13				13
IE					2	2	2
IS					1	1	1
IT	46	124	170	51	26	77	247
LU		1	1				1
LV		1	1		2	2	3
MT		1	1		1	1	2
NL	7	1	8	6	13	19	27
NO				3	1	4	4

	with exceedance			no exceedance			
Country	with LEZ	no LEZ	subtotal	with LEZ	no LEZ	subtotal	Total
PL		118	118		1	1	119
PT	1	11	12		3	3	15
RO		6	6		14	14	20
SE	4	2	6	4	1	5	11
SI		10	10		1	1	11
SK		25	25				25
Total	**125**	**627**	**752**	**79**	**123**	**202**	**954**

Out of 752 EU cities with exceedances of NO_2 or PM_{10} in 2011, 125 (17%) are on the LEZ website (have implemented an LEZ, or plan to). Exceedances were not identified for Ireland (IE), Norway (NO) and Switzerland (CH). Germany (60) and Italy (46) account for the largest number of LEZ in cities with exceedances. Nearly 50% of cities in Germany with a reported exceedance have implemented a LEZ; this high percentage may be due to the presence of a national LEZ framework.

There are 79 cities that have implemented (or are part of) an LEZ that do not have a reported exceedance of NO_2 or PM_{10} limit value. 51 (65%) of these 79 non-exceedance LEZ-cities are in Italy. The presence of an LEZ in some of these cities may contribute to their compliance with the air quality limit values. Some of these 79 cities may not have monitoring stations. Some may be small cities or towns that are part of a regional LEZ, in particular in Germany and Italy. It is difficult to make any conclusion on these non-exceedance LEZ cities without further analysis of the air quality history, LEZ implementation history and other factors.

A total of 272 cities in the combined list are in new Member States (EU12[9], prior to Croatia). Only two of these cities (Prague, Budapest), both with exceedances, have implemented LEZ. There are 249 other EU12 cities with NO_2 or PM_{10} exceedances that do not appear on the LEZ website list. Poland has the largest number (118) of cities with exceedances, but no LEZ have been implemented in Poland according to the LEZ website. Since only two LEZ are implemented in EU12 countries, this indicates that information and harmonization of LEZ will be particularly useful for these Member States.

Distribution by type of monitoring location

The above tabulations do not distinguish the type of monitoring location where the exceedance is measured. Categorization of the station types could help to narrow the types of exceedances for which a LEZ may be a useful measure for urban air quality improvement.

Air quality questionnaires and data submitted under the Exchange of Information Directive include metadata about the monitoring stations, including the type of exposure (traffic, background, industrial) and the character of the surrounding area (urban, suburban, rural). Since there can be several monitoring stations of different types within a given city, the following four exceedance categories have been derived for this study:

- traffic exceedance at one or more urban or suburban traffic (roadside) monitoring locations (regardless of other monitoring sites in the same city);
- background exceedance at one or more urban or suburban background monitoring locations (but not at a traffic monitoring location);
- industry exceedance only at an urban or suburban industrial area monitoring site;
- rural exceedance only at a rural monitoring site.

9 "EU12" new accession Member States: Cyprus (CY), Czech Republic (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Malta (MT), Poland (PL), Slovakia (SK), Slovenia (SI), Bulgaria (BG) and Romania (RO).

Each of the 746 cities with exceedances has been categorized into one of the above four exceedance categories, based on the metadata for the 1043 stations at which exceedances occurred in 2011. Table 2.3 shows the distribution of the 945 cities on the combined list of exceedance cities and LEZ/ARS cities, by type of exceedance and presence of an LEZ.

Table 2.3 Distribution of analysed cities by type of exceedance and occurrence of LEZ

Number of cities	Type of exceedance in 2011					No exceedance	Total
	Traffic	Back-ground	Industry	Rural	Total		
LEZ	113	10	1	1	125	79	204
no LEZ	240	282	41	58	621	120	741
Total	**353**	**292**	**42**	**59**	**746**	**199**	**945**

Of the 204 cities on the LEZ list, 113 (55%) have an exceedance at a traffic-related monitoring station of one or more of the NO_2 or PM_{10} limit values. Only 10 LEZ cities (5%) have an exceedance only at a background monitoring location, and one each industrial and rural location. The 621 non-LEZ cities with exceedances have 39% with traffic exceedances, 45% with background exceedances, and 16% industrial or rural exceedances.

It is noteworthy that 240 of the 358 cities with traffic exceedances (68%) have not implemented or planned an LEZ, according to the LEZ website. If cities with background exceedances are included, then there are 522 out of 645 cities with exceedances of NO_2 or PM_{10} limit values that have not implemented an LEZ (81%). This gives a better estimate of the number of European cities where an LEZ is a potential measure to attain the NO_2 or PM_{10} limit values.

As shown before, there are 79 cities without an exceedance of the NO_2 or PM_{10} limit values in 2011 that are on the LEZ list. Additional study of the exceedance history, LEZ implementation history and other city aspects would be necessary to confirm if some of these 79 cities have LEZ without justification based on non-attainment of air quality limit values.

2.4 Breakdown by type of exceedance

Note: This section is an addendum to the Task 1.1 analysis presented in Chapter 2 of the Interim Report.

This section presents a further analysis of the breakdown of exceedances by specific limit value, and by category of exceedance location (based on station surroundings where an exceedance is recorded).

Table 2.4 shows the breakdown of the 746 cities with NO_2 or PM_{10} exceedances in 2011, by pollutant with exceedance, and by type of location (monitoring station) where exceedances occur. The "traffic" category is cities where an exceedance of either NO_2 or PM_{10} occurs at least one traffic-related station (urban or suburban). The "background" category is cities where an exceedances are recorded only at an urban or suburban background station (but not at a traffic-related station). The "industry" and "rural" categories are cities where exceedances are recorded only at industrial or rural monitoring locations.

It must be noted that this analysis does not distinguish between cities with no exceedances at traffic-related stations and cities that do not have any traffic-related monitoring stations.

Table 2.4 Breakdown of number of cities with NO_2 or PM_{10} exceedances in 2011 by pollutant and exceedance location category

Number of cities	Exceedance location category				
Exceedance	**Traffic**	**Background**	**Industry**	**Rural**	**Grand Total**
NO_2 only	158	7	5	6	176
PM_{10} only	88	280	37	52	457
NO_2 and PM_{10}	107	5		1	113
Grand Total	**353**	**292**	**42**	**59**	**746**

Of 289 cities with NO_2 exceedances, 265 (92%) include an exceedance at traffic-related monitoring station. Only 24 cities (8%) have NO_2 exceedances at non-traffic locations only.

For the 570 cities with PM_{10} exceedances, 195 cities (34%) include exceedances at traffic-related locations and 285 (50%) cities have exceedances only at background locations. 90 (16%) of the cities with PM_{10} exceedances have exceedances only at industrial or rural locations, where an LEZ would not be relevant.

Among the 353 cities with traffic-related exceedances, 265 (75%) include an NO_2 exceedance and 195 (55%) include a PM_{10} exceedance. 107 cities (30%) have both NO_2 and PM_{10} exceedances, and only 88 cities (25%) have only PM_{10} exceedances.

For the 292 cities where exceedances only are recorded at background stations, 285 (98%) have PM_{10} exceedances while 12 (4%) have NO_2 exceedances.

This indicates that cities with NO_2 exceedances include exceedances at traffic-related locations (92%), while cities with PM_{10} exceedances include many cities with exceedances only at background locations. Measures to mitigate NO_2 exceedances need to clearly focus on traffic, while measures for PM_{10} exceedances may also need to focus on non-traffic sources.

Exceedances of both short-term and long-term limit values are combined in the above analyses. **Table 2.5** presents a more detailed analysis of the specific limit values exceeded for the traffic and background exceedance location categories.

Table 2.5 Breakdown of the number of cities with NO_2 or PM_{10} exceedances in 2011 by exceedance location type and specific limit values exceeded

	PM_{10} exceedance				
NO_2 exceedance	**daily and annual**	**daily**	**annual**	**none**	**Total**
Traffic					
hourly and annual	9	5		11	25
hourly		1		1	2
annual	31	60	1	146	238
none	22	64	2		88
Total traffic	62	130	3	158	353
Background					
hourly and annual					
hourly				1	1
annual	3	2		6	11
none	78	202			280

	PM_{10} exceedance				
NO_2 exceedance	daily and annual	daily	annual	none	Total
Total background	81	204		7	292
Traffic or background	143	334	3	165	645

There are nine cities where all four limit values are exceeded in 2011 – hourly and annual NO_2 limit values, and daily and annual PM_{10} limit values. All nine are cities with exceedances at traffic-related locations.

Of the 165 cities with NO_2 exceedances at traffic locations, 27 (10%) have exceedances of the short-term hourly NO_2 limit value, while 263 (99%) exceed the annual NO_2 limit value. There are 25 cities (15%) with exceedances of both NO_2 limit values.

Most of the cities with PM_{10} exceedances exceed the daily limit value. Of the 480 cities with PM_{10} exceedances at traffic or background locations, 447 (99%) exceed the short-term daily limit value, and 337 (70%) exceed the long-term annual limit value. The short-term PM_{10} limit value predominates in both the traffic and background location categories. The long-term PM_{10} limit value is more likely to be exceeded at background locations (68%) than at traffic locations (28%).

2.5 Discussion

Difficulties in using the lists of ARS and LEZ

Each dataset used slightly different naming conventions for certain cites (e.g. Vienna/Wien, Prague/Praha) so an "Alternative name" column was added to ensure cities were not missed from the lookup process. A number of spelling corrections had to be made to make the lists match, and duplicate entries removed. Even within some Member State's questionnaires for reporting, different spellings for city names can occur, such as using both the native and English spellings for a city.

A city can be part of a larger regional ARS or LEZ (see examples below), or can have more than one zone or ARS type defined within the city (for example London, Milan, Copenhagen). The two lists have no consistent approach for handling these multi-city or multi-zone situations, which complicates their use for statistical purposes. The ARS 2010 list has separate rows for LEZ when there is also a distinct ARS scheme in a city – with "- LEZ" appended to the city name on the second row.

The LEZ list includes changes in zone definitions when regulations or standards change, resulting in multiple entries for many cities. Identification of the "current" LEZ situation requires careful compilation.

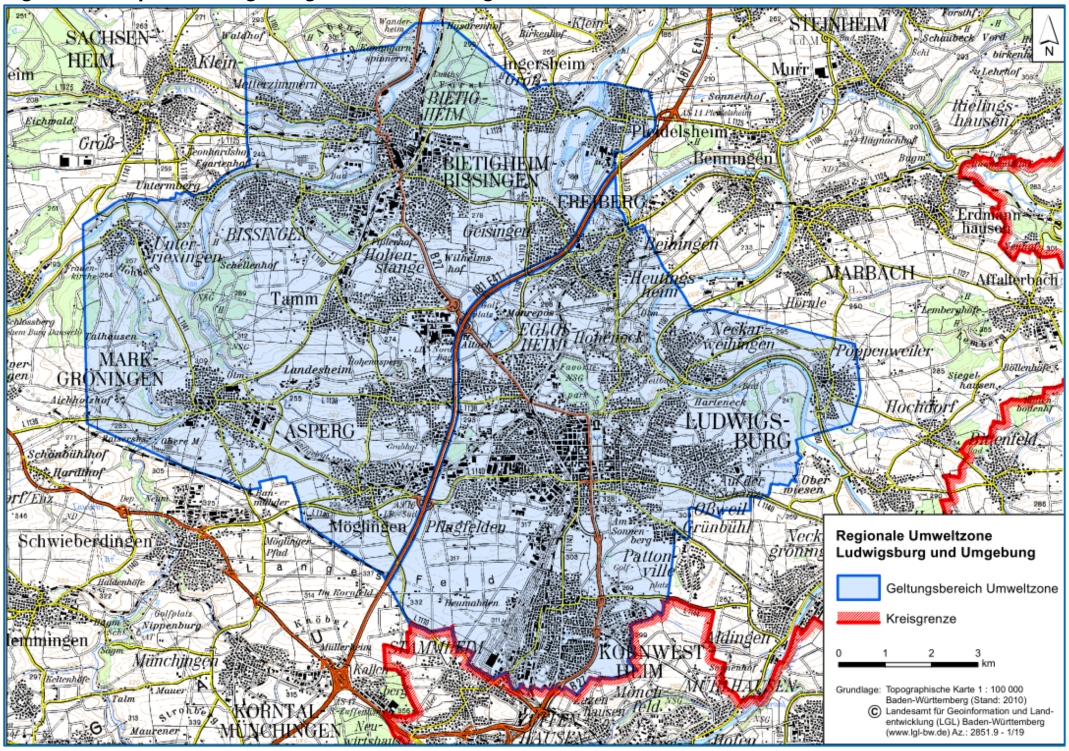
The complex nature of access restriction schemes requires a database system for full flexibility in maintenance and analysis of the information, which is beyond the scope of this investigation.

Multi-city regional LEZ

The number of cities appearing in the LEZ list is larger than the actual number of low emission zones, because some zones are regional, containing multiple cities.

For example, the "Ludwigsburg and Surroundings LEZ" in Baden-Württemberg, Germany, includes 10 cities/towns: Ludwigsburg, Markgröningen, Pleidelsheim, Ingersheim, Freiberg am Neckar, Kornwestheim, Asperg, Möglingen, Tamm and Bietigheim-Bissingen (lowemissionzones.eu), as shown in **Figure 2.1.**

Figure 2.1 Map of Ludwigsburg and Surroundings LEZ



Source: lowemissionzones.eu.

The "Ruhr area LEZ" in Nordrhein-Westfalen is a single LEZ covering 820 km², including the 13 towns/cities of: Bochum, Bottrop, Castrop-Rauxel, Dortmund, Duisburg, Essen, Gelsenkirchen, Gladbeck, Herne, Herten, Mühlheim, Oberhausen, and Recklinghausen (lowemissionzones.eu).

In Denmark, Copenhagen and Frederiksberg are two municipalities within the Copenhagen metropolitan area, which appear both separately and as a combined "city" in the LEZ list. Several other cities have similar "complexities" which make the analysis more difficult.

Limitations in the available monitoring data

By using a single year for air quality monitoring statistics, this simple analysis does not take into account the exceedance history of the cities. Some cities with exceedances prior to 2011, or where 2011 had more favourable air quality conditions than previous years, may be omitted from the compilation, for comparison to the LEZ list.

Not all cities have monitoring stations at traffic locations. The occurrence of an exceedance at an urban or suburban background station is less conclusive evidence to justify implementation of a LEZ.

The data does not include population or area size of the cities where exceedances occur. The population and geographic area are significant factors in determining the relevance of LEZ as an emission reduction measure.

2.6 Conclusions

Only one third of the European cities with exceedances of one or more NO_2 or PM_{10} limit values in 2011 at a traffic-related monitoring station have implemented (or planned) an LEZ, as listed on the LEZ website (lowemissionzones.eu). Two-thirds (240 cities) have traffic-related exceedances but no LEZ, and 51 of these (21%) are in new EU12 Member States. Including cities with exceedances only at background stations, the number of exceedance cities without LEZ rises to 522. There is a significant number of cities where implementation of LEZ could be considered as a measure to accelerate compliance with EU air quality legislation.

The current list of LEZ includes 79 cities without exceedances of NO_2 or PM_{10} limit values in 2011. About two-thirds of these are in Italy. This simple analysis is insufficient to conclude if any of these cities lack air quality justification for their LEZ based on PM_{10} or NO_2.

The annual NO_2 limit value and the daily PM_{10} limit value give rise to more exceedances than the hourly NO_2 limit value or annual PM_{10} limit value. There are few cities where the hourly NO_2 or annual PM_{10} limit values are exceeded without also exceedance of the other limit values. This suggests that focus on mitigating of the annual NO_2 limit value and daily PM_{10} limit value will also mitigate the exceedances of the other less frequently exceeded limit values.

Measures that reduce the number days with high PM_{10} concentrations may be favoured in planning for PM_{10} reductions. For NO_2, measures that reduce overall concentrations throughout the year are needed.

Cyrys et al (in press) find that the health benefits of LEZ are significant even if the reduction in PM_{10} concentrations are small, since LEZ reduce exhaust combustion particulate (including black carbon) that have the greatest correlation with health impacts. This indicates that LEZ may be beneficial even if there is no evidence of exceedance of the PM_{10} limit values.

2.7 References

- ACEA. (2013). ACEA Position Paper: Low Emission Zones. European Automobile Manufacturers Association (ACEA). Retrieved from http://www.acea.be/images/uploads/files/20130603_ACEA_position_Low_Emission_Zones.pdf;
- Cyrys, J., Peters, A., Soentgen, J., & Wichmann, H.-E. (in press). Low Emission Zones Reduce PM_{10} Mass Concentrations and Diesel Soot in German Cities. Journal of the Air & Waste Management Association. doi:10.1080/10962247.2013.868380;
- EEA. (2013a, January 10). Zones in relation to EU air quality thresholds, 2010. Retrieved 4 September 2013, from http://www.eea.europa.eu/data-and-maps/data/zones-in-relation-to-eu-air-quality-thresholds-4;
- EEA. (2013b, July 22). Datasets - AirBase - The European air quality database. Retrieved 4 September 2013, from http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-7;
- EU. (1997). Council Decision (97/101/EC) of 27 January 1997 establishing a reciprocal exchange of information and data from networks and individual stations measuring ambient air pollution within the Member States. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31997D0101:en:NOT;
- EU. (2004). Commission Decision (2004/461/EC) of 29 April 2004 laying down a questionnaire to be used for annual reporting on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC and under Directives 2000/69/EC and 2002/3/EC of the European

Parliament and of the Council. European Commission. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004D0461:EN:NOT;
- EU. (2008). Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0050:EN:NOT;
- ISIS, & pwc. (2010). Study on Urban Access Restrictions, Final Report (No. TREN/A4/103-2/2009). European Commission, DG MOVE. Retrieved from http://ec.europa.eu/transport/themes/urban/studies/doc/2010_12_ars_final_report.pdf;
- Jimmink, B., de Leeuw, F., Ostatnická, J., Schreiberová, M., & Corbet, L. (2012). Reporting on ambient air quality assessment in the European region, 2010 (No. ETC/ACM Technical Paper 2012/7). The European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM). Retrieved from http://acm.eionet.europa.eu/docs/ETCACM_TP_2012_7_AQQ2010.pdf;
- Jimmink, B., de Leeuw, F., Ostatnická, J., Schreiberová, M., & Viana, M. (2011). Reporting on ambient air quality assessment in the EU Member States, 2009 (No. ETC/ACM Technical Paper 2011/7). The European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM). Retrieved from http://acm.eionet.europa.eu/docs/ETCACM_TP_2011_7_AQQ2009.pdf;
- Sadler Consultants Ltd. (2013). Low Emission Zones in Europe. Low Emission Zone in Europe Network (LEEZEN). Retrieved 4 September 2013, from http://www.lowemissionzones.eu/.

3 Air Quality and Health Benefits of LEZ

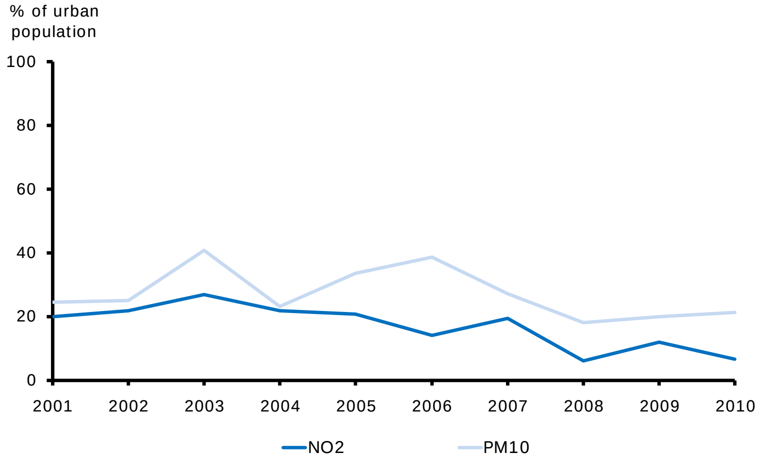
3.1 Introduction

This chapter presents a literature review of the air quality and health benefits of cordon-based low emission zones. This review focuses on the literature since the 2010 *Study on Urban Access Restrictions* ("ARS study") (ISIS 2010).

Air Quality and Low Emission Zones

The EU Ambient Air Quality Directive and fourth Daughter Directive set out Limit Values and Target Values for a number of pollutants including nitrogen dioxide, particulate matter with a diameter of less than 10 µm (PM_{10}) and particulate matter with a diameter of less than 2.5 µm ($PM_{2.5}$). Concentrations of NO_2 and PM_{10} exceed the limit values in many urban areas in Europe; Figure 3.1 shows the percentage of the urban population resident in areas where pollutant concentrations exceed the limit values between 2001 and 2010.

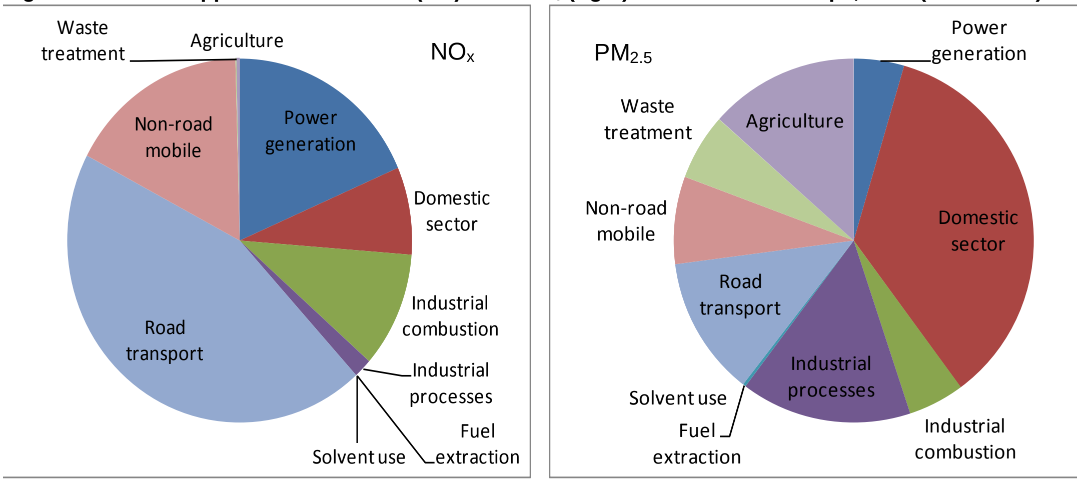
Figure 3.1 Percentage of urban population resident in areas where pollutant concentrations are higher than selected limit/target values, 2001-2010 (EU-27)



Source: European Environment Agency http://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-1/exceedance-of-air-quality-limit-4.

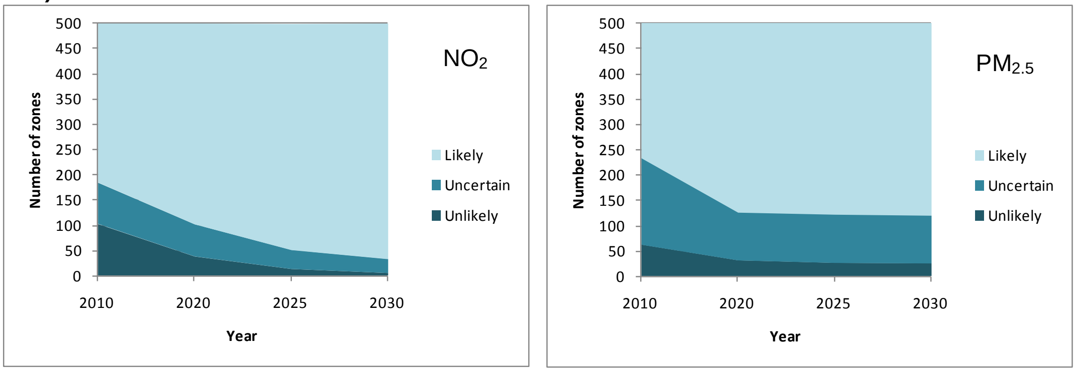
Figure 3.2 shows the breakdown of emissions of NO_x and $PM_{2.5}$ in Europe for 2010 (IIASA 2012). The impact of each source group will vary depending on the nature and locations of emissions. The impact of road transport emissions in urban areas is generally much more significant that other groups due to the proximity of the emissions from the receptors.

Figure 3.2 Source apportionment of NO_x (left) and $PM_{2.5}$ (right) emissions for Europe, 2010 (IIASA 2012)



Concentrations of NO_2 and PM_{10} in urban areas have decreased in recent years due to a combination of national and local measures. National measures include the National Emissions Ceiling Directive which sets upper limits for each Member State for the total emissions in 2010 of sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia, and the regulation of pollutant emissions from road transport through progressively tightening vehicle emissions standards. Concentrations are predicted to decrease further in future years; **Figure 3.3** shows the projected changes in the number of EU zones complying with the NO_2 and PM_{10} limit values, respectively (IIASA, 2013).

Figure 3.3 Projected number of EU zones complying with NO_2 (left) and PM_{10} (right) limit values (IIASA, 2013)



The regulation of road vehicle emissions through the Euro standards not only leads to a continual improvement in air quality through the replacement of older, more polluting vehicles with newer, cleaner vehicles, it also allows policy makers at a local level to restrict access to certain areas by vehicles which do not meet certain Euro standards through the formation of Low Emission Zones.

Low Emission Zones

A growing number of urban areas in Europe are introducing low emission zones. The details of the schemes including the objectives, types of restriction and regulatory instruments vary. **Table 3.1** gives examples of some of the LEZs considered in this study.

Table 3.1 Examples of Low Emission Zones

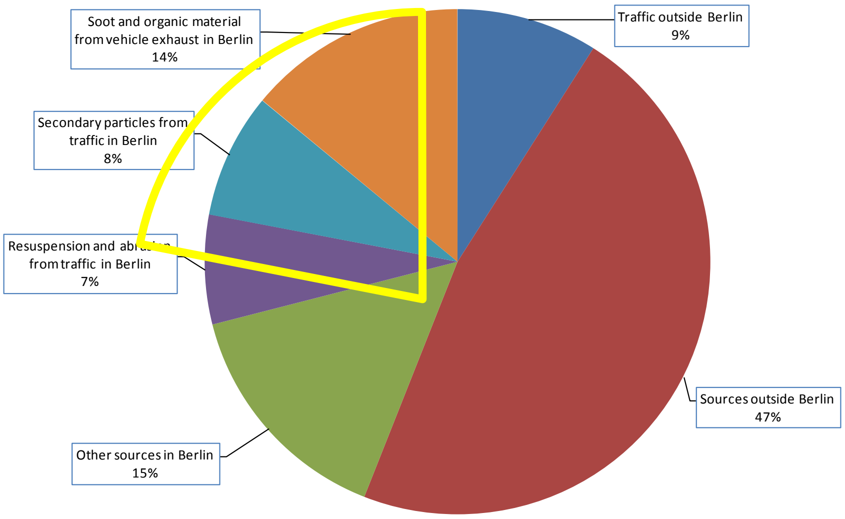
City	Regulated vehicles	Minimum engine standard	Introduction date
Lisbon	All	Euro 1	2011
		Euro 2 in central area; Euro 1 in outer area	2012
Copenhagen	HDV	Euro 3; older vehicles require particle filters	2008
		Euro 4; older vehicles require particle filters	2010
London	HDV	Euro 3	2008
		Euro 4	2012
Milan	All	Petrol Euro 3 Diesel Euro 4 with particle filter	2008
Berlin	All	Diesel Euro 2 or Euro 1 with particle filter Petrol Euro 1 with catalytic converter	2008
		Diesel Euro 4 or Euro 3 with particle filter Petrol Euro 1 with catalytic converter	2010
Amsterdam	HDV	Euro 4 or Euro 2/3 with particle filters	2008
		Euro 4 or Euro 3 with particle filters and less than 8 years old	2010
		Euro 4	2013

Low emission zones have the potential to be an effective tool in the reduction of pollutant concentrations in urban areas because:

- road traffic is usually the largest local contributor to pollutant concentrations in urban areas; and
- reductions in emissions can be made in locations where pollutant concentrations are highest.

However, the impact of any LEZ is limited by various factors including the type of vehicle restricted, the minimum engine standard required and also the local contribution of traffic emissions to pollutant concentrations. In particular, a large component of urban particulate concentrations is from sources outside the city. In addition, the traffic component is made up of contributions from exhaust, brake-wear, tyre-wear, road-wear and resuspension; only the exhaust component can be reduced by excluding vehicles with lower emission standards in a low emission zone. For example, **Figure 3.4** shows source apportionment of the total $PM_{2.5}$ concentration at a roadside location in Berlin in 2007 (Lutz & Rauterberg-Wulff, 2010). Only 22% of the total $PM_{2.5}$ concentrations results from sources which can be addressed by a LEZ: 14% from exhaust and 8% from secondary particles, outlined in yellow in **Figure 3.4**.

Figure 3.4 Source apportionment of PM2.5 at a roadside location in Berlin in 2007



Similarly, estimation of the traffic component to PM_{10} concentrations on H.C Andersen Boulevard in Copenhagen (Jensen et al 2010) showed that the average street concentration was 42.5 µg/m³, of which 4.9 µg/m³ (12%) was the contribution from vehicle exhausts. Of the 4.9 µg/m³ due to vehicle exhaust, about 1.3 µg/m³ (26%) came from heavy duty vehicles (HDVs). Diesel particulate filters (DPF) can reduce the PM exhaust emissions from HDVs by about 80% - about 1 µg/m³ reduction in this case. This means that the maximum potential reduction in PM_{10} concentrations on the street due to the LEZ requiring DPF on all HDV is about 1.0 µg/m³.

Although the reduction of the ambient PM_{10} concentration may seem small, the particles removed are ultrafine diesel combustion particles, including black carbon (soot). Diesel particulate has been declared carcinogenic by WHO (IARC 2012). Cyrys et al. (in press) show that in German LEZs can have significant health benefits even though the PM_{10} reductions are modest.

3.2 Air quality impact assessments

Before implementation of LEZ

Prior to the implementation of many of the LEZs, assessments were carried out to quantify the likely impacts on air quality. The first step is to quantify the likely change in emissions due to the LEZ by compiling emissions inventory for scenarios with and without LEZ. Such studies require various assumptions to be made based on the nature of the scheme:

- The composition of the vehicle fleet before the LEZ;
- Will the LEZ have an impact on total traffic flows?
- Will the LEZ displace more polluting vehicles to other areas?
- Will more polluting vehicles be replaced by brand new vehicles, vehicles which just meet the access criteria or will they be retrofitted with abatement technology to meet the criteria?

For example, in Copenhagen (Jensen et al 2010), the implementation of the Environmental Zone was assumed to result in the following changes to the vehicle fleet: all Euro 3 heavy duty vehicles were fitted with particle filters; Euro 0-2 heavy duty vehicles were replaced with Euro 5 vehicles; Euro 0-1 and 50% of Euro 2 buses are replaced with Euro 5 buses; and 50% of Euro 2 and all Euro 3 buses are equipped with particle filters.

Table 3.2 gives a summary of the projected changes in emissions due to the introduction of the LEZ in a number of cities.

Table 3.2 Projected reductions in NOx and PM10 emissions due to introduction of LEZs

Location	NO_x emission reduction, %	PM_{10} emission reduction, %	Emissions category	Reference
Lisbon	7	34	Total traffic emissions	Ferreira et al, 2011
Copenhagen	17	9	Total traffic emissions	Jensen et al, 2010
London	7.3	6.6	Total traffic emissions	Kelly et al, 2011
Berlin	19	35	Total traffic emissions	Lutz & Rauterberg-Wulff, 2010
Netherlands	0	20	Freight emissions only	Goudappel Coffeng and Buck Consultants International, 2010
Opava (Czech republic)	16.5	13.5	Total traffic emissions	Špička et al, 2011

Care should be taken in interpreting and comparing these emissions reductions as each study will have used different assumptions and importantly, emission factors. Recent changes to emission factors have addressed issues with differences between emission rates in real-world driving conditions compared with emission limit values (Katsis et al, 2012) meaning that older studies have tended to overestimate emission reductions due to an LEZ.

The next step is to quantify the impact of these changes in emissions on pollutant concentrations by carrying out dispersion modelling.

The air quality impact assessment of the Environmental Zone in Copenhagen (Jensen et al, 2010) used a dispersion model to calculate concentrations of NO_2, PM_{10} and $PM_{2.5}$ in 138 busy streets for the years 2010, 2015 and 2020. The modelling predicted decreases in the number of locations exceeding the NO_2 limit value from 65 streets in 2010, 22 in 2015 and 3 in 2020 to 35 in 2010, 15 in 2015 and 2 in 2020. At the 138 busy-street locations, concentrations of PM_{10} are not predicted to exceed the limit values. Concentrations of PM_{10} were predicted to decrease by 0.7 µg/m³ (2.5%) in 2010, 0.4 µg/m³ in 2015 and 0.1 µg/m³ in 2020, and $PM_{2.5}$ by 0.7 µg/m³ (3.5%) in 2010, 0.3 µg/m³ in 2015 and 0.1 µg/m³ in 2020.

The impact of the London LEZ was assessed by modelling traffic emissions on 6344 road links (Kelly et al, 2011). The modelling predicted a decrease in the area exceeding the PM_{10} limit value by 16.2% and the NO_2 limit value by 15.6% in 2012. Comparing to future scenarios without an LEZ this was estimated to accelerate the attainment of the limit values by three to four years.

Modelling for cities in the Netherlands (Goudappel Coffeng and Buck Consultants International, 2010) shows that in 2010 the introduction of the LEZ had minimal impact on NO_2 concentrations. In 2013 and 2015, the impact of the LEZ on NO_2 concentrations was predicted to increase to approximately 0.05 µg/m³. In 2010, PM_{10} concentration were predicted to decrease by an average of approximately 0.04 µg/m³, reducing to approximately 0.02 µg/m³ by 2015.

The effect varied considerably by location, particularly related to the number of HGVs using the street; in 2015 the reduction in NO_x concentrations was predicted to range from less than 0.02 µg/m³ on streets with less than 250 HGVs per day to more than 0.1 µg/m³ for streets with more than 750 HGVs per day. For PM_{10} the reduction varied between less than 0.01 µg/m³ to more than 0.4 µg/m³.

Furthermore, for those streets which are predicted to exceed the limit value for NO_2, the average impact of the LEZ was predicted to be 0.15 µg/m³, three times the average impact for all streets.

After implementation of LEZ

A number of studies have been carried out to quantify the actual impact of the LEZ on air quality by analysis of monitoring data. For example the number of days exceeding the PM_{10} 24-hour limit value in Milan reduced from 132 days in 2007, before the introduction of the Ecopass scheme, to 109 days in 2008 and further to 86 days in 2010 (Danielis et al, 2011). In the same period annual average PM_{10} concentrations decreased from 51 µg/m³ in 2007 to 44 µg/m³ in 2008 and 40 µg/m³ in 2010. However, the impact of the LEZ has not been separated from other factors which would have reduced concentrations even without the Ecopass scheme.

More detailed analysis of monitoring data has been carried out for other cities. A study of PM_{10} levels in urban areas in Germany (Malina & Fischer, 2012) analysed monitoring data controlled for meteorological conditions, traffic volumes and seasonal variations and found significant decreases in PM_{10} concentrations due to the introduction of LEZs. Moreover, the impact of Stage 2 LEZs (which ban Euro 2 diesel vehicles) was found to be greater than Stage 1 LEZs (which only ban Euro 1 diesel vehicles and petrol vehicles without catalytic converters).

A study of LEZs in five Dutch cities (Boogard et al, 2012) compared measured reductions in concentrations of NO_x, PM_{10}, $PM_{2.5}$, particle number, elemental carbon, PAHs, CO, benzene and toluene were compared with calculated emission reductions for the same period excluding any effect of the LEZ. The difference in the measured and modelled reductions in concentrations was attributed to be due to the LEZ. For example, the traffic-related reduction in $PM_{2.5}$ concentrations was 11% compared to a measured reduction of 23%; the LEZ therefore led to a reduction in concentrations of 12%, or about 0.7 µg/m³ between the beginning of 2008 and the end of 2010. These results were supported by similar reductions in concentrations of related pollutants such as elemental carbon, PAHs and particle number.

Analysis of measured concentrations on Åboulevard in Copenhagen (Jensen et al, 2010) compared data recorded in the period October to December 2004 with data from November 2008 to January 2009. The analysis could not single out the effect of the LEZ as the potential impact was small compared to the uncertainties due to differences in the length of the monitoring campaigns and the long time between campaigns. Differences in concentrations were attributed to a combination of factors including continuous improvements to the car fleet, minor reductions in traffic levels and a reduction in the fraction of heavy-duty vehicles.

3.3 Health Impact Assessments

Few recent health impact assessments for LEZs have been identified; impact assessments are mainly limited to changes in air pollutant concentrations. While these could be used to assess health impact using mortality risk coefficients, this approach would be quite simplistic.

Methodologies exist for health impact assessment that may be applied to LEZ. These are based on the impact pathway methodology modelling the links between emissions, concentrations, population exposure, dose-response, health effects and external costs. These have been applied on the European scale and originally developed in the EU ExternE project. In Denmark, a model system has been developed based on this methodology (EVA-Economic Valuation of Air Pollution, Brandt et al. 2011) and has recently been further developed to have a geographic resolution of 1x1 km^2 for assessment of the local scale.

One study (Palmgren et al, 2005) has been identified that carried out a cost-benefit analyse prior to the establishment of the LEZ in Copenhagen (HDV only). It was based the impact path methodology and assessed that the LEZ would save 160 mill. DKK in health related costs. A break-even price for particle filters was estimated to be 72,500 DKK given the affected heavy-duty vehicles, and hence it was concluded that it likely had positive social economic costs.

A more simplistic approach may also be taken that generalises the model results from the impact pathway methodology based on the health effects of one unit of emission (and external costs). Knowing the change in emissions due to a LEZ, a rough estimates can made of the saved health effects and saved external costs.

The London LEZ study does set out an innovative approach to quantifying the health impacts of LEZs. A feasibility study was carried out to investigate the possibility of linking electronic medical records to air quality data. It used NO_x concentrations to investigate relationships between exposure and indicators of respiratory and cardiovascular disease Preliminary calculations have estimated that, given a quarter of the population will experience a greater than 3% reduction in NO_x concentrations due to the LEZ, it would be possible to show a 5% decrease in common outcomes such as drug treatment for asthma or consultations for respiratory infections or a 10% decrease in less common outcomes such as new incidences of asthma.

Uncertainties in impact assessments

Quantifying the impact of an LEZ on pollutant concentrations has many areas of uncertainty either using modelling or analysis of monitoring data.

Modelling

The nationwide impact assessment of LEZs in the Netherlands (Goudappel Coffeng and Buck Consultants International, 2010) compared modelling carried out prior to the implementation of the LEZ with the impact assessment three years later. The later study showed minimal impact on NO_2 concentrations compared to a projected impact of up to 4 $\mu g/m^3$ on the busiest streets. The decrease in PM_{10} concentrations was found to be significantly lower than initially predicted. The reasons for this were:

- The number of older, more polluting vehicles only decreased by about 50% rather than the 100% assumed, due to violations and exemptions;
- The emissions reductions produced by new vehicles was much smaller than expected; and
- The retrofit of particulate filters resulted in an increase in NO_2 emissions.

The effect of different technologies on the NO_2 proportion of NO_x emissions is now better understood and so future studies are unlikely to underestimate this effect.

The behaviour of Euro V HDVs under real-world driving conditions has been found to be very varied with some vehicles producing emissions much greater than the emission limit values (Vermeulen et al, 2012). Similarly, diesel passenger cars have been found to exceed emission limit values; the latest version of the COPERT emission factors, released in November 2012, includes updated emission factors for Euro 5/6 diesel vehicles (Katsis et al, 2012).

There are also uncertainties in the fleet composition after implementation of the LEZ due to the effect of enforcement and exemptions from the scheme. While some studies have demonstrated good agreement between expected and actual vehicle fleet others have shown significant variations. For example Automatic Number Plate Recognition for a street in Copenhagen largely confirmed the assumptions regarding the vehicle fleet made prior to its implementation (Jensen et al, 2011).

Analysis of the vehicle fleet in LEZs in the Netherlands (Goudappel Coffeng and Buck Consultants International, 2010) has shown significant variations by city. In Amsterdam, LEZ compliance rates were better than in other cites (95% compared to 75 to 80%) due to the use of cameras for enforcement rather than manual checks. However, the HDV fleet is not significantly cleaner than other cities due to a higher number of exemptions being granted.

Other studies have considered a range of scenarios reflecting different changes to the fleet for example the Lisbon study (Ferreira et al) included three scenarios: restricted vehicles simply stopped being used; restricted vehicles were upgraded to the minimum access requirements; and restricted vehicles were upgraded to the most up-to-date vehicle technology.

Monitoring

The analysis of monitoring data has difficulties due to relatively small differences in concentrations occurring over relatively short time periods. Factors other than the LEZ which affect pollutant concentrations, such as inter-annual variability of meteorological data and other changes to traffic levels, need to be taken into account to correctly assign causes of any air quality improvements.

The study of LEZs in five cities in the Netherlands (Boogard et al, 2012) concluded that “with the exception of one street where traffic flows were drastically reduced, the local traffic policies including the LEZ were too modest to produce significant decreases in traffic-related air pollution concentrations.”

A comparison of modelled concentrations without any LEZ impact and measured concentration reductions in Denmark (Jensen et al 2011) showed smaller measured reductions of NO_x and CO than the modelled reductions, while reductions of other pollutants were as expected. Reasons for this included having to leave out measurements from the second half of 2010 and possible overestimation of emission reductions from 2010 due to less efficient catalysts than assumed.

A further complication is the varying health impacts of different particulate species. Recent studies (Rohr & Wyzga, 2012) have concluded that exhaust particulate emissions are more harmful to health than secondary particulates formed in the atmosphere and the World Health Organisation has recently classified diesel exhaust particulates as carcinogenic (WHO, 2012). This implies that while the impact of LEZs on total particulate concentrations can be modest, the effect on health may be much more significant. The London LEZ baseline study (Kelly et al, 2011) investigated the composition of particulates in the LEZ including the oxidative activity and metal content in view of their relatively more important health impacts.

Effectiveness of Low Emission Zones

A number of factors have been found to influence the effectiveness of Low Emission zones. Experience from Berlin (Lutz & Rauterberg-Wulff, 2010) resulted in the following recommendations for the implementation of an LEZ:

- Ambitious emissions criteria should be set;
- Exemptions for residents and businesses should be limited to avoid diluting the expected effect of the LEZ;
- A transition period should be incorporated to allow drivers to adapt;
- The LEZ needs to be large enough to affect the renewal rate of the vehicle fleet to avoid simply rerouting the more-polluting vehicles to different areas.

The study of LEZs in the Netherlands (Goudappel Coffeng and Buck Consultants International, 2010) reiterated the issue of enforcement and exemptions. Amsterdam had much better enforcement rates, but its vehicle fleet was not significantly cleaner due to the large number of exemptions granted. The study also highlighted the experience of The Hague and Utrecht in using a targeted information campaign for drivers and employers was an effective tool in improving compliance with the LEZ.

The effectiveness of low emission zones will also decrease over time. As low emission zones work by restricting access to an area by older, more polluting vehicles, their impact is greatest immediately after implementation. They effectively accelerate the uptake of cleaner vehicles which would have occurred over a longer time period. The impact then progressively decreases over time as the natural replacement of older vehicles in the fleet catches up with the LEZ fleet. For example the LEZ in Copenhagen was predicted to reduce PM_{10} concentrations in 2010 by 0.7 µg/m³ but in 2020 the reduction is only 0.1 µg/m³. Without the impact of the LEZ, the number of streets predicted to exceed the NO_2 limit value is 65 in 2010, 22 in 2015 and 3 in 2020 (Jensen et al, 2010) reducing to 35 in 2010 with the LEZ, 15 in 2015 and 2 in 2020.

Note also that the implementation of LEZs can result in significant reductions in total traffic levels, for example Milan saw a 21% reduction in traffic entering the Ecopass area in the first year of operation (Danielis et al, 2011), however, the number of vehicles started to rise again in the following two years.

Due to the decreasing impact of LEZs over time, many cities have made the access criteria more stringent after a number of years. For example, in the Berlin LEZ were required to be a minimum of Euro 2 (or Euro 1 with particle filter) for diesel vehicles and Euro 1 with catalytic converter for petrol vehicle from 2008. In 2010 the restriction on diesel vehicles was tightened to Euro 4 or Euro 3 with particle filter.

In Milan, as the impact of the Ecopass low emission zone scheme was becoming limited it was decided to progress to the “Area C” scheme which is a combined congestion charge and LEZ.

3.4 Innovative solutions to LEZs and impact assessments

Real-world driving conditions - Berlin is undertaking a pilot project to fit buses with SCRT filters and monitor emissions in real world driving conditions. This should give more accurate data on which to base emissions calculations to enable the determination of any air quality impacts due to LEZs.

Use of Automatic Number Plate Recognition (ANPR) – ANPR is used in a number of cities including London (Kelly et al, 2011) and Copenhagen (Jensen et al, 2011). Not only can this be a method for enforcement of the LEZ, it can also provide valuable information on the types of vehicles entering the LEZ area.

Progressive tightening of LEZ restrictions – a number of cities have tightened the access restrictions to the LEZ including Berlin, Copenhagen and London. Milan has moved a step further and has progressed from the Ecopass LEZ to Area C, a combined LEZ and congestion charge.

Comprehensive monitoring campaign – Modelling in London (Kelly et al, 2011) was used to determine the best locations for monitoring sites to be used to quantify the air quality impacts.

Use of electronic health records – The London baseline study (Kelly et al, 2011) has set out a methodology to evaluate health impacts using electronic medical data coupled with air quality monitoring data.

Analysis of particulate composition – The London baseline study (Kelly et al, 2011) has set up a monitoring network which enables the analysis of the oxidative potential and metal content of particulate concentrations. Studies in the Netherlands (Boogard et al, 2012) and Denmark (Jensen et al, 2011) have used measurements of elemental carbon and particle number to provide more detailed information than is available from PM_{10} concentrations.

3.5 Recommendations

The following are recommendations for the implementation of low emission zones from experience in European cities:

- Ambitious emissions criteria should be set;
- A transition period is provided at the commencement of the LEZ;
- Adequate enforcement of compliance;
- Potential to make emissions criteria more stringent in future years;
- Exemptions for residents and businesses should be limited;
- The LEZ needs to be large enough to affect the renewal rate of the vehicle fleet to avoid simply rerouting the more-polluting vehicles to different areas;
- Targeted information campaigns to non-compliant drivers/businesses.

The following are recommendations for assessing the impact of low emission zones on air quality from experience of assessments carried out in European cities:

- Modelling is carried out prior to the implementation of the LEZ to estimate the likely air quality impacts and identify areas affected;
- Monitors are installed at the locations likely to experience the greatest (positive or negative) changes;
- Automatic Number Plate Recognition – where feasible, ANPR provides a valuable resource in terms of characterising the vehicle fleet entering the LEZ area;
- Monitoring of alternative parameters – analysis of standard particulate monitoring data sometimes cannot isolate the impact of an LEZ. Measurement of alternative parameters such as elemental carbon and particle number as indicators for exhaust contributions can provide more useful information on the effect of the LEZ;
- Use of real-world emission rates – Emission rates for real-world driving conditions should be used for any impact assessment rather than those based on emission limit values to avoid overestimating the impact of the LEZ. These could use the emission factors such as the latest COPERT factors or could make use of local remote emissions sensing campaigns. In particular, information on the performance of Euro 6 vehicles in real-world conditions will be crucial in determining the effectiveness of low emission zones in the future.

3.6 References

- Boogaard, H, N.A.H. Janssen, P.H. Fischer, G.P.A. Kos, E.P. Weijers, F.R. Cassee, S.C. van der Zee, J.J. de Hartog, K. Meliefste, M. Wang, B. Brunekreef, G. Hoek, 2012. Impact of low emission zones and local traffic policies on ambient air pollution concentrations. Science of the Total Environment, Volumes 435–436, 1 October 2012, Pages 132–140, http://dx.doi.org/10.1016/j.scitotenv.2012.06.089;
- Danielis, R, L Rotaris, E Marcucci, J Massiani, 2011. An economic, environmental and transport evaluation of the Ecopass scheme in Milan: three years later. http://www.sietitalia.org/wpsiet/WPsiet_Danielis_Rotaris_Marcucci_Massiani2011.pdf;

- Ferreira, F, P Gomes, A C Carvalho, H Tente, J Monjardino, H Brás, P Pereira, 2012. Evaluation of the Implementation of a Low Emission Zone in Lisbon. Journal of Environmental Protection, Vol. 3 No. 9A, 2012, pp. 1188-1205. doi: 10.4236/jep.2012.329137. http://www.scirp.org/journal/PaperDownload.aspx?paperID=22972;
- Goudappel Coffeng & Buck Consultants Int'l, 2010. Landelijke effectstudie milieuzones vrachtverkeer 2010, effecten op de luchtkwaliteit. Agentschap NL. 28 October 2010, 58 pp. http://www.rijksoverheid.nl/bestanden/documenten-en-publicaties/rapporten/2010/11/18/landelijke-effectstudie-milieuzones-vrachtverkeer-2010/kl-2010029719a-bijlage-effectstudie-luchtkwaliteit-milieuzones.pdf;
- IIASA, 2012a. TSAP Report #1: - Future emissions of air pollutants in Europe – Current legislation baseline and the scope for further reductions TSAP Report #1 Version 1.0. http://gains.iiasa.ac.at/images/stories/reports/TSAP/TSAP-BASELINE-20120613.pdf;
- IIASA, 2012b. TSAP Report #9: Modelling compliance with NO2 and PM10 air quality limit values in the GAINS model. http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP-Report-_9-v1_final-MA.pdf;
- IIASA, 2013. IIASA 2013 - Policy Scenarios for the Revision of the Thematic Strategy on Air Pollution TSAP Report #10 Version 1.2TSAP Report #10: Policy scenarios for the revision of the Thematic Strategy on Air Pollution. Version 1.2, 10 April 2013. http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP_10-v1-2.pdf;
- WHO, 2012 IARC: Diesel Engine Exhaust Carcinogenic. Press Release N° 213, International Agency for Research on Cancer, (IARC). http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf;
- Jensen, S.S., Ketzel, M., Nøjgaard, J. K. & *Becker, T,* (2011.)What are the Impacts on Air Quality of Low Emission Zones in Denmark? *Department of Environmental Science, Aarhus University, Denmark;*
- Jensen, S.S., Ketzel, M., Nøjgaard, J. K. & Wåhlin, P. 2009: Luftkvalitetsvurdering af miljøzoner i Danmark; Midtvejsrapport [Air quality assessment of environmental zones in Denmark; Mid-term report]. Danmarks Miljøundersøgelser, Aarhus Universitet, Faglig rapport nr. 748, 64 pp. [Summary in English, pg. 13-15] http://www.dmu.dk/Pub/FR748.pdf;
- Jensen, S.S., M. Ketzel, J.K. Nøjgaard, P. Wåhlin, 2010. Air Quality Impact Assessment of the Environmental Zone in Copenhagen. Conference on Transport and Air Pollution, Dübendorf, Switzerland, May 2010. National Environmental Research Institute (NERI), Department of Atmospheric Environment, Aarhus University, Denmark., 6 pp.;
- Katsis, P, Ntziachristos, L, Mellios G, 2012. – Description of new elements in COPERT 4 v10.0 EMISIA SA Report No: 12.RE.012.V1, 3 December 2012, 71 pp. http://www.emisia.com/files/COPERT4_v10_0.pdf;
- Kelly, F, Armstrong, B, Atkinson, R, Anderson, H.R., Barratt, B, Beevers, S, Cook, D, Green, D, Derwent, D, Mudway, I, and Wilkinson, P, (2011). The London Low Emission Zone Baseline Study, HEI Report Number 163 http://pubs.healtheffects.org/getfile.php?u=669;
- Lutz M., A Rauterberg-Wulff, 2010. Berlin's Low Emission Zone – top or flop? Results of an impact analysis after 2 years in force. 14th ETH Conference on Combustion Generated Particles. London Air Quality Network Seminar, 21 Septebmer 2010, King's College London, 4 pp. http://www.londonair.org.uk/seminars/pdf/september2010/Berlin_LEZ_impacts_analysis.pdf;
- Malina, C. and F. Fischer, 2012. The impact of low emission zones on PM_{10} levels in urban areas in Germany. CAWM Discussion Paper No. 58, University of Muenster, August 20, 2012. 19 pp. http://www.wiwi.uni-muenster.de/ivm/organisation/mitarbeiter/wma/dp_fischer.pdf;
- Palmgren, F., Glasius, M., Wåhlin, P., Ketzel, M., Berkowicz, R., Jensen, S.S., Winther, M., Illerup, J.B., Andersen, M.S., Hertel, O., Vinzents, P.S., Møller, P., Sørensen, M., Knudsen, L.E., Schibye, B., Andersen, Z.J., Hermansen, M., Scheike, T., Stage, M., Bisgaard, H., Loft, S.,

Lohse, C., Jensen, K.A., Kofoed-Sørensen, V. & Clausen, P.A., (2005.): Luftforurening med partikler i Danmark [(Particulate air pollution in Denmark]). Miljøstyrelsen. - Miljøprojekt 1021: 84 pps.http://www.mst.dk/udgiv/Publikationer/2005/87-7614-720-7/pdf/87-7614-721-5.pdf;

- Rohr, A.C., &. Wyzga R.E., 2012. -Attributing health effects to individual particulate matter constituents, Atmoshpheric Environment Volume 62, December 2012, Pages 130–152. http://dx.doi.org/10.1016/j.atmosenv.2012.07.036;
- Silver, J.D., Christensen, J.H., Andersen, M.S., Bønløkke, J., Sigsgaard, T., Geels, C., Gross, A., Hansen, A.B., Hansen, K.M., Hedegaard, G.B., Kaas, E., Frohn, L.M. (2011c): Assessment of Health-Cost Externalities of Air Pollution at the National Level using the EVA Model System. CEEH Scientific Report No. 3, Centre for Energy, Environment and Health Report series, March 2011, pp. 98. http://www.ceeh.dk/CEEH_Reports/Report_3/CEEH_Scientific_Report3.pdf;
- Špička, L; Dostál, I; Dufek, J; Jedlička, J, Ličbinský, R, 2011. Environmentální a ekonomické posouzení opatření podpory čistých vozidel ve městech: Clean City (Závěrečná zpráva) - Environmentální a Ekonomické Posouzení Opatření Podpory Čistých Vozidel ve Městech [(Environmental and economicaleconomic evaluation of clean vehicles promotion: Clean City]. Transport Research Centre, for Ministerstvo dopravy [Ministry of Transport], January 2011, 104 pp. [English summary, pg. 97]) http://invenio.nusl.cz/record/118207/files/nusl-118207_1.pdf?version=1;
- Vermeulen R, Dekker H, Vonk W, 2012. Real-world NOx emissions of Euro V and Euro VI heavy-duty vehicles. TNO report TNO-060-DRM-2012-01193. http://www.tno.nl/downloads/real_world_nox_emissions_euro_v_vi_heavy_duty_vehicles.pdf.

4 Noise Benefits of Low Emission Zones

4.1 Introduction

Task 1.3 is reviewing and summarizing recent literature and Internet resources relevant to noise reductions associated with implementation of LEZ. The ARS Study (ISIS 2010) did not focus on noise. Quantitative estimates of noise reduction are only mentioned for two cities (Rome, Cork) in that study, although noise reduction is listed as an objective or benefit in survey responses for several other cities. This review has identified additional information on noise related to LEZ, and has also included a general background survey on traffic-related noise sources, and relevant EU policy and legislation.

4.2 Sources of noise emissions from road traffic

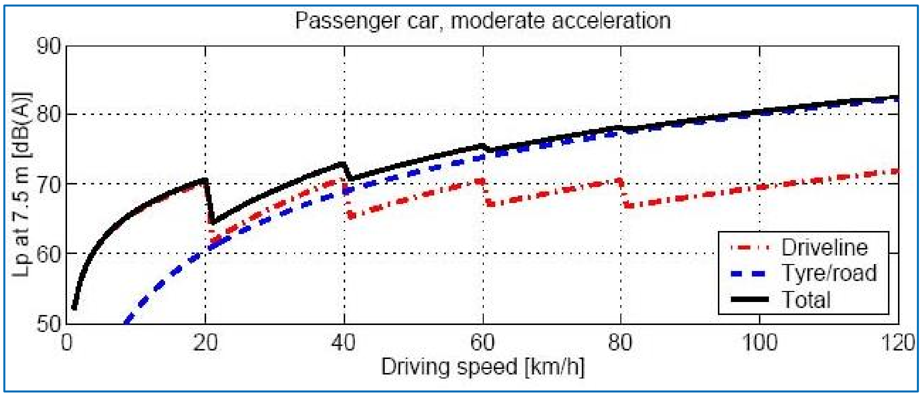
Road traffic noise is interaction of sound power generated by each single vehicle and several internal and external factors that can affect noise emission level. Noise emission generated by vehicles is a combination of powertrain noise (engine structure, exhaust system, transmission and fan noise) and rolling noise (noise emanating from interaction of vehicle's tyres with road surface). At high driving speeds aerodynamic noise can be defined as a third noise source group, but usually it is not considered as important in urban environment.

In terms of sound radiation, noise from internal combustion engines is radiated by the intake and exhaust, and by the engine block and its components. Most of this noise is ultimately generated by the combustion process in the cylinders, but other mechanical forces caused by friction, impacts and inertia/unbalance also contribute[10] (see **Figure 4.1**). Under normal driving conditions, powertrain noise dominates at driving speed below 30 - 40 km/h.

The tyre of a road vehicle and its interaction with the road is a major contributor to the total noise emission. Depending on the type of vehicle, the tyres already dominate the noise emission at constant speed from about 40 km/h upwards[1] (see **Figure 4.1**).

10 P.J.G. van Beek, M.G. Dittrich. Road Vehicle Noise versus fuel consumption and pollutants emissions. TNO. December 5, 2012.

Figure 4.1 Illustrative example of the contribution of powertrain and tyre/road noise source of an average, moderately accelerating passenger car with a five speed gearbox, as function of vehicle speed[11]



Due to the increasing traffic noise annoyance level, several steps were made to reduce noise emission level from both main sources in recent decades. Directive 70/157/EC[12] and its amendments cover the requirements for motor vehicle exterior pass-by noise and the noise from the exhaust system under test conditions, covering the type testing method and noise limits. The original Directive and subsequent amendments have two objectives. First, they aim to ensure that for certain categories of motor vehicles, noise limits of individual states did not form barriers to trade. The second goal was to tighten the noise limits to reduce environmental noise. Although Member States were originally not bound to limits in the Directive, new trade barriers could not be created by stricter national limits. The amendment of 1992 (92/97/EEC)[13] introduced mandatory common noise limits applicable to Member States from certain dates. Several of the subsequent amendments specified stricter limits (see 4.3)[14].

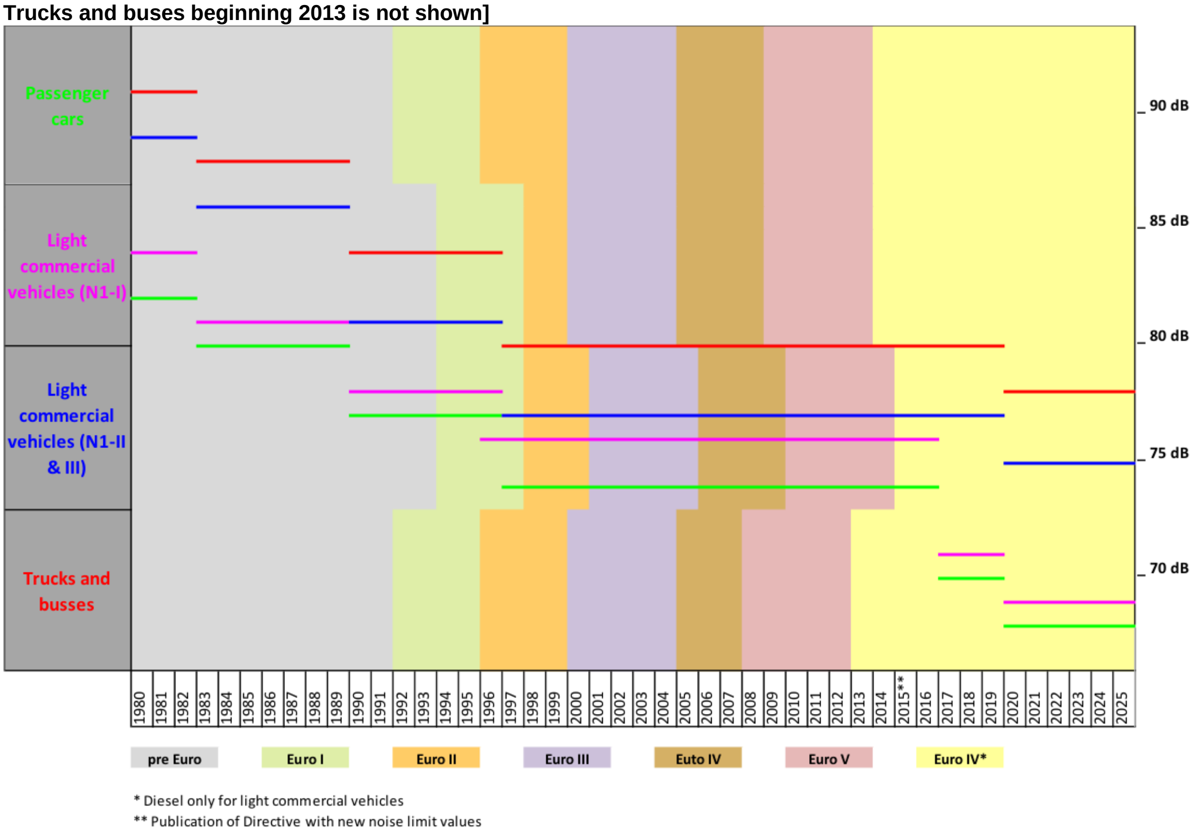
[11] van Beek, 2004, EU Road Traffic Noise Policy in the Past, Present and Future, TNO report no. 030119, TNO TPD, Delft, August 26, 2004.

[12] EU, 1970. EU Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles.

[13] EU, 1992. Council Directive 92/97/EEC of the Council of 10 November 1992 amending Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles.

[14] de Roo et al, 2011. VENOLIVA - Vehicle Noise Limit Values - Comparison of two noise emission test methods – Final Report. MON-RPT-2010-02103. TNO Science and Industry.

Figure 4.2 Development of EU road vehicle type approval noise limits (lines) and Euro emission classes (shading): Passenger car, delivery van (2 – 3.5 tonnes max. weight), small truck (> 3.5 tonnes and < 75 kW) and a heavy truck (> 3.5 tonnes and > 150 kW), including important dates of amendments and adaptations. COM (2011) 0856 proposed Directive assumed to enter into force 2015. [Errata: Euro 6 for Trucks and buses beginning 2013 is not shown]



According to proposal for a Regulation of the European Parliament and of the Council on the sound level of motor vehicles[15], it is planned to reduce the allowed level for car noise by 4 decibels and lorry noise by 3 decibels in four/five years after its entry into force. The new regulation is based on a two-step approach:

- Step 1 is expected to require a reduction of 2 decibels for noise emissions for new types of cars, and an effective reduction of 1 decibel for new types of lorries, two years after the law is adopted;
- Step 2 is expected to require a further 2 decibel cut for new types of cars, vans and lorries, three years after step 1.

In 2001, Directive 2001/43/EC was adopted, introducing limit values for noise emission from tyres for road vehicles. The limit values distinguish between different types and widths of tyres and relate to type approval of all new tyres. Current noise limits for tyres are presented in Table 4.1.

Table 4.1 Noise limit values for new tyres in force as of year 2009

Current tyre class	Nominal section width (mm)	Limit value dB (A)
C1a	≤145	71
C1b	>145 - ≤165	72
C1c	>165 - ≤185	73
C1d	>185 - ≤215	74
C1e	>215	75

15 EC, 2011a. COM/2011/0856 final - 2011/0409 (COD). http://eur lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011PC0856:EN:NOT.

Current tyre class	Nominal section width (mm)	Limit value dB (A)
Tyres for vans and light trucks		
C2 normal	-	75
C2 snow	-	77
C2 special	-	78
Tyres for heavy trucks		
C3 normal	-	76
C3 snow	-	78
C3 special	-	79

The European Commission has announced its programme to review the tyre regulations, and consider the possibilities for applying a next stage of noise limit reductions. It is anticipated that the EC will propose an amendment to the Directive 2001/43/EC that will include reductions in the permissible noise from vehicle tyres.

In several discussions on tightening of the limits, it was proposed to adopt a two stage approach. The first step would set a limit such that 70% of the current market would be able to fulfil it. The second step would set a limit such that the remaining 30% of the current market would be able to fulfil it[16]. In the FEHRL report[17] information about currently produced (year 2004) tyres that will meet future requirements of reduced limit values were analysed. Collected information is presented in the **Table 4.2**.

Table 4.2 Percentage of tyres already below current limit values

Category	Percentage – 3 dB(A) below limit value	Percentage – 5 dB(A) below limit value
C1b	68	10
C1c	45	5
C1d	66	19
C1e	57	16
C2	50	13
C3	75	53

According to the results of FEHRL report, it can be defined that insignificant reduction of limit values would not improve urban environmental noise climate.

In recent years, parallel to the development of conventional combustion engines, many car manufacturing companies have introduced hybrid and electric power engines. Current vehicle market trends show that amount of passenger cars that are fully or partially (hybrid) powered by electric engine, would increase in future, but most probably such engines would not be used in trucks.

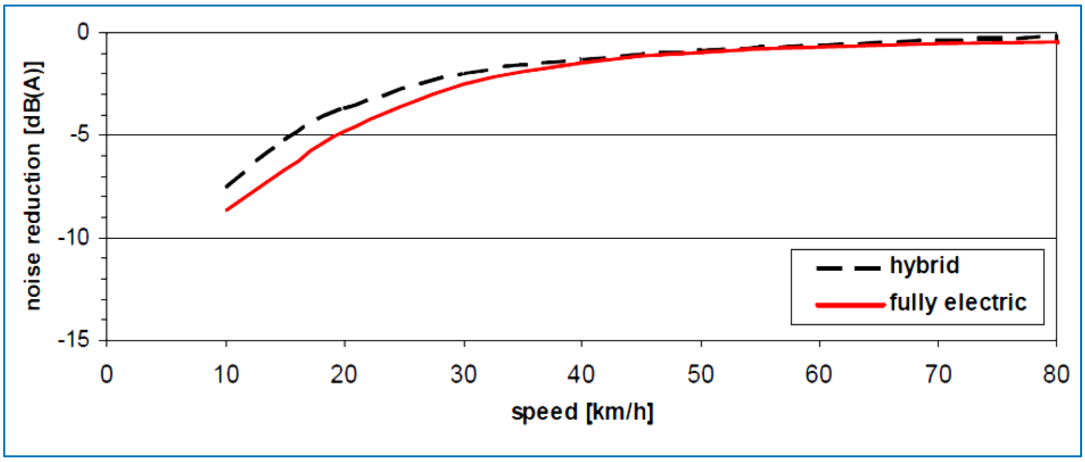
In the latest research, where noise emission level from conventional vehicles and vehicles with hybrid and electrical engines were compared, it was identified that noise emission level from conventional vehicles is significantly higher at low driving speeds. Hybrid cars are more silent than conventional cars, in particular at speeds below 30 km/h, where the vehicle is powered electrically (see Figure 4.3). Above 30 km/h, the noise reduction of the hybrid car as compared to a conventional car diminishes rapidly. Firstly, because after reaching approximately 20 km/h the car

16 M+P, 2007. Public Consultation on modification of 2001/43/EC tyre/road noise. M+P.MVM.05.1.C.1. M+P – consulting engineers. October 2007.

17 FEHRL, 2006. Final Report SI2.408210 Tyre/Road Noise – Volume 1.

switches from electric mode to the internal combustion engine. Second, the tyre-road noise (equivalent for both car types) starts dominating the sound emission above 30 km/h. Above 50 km/h there is no significant difference in noise emissions[18].

Figure 4.3 Noise reduction of hybrid and electric passenger cars compared to conventional passenger cars



According to the results of noise level measurements done at the time of CityHush project[19], these differences are even more significant at the time of acceleration (see **Table 4.3** and **Table 4.4**), that is very important in urban areas.

Table 4.3 Peak sound pressure levels (LAmax) of cars driving at constant speed

Vehicle	Const. 10 km/h	Const. 20 km/h	Const. 30 km/h
Fiat 500 electric (hybrid)	53 dB(A)	63 dB(A)	70 dB(A)
Fiat 500 combustion	60 dB(A)	63 dB(A)	70 dB(A)

Table 4.4 Peak sound pressure levels (LAmax) of accelerating cars

Vehicle	Accel. 20	Accel. 30
Fiat 500 electric (hybrid)	62 dB(A)	63 dB(A)
Fiat 500 combustion	72 dB(A)	73 dB(A)

Vehicle noise emission level is an important factor for the overall noise climate, but there are many other factors that affect road traffic noise level. The main factors are traffic intensity, driving speed, traffic flow characteristics and road surface roughness. Traffic flow impact on the noise level is analysed in a more detail in section 4.4.

Another important factor, that has significant influence on overall noise emission level, is amount of heavy vehicles. Based on results of noise level calculations, it can be derived that only ~10-20% of heavy vehicles in overall traffic composition doubles the source intensity that leads to 2-3 dB noise level increase. At present, a significant part of LEZs only have restrictions on heavy vehicles.

4.3 Policy framework for noise from vehicles

The EU has a sophisticated policy framework addressing the growing problem of environmental noise, which is most frequently connected with traffic, industrial and recreational activities. One of

18 Verheijen & Jabben, 2010. RIVM letter report 680300009. Effect of electric cars on traffic noise and safety. 2010.

19 City Hush website – http://www.cityhush.eu.

the first documents devoted to the issue of environmental noise is Green Paper on Future Noise Policy, which paved a way towards drafting the Environmental Noise Directive[20]. Since its introduction in 2002 the Directive has served as a basis for implementation of measures related to prevention or reduction of harmful effects of environmental noise from major sources.

As far as it goes to the issue of noise in urban environment, the main concerns are mostly associated with traffic, therefore it has been explicitly addressed in a number of policy instruments in urban environment sector. At the same time – noise is also among environmental considerations tackled in documents developed in the transport sector. Policy "directions" and measures proposed and foreseen in such policy instruments might have a noticeable, even if not direct, influence on reduction of noise in urban areas.

One of the first instruments to mention in relation to envisioned development of transport sector is the 2011 White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system"[21]. The document is one of the most recent strategic instruments in the transport sector, encompassing 40 concrete initiatives to be pursued in the next decade and following the aim of "supporting mobility while reaching the 60% emission reduction target"[22]. The initiatives have been grouped in four broad thematic categories, in accordance with primary "direction" of initiatives at issue – "A Single European Transport Area", "Innovating for the future – technology and behaviour", "Modern infrastructure and smart funding" and "The external dimension".

Internalise the cost of local externalities as part of a LEZ

The majority of noise-related initiatives can be associated with "Innovating for the future – technology and behaviour". Among those is a proposal for an EU framework for urban road user charging, which can be observed in the context of LEZ. This initiative outlines a development of "a validated framework for urban road user charging and access restriction schemes and their applications, including a legal and validated operational and technical framework covering vehicle and infrastructure applications"[23], thus reflecting the idea behind the LEZ, operating on the basis of "entrance charges". Accordingly, the White Paper foresees charge-based LEZ to be applicable on a wider scale. The Commission notes that such charges for the use of infrastructure will internalise the cost of local externalities such as noise, air pollution and congestion.

This approach has already been reflected in the Eurovignette Directive[24], which is applicable to heavy goods vehicles. It stipulates common rules on distance-related tolls and time-based user charges (vignettes) for vehicles above 3.5 tonnes for the use of certain infrastructure. Such charges may also include an "external cost charge" for air pollution and noise pollution provided that the external cost charges comply with maximum values defined in the annex of the Directive. Currently the EC is considering the development of similar system to be applicable to light duty vehicles. A number of studies and assessments have been carried out for this purpose.[25]

---

20 EU, 2002. Directive 2002/49/EC relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise.

21 EC, 2001. White Paper. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. Brussels, 28.3.2011. COM(2011) 144 final.

22 Ibid. p. 5.

23 Ibid. p. 27.

24 EU, 1999. Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures, as modified by Directive 2006/38/EC and by Directive 2011/76/EU.

25 EC. Road Studies web page. Mobility and Transport. European Commission, available at http://ec.europa.eu/transport/modes/road/studies/road_en.htm.

The issue of introduction of LEZs in European urban areas has been discussed in a number of policy instruments governing the area of urban environment. Taking due regard of the "polluter pays" principle, both the Action Plan on Urban Mobility[26] and the Thematic Strategy on the Urban Environment[27] suggest internalisation of external costs. Making users pay for negative impact on environment may stimulate switching to 1) more environment-friendly vehicles, 2) more environment-friendly transport modes (where entrance permission or entrance charge is dependent on emission class of vehicle), 3) use less congested infrastructure or 4) travel at different time.

The concept of sustainable mobility is also enshrined in a number of other EU instruments, yet without directly referring to LEZ as a tool. Taking into consideration the flexible approach of the major policy tools, LEZ is one of the options to reach the objectives of decreased noise and air emissions. Nevertheless, the implementation of low emission zones in European cities can be undertaken in order to pursue objectives of various legal and policy instruments.

Noise mitigation at source

Another important set of instruments to be considered in the context of noise mitigation from road traffic is addressing sources of noise emissions. The reduction of noise emissions at source is a primary way of tackling noise-related issues, therefore already since 1970s EC has been regulating permissible noise level from motor vehicles. Most important norms enshrined in the main instruments of regulatory nature have already been discussed above, when describing sources of noise emissions, yet to grasp the overall situation in field of legislation, the most relevant documents will be addressed once more.

Probably the core instrument in this respect is Council Directive 70/157/EEC relating to the permissible sound level and the exhaust system of motor vehicles[28]. The Directive has been amended a number of times, with most recent amendments incorporated in 2007[29]. The Directive applies to any motor vehicle intended for use on the road, having at least four wheels and a maximum design speed exceeding 25 km/h, with the exception of vehicles that run on rails, agricultural and forestry tractors and all mobile machinery, and lays down limits, ranging from 74 dB(A) for motor cars to 80 dB(A) for high-powered goods vehicles, for the noise level of the mechanical parts and exhaust systems of the vehicles concerned.[30] As of 1996, the EU Member States are prohibited from initial entry into service of motor vehicles that do not comply with the requirements encompassed in the Directive.

Taking into consideration that the limit values set in the above-mentioned Directive have not been changed since 1992, the EC commissioned the VENOLIVA study[31], where five policy options regarding limit values for noise emission of the different vehicle categories have been assessed. As the result study proposes a gradual shift towards new, more ambitious limit values, which are described as follows (in the study addressed as "Option 5"):

"…the limit values for light and medium size vehicles will be lowered in two steps of each 2 dB(A) and for heavy vehicles in a first step of 1 and a second step of 2 dB(A). The final limit values for

[26] EC, 2009. Action Plan on Urban Mobility [COM(2009) 490].
[27] EC, 2005. Thematic Strategy on the Urban Environment [COM(2005) 0718 final].
[28] EU, 1970. Council Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles.
[29] EU, 2007. Commission Directive 2007/34/EC amending, for the purposes of its adaptation to technical progress, Council Directive 70/157/EEC concerning the permissible sound level and the exhaust system of motor vehicles.
[30] These noise limits have been introduced with the amendment of 1992 (Council Directive 92/97/EEC amending Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles) and are still applicable.
[31] VENOLIVA - Vehicle Noise Limit Values - Comparison of two noise emission test methods – Final Report. MON-RPT-2010-02103. TNO Science and Industry, March 30, 2011.

Option 5 will be reduced with 4 respectively 3 dB(A) (…). This will result in a reduction of the noise impact L_{DEN} and L_{night} of 3.1 dB(A) for free flowing traffic and up to 4 dB(A) for intermittent traffic. The reduction of the number of highly annoyed people will be 25%"[32].

Noise from two and three wheel motor vehicles is regulated in Directive 97/24/EC[33], which sets permissible sound levels for two and three wheel vehicles and their exhaust systems, including replacement parts. The limit values range from 66 to 80 dB(A).

In addition to imposition of limit values on motor vehicles and their exhaust system, there is a complementing instrument regulating noise from tyres, aiming to limit tyre rolling noise. [34] The Directive distinguishes tyres according to the vehicle type (in 3 classes – cars, vans, trucks) and tyre width (5 classes), and determines limit values, which are not to be exceeded. These provisions are enforced through mandatory tyre rolling noise tests included in the EC type approval certificate requirements.

One of the latest developments in regards to regulation of noise from tyres is enshrined in Regulation 661/2009/EC[35]. The Regulation sets out new rolling noise requirements (depicted in Part C of Annex II of the Regulation), which have to be gradually implemented by national authorities, with complete effect by 2020.

4.4 Traffic flow and its impact on environmental noise levels

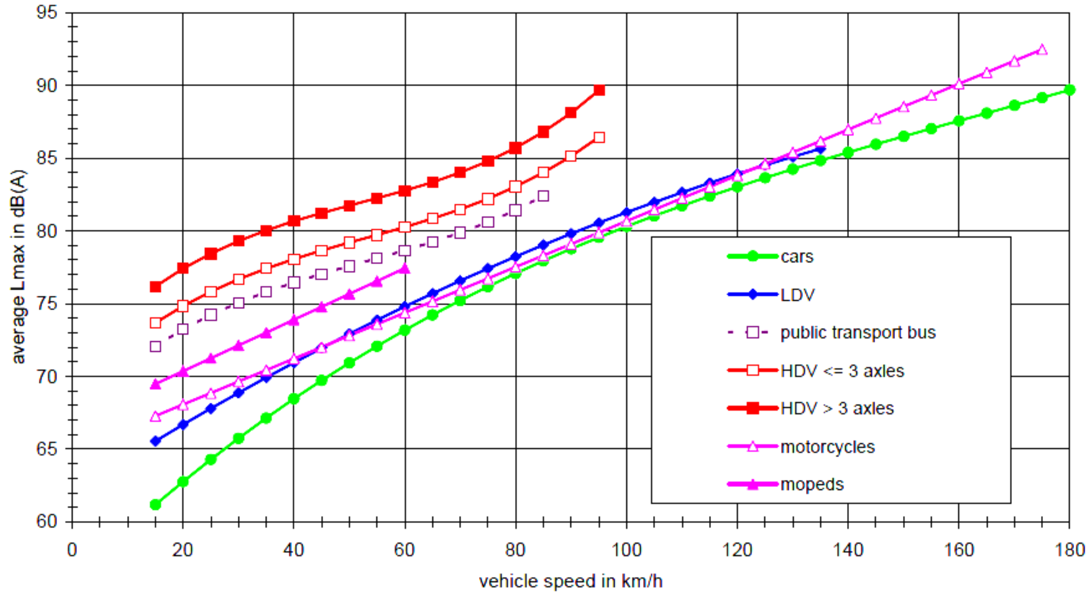
Traffic flow characteristics have significant impact on the noise emission level. It is possible to define three main factors:

1. Vehicle movement speed;
2. Traffic flow intensity;
3. Dynamics of the traffic flow.

As it was already identified in the chapter about noise sources, noise emission level increases at higher vehicle movement speed (see Figure 4.4). As it can be observed in Figure 5, vehicle movement speed has significant influence on the noise emission level for all types of vehicles.

32 Ibid., p. 110.
33 EU, 1997. Directive 97/24/EC of the European Parliament and of the Council on certain components and characteristics of two or three-wheel motor vehicles.
34 EU, 2001. Directive 2001/43/EC the European Parliament and of the Council amending Council Directive 92/23/EEC relating to tyres for motor vehicles and their trailers and to their fitting.
35 EU, 2009. Regulation 661/2009/EC of the European Parliament and of the Council concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor.

Figure 4.4 Average L_{max} values for different vehicle categories and free flowing traffic[36]



In some reports about changes of traffic flow characteristics in LEZs, it is reported that average vehicle movement speed has increased after establishment of the LEZ, because of lower traffic intensity.[37] In such cases, higher noise emission level due to higher speed offsets the noise reduction due to lower in traffic intensity. This is one of the main negative aspects and it should be considered when benefits of LEZs are analysed.

Traffic flow intensity affects the overall noise emission level from road traffic, but it is much less than the driving speed impact on noise level. According to Bendtsen et al.[38], reduction of traffic intensity by 50 % would result in 3 dB noise reduction (see **Table 4.5**).

Table 4.5 The effect on noise levels of changes in traffic volume

Reduction in traffic volume	Reduction in noise (LAeq)
10 %	0.5 dB
20 %	1.0 dB
30 %	1.6 dB
40 %	2.2 dB
50 %	3.0 dB
75 %	6.0 dB

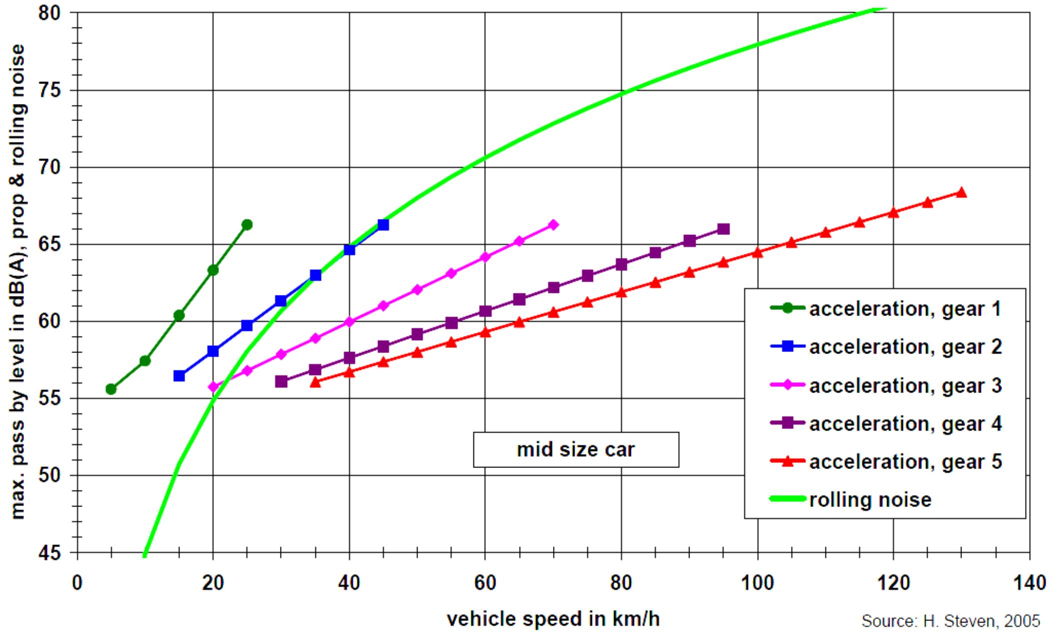
Changes of traffic intensity have significant effect on the traffic flow dynamics. In the urban environment, increasing traffic intensity would usually reduce traffic movement speed, but would also increase road congestion and the number of accelerating vehicles. As it was already identified in section 4.2 about noise sources, during acceleration, the total vehicle noise emission is higher because engine works at higher RPM rates. **Figure 4.5** shows examples of noise emission level during acceleration. This shows that the maximum noise level at low driving speed can increase significantly.

36 http://www.silence-ip.org/site/fileadmin/SP_J/E-learning/Engineers/average_lamax.pdf based on Steven, H., 2005. Investigations on Noise Emission of Motor Vehicles in Road Traffic. Research Project 200 54 135, Final Report. Wuerselen: RWTUEV Fahrzeug GmbH.

37 Infra note 39, pp. 332, 339, 390.

38 Bendtsen, H., Michelsen, L., Reif, K. and Reiff, L., 1998. *Vejtrafik og støj – en grundbog*. Copenhagen: Danish Road Directorate. Report 146.

Figure 4.5 Example of noise emission level during acceleration



Similar relations in noise emission levels can be observed for all types of vehicles (see **Table 4.6**).

Table 4.6 Effect of accelerations vs. steady speed (source: Steven 2005)

Vehicle category	At 30 km/h	At 50 km/h
Car	+2.0	+1.4
Light goods vehicle	+3.5	+2.3
HGV, Pn< 75 kW	+4.4	+3.5
HGV, 75 < Pn < 150	+4.4	+3.6
HGV, 150 < Pn < 250	+3.5	+3.0
HGV, Pn ≥ 250 kW	+3.5	+2.7

4.5 Assessment of existing LEZs

Low emission zones are usually distinguished in two broad groups according to their operational nature – 1) charging, and 2) restricting the access on the basis of emission standard or type of vehicle. According to the ARS report (ISIS, 2010), the proportion of charge-based LEZs and LEZs without charges is rather similar – 55% and 45% accordingly.[39] Another consideration to keep in mind is that some of the LEZ restrict the access solely for heavy duty vehicles > 3.5 t, while others are also applicable to passenger cars. In order to grasp a better understanding these systems, a selected number of existing LEZ will be assessed. To avoid complexity, LEZ will be distinguished on the basis of charging/emission standard or type of vehicles, without subdividing them into heavy duty or light duty vehicle LEZ.

London has both a LEZ based on Euro emission classes and within it a central congestion charging zone (CCZ) based on time of day[40]. The congestion charge applies 7.00 am - 6.00 pm, Monday - Friday excluding bank holidays. Driving within the congestion charging zone during these times

39 ISIS, 2010. Study on Urban Access Restrictions. Final Report. Rome. December, 2010, p. 37.

40 TfL London congestion charging zone web page. http://www.tfl.gov.uk/roadusers/congestioncharging/default.aspx.

requires payment of the congestion charge, even if vehicles meet the LEZ standards or the LEZ daily charge has already been paid.

4.5.1 LEZs operating on the basis of charges

Establishment of LEZ on the basis of charging system is a practical example of implementation of “polluter pays” principle. It is important to note that even though the prime aspect of charge-based LEZs is that entrance is allowed based on a “fee”, it is still determined in accordance with the emission standard and the vehicle type. Therefore the factor of emission standard is present in all of LEZs, notwithstanding their operational nature. Despite the common operational basis of charge-based LEZs, they differ significantly, not only in terms of actual amount to be paid, but also regarding a number of other aspects overarching the access to the LEZ and the objective behind charging.

London

London LEZ is among the most well-known LEZs in Europe. The London LEZ was established with an objective of improving air quality by deterring the most polluting vehicles from driving in the area. The access to the LEZ is based on the emission standards and affects older diesel-engine lorries, buses, coaches, large vans, minibuses and other heavy vehicles that are derived from lorries and vans, such as motor caravans and motorised horse boxes. All of the LEZ entry points have indicative signs (see figure below).

Figure 4.6 London LEZ entrance sign

The LEZ operates 24 hours a day, 7 days a week, every day of the year including weekends and public holidays, and foresees a charge to be paid for vehicles that do not meet the emission standard required for entering the zone. All of the vehicles affected by the LEZ have to be registered with Transport for London. In case the vehicle does not meet the emission standard a daily charge ranges from 100 GBP to 200 GBP (~117 EUR to 235 EUR) can be paid to enter the zone. The LEZ is enforced using cameras which read vehicle's registration number plate as it drives within the zone, and in case the charge for the vehicle, which does not meet the standard, is not paid, the enforcement mechanism envisages penalty.[41] [42]

Even though the ex-post impacts monitoring of the LEZ, which was carried out not long after implementation of the LEZ, mainly underlines the effects in relation to air pollution, it also mentions “other impacts”. Among these other impacts, the report mention that there “may be a small overall reduction in ambient noise levels as older, noisier vehicles are removed from the fleet, though the overall effects on the London noise climate are likely to be very marginal”[43]. Accordingly, the available information does not quantify the impacts on ambient noise levels in the LEZ, yet it can be derived, that the decrease of older vehicles with louder engines will have positive impact on noise emissions.

[41] LEEZEN. London LEZ web page - http://www.lowemissionzones.eu/countries-mainmenu-147/united-kingdom-mainmenu-205/london.

[42] ELTIS. London LEZ web page – http://www.eltis.org/index.php?id=13&study_id=1844.

[43] TfL, 2008. London Low Emission Zone. Impact Monitoring. Baseline Report. Transport for London, July 2008, p. 24.

Milan

Another example of LEZ operating on a charge-based system can be observed in the case of the traffic pollution charge system – **Area C - in Milan** (replaced ECOPASS scheme in 2011). Although the system has been implemented following the similar ideology as the one behind LEZs, which is reduction of pollution levels, it is entitled "traffic pollution charge system" and has a dual objective – reduction of pollution *and* congestion. Even though LEZs in general also pursue an objective of reducing congestion, it is mostly positioned as a measure for reduction of emissions. At the same time, Area C does not embody all of the features that are characteristic of typical congestion charging systems, as it charges only most polluting vehicles. Accordingly, Area C operates as a LEZ in synergy with a congestion charging scheme.

As to the implementation aspects, the tariff within the system depends on the engine Euro emission class, and consists of three categories: 1) free access granted to electric vehicles, mopeds and motorcycles, and until December 31, 2016 to hybrids, bi-fuel, CNG and LPF fuelled vehicles (after the determined date additional cost will apply); 2) access subject to charge applies to Euro 1 and newer gasoline-fuelled vehicles, Euro 4 and newer gasoline- and diesel-fuelled vehicles (incl. Euro 3 diesel vehicles fitted with particulate filter), until December 31, 2016 Euro 4 gasoline- and diesel-fuelled vehicles without particulate filter (after the determined date the access will be prohibited); 3) access and transit prohibited for Euro 0, 1, 2 and 3 diesel-fuelled vehicles (except the exempted vehicles), Euro 0 gasoline-fuelled vehicles (except the exempted vehicles), vehicles and combination of vehicles greater than 7.5 m in length (except the exemptions). Standard daily access charge amounts to 5 EUR.[44]

The enforcement relies on "Automatic Number Plate Recognition" technology, carried out with the help of cameras installed at toll gates. [45] While the above-discussed London LEZ operates constantly, Area C has particular time restrictions, namely, it operates from 07:30 to 19:30 and does not operate on weekends or bank holidays.[46]

One year after the implementation of the LEZ in Milan (when it still was addressed as ECOPASS), the amount of cars in the area at issue had decreased by 14.4%, thus fulfilling the congestion-related objective. This also coincided with the decrease of air pollution, which is rather logical effect of reduced traffic.[47] Another aspect is the decrease in noise levels, which is not measured but can be derived from the decreased traffic flow. The decrease of ambient noise is one of the elements behind the objective "improve the quality of urban life", which has been put forward in the framework of introduction of the LEZ.[48]

The introduction of the charging system has resulted in a gradual shift towards more environment-friendly vehicles. Currently, (i.e. at the time when the data was put on the respective website) about 80% of the vehicles entering the traffic restricted zone do not have to pay, as they meet the required air quality standards.[49] While it still has a positive effect on air quality, the noise reduction is most probably rather minimal, yet presumptively is still observable, as the older vehicles emit more noise than the new ones, and presence of LEZ still ensures lower level of older vehicles in the area at issue.

---

[44] Area C. Comune di Milano, available at http://www.comune.milano.it/portale/wps/portal/CDM?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/ContentLibrary/elenco+siti+tematici/elenco+siti+tematici/area+c.

[45] ELTIS. ECOPASS, the traffic pollution charge of Milan (Italy). http://www.eltis.org/index.php?id=13&lang1=en&study_id=2955.

[46] LEEZEN. Central Milano LEZ web page. Low Emission Zones in Europe, available at http://lowemissionzones.eu/countries-mainmenu-147/italy-mainmenu-81/lombardia/milan-ecopass.

[47] Ibid.

[48] Supra note 44.

[49] Supra note 45.

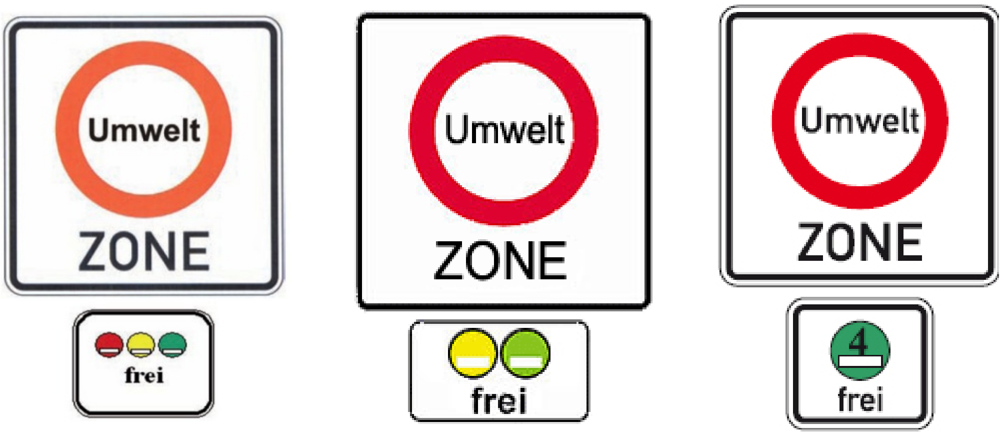
4.5.2 *LEZs operating on the basis of emission standards*

Another type of LEZs, as it was already mentioned, follow the emission standards in a more restrictive manner, namely, vehicles that do not comply with the determined standard are prohibited to enter the zone (in contrary to the charge-based LEZs, where there was no absolute prohibition, as the more polluting vehicles were subject to charge).

Germany

One of the most comprehensive and widespread LEZs in this category are German LEZs (Umweltzone). German LEZs were introduced in 2008 when a considerable number of German cities (Berlin, Bochum, Bottrop, Dortmund, Duisburg, Essen, Frankfurt/M., Gelsenkirchen, Hannover, Herne, Ilsfeld, Köln, Leonberg, Ludwigsburg, Mannheim, Mülheim/Ruhr, München, Oberhausen, Pleidelsheim, Recklinghausen, Reutlingen, Schwäbisch-Gmünd, Stuttgart, Tübingen) established LEZs in order to mitigate their air pollution issues. The LEZ operates on a basis of sticker system, depending on the vehicle's Euro emission standard. The vehicle is assigned a red, yellow, or green sticker, which has to be bought by a vehicle owner and displayed in the windscreen of the car. The system affects all diesel vehicles, and petrol vehicles without a closed loop catalytic converter (Euro 1 or equivalent). In order to determine which vehicle can enter, each LEZ has a sign at its entry point, indicating, which vehicle "class" can enter it (see **Figure 4.7**).

Figure 4.7 German LEZ road signs



a. Euro 2 LEZ **b. Euro 3 LEZ** **c. Euro 4 LEZ**

The German LEZs operate continuously 365 days a year. In the contrast to the system of cameras, recognizing vehicles' number plates, described in case of LEZs in London and Milan, German LEZs have a "manual" enforcement mechanism. It means that police performs checks of vehicles' windscreens. In case the vehicle lacks the sticker, even if it fulfils the emission standard requirements, it is considered to be illegal in the zone and is subject to a penalty, amounting to 40 EUR fine and one point in the national traffic penalty register for German vehicles.[50]

Similar to the situation with other LEZs, the German system does not provide any insight into possible noise mitigation benefits. Therefore the same assumptions can be applied in the case of German LEZs – decreased traffic flow as well as admission of newer vehicles (inside LEZs) can result in lower noise emissions. Though there still is a lack of specific evaluation of noise-related benefits.

---

50 LEEZEN. Germany LEZ web page. Low Emission Zones in Europe, available at http://www.lowemissionzones.eu/countries-mainmenu-147/germany-mainmenu-61.

The Netherlands

Another LEZ system to consider in the context of purely emission-standard-based LEZs is the one operating in the Netherlands. Dutch LEZs (called “environmental zones”) operate without any time limits and are established in 11 cities in Netherlands, being applicable to heavy-duty diesel-engine lorries over 3.5 t Gross Vehicle Weight. As of July 2013 the Dutch LEZ system will be also applicable to vans. Currently heavy duty vehicles with Euro 4 or Euro 5 engines may enter environmental zones without having to be modified - the admission of lower-standard HDV is prohibited. The Dutch LEZs are identified with three types of signs (see figures below).[51]

Figure 4.8 Dutch LEZ road signs.

a. Approaching LEZ **b. Entering LEZ** **c. Leaving LEZ**

Enforcement of the established system is carried out either by cameras, performing number plate recognition, or manually in LEZs where cameras are not yet installed. Fine for not complying with the LEZ’s requirements is set to 220 EUR[52] (though according to the information available on Centrum Milieuzones website[53], the fine amounts to 160 EUR).

The introduction of environmental zones in the Netherlands was carried out in 2007. In 2009, a comprehensive report, analysing the effects of the LEZs, was published[54]. Keeping in mind the general aim behind the introduction of LEZs – reduction of ambient NO_2 and PM_{10} concentrations – the report focused on the assessment of changes in air quality.

According to the study results, in the first period after introduction of LEZs the amount of HDV decreased, as only 60 – 75% of vehicles were compliant. In 2009 already 80 – 85% of HDV could enter LEZs. As mentioned above, the traffic flow is one of the determinant factors for LEZs interrelation with ambient noise levels.

The report also mentions that the introduction of LEZs in some of the areas brought about the reduction of loading/unloading processes[55], which resulted in reduction of noise emissions that accompany such activities. Yet the report underlines, that the sole introduction of LEZs does not solve noise related issues, as the resultant reductions are minimal.[56] Therefore, in order to achieve noteworthy results in terms of noise reduction, additional measures within LEZs should be implemented.

51 Netherlands, Low Emission Zones in Europe, available at http://www.lowemissionzones.eu/countries-mainmenu-147/netherlands-mainmenu-88.

52 Ibid.

53 Environmental Zones in the Netherlands. Centrum Milieuzones.nl, available at http://www.milieuzones.nl/englishhttp://www.milieuzones.nl/english.

54 Effectstudie Milieuzones Vrachtverkeer, Stand van Zaken 2009, available at http://www.milieuzones.nl/sites/default/files/Effectstudie%202009.pdfhttp://www.milieuzones.nl/sites/default/files/Effectstudie%202009.pdf.

55 Ibid. p. 58.

56 Ibid. p. 95.

4.6 Summary of advantages and disadvantages of LEZs

As it can be deduced from the sections above, the information on noise aspects of LEZs is rather scarce and in the majority of cases the noise is not addressed at all in the context of assessment of already implemented LEZs.
Table **4.7** summarises the advantages and disadvantages of LEZ with respect to noise that can be deduced from the available studies.

Table 4.7 Advantages and disadvantages of LEZs

Type of LEZ	Advantages	Disadvantages
LEZs operating on the basis of charges	• Revenues raised from operation of LEZs can be invested in additional noise-mitigating measures; • Noise reduced if charge leads to reduced traffic volume.	• The charge differs from country to country rather significantly; • In some countries where the charge is low, LEZ does not change the situation enough to have an impact on noise levels; • If reduced traffic leads to higher vehicle speed, the noise benefit is lost, or noise may be worse.
LEZs operating on the basis of emission standards	• Have immediate impact on traffic volumes; • Restricting access of HDV, which are generally responsible for higher noise emissions than passenger cars, effectively reduces noise levels without restricting passenger traffic.	• Some of the observed LEZs do not restrict access to foreign vehicles; • Same tonnage to/from city centre shall be split among many light duty vehicles, thus generating more traffic[57]; • May require considerable investments without immediate/direct financial return.

In addition to the above-provided advantages and disadvantages relevant to particular types of LEZs, there are common pros and cons, applicable to all LEZs, notwithstanding their operational specifics. The advantages include:

- Introduction of LEZs encourage replacement of old vehicles with new ones, which generally produce lower noise emissions;
- LEZs can be easily combined with other sustainable mobility measures;[58]
- Shift in means of transportation in favour of public transportation, cycling, walking.

At the same time, there are also a number of disadvantages or potential threats that can undermine the effectiveness of LEZs:

- According to the reports on the already implemented LEZs, the direct effects of LEZs on noise levels are either disregarded or considered as insignificant;
- Few LEZs take into consideration the potential of hybrid and electric vehicles;
- Need to carefully plan infrastructure outside LEZs, so as to avoid congestions in areas nearby designated zones;
- Economic inefficiency rooted in imposing replacement of vehicles before the end of their economic life;[59]

57 Supra note 39, p. 101.
58 Ibid.
59 Ibid.

- LEZs that operate with time restrictions (according to the ARS study, 18% of LEZs operate only during day time)[60] and do not provide benefits in terms of noise reduction during the most sensitive time of day (i.e. at night[61]);
- Without appropriate additional designation of speed limits, the average traffic speed might increase thus leading to increase of noise levels.

60 Ibid., p. 39.

61 "…sleep disturbances caused by traffic noise may induce primary effects during sleep and secondary effects during the day after night-time noise exposure." Ausejo, M. et al. Design of Noise Action Plan based on a Road Traffic Noise Map. Acta Acustica United with Acustica, Vol. 97 (2011), p. 492.

5 Innovation and Best Practices

5.1 Introduction

Innovation in the context of LEZs can be taken to mean different approaches taken to solve issues. Some of the LEZ innovations use new technology, while others are innovative ways to resolve issues that are very 'low-tech'.

Innovation can help broaden and develop what can then become best, or ideal, practice. Innovation or 'ideal practice' is often easier where there are more resources, be it funding or monitoring data. Innovation can also look to resolve problems. Innovation does not always move in the same direction as harmonisation, if it is appropriate to one situation but not others. Many innovations have been taken up by others, so no longer appear innovative and become best practice that can be harmonised. There are many best practices that are not particularly innovative. This section focuses on innovation that is good practice. Where innovation is not seen as good practice this is indicated.

5.2 LEZ Planning, Design and Implementation

Enforcement

An LEZ needs good compliance, and good enforcement helps achieve this. Automatic number plate recognition (ANPR) enforcement can ensure high compliance rate. ANPR is used in a number of cities including London, the Netherlands and Milan (Sadler 2010). Over 95% compliance rate is acheived in London (TfL 2010), building on the existing Congestion Charge enforcement. London uses static cameras at key entrances to the LEZ as well as mobile cameras to achieve this high compliance.

Innovation used elsewhere in the country or city has also been used for LEZs, both in London (building on the congestion charge enforcement), but also for the technological payment methods for the two payment-related LEZs, Milan and Norway. Technological enforcement has been more relevant to LEZs with payment. Milan's Area C allows the use of the Telepass transponder scheme used for Italian motorway tolls for payments of vehicles. To ensure the widest range of possibilies payment methods have been developed through direct debits, Milan's website, paypal, ATMs, parking meters as well as authorised retailers, call centre, and participating garages (Milan 2013). The Norwegian LEZs that are being considered envisage enforcement using 'AUTOPASS' transponders used in the urban tolling schemes in the same cities and on motorways. In the current Autopass system, cameras identify those who do not have a transponder and an invoice is then sent to the vehicle owner. A sliding scale of charges would enable Euro VI vehicles to be encouraged earlier than would be possible otherwise. Income from the existing urban tolling schemes is used for transport projects and incorporation of an emissions aspect could give funds for cleaner vehicles.

The enforcement mechanism choice is affected by many factors, and automatic enforcement is not always possible. Manual enforcement is cheaper to implement, but can be expensive to achieve high compliance rates – but therefore a potential for job creation. In most countries enforcement of moving vehicles requires the use of police officers, however enforcement of stationary vehicles does not. Innovation in Denmark allows enforcement at lorry unloading points to reduce costs. In Germany the penalty for non-compliance has included a point on the drivers licence in addition to the fine. This gives a significant incentive to comply which helps counteract the lower chance of getting caught by the manual enforcement, especially for those who rely on their vehicle for work and are likely to do higher mileage.

The penalty for Danish LEZs is set relative to the cost of compliance, ie the fitting of a filter. This gives a proportional penalty and a link to compliance.

Integration into SUMPS
LEZs are implemented as part of a package of air quality measures. Londons LEZ is an integral part of their Air Quality Strategy. This is required to be consistent with all other London Strategies, in particular the Transport and Spatial Development Strategies as well as sustainable development and equal equalities. This enables the LEZ to be integrated into the whole of the authority's work, and enabling Sustainable Urban Mobility Planning.

Combined LEZ and congestion charging schemes can allow mobility and emissions to be tackled jointly as sustainable urban mobility, as in the Milan scheme that bans some vehicles and charges others. They also require more high tech enforcement for payment that can enforce the LEZ.

Forward planning
LEZs including Berlin, the Netherlands and London have tightened the access restrictions to the LEZ over time, giving a clear outline of the stages early in the process. This allows vehicle operators to plan and stage their compliance and to achieve emissions standards that would not be possible in one stage. This innovation is now mainstream LEZ practice. Milan progressed from the regional Lombardy LEZ to add to this the emissions-related Ecopass to the Area C, a combined LEZ and congestion charge.

Using state of the art emissions reduction technology
In London state of the art de-NOx equipment has been tested in the demanding real world cycles of London Buses. Once found successful in reducing on-road NOx emissions, TfL funded fitting to 900 public buses through green procurement. This used the the newly developed technology to enable Euro III standard buses to meet Euro VI PM and nearly Euro VI NOx for much less cost than replacing the vehicles.

Euro standards are key to LEZs. However, many Euro V heavy duty vehicles in particular have not delivered the expected NOx emissions reduction in urban areas. Requiring Euro VI emissions for the general LEZ is not yet feasible. London has therefore ensured that all public buses, with their high usage in London meet or approach Euro VI standards, through new Euro VI purchase, retrofit and hybrid buses. The buses high usage in polluted parts of London enable this to have significant impact.

Most LEZs allow retrofitting of certified DPFs to reduce the burden on vehicle operators to comply with LEZs and at the same time increase the impact of the LEZ on particulate emissions. In the absence of an EU-wide DPF certification, the certification has been aligned to the Euro standards. Full filters reduce *all* PM, including ultrafines which are of particular health concern, by over 90% and are appropriate for the more heavy duty vehicles (HDVs). Partial filters reduce PM by up to 50%, but reduce ultrafines less. In addition, some DPFs increase the emissions of primary NO_2, which was not included in Euro standards. In terms of air quality and health, the full filters give a significant advatage over partial filters.

Denmarks innovation was to require DPFs that reduce vehicle PM emissions from the Euro 3 to at least Euro 4, as the second phase of the LEZs required Euro 4 standard. This PM reduction of 80%

ensured that only the more effective DPFs were allowed. London used industry consultation to upgrade the DPF requirement to full filters and bring in a limit of the increase of primary NO_2 allowed in certified DPFs. The UNECE 2013 REC Regulation allows DPF reductions of at least 90% PM, 97% particle number and 60% NOx and allowing for limited primary NO_2 emission will avoid the need for this innovation in the future and increase harmonisation. New certifications can now refer to the UNECE regulation, as the new French DPF certification does.This has allowed LEZs to have a greater impact on PM, where the concensus is the greater health impact is and the greater cost benefit impact.

Green procurement
While many Euro V heavy duty vehicles in particular have not delivered the expected NOx emissions reduction in urban areas, others have. The Netherlands has developed guidance for local authorities and others to enable green procurement to ensure that the Euro V vehicles purchased are those that reduce emissions most effectively in urban areas (TNO 2013). It includes the real world test procedures that can be used to identify the better performing vehicles for each city. This is able to feed into the LEZ complimentary measures of reducing emissions from the public fleet.

5.3 Overcoming Barriers

Public, stakeholder and political opinions can be seen as barriers to LEZ implementation. A number of innovative approaches have been used in LEZs, which are detailed in section 5.4.

Public and stakeholder opinion
Complimentary measures are a key measure in terms of barriers such as inequality, public opinion and supporting urban logistics. These can range from financial incentives to logistics measures. Some complimentary measures are clearly specifically linked to LEZs, with increasing integration in SUMPS, the measures while being there, can be less obviously linked, as in London's LEZ and the wider Transport Strategy which inlcudes many measures to improve urban logistics.

The Dutch covenant or LEZ framework includes complimentary measures, including measures to support logistics operators, improving and cleaning public transport and an extensive grant program for retrofits (MINVROM 2006).

Measures have been taken to enable LEZ compliance for those on lower incomes. Most LEZs allow diesel vehicles to be retrofitted with DPFs reduces the cost of compliance for many operators, making it easier for those on lower incomes or economic margins. The Netherlands, Denmark, Germany and many Italian regions have also provided grants or other financial support for the retrofitting of vehicles (Sadler 2009).

Social inequality
German and Italian LEZs are the only ones that affect cars and in Italy's case also motorcycles. In terms of setting the emissions standard, the restriction on petrol cars is at vehicles pre-Euro 1, where the significant reduction in emissions occurred through the introduction of the catalytic converter. This allows vehicles up to 20 years old), and therefore inexpensive, vehicles access to the LEZs. Germany as well as many other countries had scrappage schemes to support the replacement of older (LEZ non-compliant) vehicles by new vehicles. Some Italian regions such as have also given financial support for new vehicle purchase to households on low incomes.

Exemptions have been used to overcome social inequality. Exemptions need to be chosen with care, as the more exemptions, the less air quality impact the LEZ will have - making it ineffective as well as it being unfair on those who do comply. Germany and the Netherlands have ‘hardship exemptions’, where those individuals or businesses that can prove that they cannot afford to comply with the LEZ are granted LEZs. There have been relatively few of these exemptions applied for.

In some German and Italian LEZs, where private cars are affected there are also exemptions for those who are unable to afford a compliant vehicle and their working times are when there is no public transport available. However, as 20 year old petrol vehicles are allowed access, this should not be required by many commutors.

Some of the Italian LEZs have time periods where those on lower incomes can access the area. Bozen LEZ is in operation 7:00 – 10:00 & 16:00 – 19:00, Monday – Friday (LEEZEN 2013). This allows those on lower incomes or operating on lower economic margins to access the LEZ during the non-rush hour time. However, the range of times creates confusion and makes enforcement, for example manual enforcement of parked vehicles, less clear cut.

Impact on tourism

Nearly all LEZs are permenant, increasing clarity and working towards the annual average air quality limit values. Some of the Italian LEZs are in place during the winter months only, as this is where the vast majority of PM_{10} exeedences occur. They end on 31st March and starting anywhere between 15th September and 1st November, often harmonised by region (LEEZEN 2013). While a permenant LEZ is more effective and clearer to communicate, the winter LEZs allow the impact on tourism to be reduced. However the range of dates and the sometimes only few days notice of the LEZ implementation creates confusion for vehicle operators.

5.4 Public Participation

Stakeholder involvement

Public and stakeholder opinion can be positively influenced by early involvement in the LEZ. The Dutch lorry-based LEZs used a very Dutch approach and were negotiated with the national government, municipalites and national haulier organisations. This enabled them to be implemented with public support. A covenant was set up which included guidance and ‘roadmap’ on how to introduce an LEZ, assessment measures required prior to the introduction of an LEZ, complimentary measures required.

Referendum and consultation

Milan’s Area C was implemented after a referrendum, which was returned with 79.1% approval. The referendum was undertaken when a similar, Ecopass, scheme where vehicles were charged according to their emissions was in place, enabling residents to see the benefits of such a scheme (Milan 2013).

London undertook a series of consultations on the LEZ before implementation, both of the scheme and the Strategies in which it was included to ensure public and stakeholder participation in the scheme development. The London Mayor who introduced the LEZ in his second term of office, Ken Livingstone, had a promise to clean up Londons air with an LEZ as a key re-election manefesto commitment, which also enabled the LEZ to be viewed by the public.

Public information
Public information is an essential part of operating an LEZ, and many methods are used. All good practice LEZs have their own websites. In 2007 a group of cities formed the Low Emission Zones in Europe Network with one of the key aims to produce a joint website, www.lowemissionzones.eu, enabling an updated one-stop-(free)-shop to provide all the information vehicle operators required on all LEZs to be available from one website. This is something that could only be done jointly. The Network also allows the sharing of best practice between members.

Denmark presented the pre-ante impacts of the LEZs in terms of health impacts and health costs more than the air quality figures. This gave it more relevance to the public, and helped understand the reasons for the LEZ.

5.5 Financing

LEZs cost money to implement and comply with. Funds so far have come from national and municipal funds. Combining LEZs with congestion or payment schemes has help fund very effective technological enforcement, as discussed in section 5.2, where this technology has been more relevant. LEZ compliance has often been financially supported by public authorities, see section 5.4.

5.6 Monitoring

Extricating the air quality and other impacts of the LEZ from the impact of other measures can require significant innovation, and requires care to be done well. This is especially the case for air quality, which is also affected by different meteorology each year. This can however consume significant resources, and ideally there would have been sufficient appropriate monitoring stations in operation a number of years before the LEZ is implemented, which are not always available in retrospect. Various innovative methods to, both high and lower cost have been undertaken to be able to assess the impact of LEZs.

London has used the data collected from the ANPR enforcement to provide data for the assessments of the emissions impact of the LEZ that reflect the actual action of vehicles operators travelling along Londons roads to comply with the LEZ, eg buy a new second hand vehicle or retrofit a DPF (TfL 2010). Berlin used data from the vehicles registerd in Berlin and sample data gathered for some of its assessments.

London prepared a comprehensive wide-ranging monitoring program, set out in a baseline report. Methods and data sources were set out to assess air quality impacts within and without the LEZ, health, business and economic impacts (London 2008, Kelly et al, 2011). A methodology was established to evaluate health impacts using electronic medical data coupled with air quality monitoring data (Kelly et al, 2011).

The Rhur area of Germany, has a large number of monitoring sites around a number of comparable cities with and without LEZs. They have compared air quality monitoring data inside and outside the LEZ, however it is likely to give an underestimate as vehicles will be cleaner outside the LEZs, due to vehicles travelling through them.

Hannover did not have the large network of air quality monitoring sites, or a similar city to compare with, so it used ratios of air quality measurements at background and roadside/traffic sites for different years. If the impact of the LEZ was zero, then the ratio between the averaged background monitoring sites from 2004-7 over that for 2008 should be the same as the averaged *roadside* sites from 2004-7 over that for 2008. However, if this is significantly different, and the major traffic air quality measure in the area was the LEZ, then this difference can be attributed to the LEZ.

LEZs are implemented to meet the EU Limit Values and improve health. The Limit Values are set in terms of PM_{10} and $PM_{2.5}$, however there is increasing evidence that it is the smaller combustion particles and particularly diesel emissions that are of greater health importance, also in terms of cost-benefit analysis (WHO 2012, WHO 2012a). LEZs have a larger impact on these smaller combustion particles than they do on PM_{10}. Berlin used $PM_{2.5}$ source apportionment to help assess the black carbon, PM_{10} and $PM_{2.5}$ impact. While absolute concentrations of pollutants strongly depend on the meteorological conditions, the relative contribution of the source sectors is less prone to weather changes. The results of the source apportionment were used to transpose the LEZ-related emission reductions into equivalent pollution reduction figures (Sadler 2010).

Analysis of particulate composition – The London baseline study (Kelly et al, 2011) describes a the set up of a monitoring network which enables the analysis of the oxidative potential and metal content of particulate concentrations. Studies in the Netherlands (Boogard et al, 2012) and Denmark (Jensen et al, 2011) have also used measurements of elemental carbon and particle number to provide more detailed information than is available from PM_{10} concentrations.

5.7 Recommendations

1) policy recommendations for EU and/or MS on promoting innovation for LEZ:

   The penalty for non-compliance should reflect the chances of getting caught, in particular manual enforcement should consider higher or more innovative penalties, such as the point on a driving license.

2) policy or implementation recommendations for municipalities:

   Where innovative technology is used for payment-related LEZs, those that are coordinated with existing systems, and where relevant European EETS, is a significant advantage.

   Use different PM metrics in LEZ assessments where possible, including Black Smoke, particulate number, PM1 etc. Consider translating these into health cost savings.

   LEZs should be integrated in a wider air quality and transport plan and SUMPs and part of a well planned and timetabled measure with phased introduction and sufficient notice to stakeholders.

3) recommendations for incorporation of innovation in a harmonized EU LEZ system:

   Permenant LEZs are most effective and more simple to communicate and should be encouraged as best practice. However, where PM10 exceedences are only in the winter months and winter LEZs is implemented, common starting dates should be agreed and as elsewhere, part of a well planned out and timetabled scheme giving sufficient notice.

5.8 References

- Berlin 2009, “Ein Jahr Umweltzone Berlin: Wirkungsuntersuchungen” May 2009;
- DUH, Deutsche Umwelthilfe 2013 „Kontrollverhalten in den deutschen Umweltzonen im Jahr 2012”;
- LEEZEN 2013 – www.lowemissionzones.eu;
- MINVROM 2006, Dutch LEZ covenant and guidance: CONVENANT STIMULERING SCHONE VRACHTAUTO'S EN MILIEUZONERING 2006 http://www.milieuzones.nl/het-convenant;
- Milan 2013 Area C website http://www.comune.milano.it/areac;
- Niedersachsen 2009, „Auswirkungen der Umweltzone Hannover auf die Luftqualität.“ April 2009;
- Sadler Consultants, 2010. Low Emission Zones in Europe, for the UK Department for Transport. February 2010;
- Sadler Consultants, 2011. Low Emission Zones in Europe, for ADEME. July 2011;
- Transport for London, 2008. London Low Emission Zone, Impacts Monitoring. Baseline Report, July;
- TfL 2010 Travel in London Report 3, TfL 2010;
- TNO 2013, Guidance document for procurement of city buses and trucks in view of in-service exhaust emissions and fuel consumption. October 2013;
- WHO 2012 “IARC: DIESEL ENGINE EXHAUST CARCINOGENIC” 12 June 2012;
- WHO 2012a “Health effects of black carbon”, 2012;
- WHO 2013 “IARC: Outdoor air pollution a leading environmental cause of cancer deaths” 17 October 2013 http://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf.

6 Potential for Harmonisation

6.1 Introduction

Tasks 2.1 and 2.2 represent a two-step approach to defining the scope of the city pass system for harmonisation and mutual recognition of standard European low emission zones. Task 2.1 (this chapter) identifies the potential aspects to consider, while Task 2.2 (next chapter) proposes the actual scope.

Task 2.1 presents a long list of aspects of LEZ that have potential to be standardized or harmonized at EU level. The list is based on the work done in Task 1 and other studies, especially the 2010 ARS study (ISIS 2010) and the COWI Ecorys study for DG MOVE titled "Study to support an Impact Assessment of Urban Mobility Package – Activity 32: EU Framework for Urban Road User Charging and Access Restriction Schemes". The aspects are screened on their advantages and disadvantages. This compilation will serve as input for defining the scope of the proposed City Pass system.

The COWI Ecorys study concludes that standardisation and harmonisation of several aspects might have substantial efficiency and cost savings benefits. The main beneficiaries will probably be the service providers that serve different cities with LEZ on a regular basis can be expected to be the main beneficiaries. This is due to the following reasons (COWI Ecorys 2013, p. 70ff):

- Time and operational costs to find and obtain all relevant information for more than one low emission zone may significantly decrease;
- Service provider fleets may be more efficiently applied;
- Planning of delivery becomes easier as exchangeability between the vehicles will increase (efficiency improvement);
- There may be economies of scale for providers as the required types of goods vehicles may decrease. The fleet composition becomes more efficient. For example, a provider can handle its operations with 5 types of vehicles (specific environmental performance and fuel type) instead of 10 types of vehicles;
- The fleet can be more efficiently used. Fewer vehicles may be required (lower operational costs).

The COWI Ecorys study refers to comparatively small benefits for passengers, as it “becomes easier to find and obtain all relevant information and also passenger cars can be applied more efficiently”. Employees that frequently visit LEZ in different cities (e.g. salesmen) are expected to have the largest benefits in terms of time savings within this category of users.

Other potential benefits are also highlighted in the same study in the context of EU-wide harmonisation of access restriction schemes. These are not LEZ-specific but deserve consideration nevertheless (COWI Ecorys 2013, p. 74):

- Economies of scale for manufacturers of charging and payment technological devices, which may in turn result in lower purchasing and maintenance costs for competent authorities;
- Lower operating costs for logistic service providers and other road users as a result of mainstreamed design requirements for vehicles (via economies of scale for car manufacturers, although this assumes environmental technical standards to be a key determinant of manufacturing choices);
- Positive impact on “the image and the business climate of (in particular) inner-cities”. “In the present situation companies may be deterred by the different schemes in use and the

unpredictability of possible adaptions. Harmonisation may lead to more consistently applied access restriction schemes and also to greater predictability. This can contribute to the business climate and functioning of inner-cities in general";
- Potential reductions in the amount of vehicles and vehicle-kilometres, resulting in external benefits such as fewer emissions, lower noise, improved road safety, etc. However, "some cities could benefit from harmonisation, others may not";
- With regard to the "lack of information" hypothesis, it is stated that harmonising may contribute to a better knowledge and better information of traffic participants (thus reducing uncertainty). As a result, negative effects due to imperfect information "may decrease" along with efficiency losses in terms of delay-induced costs.

The advantages of harmonisation and standardisation also include:
- greater citizen acceptance;
- uniform requirements and procedures are easier to adapt to;
- increases transferability of information and best practices;
- facilitate development of innovative approaches with wider applicability;
- cost and time savings for users and suppliers;
- help cities to efficiently implement LEZ.

These are taken into consideration in assessing the appropriate aspects and measures to be included in the European Standard Low Emission Zone system.

Table 6.1 on the following pages presents the long list of aspects to be considered for harmonisation or standardization including an assessment of the appropriate level of harmonisation i.e. guidelines, harmonised guidance, or well-defined standards.

Error! Reference source not found. is organised into five sections:
1. LEZ planning and Implementation;
2. Administration;
3. Financial aspects;
4. Information systems;
5. Monitoring, evaluation and impact assessment.

The table consists of aspects mentioned in this project's Inception Report[62] section 2.4.2 (Task 2.2 Identify the possible scope of a European City Pass system), numbered in parentheses and shown in bold. The comments, advantages and disadvantages as submitted by DG environment and DG move are included in the table. The other aspects are the possible topics to be included in the guidance not included in section 2.4.2 but mentioned in section 2.4.5 (Task 2.5 Guidance and requirements document for the European City Pass system).

Three levels of presentation are envisioned. These levels are further described below.

Guidelines indicate the general approach to implement the aspect; the steps to be followed. Existing resources and sources of guidance are identified and evaluated, with best sources highlighted.

Harmonised guidance provides a stricter definition of the approach and methods to be used.

Standardisation essential requirements are identified and specific characteristics are defined. A limited number or range of variations is allowed.

[62] FEASIBILITY STUDY: EUROPEAN CITY PASS FOR LOW EMISSION ZONES, Inception Report, 8 February 2013.

For the purposes of the proposed City Pass system of harmonisation and mutual recognition of standard European low emission zones, low emission zones are defined as 'urban areas or roads where the most polluting vehicles are selectively excluded based on EURO emission standard. The restriction may be for one or several types of vehicles, and may be limited to certain periods of the day or week. Low emission zones may also be based on payment for access, where payment is differentiated in relation to vehicle emissions (e.g. EURO classes).

Table 6.1 Long list of aspects of low emission zones to be considered for standardisation or harmonisation

	Standardization / harmonization		Assessment of possible options		
Aspect	**Advantages**	**Disadvantages**	**Guidelines**	**Harmonized guidance**	**Standardization**
1. LEZ planning and Implementation					
Criteria defining LEZ: **- vehicle exclusion criteria based on technical criteria e.g. Euro emission classes;(1)** - vehicle inclusion criteria e.g. vehicles equipped with particle filters, electric cars etc.; - high-emitting vehicles; - regulation criteria based on charging in relation to emissions; **- geographical criteria (6).**	* maximum use of existing knowledge and experiences; * preventing cities from pitfalls; * cost and time savings for users and suppliers.	* subsidiarity issue; * costs for adjusting existing local practices **exclusion / inclusion criteria:** * no legal context / base; cannot be more specific than using Euro X standards; * tension between overall mobility and air quality (for example old but full buses). **geographical criteria**: * situation of each city is different, area should always be locally defined; * not sure what EU level can do: recommend minimum size?		X	X
issues to be involved in LEZ. (including possible integration in SUMP's).	* integration of LEZ's in an integrated package of sustainable urban transport measures might increase the impact compared to a LEZ as a single measure; * it will increase the uptake of LEZ's, benefiting from the EU actions on promoting SUMP's.	* There is not a 'one size, fits all' LEZ planning and implementation solution.	X	X	

	Standardization / harmonization		Assessment of possible options		
Aspect	**Advantages**	**Disadvantages**	**Guidelines**	**Harmonized guidance**	**Standardization**
guidance to assist cities in their planning and decision making process (including stakeholder and public participation).	* tool for cities, making optimal use of existing knowledge and experiences; * preventing cities for pitfalls; * time and cost savings.	* local decision making and participation culture differs between cities across Europe.	X	X	
type of access regulation: - charging / restriction; - gate, toll collection or vignette; - weekdays and begin/end times for time-limited LEZ.	* cost and time savings for users and suppliers.	* costs for adjusting existing local practices; * subsidiarity aspect.	X	X	
method for identifying vehicle eligibility, such as: - stickers (building on the German/Czech agreement?); - electronic ID systems (for example London/Milan); - vehicle registration documents; - licence plate recognition systems.(3)	* cost and time savings for users and suppliers; * using stickers will prevent 'big brother effect' compared to electronic access and recognition.	* costs for adjusting existing local practices; * subsidiarity aspect; * possible 'big brother' effect when using electronic access and recognition; * EU car database or access of Members states to each other's national car database needed to determine emission category.	X	X	
services or special considerations for (13): 1) foreign drivers; 2) urban freight; and 3) regional and tourist coach operators.	* cost and time savings for users.	* possible conflict with existing local practices; * subsidiarity aspect; * exempting foreign vehicles in the long run will lead to competition issues.	X	X	
1. LEZ planning and Implementation (continued)					
signage (road signs at LEZ boundaries and approach roads to LEZ) (12).	* cost savings design; * service for the users (recognition).	* costs for adjusting existing local practices; * subsidiarity aspect.	X	X	X
legal requirements (local, national, EU).	* efficiency gains through harmonisation.	* subsidiarity issue.	X	X	X

	Standardization / harmonization		Assessment of possible options		
Aspect	**Advantages**	**Disadvantages**	**Guidelines**	**Harmonized guidance**	**Standardization**
traffic safety aspects (15)	* guarantees that safety aspects are taken into account; * In a LEZ, there might be more cycling and walking. This might require some additional infrastructure for these categories.	* taking traffic safety aspects into account, is normal practice in urban transport planning; * when a LEZ only forbids older Euro Emission classes, then it may just lead to substitution by newer vehicles and not to more walking and cycling.	X		
provision of alternative mobility and parking solutions (7)	* see integration in SUMP's; * for example cars with better environmental performance could be given easier access to parking facilities or could be allowed to use bus lanes, etc. (cfr Oslo); * recommendations on how to service mobility needs inside the zone could help.	* should be part of a broader sustainable urban transport plan	X		
recharging or battery exchange facilities for electric vehicles.	* see integration in SUMP's.	* Is an aspect of broader sustainable urban transport policy.	X	X	
green procurement specifications for LEZ infrastructure and alternative mobility solutions (14).	* see integration in SUMP's.	* subsidiarity and proportionality aspect; * if considered necessary, these could be built into the Directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles. But there seems no direct need to link this.	X	X	
2. Administration (9)					

	Standardization / harmonization		Assessment of possible options		
Aspect	**Advantages**	**Disadvantages**	**Guidelines**	**Harmonized guidance**	**Standardization**
procedure to obtain permits including applications for exceptions (8).	* cost and time savings for users and cities.	* how to deal with occasional / foreign visitors; * to be sent by post ?? * It has to be determined which Euro class the vehicle is type approved into. This implies making available the conformity certificate to the authority or organization that issues the sticker.			X
rules for the approval, verification and certification of after-treatment or retrofitting devices for older vehicles (particle filters, catalysts, etc.); to meet a higher EURO emission standard (2).	* cost and time savings for users, suppliers and cities.	* costs for adjusting existing national/local practices; * subsidiarity aspect.		X	X
2. Administration (9) (continued)					
method of payment, if any (5) (interoperable fare management, such as the European Electronic Toll Service, EETS).	* cost and time savings for users and cities.	* costs for adjusting existing local practices; * very subsidiary as with parking and traffic subsidiarity aspect; * how to deal with occasional / foreign visitors; * uniform system difficult: Annual fee? Per entry fee? Link to actual km driven/pollution?	X	X	X

	Standardization / harmonization		Assessment of possible options		
Aspect	**Advantages**	**Disadvantages**	**Guidelines**	**Harmonized guidance**	**Standardization**
method of enforcement and penalties for violations (electronic vehicle ID systems, gate or toll collection systems, license plate recognition systems) (4)	* cost and time savings cities * higher payment rate	* costs for adjusting existing local practices; * subsidiarity aspect; * a key issue and important topic in some regions – but how to progress? * similar problems with parking and traffic infringement fining.	X	X	
3. Financial aspects (10)					
funding modalities for LEZ (with and without charges).	* useful tool for cities, to set up the most appropriate funding scheme.	* subsidiarity aspect; * no good insight in cost effectiveness of these measures, to be impact assessed.	X		
setting fees, usage charges and fines.	* useful tool for cities, to set up the most appropriate pricing scheme.	* subsidiarity aspect; * no good insight in cost effectiveness of these measures, to be impact assessed.	X		
4. Information systems					
e-reporting and database notification.	* cost and time savings for cities; * guarantee that the relevant info on LEZ's is up to date and reliable.	* costs for adjusting existing local practices; * subsidiarity aspect.	X	X	X
information systems and services, including (11): - translation; - best practices and harmonization; - information for users on LEZ status and requirements; - real-time "mobility data" openly accessible to public and commercial users.	* useful tool for cities, to set up and implement the LEZ scheme in the most efficient way.	* costs for adjusting existing local practices; * subsidiarity aspect; * Stickers should be graphical (shapes, icons, colours) so that no translation is needed; * Information campaigns must be set up to inform citizens. Without harmonisation, there is a threat that it will lead to an enormous confusion.		X	X

	Standardization / harmonization		Assessment of possible options		
Aspect	**Advantages**	**Disadvantages**	**Guidelines**	**Harmonized guidance**	**Standardization**
5. Monitoring, evaluation and impact assessment					
Methodologies for monitoring and impact assessment: - defining SMART objectives; - evaluation framework and minimum data requirements; - definition for key assessment indicators; - guidance on how to conduct surveys and consultation exercises; - environmental impact assessment (air, noise, health, climate, mobility, traffic safety); - cost benefit analysis.	* common methodologies for defining SMART objectives, indicators, monitoring and impact assessment will increase the knowledge regarding do's and don'ts and impacts; * will lead over time to a more predictable and transparent system of AR schemes because of the availability of comparable evaluations; * useful tool for cities, to set up and conduct survey's in the most efficient way; * time and cost savings.	* data availability and data collection possibilities differs between cities; * possible conflict with existing local practices.	X	X	

6.2 Selection of elements for harmonisation

The second step in the process (Task 2.2) is the proposal of elements that could be included in a Standard European Low Emission Zone system. The purpose of such a standardised system would be to harmonize the essential aspects of European low emission zones across Member States. The selection of aspects to include is based on the results of Task 1 and Task 2.1.

The agreed scope will form the basis for the remaining tasks and preparation of the specification and guidance document for the Standard European Low Emission Zone system prepared in Task 2.5.

These specifications and guidance will be consistent with the Commission proposal foreseen for autumn 2013 for ARS in the context of the Urban Mobility Package. To this effect, DG ENV and DG MOVE will make appropriate co-ordination arrangements.

The purpose of a Standard European Low Emission Zone system would be to enable cities to implement low emission zones with minimum adverse impact for drivers and users. Standard or harmonised approaches and information will facilitate use by non-resident and international drivers, and allow logistics operators to efficiently adapt and deploy their fleets. The system is intended to highlight best practices and innovative solutions that can be taken on by cities to meet a range of primary objectives (traffic congestion, air quality, quality of life, road safety, etc.).

In Task 2.1, an overview is presented of aspects which could be considered for harmonisation / standardization. In this task, the list is reviewed and assessed whether they should be included in the draft fiche to be prepared for a candidate system for a European Standard Low Emission Zone.

This will include aspects for which harmonisation/standardisation is recommended as well as aspects for which guidelines are included for example the process aspects.

The audience for the guidance and requirements document is the Member States and local authorities. The guidance will be directed primarily to local authorities who have decided to implement a LEZ in their city.

The aspects were assessed on the following criteria:

- Efficiency gains and cost savings for:
    - Local / national authorities;
    - Industry;
    - Logistic service providers;
    - Other road users national;
    - Other road users foreign.
- Environmental Impact (air, noise);
- Type (guidelines, harmonized guidance, standardization);
- Level of detail to be included in the guidance.

Table 6.2 is organised into the same five sections as Table 6.1 in the previous section.

Table 6.2 Assessment of aspects of LEZ for the proposed scope of specifications and guidelines for a standard European Low Emission Zone system

	Efficiency gains / cost savings						Type				
Aspect	**local / national authorities**	**Industry**	**Logistic service providers**	**Other road users (national)**	**Other road users (foreign)**	**Environmental Impact (air, noise)**	**Guidelines**	**Harmonized guidance**	**Standardization**	**Recommended to include?**	**comment / argumentation**
1. LEZ planning and Implementation											
Criteria defining LEZ: **- vehicle exclusion criteria based on technical criteria e.g. Euro emission classes. (1);** - vehicle inclusion criteria e.g. vehicles equipped with particle filters, electric cars etc.; - high-emitting	+	+	+	+/-	+/-				X	yes	*level of detail:* description of options. *argumentation:* Authorities, industry, logistic service providers will most likely benefit from standardisation of exclusion-, inclusion and regulation criteria. This is probably

	Efficiency gains / cost savings						Type				
Aspect	**local / national authorities**	**Industry**	**Logistic service providers**	**Other road users (national)**	**Other road users (foreign)**	**Environmental Impact (air, noise)**	**Guidelines**	**Harmonized guidance**	**Standardization**	**Recommended to include?**	**comment / argumentation**
vehicles; - regulation criteria based on charging in relation to emissions; **- geographical criteria (6).**											also the case with geographic criteria, because it contributes to more predictability.
issues to be involved in LEZ (including possible integration in SUMP's).	+	+	+	+	+	++	X			yes	*level of detail:* the issues + short description. *argumentation:* Planning and implementation of a LEZ in which all relevant issues are addressed, will probably increase the impact, acceptance and user friendliness of the LEZ. On the other hand there is not 'one size fits all solution'. Therefore harmonisation or standardisation is not an option. Guidelines though on the issues to be addressed, building on existing knowledge and experiences, will be a useful tool for cities.

Aspect	Efficiency gains / cost savings: local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)	Environmental Impact (air, noise)	Type: Guidelines	Harmonized guidance	Standardization	Recommended to include?	comment / argumentation
guidance to assist cities in their planning and decision making process (including stakeholder and public participation).	+	+/-	+/-	+/-	+/-	+/-	X			yes	*level of detail:* global description: the process and steps. *argumentation:* Local decision making and participation culture differs between cities across Europe. Therefore harmonisation or standardisation is not an option. Guidelines though on the planning and decision making process, building on existing knowledge and experiences, will be a useful tool for cities.
1. LEZ planning and Implementation (continued)											
type of access regulation: - charging / restriction; - gate, toll collection or vignette; - weekdays and begin-/endtimes for time-limited LEZ.	+/-	+	+	+/-	+/-	+/-	X			yes	*level of detail:* global description. *argumentation:* Harmonisation or standardisation might be beneficial for industry and logistic service providers, but is hardly feasible given the

Aspect	Efficiency gains / cost savings: local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)	Environmental Impact (air, noise)	Type: Guidelines	Harmonized guidance	Standardization	Recommended to include?	comment / argumentation
											subsidiarity aspect. An overview of the options and considerations when choosing the local type of access regulation will assist cities in their decision process.
method for identifying vehicle eligibility, such as: - stickers (building on the German/Czech agreement?); - vehicle registration documents; - licence plate recognition systems; (3).	+	+	+	+/	+/	+			X	yes	*level of detail:* global description + examples. *argumentation:* Standardisation of the identification tools will be beneficial for authorities, industry and logistic service providers and other road users.
services or special considerations for (13): 1) foreign drivers, 2) urban freight; and 3) regional and tourist coach operators.	+/-	+	+	+/-	+	+/-	X			yes	*level of detail:* global description + examples. *argumentation:* Harmonisation or standardisation might be beneficial for industry and logistic service providers, but is hardly feasible given the subsidiarity aspect. An overview of the options, pro's and con's of the

Aspect	Efficiency gains / cost savings						Type				comment / argumentation
	local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)	Environmental Impact (air. noise)	Guidelines	Harmonized guidance	Standardization	Recommended to include?	
											options and considerations when choosing the identification method. will assist cities though in their decision process. Important topic to be handled here is that in the long run exempting foreign vehicles will lead to competition issues.
1. LEZ planning and Implementation (continued)											
signage (road signs at LEZ boundaries and approach roads to LEZ) (12).	+	+/-	+/-	+/-	+/-	+/-			X	yes	*level of detail:* description general principles. *argumentation:* Standardisation will be beneficial for authorities when the can use standard signage. Uniform signage is beneficial for users as well since it eases recognition when approaching and entering LEZ zones.

Aspect	Efficiency gains / cost savings					Environmental Impact (air, noise)	Type			Recommended to include?	comment / argumentation
	local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)		Guidelines	Harmonized guidance	Standardization		
legal requirements (local, national, EU).	+	+	+	+/-	+/-	+		X		yes	*level of detail:* the issues + short description. *argumentation:* Standardisation is not feasible given the subsidiarity aspect as well given the differences between the LEZ zones that will - even in a situation with more harmonisation will remain. Harmonized guidance on the topics to be addressed though can be beneficial for authorities, industry and logistic service providers.
traffic safety aspects (15).	+/-	+/-	+/-	+/-	+/-	+/-	X			no	*argumentation:* Traffic safety aspects should be part of sustainable urban transport planning. There is no evidence yet there is such a substantial increase in cycling and walking in LEZ zones that specific to LEZ zones related traffic safety measures should be taken.

Aspect	Efficiency gains / cost savings: local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)	Environmental Impact (air, noise)	Type: Guidelines	Harmonized guidance	Standardization	Recommended to include?	comment / argumentation
provision of alternative mobility and parking solutions (7).	+/-	+/-	+/-	+/-	+/-	+/-	X			no	*argumentation:* Provision of alternative mobility and parking solutions (such as P+R) is very important, but should be part of a SUMP, since these are not only related to LEZ, but to the whole urban mobility and transport system.
recharging or battery exchange facilities for electric vehicles.	+/-	+/-	+/-	+/-	+/-	+/-	X			No	*argumentation:* Provision of recharging or battery exchange facilities is very important, but should be part of a SUMP, since this is not only related to vehicles entering a LEZ, but to all motorized vehicles in the city.
green procurement specifications for LEZ infrastructure and alternative mobility solutions (14).	+/-	+/-	+/-	+/-	+/-	+/-	X			no	*argumentation:* This conflicts with the subsidiarity principle and probably with existing local practices regarding (green) procurement.
2. Administration (9)											

Aspect	Efficiency gains / cost savings					Environmental Impact (air, noise)	Type			Recommended to include?	comment / argumentation
	local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)		Guidelines	Harmonized guidance	Standardization		
procedure to obtain permits including applications for exceptions (8).	+	+/-	+	+	+	+/-			X	yes	*level of detail:* global description. *argumentation:* Standardisation of the procedure to obtain permits will be beneficial for authorities, logistic service providers and other road users.
rules for the approval, verification and certification of after-treatment or retrofitting devices for older vehicles (particle filters, catalysts, etc.); to meet a higher EURO emission standard (2).	+	+	+	+	+	+		X		yes	*level of detail:* description general principles. *argumentation:* Standardisation of rules for the approval, verification and certification of after-treatment or retrofitting will be beneficial for authorities, industry, logistic service providers and other road users.
method of payment, if any (5) (interoperable fare management, such as the European Electronic Toll Service, EETS).	+	+	+	+	+	+/-			X	yes	*level of detail:* description general principles. *argumentation:* Standardisation of payment options will be beneficial for authorities, logistic service providers and other road users.

Aspect	Efficiency gains / cost savings					Environmental Impact (air, noise)	Type			Recommended to include?	comment / argumentation
	local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)		Guidelines	Harmonized guidance	Standardization		
method of enforcement and penalties for violations (electronic vehicle ID systems, gate or toll collection systems, license plate recognition systems) (4).	+	+/-	+/-	+/-	+/-	+/-	X			yes	*level of detail:* global description. *argumentation:* Harmonisation of enforcement methods is not feasible given the subsidiarity aspect and this should be part of the general national/local traffic and parking enforcement methods. General guidelines on this might be useful for cities. Special aspect will be enforcement of foreign vehicles.
3. Financial aspects (10)											
funding modalities for LEZ (with and without charges)	+	+/-	+/-	+/-	+/-	+/-	X			yes	*level of detail:* global description CBA principles. *argumentation:* Local situations and possibilities differs between cities across Europe. Therefore harmonisation or standardisation is not an option. Guidelines on CBA principles and how to set up the most appropriate funding scheme

Aspect	Efficiency gains / cost savings: local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)	Environmental Impact (air, noise)	Type: Guidelines	Harmonized guidance	Standardization	Recommended to include?	comment / argumentation
											will be a useful tool for cities.
setting fees, usage charges and fines	+	+/-	+/-	+/-	+/-	+/-	X			yes	*level of detail:* global description pricing principles. *argumentation:* Harmonisation or standardisation on this is not an option. Differences in purchasing power, the subsidiarity principles are few reasons for this. Guidelines on how to determine the appropriate prices of fees, charges and fines at such a level that objectives of the LEZ are met and at the same time negative impacts are prevented will be a useful tool for cities.
4. Information systems											

	Efficiency gains / cost savings						Type				
Aspect	local / national authorities	Industry	Logistic service providers	Other road users (national)	Other road users (foreign)	Environmental Impact (air. noise)	Guidelines	Harmonized guidance	Standardization	Recommended to include?	comment / argumentation
e-reporting and database notification	+	+	+	+	+	+/-			X	yes	*level of detail:* Global description. *argumentation:* Authorities, industry, logistic service providers will benefit from standardised e-reporting procedures and formats. It will guarantee that the relevant info on LEZ's is up to date and reliable.
information systems and services, including (11): - translation; - best practices and harmonization; - information for users on LEZ status and requirements; - real-time "mobility data" openly accessible to public and commercial users.	+	+	+	+	+	+/-		X		yes	*level of detail:* only specification of the needs. *argumentation:* Standardisation is not feasible given the subsidiarity aspect as well given the differences between local practices and LEZ zones that will - even in a situation with more harmonisation will remain. Harmonized guidance on the information topics to be addressed though can be beneficial for authorities, industry and logistic service

Aspect	Efficiency gains / cost savings: local / national authorities	Efficiency gains / cost savings: Industry	Efficiency gains / cost savings: Logistic service providers	Efficiency gains / cost savings: Other road users (national)	Efficiency gains / cost savings: Other road users (foreign)	Environmental Impact (air, noise)	Type: Guidelines	Type: Harmonized guidance	Type: Standardization	Recommended to include?	comment / argumentation
											providers and other road users.
5. Monitoring, evaluation and impact assessment											
Methodologies for monitoring and impact assessment: - defining SMART objectives; - evaluation framework and minimum data requirements; - definition for key assessment indicators; - guidance on how to conduct surveys and consultation exercises; - environmental impact assessment (air, noise, health, climate, mobility, traffic safety); - cost benefit analysis.	+	+/-	+/-	+/-	+/-	+/-		X		yes	*level of detail:* global description. *argumentation:* Standardisation is not feasible given the differences in local circumstances and existing local practices Harmonized guidance on monitoring, evaluation and impact assessment methods building on existing knowledge and best practices will be a useful tool for authorities and probably contribute to more cost-effective LEZ's.

6.3 Standardisation

Table 6.3 summarises the aspects of LEZ which are proposed for standardisation in the European Standard LEZ system, as indicated above in Table 6.2 Standardisation means specification of requirements with a limited range of acceptable variations or alternatives. In cases where a formal technical standard is appropriate, the work to be done will provide an initial draft proposal for further consideration by an appropriate standards body.

Table 6.3 Aspects of LEZ proposed for standardisation

Aspect	Proposed scope	Purpose of standardisation	Comments
Vehicle exclusion criteria	Identify a limited number of standard vehicle exclusion or charging criteria based on EURO classes, vehicle types and retrofit devices. Recommend the range of years for application of each criteria (earliest, latest).	Standard criteria are easier for users to learn and adapt to, and allow logistics operators to efficiently deploy fleets with a minimum number of vehicle types. Variations in criteria that produce the same benefits are avoided.	Case studies: identify cities where each criteria is employed. Present and compare example emissions calculations for each criteria over time.
Vehicle inclusion criteria (exceptions)	Identify a limited number of standard vehicle access or exempt charging criteria for example equipped with particle filters, electric cars.	Standard criteria are easier for users to learn and adapt to, and allow logistics operators to efficiently deploy fleets with a minimum number of vehicle types. Variations in criteria that produce the same benefits are avoided.	Case studies: identify cities where each criteria is employed. Present and compare example emissions calculations for each criteria over time.
Signage [as starting point for initiation of formal standardisation process]	Propose standard set of information to be presented on signage. Propose items to be represented or distinguished by symbols, icons, and colours. Proposed use of English words, either alone or in bilingual use. Example symbols, colours from existing signage.	Facilitate access and compliance by non-local and international drivers. Standardised shapes and colours are to be used for indicating identical purposes –.	Compare existing signage. Compatible with Vienna Convention on Road Signs and Signals.[63]
Identification means: - vehicle stickers; - number plate.	Propose standard set requirements for each type of identification. For stickers for example propose symbols and colours. For number plate for example propose procedures for use of vehicle registration databases including privacy protection.	Facilitate: - mutual recognition of stickers from other Member States; - use of electronic devices in other LEZ's; - use of number plate recognition method.	Compare: - existing stickers: Building on the German/Czech agreement[64]; - number plate: Building on experiences London/Netherlands.

[63] Wikipedia (2013) Vienna Convention on Road Signs and Signals http://en.wikipedia.org/wiki/Vienna_Convention_on_Road_Signs_and_Signals.

[64] Czech Republic (2012).

Aspect	Proposed scope	Purpose of standardisation	Comments
Administrative procedures for subscription and permits for LEZ access and payment	Identify standard procedures and information required for obtaining permits and exceptions. Standard wording in English.	Facilitate compliance for non-resident and international drivers and logistics providers.	Process to obtain and/or verify EURO class of a vehicle.
Approval and recognition of retrofit emission control devices (REC)	Propose adaptation of UNECE (draft) regulation on approval of retrofit emission control devices for HDV[65]. For LDV?	Mutual recognition of retrofit devices approved by other MS, where relevant for LEZ criteria.	
e-reporting and database notification	Identify items and procedures for standardised e-reporting and database notification.	Guarantee that the relevant info on LEZ's is up to date and reliable.	Data should be available for the LEZ website as well as other public and private info providers.

6.4 References

- COWI, & Ecorys. (2013). Study to support and Impact Assessment of Urban Mobility Package - Activity 32: EU Framework for Urban Road User Charging and Access Restriction Schemes. European Commission, DG MOVE;
- COWI, & Ecorys. (2013). Study to support and Impact Assessment of Urban Mobility Package - Activity 32: EU Framework for Urban Road User Charging and Access Restriction Schemes. European Commission, DG MOVE;
- Czech Republic. (2012). Guidelines for the mutual acceptance of low emission zones vignettes and the exchange of best practices - information from the Czech delegation [information note for Council (Environment) meeting on 25 October 2012] (No. 14965/12). Retrieved from http://register.consilium.europa.eu/pdf/en/12/st14/st14965.en12.pdf;
- Czech Republic. (2012). Guidelines for the mutual acceptance of low emission zones vignettes and the exchange of best practices - information from the Czech delegation [information note for Council (Environment) meeting on 25 October 2012] (No. 14965/12). Retrieved from http://register.consilium.europa.eu/pdf/en/12/st14/st14965.en12.pdf;
- EC DG MOVE (2013). European Electronic Toll Service (EETS). http://ec.europa.eu/transport/themes/its/studies/eets_en.htm;
- GRPE REC. (2013). Proposal for a new Regulation on uniform provisions concerning the approval of Retrofit Emission Control Devices (REC) for heavy duty vehicles, agricultural and forestry tractors and non-road mobile machinery equipped with compression ignition engines (No. ECE/TRANS/WP.29/GRPE/2013/6). UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), Working Party on Pollution and Energy (GRPE), informal working on Retrofit Emission Control devices (REC). Retrieved from http://www.unece.org/fileadmin/DAM/trans/doc/2013/wp29grpe/ECE-TRANS-WP29-GRPE-2013-09e.pdf;
- ISIS, & pwc. (2010). Study on Urban Access Restrictions, Final Report (No. TREN/A4/103-2/2009). European Commission, DG MOVE. Retrieved from http://ec.europa.eu/transport/themes/urban/studies/doc/2010_12_ars_final_report.pdf;

[65] GRPE REC (2013).

- MWH (2013). Feasibility Study: European City Pass for Low Emission Zones; Inception Report. 8 February 2013. [this project];
- Wikipedia. (2013, August 27). Vienna Convention on Road Signs and Signals - Wikipedia, the free encyclopaedia. Retrieved 3 September 2013, from http://en.wikipedia.org/wiki/Vienna_Convention_on_Road_Signs_and_Signals.

7 Assessment of Potentials and Risks

7.1 Introduction

This chapter presents an assessment of the potentials and risks of a harmonised City Pass system for Standard European Low Emission Zones. The assessment is carried out under the SWOT analysis format, building on the SWOT analysis in the 2010 ARS Study (ISIS & pwc, 2010), the results presented in the previous chapters, as well as previous experience of the whole project team. Innovative cities and LEZ approaches are used as examples where appropriate.

The European Commission has announced as Initiative 32 of the current Transport White Paper, the development on an EU framework for urban road user charging and access restriction schemes. Actions as part of Initiative 32 would need to contribute to achieving specific targets set in the White Paper to “halve the use of ‘conventionally-fuelled’ cars in urban transport by 2030; phase them out in cities by 2050; and achieve essentially CO_2-free city logistics in major urban centres by 2030”. A study to support the Commission's impact assess of actions under Initiative 32 has been carried out by COWI Ecorys (2013).

Many cities within the EU cities apply a great variety of Access Regulation Measures (ARM) which include Access restriction schemes (ARS), Low Emission Zones (LEZs); Charging / toll, and parking measures. Moreover, many cities have introduced measures to optimize road transport demand and to minimize the occurrence of congestions.

This task aims to assess potentials and risks related to the introduction of a European city pass that would allow low emission/electrical vehicles obtaining unrestricted access into any standardized European Low Emission Zone across Europe.

Low emission zones (LEZ) are urban areas or roads where the most polluting vehicles are restricted from entering. Vehicles can be excluded based on their emission levels, or in some cases charged a fee that depends on the emission level. An example of legal provisions related to the establishment of LEZ is presented in Box 1.

Box 1: Example of legal provisions on LEZ – Czech Republic

Act No 201/2012 Coll., on Air Protection, Article 14: Low emission zones:

1) in the case of exceedance of one of air quality limit values…municipality may decide to establish low emission zone (LEZ) either at its whole territory or at its part;
2) Municipality …specifies the LEZ territory as well as emission categories of vehicles allowed to enter LEZ….Exception from restricted entry may be granted to permanent residents…… In the case that LEZ includes a part of transit highway or motorway, LEZ can only be established if alternative transit road connection of the same category is available (for vehicles not eligible for entering LEZ).

According to the specialized website Low emission zones in Europe[66], there were at least 180 LEZs operated in 9 Member States as from 1 January 2013. The highest number of LEZ can be found in Italy (79) and Germany (65), followed by the Netherlands (14). In the majority of cities, no charges apply, although the number of cities which require payments to access the LEZ is

[66] See http://www.lowemissionzones.eu/.

increasing. Payments are introduced in several countries (e.g. Italy, UK, Sweden, the Netherlands), however not in Germany.

Obviously, access to LEZ is based on license or visual sign (sticker) but certain cities have introduced Automatic Number Plate Recognition systems (ANPR).

Some cities have adopted innovative approaches in their implementations of LEZ, especially in the field of impact assessment (e.g. comprehensive monitoring campaign together with advanced modelling, use of electronic health records or analysis of particulate composition. Innovative approaches and technology that solve environmental problems and contribute to effective urban mobility and economic growth are among the objectives of the Europe 2020 strategy, and referred to as eco-innovation.

Low emission zones (LEZ) can be an effective measure to reduce traffic-related pollutant levels and shorten the time needed to achieve compliance with air quality limit values. There are many approaches to implementing a LEZ. Requirements and procedures vary widely between cities and can be difficult for foreign drivers to understand.

Introduction of LEZ at the EU level must be considered from the complex point of view of comparing pros and cons and to find optimal solution with balanced environmental improvements, technical and economic feasibility and social acceptability.

This study aims to help European cities to more quickly comply with air quality limit values and other environmental objectives through guidance and standardized techniques for implementing LEZ. Standardisation across Member States will benefit mobility and improve cost-effectiveness of LEZ.

For the purposes of this task, LEZ are therefore divided into two categories:
- LEZ type A – without payment;
- LEZ type B – with payment.

Potentials and risks of each type is assessed separately using standard method of SWOT analysis where “threats” should be understood as “risks” and “opportunities” as “potentials”. Analysis takes into account three basic dimension of sustainability:
- Environmental dimension (including human health impacts);
- Economic dimension;
- Social dimension.

Inclusion of human health impacts into the environmental dimension rather than into the social dimension is supported by the proposal on General Union Environment Action Programme to 2020 "Living well, within the limits of our planet" [1], which states that “EU environment legislation has delivered significant benefits for the health and wellbeing of the public. However, water, air pollution and chemicals remain among the general public's top environmental concerns in the EU“. In addition, air quality limit values are defined by the relevant EU legislation [2] as “limit values for the protection of human health”.

The environmental dimension is mainly focused on priority air pollutants in urban areas – $PM_{2.5}$, PM_{10} and NO_2 – which represent major environmental risk[67] and on noise.

[67] Besides direct health impact, NO_2 represents precursor of both ground-level ozone and secondary inorganic aerosols.

7.2 Background - Analysis

7.2.1 Emissions

Emissions of pollutants into the air originated in road transport represent an important part of total emissions in the EU. Results of key category analysis for the EU27 in 2010 – contributions of emission sources (expressed in NFR categories) to total emissions of PM_{10}, $PM_{2.5}$, NO_X, non-methane volatile organic compounds (NMVOC) and Pb are presented in **Table 7.1**.

Table 7.1 Contributions of emission sources to total EU27 emissions of PM_{10}, $PM_{2.5}$, NO_X, NMVOC, CO and Pb in 2010, in percent

NFR code	NFR category	PM_{10}	$PM_{2.5}$	NO_X	NMVOC	CO	Pb
1A3 b i	Road transport: Passenger cars	3 %	5 %	17 %	7 %	21 %	-
1A3 b ii	Road transport: Light duty vehicles	-	2 %	5 %	-	-	-
1A3 b iii	Road transport: Heavy duty vehicles	3 %	3 %	20 %	-	2 %	-
1A3 b iv	Road transport: Mopeds and motorcycles	-	-	-	4 %	4 %	-
1A2 b v	Road transport: Gasoline evaporation	-	-	-	2 %	-	-
1A3 b vi	Road transport: Automobile tyre and brake wear	4 %	4 %	-	-	-	6 %
1A3 b vii	Road transport: Automobile road abrasion	2 %	2 %	-	-	-	-
!A3 b	Total road transport	12 %	16 %	42 %	13 %	27 %	6 %
	Of which non-exhaust emissions (1A3 b v, 1A3 b vi and 1A3 b vii)	6 %	6 %	-	2 %	-	6 %

Source: European Union emission inventory report 1990 – 2010 under the UNECE Convention on Long-range Transboundary Air Pollution [3].

It can be concluded, **that:**

- road transport sector represents important part of total emissions in the EU, especially in the case of nitrogen oxides and carbon monoxide;
- in the case of PM_{10}, the share of exhaust and non-exhaust emissions (automobile tyre and brake wear, automobile road abrasion) in total 2010 emissions from road transport is equal;
- in the case of $PM_{2.5}$ non-exhaust emissions represent 37.5 % of total emissions from road transport.

7.2.2 Air quality

Percentage of the urban population in the EU exposed to air pollutant concentrations above the EU and WHO reference levels (2008–2010) is presented in **Table 7.2**.

Table 7.2 Percentage of the urban population in the EU exposed to air pollutant concentrations above the EU limit and target values and WHO guideline levels (2008–2010)

Pollutant	EU reference value	Exposure estimate (%)	WHO guideline value	Exposure estimate (%)
$PM_{2.5}$	Year (20 µg/m^3)	16 – 30	Year (10 µg/m^3)	90 - 95
PM_{10}	Day (50 µg/m^3)	18 – 21	Year (20 µg/m^3)	80 - 81
O_3	8-hour (120 µg/m^3)	15 – 17	8-hour (100 µg/m^3)	> 97
NO_2	Year (40 µg/m^3)	6 – 12	Year (40 µg/m^3)	6 - 12
BaP	Year (1 ng/m^3)	20 – 29	Year (0.12 ng/m^3)	93 - 94
SO2	Day (125 µg/m^3)	< 1	Day (20 µg/m^3)	58 - 61
CO	8-hour (10 mg/m^3)	0 – 2	8-hour (10 mg/m^3)	0 - 2
Pb	Year (0.5 µg/m^3)	< 1	Year (0.5 µg/m^3)	< 1
Benzene	Year (5 µg/m^3)	< 1	Year (1.7 µg/m^3)	7 - 8

Source: Air quality in Europe – 2012 report [4].

Notes:
The pollutants are ordered in terms of their relative risk for health damage — highest on top.

This estimate refers to a recent three year period (2008–2010) and includes variations due to meteorology, as dispersion and atmospheric conditions differ from year to year.

The reference levels included EU limit or target levels and WHO air quality guidelines (AQG).

The reference levels in brackets are in µg/m^3 except for CO which is in mg/m^3 and BaP in ng/m^3.

For some pollutants EU legislation allows a limited number of exceedances. This aspect is considered in the compilation of exposure in relation to EU air quality limit and target values.

The comparison is made for the most stringent EU limit or target values set for the protection of human health. For PM_{10} the most stringent standard is for 24-hour mean concentration.

For $PM_{2.5}$ the most stringent EU standard is the 2020 indicative annual limit value (20 µg/m3).

As the WHO has not set AQG for BaP and benzene (C_6H_6), the WHO reference level in the table was estimated assuming an additional lifetime risk of 1 x 10^{-5}.

A number of studies have identified and quantified the contributions of various sources to ambient PM concentrations by using modelling techniques [5]. An EEA analysis of source apportionment reported in the notifications submitted by twenty EU Member States for time extension of PM_{10} limit values shows that **the combined urban and local traffic contribution to PM_{10} concentration levels measured at 29 urban traffic sites ranges from 13 % (Duisburg) to 61 % (Glasgow) with an average of 34 %**. The contribution of traffic to PM_{10} concentration levels measured at five urban background sites is estimated at 15 %, ranging from 6 % (Yorkshire) to 22 % (Brno). These finding indicate that **traffic contributions to urban PM concentrations should be addressed when applying measures to reduce ambient PM concentrations.**

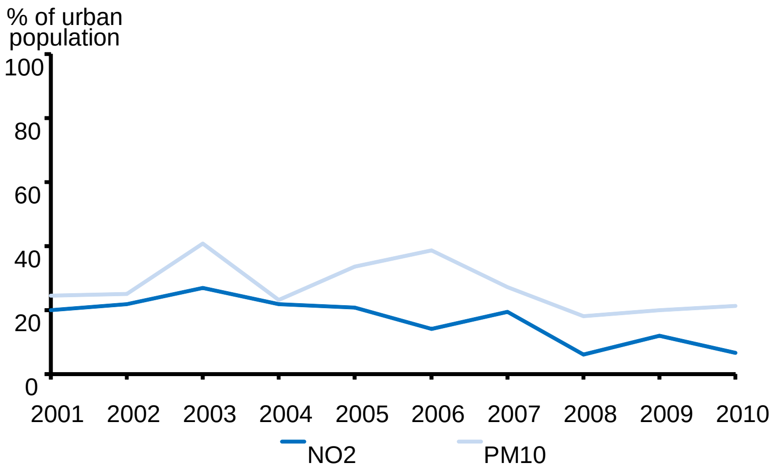
It has been indicated that that a large part (about 50–85% depending on the location) of the total PM_{10} concentrations originates from non-exhaust emissions [e.g. 6]. This implies that reduction measures for the exhaust part of the vehicle emissions will only have a limited effect on ambient PM_{10} levels. However, particles in exhaust gases are obviously "smaller" and contain very hazardous components like black carbon. As a result, positive health effects of LEZ may be much higher than their contribution to the reduction of PM_{10} or $PM_{2.5}$. The EURO vehicle emission standards only regulate exhaust emissions of PM. Requiring vehicles to have higher EURO emission standards will only reduce the exhaust emission of PM. Even zero-emission vehicles will continue to cause substantial PM_{10} and $PM_{2.5}$ emissions due to tyre, road and brake wear and resuspended dust.

Black carbon (BC), which is produced solely from combustion processes, is a component of $PM_{2.5}$ which has a strong association with traffic emissions. BC is therefore a potential tracer which can be used to monitor the impacts of transport policies on vehicle exhaust emissions of PM. A recent report for DG Environment estimated that 68 % of all BC emitted in EU‑27 Member States was from vehicle exhausts, the vast majority from diesel vehicles [15]. Emissions are predicted to fall in the future in line with reductions in PM exhaust emissions. Concentrations of BC in urban sites can reach 3–14 % of PM_{10} levels in Europe and can reach levels of 8 $\mu g/m^3$ at kerbside sites [11].

The concentrations of NO_2 found in air originate both from directly emitted NO_2 and from chemical reactions forming NO_2 in the atmosphere, predominantly between NO and O_3. An EEA analysis [4] of source apportionment in the notifications submitted by sixteen EU Member States for time extension of NO_2 limit values shows that **the urban and local traffic contribution to NO_2 levels measured at 74 urban traffic sites averages at 64 %, ranging from 33 % (Essen) to 91 % (Catania).** The higher fraction of NO_2 in NO_X emissions from diesel vehicles could lead to increased NO_2 concentrations in traffic exposed areas and possibly also in urban areas in general. It should be taken into account that NO_2 is precursor of formation of both ground-level ozone and of secondary inorganic aerosols (SIA), which contribute on average one third of the PM_{10} mass in rural air in central Europe [7]. In the case of $PM_{2.5}$, SIA make up about half of the total mass [4].

Percentage of population exposed to concentrations of NO_2 and PM_{10} exceeding limit values is presented in **Figure 7.1**.

Figure 7.1 Percentage of urban population resident in areas where concentrations of NO_2 and PM_{10} are higher than limit values, 2001-2010 (EU-27)



Source: European Environment Agency.

7.2.3 *Noise*

Noise from road transport affects a large number of people: in the largest European cities (with populations of more than 250 000) almost 70 million people are exposed to long-term average road traffic noise levels exceeding 55 dB Lden (weighted average day, evening, night). That equates to more than 62 % of the population of those same cities. Of these, around 15 % are exposed to noise levels above 65 dB Lden. At night in the same urban areas, there are more than 48 million people exposed to long term average road noise levels higher than 50 dB Lnight. As a result, 44 % of the population is exposed to noise levels during sleeping hours that can cause adverse health effects.

7.2.4 Policies

Within the European Union, the **Sixth Environment Action Programme** [8] called for the development of a thematic strategy on air pollution with the objective of achieving levels of air quality that do not result in unacceptable impacts on, and risks to, human health and the environment. Formulated in 2005, the **Thematic Strategy on Air Pollution** - TSAP [9] sets specific long-term objectives for improvements in 2020 relative to the situation in 2000, specifically:

- a 47 % reduction in loss of life expectancy as a result of exposure to PM;
- a 10 % reduction in acute mortalities from exposure to O_3;
- a 74 % reduction in excess acid deposition in forest areas and a 39 % reduction in surface freshwater areas;
- a 43 % reduction in areas or ecosystems exposed to eutrophication.

To achieve these objectives, it was estimated that key emissions would have to fall significantly in the period 2000–2020, specifically:

- SO_2 emissions to decrease by 82 %;
- NO_X emissions by 60 %;
- VOC by 51 %;
- NH_3 by 27 %;
- Primary $PM_{2.5}$ (fine particles emitted directly into the air) by 59 %.

Recently, TSAP is undergoing substantial revision.

General Union Environment Action Programme to 2020 "Living well, within the limits of our planet" [1], which states that “A substantial portion of the EU's population remains exposed to levels of air pollution exceeding WHO recommended standards. Action is especially needed in areas where people, particularly sensitive or vulnerable groups of society, and ecosystems are exposed to high levels of pollutants, such as in cities or in buildings” (paragraph 43) and that “Achieving the goals set out in the Roadmap to a Single European Transport Area will also lead to more sustainable mobility in the EU, thereby addressing a major source of noise and local air pollution” (paragraph 46).

White paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system [10] provides for the following key goals to be achieved by 2050:

- No more conventionally-fuelled cars in cities;
- A 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport;
- All of which will contribute to a 60% cut in transport emissions by the middle of the century.

A **European strategy on clean and energy efficient vehicles** (COM(2010) 186 final) [12] provides for further reduction of emissions of air pollutants, GHGs and noise from vehicles and for specific actions to support use of electric vehicles.

7.2.5 Legislation

Explicit provisions for the establishment of LEZ are not in place in current EU legislation with the exception of **Directive 2008/50/EC on ambient air quality and cleaner air for Europe [2]** (Annex XV, section B, paragraph 3, indent d) which provides for "measures to limit transport emissions through traffic planning and management (including congestion pricing, differentiated parking fees or other economic incentives; establishing low emission zones)" to be included in in the local, regional or national air quality plans for improvement in ambient air quality.

Directive 2011/76/EU on the charging of heavy good vehicles for the use of certain infrastructures [13] provides for the introduction of tolls or user charges including detailed methodology for calculation of rates based on the assessment of external costs.

The Environmental Noise Directive (2002/49/EC) is one of the main instruments to identify noise pollution levels and to trigger the necessary action both at Member State and at EU level.

A complete list of relevant legislation is presented in Annex A.

7.2.6 Measures

Measures for reducing the impact of transport emissions on urban air pollutant concentrations can be either **technical** or **non-technical**.

7.2.7 Technical measures

Introduction of cleaner vehicles (electric vehicles, hybrid vehicles, gas vehicles (see Box 2):

Box 2: Different cleaner vehicle technologies

Electrified vehicles mainly comprise of Battery Electric Vehicles (BEVs) and Hybrid Electric Vehicles (HEVs), either full or semi hybrids, as well as variations such as Range Extender Electric Vehicles (REEVs), a combination of battery with an internal combustion engine (ICE) acting as a range extender and Plug-in Hybrid Electric Vehicles (PHEVs), which are essentially hybrid vehicles capable of charging directly from the grid.

Hydrogen Fuel Cell Vehicles (HFCVs) can also be considered electric vehicles, since they use fuel cells as an energy converter, producing electricity from chemical reaction, which results in zero tailpipe emissions of NO_X and SOX compared to conventional gasoline and diesel vehicles (Euro 5 standards). Tailpipe emissions of PM from hydrogen vehicles are also zero, but overall PM levels in a country will depend on the fuel production process (AEA/TNO/CE Delft, 2012). Fuel-cell Range Extender vehicles (FCREVs) are a combination of a BEV with a fuel-cell range extender and their performance in terms of emissions is expected to be somewhere between a BEV and a HFCV.

Flexi-fuel Vehicles (FFVs) use high liquid biofuel blends (such as E85) which demonstrate slightly higher energy efficiency and can potentially substitute current conventional fuels while reducing GHG emissions, subject to the availability of sustainable biofuels. Biodiesel is the diesel equivalent biofuel.

Methane vehicles (Compressed Natural Gas — CNG) represent a mature technology, which from a reduction of emission of NO_X and particles as well as a moderate reduction in CO2, compared to their gasoline or diesel driven equivalents. Natural gas can moreover be blended with bio-methane, generated from biomass, leading to a further reduction of CO_2 emissions. Methane could be also used in the form of Liquefied Natural Gas (LNG) for fuelling combustion engines in boats and ships and heavy duty road transport vehicles, up to now mainly through dual fuel systems (engines burning together diesel and methane), which can offer significant CO_2 reduction. As an alternative, dedicated gas engines can deliver low pollutant emissions (mainly NO_X and CO) and CO_2 reduction.

Liquefied Petroleum Gas (LPG) vehicles employ another mature form of ICE fuel, a by-product of the hydrocarbon fuel. LPG fuel can be environmentally beneficial by offering a reduction of CO2 emissions, lower NO_X emissions and no soot at all; nevertheless, retrofitted LPG vehicles can emit, on average, more than twice as much NO_X and 2.5 times as much PM as gasoline vehicles.

Source [11].

- Abatement technologies at classis vehicles (three-way catalytic converters, diesel particulate filters, selective catalytic reduction, exhaust gas recirculation).

Box 3: Advantages and disadvantages of widely applied emission abatement technologies

Three-way catalytic converters are used to reduce emissions of unburned hydrocarbons, CO and NO_X from gasoline vehicles. Reductions of around 70–90 % have been achieved. However, their introduction has been associated with an increase in tailpipe emissions of NH_3, a source of secondary particulates, by over a factor of 10. However, gasoline vehicles remain a relatively low source compared to other sources of this gas mainly from the agriculture sector. Low sulphur fuels, which help improve catalyst performance, have been reported to reduce the formation of nitrous oxide (N_2O), a greenhouse gas, while favouring the formation of NH_3. However, catalyst systems fitted on current gasoline cars generate lower emissions of these gases than older generation catalyst systems.

A diesel particulate filter (DPF) is an exhaust after-treatment technology, which reduces PM emissions from diesel vehicles by 85 % or more. DPFs will also reduce BC emissions, helping to reduce global warming. However, some evidence suggests that certain DPFs with catalytic filter regeneration systems have a small negative impact on fuel economy as well as increasing primary NO_2 emissions. The impact on fuel economy is variable and dependent on DPF technology and duty cycle.

Selective Catalytic Reduction (SCR) is a technology used to reduce NO_X emissions from diesel vehicles. Reductions of around 60–80 % are achieved. However, there is evidence to suggest that this can lead to higher emissions of N_2O as well as potentially increasing NH_3. Again, many factors are at play that do not allow for a precise quantification of how significant these unintended emissions are.

Exhaust gas recirculation (EGR) is a technique whereby a portion of an engine's exhaust gas is re-circulated back through the engine cylinders. Depending upon the engine type, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture and/or reduces peak combustion chamber temperatures. This, in turn, reduces the formation of NO_X. The effect of EGR on NO_X emissions is variable but is typically around 40–80 %.

Source [11].

7.2.8 Non-technical measures

- Low emission zones (LEZ):
  See following subsection below.

- Access Restriction Schemes (ARS):
  ASR include historical centres, pedestrian zones, etc., where access is denied to practically all vehicles (e.g. emergency vehicles or maintenance/freight vehicles with a temporary permit being exemptions). Generally access is not related to any form of user payment. Most

frequently stated policy objectives are reducing traffic, improve liveability and improving air quality.

- Parking measures:
  Parking measures include all forms of parking measures, intended to control the availability or price of parking spaces. The policy aims of these parking measures are multiple, ranging from traffic management goals, accessibility for business and shoppers, land use, etc., as well as generating revenues for the city.

- Optimization of road transport demand:
  Measures include integrated multi-modal systems, park + ride systems, park + bike systems, park + go systems, car sharing, car-pooling.

- Transport management – minimization of occurrence of congestions:
  'Slow, stop and start' congested urban traffic conditions and frequent short journeys can result in higher emissions per kilometre compared to free-flowing longer journeys. This is a consequence of increased cold engine operation, higher fuel consumption and less efficient performance of exhaust emission abatement systems. Measures that reduce traffic congestion include speed management or Intelligent Transport Systems (ITS).

Box 4: Speed limits and their effects on emissions and concentrations

Lower speed limits on motorways are expected to reduce fuel consumption and pollutant emissions, particularly for passenger cars. It has been estimated that a reduction of the motorway speed limit from 120 to 110 km per hour would reduce fuel consumption by 12 % for diesel cars and 18 % for gasoline cars, if smooth driving (i.e. little acceleration and braking) and total compliance with speed limits is assumed. In reality, fuel savings are likely to be lower, approximately 2 % to 3 %, due to a variety of factors such as driving patterns, fluctuations in driving speeds and traffic congestion.

Various studies have assessed the impacts of speed reductions on motorways on air pollutant emissions. A 4 % NO_X emission reduction has been estimated when decreasing maximum speed limits from 120 to 80 km/h on Swiss motorways, while peak O_3 levels decreased by less than 1 %. Daily average concentrations of NO_2, SO_2 and PM_{10} have been estimated to decrease by 6 %, 5 % and 3 % respectively when limiting the speed to 80 km/h on motorways, dual carriageways and main roads in the Barcelona Metropolitan area.

Stricter speed limits and speed management policies, such as speed control by camera surveillance, have been introduced in various countries to improve road safety, as well as reduce emissions from motorway traffic. For example, in the Netherlands speed management reduced NO_X emissions 5 % to 30 % and PM_{10} emissions 5 % to 25 %.

The European Parliament Transport Committee has called for 30 km/h speed limits to be introduced in all residential areas, primarily to improve the safety of children. While reducing residential speed limits from 50 km/h to 30 km/h should not be expected to result in large rises or falls of most pollutants, modelling using real-life urban drive cycles indicates that PM exhaust from diesel vehicles may show a significant decrease. In addition, lower speed limits in residential areas can help in further promoting active travel. This may reduce numbers of short motorised journeys which can be some of the most polluting as the engine and emissions after-treatment system may not reach efficient operating temperatures.

Source [11].

- Charging / toll measures:
  These measures include any form of charging on a stretch of infrastructure. The most frequently

stated policy objectives are reduction of congestion and emissions, but also generating funds to develop and maintain transport infrastructure, including for public transport.

7.2.9 Low Emission Zones (LEZ)

A growing number of urban areas in Europe are introducing low emission zones. The details of the schemes including the objectives, types of restriction and regulatory instruments vary.

Error! Reference source not found. gives examples of some of the LEZs.

Table 7.3 Examples of Low Emission Zones

City	Regulated vehicles	Minimum engine standard	Introduction date
LEZ operating on the basis of charges			
London	HDV	Euro 3	2008
		Euro 4	2012
Milan	All	Petrol Euro 3 Diesel Euro 4 with particle filter	2008
LEZ operating on the basis of emission standards			
Berlin	All	Diesel Euro 2 or Euro 1 with particle filter Petrol Euro 1 with catalytic converter	2008
		Diesel Euro 4 or Euro 3 with particle filter Petrol Euro 1 with catalytic converter	2010
Amsterdam	HDV	Euro 4 or Euro 2/3 with particle filters	2008
		Euro 4 or Euro 3 with particle filters and less than 8 years old	2010
		Euro 4	2013

Low emission zones have the potential to be an effective tool in the reduction of pollutant concentrations in urban areas because:

- road traffic is usually the largest local contributor to pollutant concentrations in urban areas; and
- reductions in emissions can be made in locations where pollutant concentrations are highest.

However, the impact of any LEZ is limited by various factors including the type of vehicle restricted, the minimum engine standard required and also the local contribution of traffic emissions to pollutant concentrations. In particular, a large component of urban particulate concentrations is from sources outside the city. In addition, the traffic component is made up of contributions from exhaust, brake-wear, tyre-wear, road-wear and resuspension; only the exhaust component can be reduced by excluding vehicles with lower emission standards in a low emission zone. For example, s source apportionment of the total $PM_{2.5}$ concentration at a roadside location in Berlin in 2007 [16]; only 22% of the total $PM_{2.5}$ concentrations results from sources which can be addressed by a LEZ.

Similarly, estimation of the traffic component to PM_{10} concentrations on H.C Andersen Boulevard in Copenhagen [17] showed that the average street concentration was 42.5 µg/m^3, of which 4.9 µg/m^3 (12%) was the contribution from vehicle exhausts. Heavy duty vehicles (HDVs) were calculated to contribute 26% of particle exhausts and of this particle filters can reduce emissions by up to 80%. This means that the maximum potential reduction in PM_{10} concentrations on the street due to the LEZ is 1.0 µg/m^3.

Obviously, LEZ are being established in cities with population above 100 000 (more than 80 % of cases), however, much smaller cities with LEZ can be found, e.g. [19]:

- Neu-Ulm (DE): population 53,504;
- Rijswijk (NL): population 47,117;
- Muehlacker (DE): population 25,369;
- Markgroniningen (DE): population 14,390.

Box 5: Case study: Potential for the introduction of LEZ in the Moravian-Silesian Region – Czech Republic [19]

City	Population	Area (km2)	Future LEZ	Reason
Ostrava	306 006	214.22	Yes	
Havířov	82 896	32.08	No	Missing road infrastructure
Karviná	61 948	57.52	Maybe	Part of infrastructure must be completed
Frýdek-Místek	58 582	51.53	No	Missing road infrastructure
Opava	58 440	90.61	Yes	
Třinec	37 405	85.37	Yes	
Orlová	32 430	24.67	No	Very low impact on air quality
Nový Jičín	25 862	44.70	Maybe	Part of infrastructure must be completed
Český Těšín	25 499	33.81	Yes	
Krnov	25 059	44.30	No	Missing road infrastructure
Kopřivnice	23 044	27.48	No	Very low impact on air quality
Bohumín	22 818	31.03	Maybe	Part of infrastructure must be completed
Bruntál	17 264	29.35	No	Limit values not exceeded
Hlučín	14 236	21.14	No	Very low impact on air quality
Frenštát p.R.	11 124	11.43	No	Very low impact on air quality
Studénka	10 129	30.91	No	Very low impact on air quality

In certain cities, especially in EU12 countries, missing road infrastructure (by-passes, parking facilities, alternative roads for non-compliant vehicles of for drivers not willing to pay may) represent serious obstacle for the establishment of LEZ (see Box5).

Based on the data and case studies available [18], it can be concluded that:

- The effects of LEZ's on traffic and congestion are reported to a lesser extent than the effect on emissions, which is also the main objective of these schemes;
- The effect on the number of vehicles in the zone is reported to be between 4% and 25% reduction in number of vehicles;

- The effect on pollution is in almost all cases reported by the cities: the results vary between 5% and 15% reduction of several pollutants;
- LEZs have proved to be effective in stimulating the use of cleaner vehicles (especially cleaner internal combustion engines) and the usage of public transport. Especially the 24/7 non-paid schemes were effective in several countries and cities;
- The cases show that LEZ's are often determined by regulation and in most cases not maintained by charging. It is regularly shown that certain vehicles have to acquire a license or visual sign which is less expensive for a municipality than installing Automatic Number Plate Recognition (ANPR) systems. Only in a few cases an ANPR system is used which can costs several million Euros. An ANPR system can however be used for other regulatory or data gathering matters. The municipality might acquire some revenues from an LEZ because the license has to be purchased by the users;
- Most direct costs for municipalities can be expected in terms of traffic sign placement and administrative costs;
- Some cities have introduced an LEZ in which the users of the area are charged on the basis of their vehicle's pollution level (Reading, Rotterdam and Bologna). This means an advanced and expensive system but also a revenue per charge;
- In the 2009 evaluation report of the Dutch LEZ's for HGV's, the eight involved cities' investments in the preparation of environmental zones sum up to €1.440. 000 for all 8 cities combined. Yearly total costs for running the environmental zones in the 8 cities (i.e. enforcement) are €600.000. Per city these values correspond to €180.000 investments and €75.000 annual costs;
- Further, the Dutch business community invested some €15 million to €18 million in cleaner vehicles and particle filters. With a depreciation period of eight years, the yearly costs are €1.9 million to €2.25 million for the business community involved. These investments are additional investments done by the companies complying with the restriction rules, incorporating reserves which were already (assumed) to be made for buying new vehicles;
- The average of both investment costs and the operating costs for a LEZ without ANPR is relatively low, as shown in case studies: around €200.000 investment costs and €100.000 per year operational costs. These costs will increase when ANPR is introduced: in the case of Reading in the UK, the costs for design and implementation amount to roughly €2.3 million and yearly operating costs of roughly €600.000.

7.3 LEZ type A – without payment

SWOT analyses of LEZ type A (without payment) for environmental, economic and social dimensions are presented in tables **Table 7.4**, **Table 7.5** and **Table 7.6**. For each of four parts of SWOT table, factors are presented in the order of decreasing importance.

Table 7.4 SWOT analysis: LEZ type A – without payment – environmental dimension (including human health impacts)

Strong factors	Weak factors
Reduction of exhaust emissions of air pollutants in populated areas within LEZ.	Non-exhaust emissions of PM not influenced.
Reduction of exposure of population within LEZ to air pollutants.	Sources of emissions moved to populated areas outside LEZ.
Contribution to overall reduction of national emissions (higher in the case of nitrogen oxides, moderate in the case of PM).	Increased exposure of population to air pollutants and noise outside LEZ.

	Does not influence transport intensity within LEZ (once permit obtained, no restriction of entries in place); appearance of "clean congestions".
	Potential problems outside LEZ (congestions with higher share of obsolete vehicles).
Opportunities (Potentials)	**Threats (Risks)**
Stimulation for incremental alteration of classic vehicle fleet (above natural alteration).	Effect is decreasing in time (with increasing quality of vehicle fleet).
Stimulation for introduction of clean alternative vehicles (electric vehicles, hybrid vehicles, gas vehicles).	Effect reduced by exceptions.
Combination with other relevant instruments (e.g. ITS, Park and ride systems, improved public transport, economic stimulation – contribution to buy new car or to retrofit existing cars).	

Table 7.5 SWOT analysis: LEZ type A – without payment – economic dimension

Strong factors	**Weak factors**
Positive impact on car industry.	Cost of necessary infrastructure (by-passes, alternative roads for non-compliant vehicles, parking facilities, optionally ANPR).
Revenue from penalties.	Costs of implementation and enforcement.
Reduced cost of health care.	Potential additive costs in the case of financial incentives to citizens for buying new car or retrofitting existing car.
Opportunities (Potentials)	**Threats (Risks)**
Incremental positive impact on car industry in the case of financial support to citizens for buying new car or retrofitting existing car.	Lack of financing for building necessary infrastructure (by-passes, alternative roads for non-compliant vehicles, parking facilities, optionally ANPR).
	Additional expenditure in the case of subsidies for low income citizens.

Table 7.6 SWOT analysis: LEZ type A – without payment – social dimension

Strong factors	Weak factors
Improved quality of life within LEZ.	Additional complication for a part of urban community (both real - and psychological).
Motivation to use public transport and other environmental friendly transport modes.	
Opportunities (Potentials)	**Threats (Risks)**
Financial support to citizens for buying new car or retrofitting existing car.	Refusal / non-acceptance by a part of urban community.
	Increased social tensions in urban community (based on the feeling of exclusion).

7.4 LEZ type B – with payment

SWOT analyses of SWOT type B (with payment) for environmental, economic and social dimensions are presented in

Table 7.7, **Table 7.8** and **Table 7.9**. For each of four parts of SWOT table, factors are presented in the order of decreasing importance.

Table 7.7 SWOT analysis: LEZ type B – with payment – environmental dimension (including human health impacts)

Strong factors	**Weak factors**
Reduction of exhaust emissions of air pollutants in populated areas within LEZ.	Non-exhaust emissions not influenced.
Reduction of exposure of population to air pollutants and noise.	Sources of emissions moved to areas outside LEZ.
Reduction of transport intensity within LEZ.	Efficiency reduced by exceptions.
Contribution of overall reduction of national emissions.	
Opportunities (Potentials)	**Threats (Risks)**
Stimulation for incremental alteration of classic vehicle fleet.	Effect is decreasing in time (with increasing quality of vehicle fleet).
Stimulation for introduction of alternative vehicles (electric vehicles, hybrid vehicles, gas vehicles).	Problems outside LEZ (congestions with higher share of obsolete vehicles).
Combination with other relevant instruments (e.g. ITS, Park and ride systems, improved public transport, economic stimulation – contribution to buy new car or to retrofit existing cars).	

Table 7.8 SWOT analysis: LEZ type B – with payment – economic dimension

Strong factors	**Weak factors**
Revenue from entry charges.	Cost of necessary infrastructure (by-passes, alternative roads for non-compliant vehicles or drivers not willing to pay, parking facilities, optionally ANPR).
Positive impact on car industry.	Costs of implementation and enforcement are higher than in the case of LEZ type A.
Reduced cost of health care.	Potential additive costs in the case of financial support to citizens for buying new car or retrofitting existing car.
Opportunities (Potentials)	**Threats (Risks)**
Revenue from entry charges can be used to support additive environmental measures.	Lack of financing for building necessary infrastructure.
Incremental positive impact on car industry in the case of financial support to citizens for buying new car or retrofitting existing car.	Additional expenditure in the case of financial support to low income citizens.

Table 7.9 SWOT analysis: LEZ type B – with payment – social dimension

Strong factors	**Weak factors**
Improved quality of life within LEZ.	Additional complication for a part of urban community (both real and psychological).
Motivation to use public transport and other environmental friendly transport modes.	
Opportunities (Potentials)	**Threats (Risks)**
Financial support to citizens for buying new car or retrofitting existing car.	Refusal / non-acceptance by a part of urban community.
	Increased social tensions in urban community (based on the feeling of exclusion).

7.5 Conclusions and recommendations

7.5.1 Conclusions – Joint SWOT Tables

Note: These joint tables include only those environmental, economic and social factors which are considered most important. Separate detailed SWOT tables for environmental, economic and social dimensions are presented in sections 7.3 and 7.4.

Table 7.10 *Joint SWOT analysis: LEZ type A – without payment*

Strong factors	Weak factors
Reduction of exposure of population within LEZ to air pollutants.	Non-exhaust emissions of PM not influenced.
Improved quality of life within LEZ.	Increased exposure of population to air pollutants and noise outside LEZ.
Motivation to use public transport and other environmental friendly transport modes.	Does not influence transport intensity within LEZ (once permit obtained, no restriction of entries in place); "clean congestions".
	Efficiency reduced by exceptions.
	Cost of necessary infrastructure (by-passes, alternative roads for non-compliant vehicles, parking facilities, optionally ANPR), implementation and enforcement.
	Additional complication for a part of urban community (both real - and psychological).
Opportunities (Potentials)	**Threats (Risks)**
Stimulation for incremental alteration of classic vehicle fleet and introduction of alternative vehicles (electric vehicles, hybrid vehicles, gas vehicles).	Effect is decreasing in time (with increasing quality of vehicle fleet).
Combination with other relevant instruments (e.g. ITS, Park and ride systems, improved public transport, economic stimulation – contribution to buy new car or to retrofit existing cars).	Potential problems outside LEZ (congestions with higher share of obsolete vehicles).
	Lack of financing for building necessary infrastructure (by-passes, alternative roads for non-compliant vehicles, parking facilities, optionally ANPR).
	Refusal / non-acceptance by a part of community (low-income citizens, business community).
	Increased social tensions in community (based on the feeling of exclusion).

Table 7.11 *Joint SWOT analysis: LEZ type B – with payment*

Strong factors	Weak factors
Reduction of exposure of population to air pollutants and noise within LEZ.	Non-exhaust emissions not influenced.
Reduction of traffic intensity within LEZ (lower frequency of congestions).	Increased exposure of population to air pollutants and noise outside LEZ.
Revenue from entry charges.	Efficiency reduced by exceptions (see Box 6).

Strong factors	Weak factors
Improved quality of life within LEZ.	Costs of necessary infrastructure (by-passes, alternative roads for non-compliant vehicles, parking facilities, optionally ANPR), implementation and enforcement are higher than those in the case of LEZ type A.
Motivation to use public transport and other environmental friendly transport modes.	Additional complication for a part of community (both real and psychological).
Opportunities (Potentials)	**Threats (Risks)**
Stimulation for incremental alteration of classic vehicle fleet and introduction of alternative vehicles (electric vehicles, hybrid vehicles, gas vehicles).	Effect is partially decreasing in time (with increasing quality of vehicle fleet).
Revenue from entry charges can be used to support additive environmental measures.	Problems outside LEZ (congestions with higher share of obsolete vehicles).
Combination with other relevant instruments (e.g. ITS, Park and ride systems, improved public transport, economic stimulation – contribution to buy new car or to retrofit existing cars).	Refusal / non-acceptance by a part of urban community (low-income citizens, business community.
	Increased social tensions in community (based on the feeling of exclusion).

7.5.2 Final conclusions – potential

- According to the results of Task 1.1, there are more than 600 European cities with exceedances of NO_2 or PM_{10} limit values where implementation of LEZ can be considered,
- In certain cases, especially in EU12 countries, lack of necessary road infrastructure represents major obstacle for the establishment of LEZ, as road infrastructure in these new EU Member States is far from being completed (many cities do not have by-passes and transit transport is passing through their centres). For instance, the City of Prague has a half of city by-pass completed by now.

7.5.3 Final conclusions comparison

- LEZ type B (with payment) seems to have higher and longer emission reduction potential comparing to LEZ type A (without payment) as it may reduce excess traffic (which is not the case of LEZ type A where there is no limitation for cars compliant with the LEZ technical requirements);
- LEZ type A (without payment) have high potential in respect to the introduction of pan-European rules as EURO standards and other technical requirements are identical in all EU Member States;
- LEZ type B (with payment) have limited potential in respect to the introduction of pan-European rules as the charges applied may differ from country to country (taking into account general economic conditions in particular countries);
- Both investment (technique necessary for the collection of payments) and operational (transaction) costs of LEZ type B are higher, especially in the cases when ANPR system is introduce;
- LEZ type B generate revenue which might be used to cover investment and operational costs and/or to finance other environment friendly measures).

7.5.4 Recommendations - municipalities

- LEZ (both type A and type B) should be introduced within the framework of Sustainable Urban Mobility Plans and should be combined with other measures; especially with those non-technical measures focused on the decrease of car transport demand and on optimization of car traffic flow;
- Ambitious emission and noise criteria should be set;
- Sufficient rates of charges should be introduced in the case of LEZ type B;
- A transition period should be provided at the commencement of the LEZ;
- Adequate enforcement of compliance should be introduced;
- Potential to make emissions and noise criteria more stringent in future years should be taken into account;
- Exemptions for residents and businesses should be limited;
- The LEZ needs to be large enough to affect the renewal rate of the vehicle fleet to avoid simply rerouting the more-polluting vehicles to different areas;
- Targeted information campaigns to non-compliant drivers/businesses should be in place;
- Special attention should be paid to the assessment of the impact of LEZ on air quality and noise levels (see Annex B).

7.6 Annexes

7.6.1 Annex A: Relevant EU legislation

- Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles;
- Directive 92/97/EEC of the Council of 10 November 1992 amending Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles;
- Directive 94/12/EC of the European Parliament and the Council of 23 March 1994 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Directive 70/220/EEC;
- Directive 98/69/EC of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Council Directive 70/220/EEC;
- Directive 1999/94/EC of the European Parliament and of the Council of 13 December 1999 relating to the availability of consumer information on fuel economy and CO2 emissions in respect of the marketing of new passenger cars;
- Directive 2001/81/EC of the European Parliament and the Council on National Emission Ceilings for certain atmospheric pollutants;
- Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise;
- Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information;
- Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe;
- Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles;

- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC;
- Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC;
- Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles;
- Directive 2011/76/EU of the European Parliament and of the Council of 27 September 2011 amending Directive 1999/62/EC on the charging of heavy good vehicles for the use of certain infrastructures;
- Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light-duty vehicles.

7.6.2 Annex B: Assessment of the impact of LEZ on air quality

The following are recommendations for assessing the impact of low emission zones on air quality from experience of assessments carried out in European cities:

- Modelling is carried out prior to the implementation of the LEZ to estimate the likely air quality impacts and identify areas affected;
- Monitors are installed at the locations likely to experience the greatest (positive or negative) changes;
- Automatic Number Plate Recognition – where feasible, ANPR provides a valuable resource in terms of characterising the vehicle fleet entering the LEZ area;
- Monitoring of alternative parameters – analysis of standard particulate monitoring data sometimes cannot isolate the impact of an LEZ. Measurement of alternative parameters such as elemental carbon and particle number as indicators for exhaust contributions can provide more useful information on the effect of the LEZ;
- Use of real-world emission rates – Emission rates for real-world driving conditions should be used for any impact assessment rather than those based on emission limit values to avoid overestimating the impact of the LEZ. These could use the emission factors such as the latest COPERT factors or could make use of local remote emissions sensing campaigns. In particular, information on the performance of Euro 6 vehicles in real-world conditions will be crucial in determining the effectiveness of low emission zones in the future.

7.7 References

1) Proposal for a decision of the European Parliament and of the Council on a General Union Environment Action Programme to 2020 "Living well, within the limits of our planet", COM(2012) 710final;
2) Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe;
3) European Union emission inventory report 1990 – 2010 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP), EEA Technical report No 8/2012;
4) Air quality in Europe – 2012 report, EEA Technical report No 4/2012;
5) The application of models under the European Union´s Air Quality Directive, EEA Technical report No 10/2011;

6) Matthias Ketzel et al.: Estimation and validation of $PM_{2.5}$/PM_{10} exhaust and non-exhaust emission factors for street pollution modelling; Atmospheric Environment 41 (2007) 9370–9385;
7) Transboundary particulate matter in Europe, EMEP Status Report 4/2011;
8) Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme;
9) Communication from the Commission to the Council and the European Parliament 'Thematic Strategy on air pollution' (COM(2005) 0446 final;
10) White paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144 final;
11) The contribution of transport to air quality: TERM2012: transport indicators tracking progress towards environmental targets in Europe; EEA Report No 10/2012;
12) Communication from the Commission to the European Parliament, the Council, and the European Economic and Social Committee 'A European strategy on clean and energy efficient vehicles' (COM(2010) 186 final);
13) Directive 2011/76/EU of the European Parliament and of the Council of 27 September 2011 amending Directive 1999/62/EC on the charging of heavy good vehicles for the use of certain infrastructures;
14) Laying the foundations for greener transport TERM 2011: transport indicators tracking progress towards environmental targets in Europe; EEA Report No 7/2011;
15) The potential for further controls of emissions from mobile sources in Europe. TSAP Report #4, IIASA 2012;
16) Lutz M., A Rauterberg-Wulff, 2010. Berlin's Low Emission Zone – top or flop? Results of an impact analysis after 2 years in force. 14th ETH Conference on Combustion Generated Particles. London Air Quality Network Seminar, 21 September 2010, King's College London, 4 pp. http://www.londonair.org.uk/seminars/pdf/september2010/Berlin_LEZ_impacts_analysis.pdf;
17) Jensen, S.S., M. Ketzel, J.K. Nøjgaard, P. Wåhlin, 2010. Air Quality Impact Assessment of the Environmental Zone in Copenhagen. Conference on Transport and Air Pollution, Dübendorf, Switzerland, May 2010. National Environmental Research Institute (NERI), Department of Atmospheric Environment, Aarhus University, Denmark, 6 pp.;
18) Study to support an Impact Assessment of Urban Mobility Package (Activity 32: EU framework for urban road user charging and access restriction schemes).; Final Report, ECORYS and COWI, May 2013;
19) Feasibility study for the establishment of LEZ in the Moravian-Silesian Region of the Czech Republic (in Czech), Centre for Transport Research. Brno, December 2011;
20) COWI, & Ecorys. (2013). Study to support and Impact Assessment of Urban Mobility Package - Activity 32: EU Framework for Urban Road User Charging and Access Restriction Schemes. European Commission, DG MOVE.

8 Costs and Benefits of Low Emission Zones

8.1 Introduction

The purpose of this section is twofold. The aim of first subsection – Section 8.2 below – is to present a high-level overview of the likely overall costs and benefits resulting from the establishment of stand-alone LEZs in Europe.

The aim of the second part – Section 8.3 – is to assess the possible cost savings and additional benefits resulting from the harmonisation of LEZs at national or EU level. Here the possible savings resulting from harmonisation are presented under two scenarios: – the first concerning a full harmonisation scenario and the second a partial harmonisation situation.

8.2 Information on Costs & Benefits of LEZ Implementation

8.2.1 Introduction

The aim of this section is to provide a summary of findings from the literature review concerning the socioeconomic impacts, e.g. costs and benefits, of the implementation of low-emission zones (LEZ). This includes two main sets of items. First, capital, as well as operational, expenditure associated with the development and management of LEZ is presented from both a city authority perspective, and from a user point of view. Second, this section also lists the broader impacts issues examined by local authorities, for example in terms of local economic activity and quality of life, in establishing LEZs.

The literature review undertaken was primarily based on two sources: The 2010 “Study on Urban Access Restrictions” (ARS study, ISIS 2010) and “Study to support an Impact Assessment of Urban Mobility Package” (COWI Ecorys, 2013), which is being conducted for DG MOVE as part of a broader set of studies to support an impact assessment on the Urban Mobility Package 2013. In addition, the following studies have been reviewed:

- “CURACAO” study (CURACAO, 2009);
- “Study on Urban Aspects of the Internalisation of External Costs” (UAIEC)(Ecorys 2012);
- “The impact of low emission zones on PM10 levels in urban areas in Germany” (Malina & Fischer, 2012);
- “Keep Your Clunker in the Suburb: Low Emission Zones and Adoption of Green Vehicles” (Wolff & Perry, 2011);
- “Landelijke effectstudie milieuzones vrachtverkeer 2010” [National impact assessment environmental zones freight traffic] (Goudappel Coffeng & Buck Consultants Int'l, 2010);
- “A Low Emissions Zone framework for inclusion in the Time Extension Notification for compliance with the EU limit value for NO2: Impact Assessment (DEFRA, UK Government, 2011);
- “Local Air Quality Management: practice Guidance 2 – Practice Guidance to Local Authorities on Low Emissions Zones” (DEFRA, UK Government, 2009);
- “Assessment of the impact on costs and emissions of technical measures on existing heavy duty vehicles and captive fleets” (Sadler Consultants, 2006);
- “Low Emissions Zones in Europe: for Ademe” (Sadler Consultants, 2011);
- “Low Emissions Zones in the UK: The case for a national network of low emissions zones to improve urban air quality”, Client Earth, 2013.

The assessment made below focussed on LEZs as defined in the ontology[68] matrix of the COWI Ecorys draft report (p. 25); i.e. access restriction schemes that are based on vehicles' emission levels and that are not usage-based. In a limited number of instances, relevant data and information from non-LEZ schemes are also reported (e.g. to ensure comprehensive geographical coverage).

The structure of this subsection is as follows. First, a brief methodological note summarises the main caveats applying to the literature review findings. Second, findings regarding capital and operational and maintenance expenditure linked to establishing and operating LEZs is presented. Third, findings relating to broader socioeconomic impacts are discussed. Fourth, preliminary findings on the potential benefits of EU-wide harmonisation of LEZ design are briefly discussed. Fifth, brief conclusions are drawn.

8.2.2 Methodological Note

A first, overarching remark to be made is that available data and information on the socioeconomic implications of implementing LEZ schemes do not easily lend themselves to general conclusions or to extrapolations. The bulk of these data and information is survey-based, with considerable variations in terms of reporting methodologies and associated indicators.

As the 2010 ARS study points out, there are considerable information gaps, which for the most part regard environmental aspects, economic issues and liveability (p. 61). For the full range of access restriction schemes explored in the ARS study, information was often unavailable with regard to: investment costs (information unavailable in 78% of the 58 responding cities); operating costs (85%); revenue (67%); impacts on the urban economy (87%); "network" (mobility- and congestion-related aspects)" (53%). Furthermore, data and information are "hardly comparable across schemes" (COWI Ecorys 2013, p. 62), which differ widely with regard to perimeter, technology, and monitoring and enforcement modalities. In addition, counterfactual reference scenarios (i.e. expected developments in a situation without LEZ, or "business as usual") have rarely been used to assess LEZ-related impacts.

As will be further discussed, while useful observations can be made, findings are likely to be tenuous thus limiting the extent to which meaningful comparisons can be established. Methodological considerations pertaining to specific cost parameters assessed in the reviewed literature can be found in the corresponding sections.

8.2.3 Main cost drivers associated with the implementation of LEZs

This subsection focuses on two of the main cost items associated with establishing and running LEZ schemes. Firstly, the majority of costs fall on those vehicle owners who must either stop driving in the LEZ area or replace or retrofit their vehicles. The second main set of costs concerns those reported by municipalities having implemented a LEZ scheme.

In terms of costs for vehicle owners, for example, in the impact assessment carried out by the UK's DEFRA in 2011, it was estimated that the costs of introducing LEZs for 16 towns and cities for HGVs and businesses by 2015 would amount to £277 million. Of this, the vast majority of the costs (£267 million) would be the result of vehicle (e.g. HGV, bus) owners having to replace or retrofit their vehicles while the cost for the local authorities would amount to only £10 million. Under the assumptions made here, the vast majority of the costs would fall on vehicle owners in terms of new vehicle purchases and retrofits. Therefore, perhaps the largest scope for improving costs relates to the vehicle emission (e.g. EURO) standard set and the effectiveness of such a standard in

[68] Ontology in this context means a conceptual classification.

improving urban air quality. Based on the UK data, if the standard set is not effective in improving air quality then the entire business case for an LEZ is undermined.

With regards to the second cost driver, although this may be overshadowed by the costs to vehicle owners, the costs of establishing and operating LEZ are still considerable. The main cost drivers here relate to the related issues of vehicle identification and city enforcement systems. In terms of vehicle identification, the choice of an automatic (e.g. automatic number plate recognition system, ANPR) or a manual (e.g. vehicle sticker) system affects costs in different ways. For example, while upfront capital costs are higher under an 'automatic recognition' system, on-going costs – enforcement for instance – may be lower. The reverse may be true under a manual system.

With regards to typical LEZ establishment and operating costs, COWI Ecorys (2013) report that, on average, a typical LEZ scheme without ANPR has investment costs of about EUR 200,000 and operational costs of about EUR 100,000 p.a., but that these costs increase substantially when ANPR is introduced. In that vein, the study refers to data from Reading's proposed LEZ: where "costs for design and implementation amount to roughly EUR 2.3 million[69] and yearly operating costs to roughly EUR 600,000. These findings are consistent with the 2009 evaluation report of the Dutch LEZ's for HGV's, which, for a typical city, reported average investment costs of EUR 180.000 and operating costs of EUR 75,000. As an example of a LEZ scheme involving charges, annual operation costs for the Trondheim scheme have been 10-11% of gross revenues throughout its period of operation (ISIS 2010). In terms of how both schemes compare, while the use of ANPR systems is a major cost driver, there is little to no information on potential efficiency gains associated to the use of these systems compared to more rudimentary, manual systems.

Average values are, however, of only relative significance given the very broad range of reported values. In the ARS study, reported operating costs are ten times higher for Burgos (EUR 300,000) than for Cork, despite the fact that both are zone-based schemes using automatic bollards and cover comparably sized urban areas. In per capita terms, reported investment costs range from barely EUR 1 in Rotterdam to almost EUR 100 in Stockholm. Reported per capita operating costs range between approximately EUR 0.2 (Rotterdam) and EUR 19 (London CCZ)[70]. These differences reflect, as previously stated, design, implementation and enforcement choices as well as location-specific constraints.

Table 8.1 presents the characteristics of each LEZ or ARS for which capital and operating expenses data is available. Table 8.2 displays the capital and operating expenditure data for each city, and the expenditure per capita, expenditure per sq. km, and expenditure per vehicle.

Table 8.1 Characteristics of LEZ which have cost data

City	LEZ	Type of scheme	Population ('000)	Area km^2	No. of cars ('000)
Burgos	Yes	Cordon based − Automatic bollards	180	26	25
Cork	Yes	Cordon based − Automatic bollards	119	37	29
La Rochelle	Yes	Cordon based	150	206	85
London LEZ	Yes	Environmental zones - targets LDV, Euro 4 vehicles and under	7620	1623	2497

69 Unless otherwise stated, amounts for capital expenditures quoted in this section of the report correspond to lump sums, as the amortisation periods are not specified in most cases.

70 For this and subsequent calculations, data contained in Annex 4 of the 2010 ARS study have been used. Given varying levels of reporting details, these figures should be considered for illustrative purposes only.

City	LEZ	Type of scheme	Population ('000)	Area km²	No. of cars ('000)
London CCZ	No	Congestion Charge Zone. Area licence-based with Automatic Number Plate Recognition (ANPR) cameras. Congestion Charge Zone.	As above	As above	As above
Modena	No	Cordon based	176	184	116
Perugia	Yes	Cordon based/time based. Targets private, LDV, Euro 4 vehicles and below	149	449	113
Rome	No	Cordon based - complex Access Control System	26800	1283	2250
Rotterdam	Yes	Environmental zones, targets Euro 4 vehicles and below	600	204	192
Reading	Yes	Cordon-based LEZ targeting LDV > 3,5t and under EURO 5	144	55	61920
Stockholm	Yes	Cordon pricing. Introduced in 2007 after six month trial in early 2006.	2019	6488	8471
Average			4,143	1,107	7,109
Median			180	206	192

Table 8.2 Capital and operating expenditure for LEZ and ARS with available data[71]

City	Capital expenditure				Operating expenditure, p.a.			
	EUR ('000)	EUR per capita	EUR per km²	EUR per car	EUR ('000)	EUR per capita	EUR per km²	EUR per car
Burgos	3,000	16.67	116,414	120	300	1.67	11,641	12
Cork	500	4	13,401	17	30	0.25	804	1.0
La Rochelle	251	2	1218	3	73	0.49	354	0.9
London LEZ	65,000	9	40,049	26	11,900	1.56	7332	4.8
London CCZ	250,000	33	154,036	100	144,000	18.90	88,725	58
Modena	370	2	2,015	3	147	0.84	801	1.3
Perugia	450	3	1,002	4	160	1.07	356	1.4
Rome	1,900	0	1,481	0.84	1,500	0.06	1,169	0.7
Rotterdam	500	1	2,451	3	100	0.17	490	0.5
Reading	1,990	14	35,953	0.03	540	3.75	9,756	0.01
Stockholm	200,000	99	30,826	24	2,2000	10.90	3,391	2.6
Average	47,633	17	36,259	27	16,432	4	11,347	8
Median	1,900	4	13,401	4	300	1	1,169	1

Reported investment costs per sq. km covered by the LEZ schemes also vary greatly: from slightly over EUR 1,200 per sq. km in La Rochelle to EUR 116,000 per sq. km in Burgos and EUR 154,000 per sq. km in London's CCZ. Reported operational costs per sq. km range between EUR 350 in La Rochelle and EUR 11,600 in Burgos. Finally, reported investment costs per car go from less than EUR 5 to more than EUR 100 depending on the cities (very likely statistical effects here).

Overall, one can conclude that the costs of establishing and running LEZs vary considerably. Combined with the fact that very little cost data is available, this means that costs to authorities of establishing LEZs are difficult to compare. Given this divergence, a first step towards reducing such costs could involve cities exchanging detailed cost information.

---

[71] As quoted in the reviewed literature. Amounts in current euros, various base years and implementation periods.

8.2.4 *Summary of main socioeconomic impacts associated with the implementation of LEZ*

On the benefits side, from a review of the literature, these concern not only air quality improvements but also may accrue in a number of other areas such as changes in real estate prices, travelling times, accident rates, and local business-life to name a few. However, as with costs above, the almost pervasive absence of "good monitoring and credible impact assessments" (COWI Ecorys 2013, p. 40), means that a detailed quantitative assessment of benefits is difficult.

In terms of what quantitative information is available, the COWI Ecorys study reports decreases in the number of vehicles in LEZ of between 4% and 25%, but the implications of LEZ on congestion and "liveability" (e.g. increased perception of pedestrian safety due to lower traffic volumes, as in the case of Singapore, or annoyances due to overcrowded public transport systems) these have rarely been assessed in monetary terms.[72] When they have, this assessment seems to be limited almost exclusively to changes in real estate prices (e.g. Burgos, London).

In addition, in the UK 2011 impact assessment example cited above, the authors estimated that benefits in terms if NO_2 concentration reductions and health benefits would amount to 432 million over five years (against 277 million in costs) for the 16 towns and cities covered.

As indicated in Chapter 4, few impacts of LEZ on noise levels have been reported in available literature. Therefore, it could be said that based on currently available data and information, any LEZ-related socioeconomic impact assessment would have to be based either on primary data or on a qualitative assessment of the expected consequences of a given LEZ design type.
Table 8.3 provides qualitative information on some of the many socioeconomic impacts documented for cities currently operating LEZs. In order to separate economic from other impacts, the table is separated into impacts on commercial life on the one hand, and impacts on quality of life and wealth effects (i.e. through changes in real estate asset prices) on the other hand.

Table 8.3 Selected socioeconomic impacts of LEZ (as reported by cities surveys for the 2010 ARS study)

City	Impacts on commercial life	Impacts on quality of life and/or wealth
Burgos		Real estate prices increased by EUR 600 per sq. m.[73]
London CCZ*	Retail sales growth in central congestion charging zone: 2.1% per annum pre-charge (2000-2002), 4.4% per annum post-charge (2003-2007). Sales performance of retail businesses located within zone: 24% of business reported increase, 7% reported decrease (no data reported for the remaining 69%). According to Transport for London (2005), registrations for VAT remained stable, (2008) no evident cumulative impacts from the introduction of charging in terms of business or economic output.	Rental values of shops within the inner core of the charging zone saw increases in their rental values.
London LEZ	Pre-implementation estimates for business and economic impact: GBP 100m to GBP 270m. Potential net loss of 140 to 420 full-	

[72] The same applies to reductions in delays, which according to the CURACAO study (CURACAO, 2009) can be of up to one-third.

[73] According to a 2008 study (decision on LEZ 2004, entry into force 2006).

City	Impacts on commercial life	Impacts on quality of life and/or wealth
	time equivalent jobs.	
Rome		The better liveability inside the zones has increased the value of all the buildings and commercial activities.
Stockholm	Turnover monitored before and after the implementation of the congestion tax for three statistical sectors: retail, wholesale and sales of motor vehicles and fuel: results suggest that the congestion tax has not had any negative impact on the overall turnover in the inner city when compared to the rest of Stockholm county. Both the retail and wholesale sectors show a more positive development of turnover in the inner city than in the rest of the county.	Mobility - 22% reduction of traffic during trial, 16% reduction in morning peak and 24% reduction in evening peak. 14% reduction in vehicle-kilometres travelled inside the cordon, compared with 2% for the region as a whole. Reduction in travel times, to and from the inner city and increase public transport use by 6% - 9% (not all attributable to the congestion charge).
Trondheim	Sales in the central business district decreased in real terms in the period 1987-1990, then picked up starting the year of the toll ring introduction and stayed on a “modest but steady growth” trend afterwards. The loss in market share to other sectors in the municipality “is simply a result of these sectors having a faster growth”. The long term trend of decreasing market shares has continued, even though the net sales volumes have grown modestly. However, the market share did not drop during 2005, and the drop during 2006 was smaller than in previous years. Still, the annulment of road user charging did not lead to an upswing in city centre trade during 2006.	During the 5-year period, slower average annual growth in total traffic crossing the toll cordon (1.8 %), compared to the general growth in the Trondheim area (2.8 %) or the County of Sør-Trøndelag (2.6 %).
Milan		Traffic reduction measured both inside (17.1%) and outside (8.1%) the charging zone. Public transport speeds increased by 8.1%.
Singapore*	No migration of business out of the city centre, likely to be due to it being a small area.	Perception of increased pedestrian safety in RZ due to reduced traffic flows. Initially, the scheme led to increased journey times for 44.1% of commuters (from cars to slower crowded buses) and decreased journey times for 36.1% of commuters.
Gothenburg		45% reduction in the number of traffic accidents.
Bologna		19.5% reduction in the number of traffic accidents.

* Non-LEZ ARS scheme.
Sources: ARS study (ISIS 2010), COWI Ecorys (2013), UAIEC study (Ecorys 2012).

In terms of the expected distribution of LEZ-related socioeconomic impacts, the most comprehensive account is provided in the ARS study (ISIS, 2010). Survey responses in the context of this study referred to expected beneficiaries and possibly negatively affected stakeholders due to a LEZ. Residents inside the zone as well as public transport users were identified as groups that would benefit. Conversely, freight distributors (Heavy Goods Vehicles (HGVs) in particular) and private motorised vehicle users were expected to be negatively affected overall (ARS study, quoted in COWI Ecorys 2013, p. 38ff).

Overall, beyond estimated reductions in emissions and traffic, there is a lack of literature on the global direct and indirect effects of LEZs. The impact assessment framework provided in the guidance note accompanying this study is therefore a useful first step in understanding all the main issues to be considered in establishing an LEZ.

8.3 Harmonisation Potential & Resulting Costs Savings

This section examines the possible savings or additional benefits for authorities and users of moving from individual LEZs to a more harmonised system. Here the level of the possible savings made depends on the level of harmonisation chosen. On the one hand, the greater the level of harmonisation achieved the greater the likely savings, especially for users. However, on the other hand, full harmonisation could limit the flexibility of authorities to tailor their LEZ to local conditions.

8.3.1 Level of Harmonisation and resulting cost savings

Any move from a city-specific LEZ to a more harmonised national or EU approach could, in theory, lead to cost reductions or increased benefits in terms of economies of scope for authorities and lower administration-related compliance costs for users.

However, the level of savings made and benefits enjoyed depends on the level of harmonisation put forward. At one end of the spectrum, greater harmonisation, which may entail the adoption of the same rules and standards in each LEZ, could result in relatively high cost savings. The upside to this is that it could result in lower establishment and operating costs for cities – especially those which have not yet invested in LEZ systems and processes. It would also lead to greater efficiency savings for users, which are presented in the box below.

Box: The COWI Ecorys Study, full harmonisation & user benefits

The COWI Ecorys (2013) study attempts to assess the potential benefits to users of harmonising LEZ design at EU level. It distinguishes between “full information” (i.e. assuming users have comprehensive knowledge of LEZ access requirements) and “lack of information” (i.e. assuming imperfect knowledge of LEZ access requirements by users) situations. It compares a situation without harmonisation (requirements and areas differ between cities) to a harmonisation situation, whereby “the same requirements are applied” across LEZ (at least within each vehicle category).

The bulk of the assessment refers to the full information hypothesis. In this context, overall, harmonisation is expected to lead to increased efficiency in logistics planning and resource (e.g. fleet vehicles) utilisation.

Table 8.4 Expected benefits from harmonisation of access restriction schemes (as reported in the 2013 COWI Ecorys study)

	ARS	LEZ	Parking	Charging
Work-related passenger trip	Small benefits	Small benefits	Significant benefits salesmen	Significant benefits salesmen
Non-work related passenger trip	Small benefits	Small benefits	Small benefits	Small benefits
Freight trip	Substantial benefits in delivery	Substantial benefits in delivery	Small benefits	Small benefits

Source: COWI Ecorys 2013, p. 72.

As can be seen in the table above, according to the COWI Ecorys study, service providers that serve different cities with LEZ on a regular basis can be expected to be the main beneficiaries. This is due to the following reasons (COWI Ecorys 2013, p. 70ff):

- Time and operational costs in order to find and obtain all relevant information for more than one time low emission zone may significantly decrease;
- The fleet of service providers may be more efficiently applied:
  - Planning of delivery becomes easier as exchangeability between the vehicles will increase (efficiency improvement);
  - There may be economies of scale for providers as the required types of goods vehicles may decrease. The fleet composition becomes more efficient. For example, a provider can handle its operations with 5 types of vehicles (specific environmental performance and fuel type) instead of 10 types of vehicles;
  - The fleet can be more efficiently used. Fewer vehicles may be required (lower operational costs).

The COWI Ecorys study refers to comparatively small benefits for passengers, as it "*becomes easier to find and obtain all relevant information and also passenger cars can be applied more efficiently*". Employees that frequently visit LEZ in different cities (e.g. salesmen) are expected to reap the largest benefits in terms of time savings within this category of users.

Other potential benefits are also highlighted in the same study in the context of EU-wide harmonisation of access restriction schemes. These are not LEZ-specific but deserve consideration nevertheless (COWI Ecorys 2013, p. 74):

- Economies of scale savings for manufacturers of charging and payment technological devices;
- Lower operating costs for logistic service providers and other road users as a result of mainstreamed design requirements for vehicles (via economies of scale for car manufacturers, although this assumes environmental technical standards to be a key determinant of manufacturing choices);
- Positive impact on "the image and the business climate of (in particular) inner-cities". "In the present situation companies may be deterred by the different schemes in use and the unpredictability of possible adaptions. Harmonisation may lead to more consistently applied access restriction schemes and also to greater predictability. This can contribute to the business climate and functioning of inner-cities in general";
- Potential reductions in the amount of vehicles and vehicle-kilometres, thus resulting in external benefits, such as lower emissions, lower noise, improved road safety, etc. However, "some cities could benefit of harmonisation, others may not".

With regard to the “lack of information” hypothesis, it is stated that harmonising may contribute to a better knowledge and better information of traffic participants (thus reducing uncertainty). As a result, negative effects due to imperfect information “may decrease” along with efficiency losses in terms of delay-induced costs.

Given the lack of available information, the above study provides “indicative calculations” suggesting that “the benefits of harmonisation might be significant” (between EUR 120m and EUR 250m p.a. for freight trucks, depending on assumptions on efficiency gains).

The downside to full harmonisation this is that while it may bring about efficiency savings to users and cities, it would also restrict the ability of cities to tailor LEZ rules, namely to local air quality conditions. As the *raison d’être* of establishing LEZs is to combat local air quality conditions, harmonisation of vehicle emissions standards would appear to be city-specific and, therefore, not subject to harmonisation. If cities maintain separate emissions limits, this could significantly limit many of the potential harmonisation ‘efficiency’ benefits outlined in the table above.

As an alternative, at the other end of the spectrum, harmonisation could be limited to ensuring interoperability of systems whereby cities establish a common LEZ framework, but remain free to set their own rules within this framework. For example, under a limited, interoperable system, cities may use the same type of vehicle identifier but would be free to set their own rules regarding emissions restrictions applied, exemptions granted, LEZ operation times etc. This partial harmonisation model could be in line with that put forward in the Standards and Guidance for European Low Emission Zones document accompanying this report (Annex A) whereby EU, national and local authorities are recommended to voluntarily put in place:

1. harmonised vehicle emission classes for defining LEZs;
2. standards for sticker-based LEZ using the harmonised emission classes;
3. a European database for vehicle emission characteristics to facilitate automatic recognition of the emission class of vehicles and provide an "electronic LEZ certificate" for each registered vehicle for obtaining stickers and permits; and
4. a European database and Internet information service for users on existing and planned LEZ.

This reflects both the fact that air quality control is inherently local/regional as well as the diverse reality on the ground across the EU, where some countries have adopted highly harmonised systems (such as the Netherlands), others have allowed for a certain amount of local autonomy within a common framework (such as in Germany), while others again (London; parts of Italy) have maintained stand-alone systems to date.

8.3.2 *Possible savings from partial harmonisation*

That said, the introduction of the above LEZ framework (harmonised emissions classes, databases etc.) can, at the very least, still lead to significant and identifiable savings in the following areas:

- Regulatory costs for local authorities to identify vehicles, as well as prepare, establish and implement and LEZ, could be reduced in certain areas through learning from other cities and through centralisation and/or common management of certain activities; and
- Administration- and information related compliance costs for vehicle users could be reduced if they avoid bother the costs of familiarising themselves with different LEZ systems as well as in paying certain LEZ related costs such as vehicle stickers etc.

The following two sections deal with the above related costs areas. The first outlines in detail the types of regulatory and administration related costs which are faced by local authorities and users while the second analyses where there is potential scope for savings.

8.3.3 *Types & incidence of possible cost savings*

The main direct establishment, management and enforcement costs fall on the local authorities running an LEZ, while the implementation costs fall on both authorities and users.

The main possible areas of savings for authorities are expected to concern those actions (i) which can be centrally managed to one entity, or shared between cities, instead of being managed individually by each city or (ii) where experiences in other LEZs can result in savings. The main establishment costs falling on authorities can be split between up-front capital costs and non-capital costs.

Non-capital establishment costs include:

- initial feasibility studies;
- scheme design and planning, including analysis of effects on traffic flows etc.;
- legal support, changes to local by-laws; and
- public consultation and information dissemination.

As seen in many jurisdictions, this establishment process can take several years. Therefore, harmonisation and/or greater cooperation (e.g. sharing of best practices) could in theory lead to cost and time savings. On the other hand, many elements of non-capital costs are site-specific, e.g. traffic flows have to be analysed for a given location, and changes to local by-laws and public consultation processes have to be carried out locally as well. Thus the scope for savings related to harmonisation is not very broad.

Once a scheme has been decided upon, the capital costs faced by the authority may include investments in:

- roadside and related equipment (signing, detection, enforcement); and
- central administrative and IT systems capable of fulfilling certain back-office functions such as facilitating vehicle records, certification, enquiry handling).

These equipment and systems, in turn, require testing. This is an element of costs which could be shared in case of harmonisation, creating thus an opportunity for cost savings.

In a report prepared for the Dutch environment ministry in 2009, for a small city (100,000 to 200,000 residents, initial 'preparation' costs incurred could amount to EUR 60,000. Most of these costs refer to research, including calculation of economic impacts. Establishment costs including communications, road equipment and set-up of enforcement mechanisms would add another EUR 80,000, bringing the total preparatory costs to EUR 140,000. Another Dutch study put the total for preparatory activities (including feasibility studies) at between EUR 175,000 and EUR 300,000.

In the UK, the London LEZ cost an estimated £57m to set up and an additional £10.7m per year to operate. However, London is outlier[74] given its size as DEFRA estimates the average establishment costs to include £82,000 for LEZ preparation and £110,000 for other establishment costs.

---

[74] Though the London example does appear to be an outlier, its use of automatic vehicle identification raises a few challenges with regards to the identification of vehicles from other cities LEZs using manual identification systems (e.g. stickers). Specifically, the London LEZ, and indeed other cities using this technology (namely in the Netherlands), may not be able to recognise vehicles registered under other LEZs. At the moment, the London LEZ requires vehicles from outside London or the UK to register online. As there are no other LEZs in place in the UK at present which cover private vehicles, this does not appear to create a problem for many users. However, as the number of LEZs expands, and as some move towards automatic systems and some choose manual identification methods, there is a risk that the two different systems may be incompatible.

Regarding the latter (including management and enforcement), these include those costs covering:

- labour costs (e.g. costs for hiring, training and accommodating staff);
- operating costs relating to registration and validation of vehicles;
- issuing vehicle identifiers (e.g. stickers) and certifying and processing retrofits;
- replacing/maintaining equipment and systems; and
- issuing fines and ensuring follow-up (e.g. legal costs).

Regarding national experience, data from the Netherlands suggests that implementation costs for simpler systems (e.g. those based on manual enforcement) are driven by labour costs which vary according an array of factors e.g. exemptions processing, legal costs, enforcement. In the UK, operation costs for local authorities are estimated at £85,000 per year for typical small cities/towns. As with establishment costs, no city has provided a detailed breakdown of the costs of implementation.

In terms of <u>administration-related user costs</u>, the literature review identified the large intercity transport firms (e.g. freight operators; passenger transport) as being the main use stakeholder group affected. Regarding implementation costs for these users, these include:

- capital-related administrative costs (in the form of certifying retrofitting devices);
- opportunity costs (resulting from having to change travel and delivery patterns or from spending time dealing with LEZ administration); and
- other administrative costs (relating to charges paid to authorities for stickers, etc.).

These implementation costs do not give much possibility for cost savings in case of harmonisation. However, time savings may be related to avoiding becoming familiar with the system and to facilitating the logistics because of participation in multiple LEZ systems with the same rules.

8.3.4 Scope for savings from partial harmonisation

In terms of <u>possible savings to cities/local authorities</u>, to our knowledge, no analysis has been published in the area of possible costs savings for local authorities in pooling some of the above-mentioned activities involved in establishing and maintaining LEZs. Therefore, while much can be surmised regarding possible economies of scope, this is an area where further work would be required.

In terms of potential lines for future analysis, certain local authority activities may gain from greater national coordination in the following areas:

- Preparatory activities: As many cities face the same issues, national authorities could support the development of LEZ feasibility plans though the development of a common framework of detail issues to consider and cost/benefit tools which could be used when assessing an LEZ. This would, of course, go beyond the type of information available on established websites (www.lowemissionszones.eu) and beyond the guidance found in this report;
- Establishment costs: While national authorities could assist in certain areas – such as in the provision of legal support and information dissemination – it would appear that scheme planning and local public consultation would still have to be conducted locally. Regarding upfront capital costs involved, roadside equipment would undoubtedly depend on local conditions. However, central administration and IT systems do not necessarily have to be local;
- Implementation/operation costs: National cooperation in the area of registration of vehicles, vehicle identification systems, retrofit certification, legal costs and follow-up do not per se have to be managed at local level which gives some scope for savings. On the other hand, it is assumed that enforcement would be still required at local level.

In terms of possible savings for users under partial harmonisation, as it is assumed that local authorities could maintain separate vehicle emissions standards under a harmonised system, there would be limited scope for savings related to LEZs harmonisation regarding capital costs of retrofit and new vehicles. Therefore, the potential savings would relate more to capital related administration costs (e.g. certification of retrofitted vehicles), opportunity costs in terms of time spent registering and other user administration-related compliance costs such as paying for stickers etc.

Common or streamlined approaches to certification of retrofitted vehicles may also assist in reducing complexity for vehicle owners.

In terms of opportunity costs, a national system – with coordinated information provision – could save suppliers/hauliers a considerable amount of time and effort needed to get used to how the system works. Moreover, on a cross-border basis, savings through registration on a common website are conceivable. For example, at present, international operators delivering to London must register on the London LEZ website. If all LEZs did this, the amount of savings in both the compliance costs on the side of the user and administration costs on the authorities' side could be considerable. In addition, cross-border enforcement may be an issue where joint systems are not in place.

With regards to other administrative and user compliance costs, the manual identification systems could benefit from the use of a common vehicle identification/sticker system, such as those used in Germany and Denmark.

Overall, the business case for partial harmonisation from a user perspective increases when more and more cities adopt LEZs.

8.4 Conclusions

It appears from a very limited number of available sources that the business case for an LEZ depends primarily on the benefits brought about by air quality improvements on the one hand, and costs to vehicle operators of compliance on the other. The costs and benefits to local authorities in establishing and operating LEZs and to vehicles users in terms of logistics impacts are secondary. As air quality is very much a local consideration, cities set vehicles emission targets according to local conditions. Therefore, it is not expected that any city-pass system would recommend a common or harmonised emissions standard. This limits the scope for potential benefits from greater harmonisation or interoperability of individual LEZs.

That said, there is still considerable scope for savings from greater harmonisation. Under a full harmonisation model, the financial impact could be considerable, in particular to freight firms in terms of vehicle logistics. However, these savings may not materialise if a move to full harmonisation is deemed impractical or politically unacceptable. But even under partial harmonisation (e.g. of vehicle emission classes for defining LEZs, standards for sticker design/information and the creation of vehicle databases) could still lead to savings.

For users, the main benefits of partial harmonisation would concern administrative compliance-related costs. These could include lower retrofit certification costs, opportunity costs (resulting from less time spent registering and finding out about different LEZ rules) and other administrative costs relating to LEZ charges (e.g. stickers). The savings possible depend on the extent to which the various LEZs would like to harmonise their activities.

For local authorities, while it would appear that much of the work involved in preparing, establishing and operating LEZs would be city specific, there are certain activities – such as preparing feasibility studies in the preparatory phase, establishing back-office systems and issuing fines etc. in operations phase – which could conceivably be coordinated or shared, which would allow economies of scope savings. Again, the savings possible depend on the extent to which the various LEZs would like to harmonise their activities.

However, the main challenge in identifying the extent of these possible savings relates to the almost complete lack of detailed quantitative cost and benefit information on LEZ. Therefore, a better sharing of information on the above by existing LEZs would appear to be a prerequisite to any attempt to ascertaining the costs and benefits of establishing new LEZs or harmonising existing LEZs.

8.5 References

- ClientEarth. (2013). Low emission zones in the UK - The case for a national network of low emission zones to improve urban air quality [draft report for consultation with local authorities and other stakeholders]. Retrieved from http://www.healthyair.org.uk/documents/2013/06/lezs-in-the-uk-draft-report-for-consultation.pdf;
- COWI, & Ecorys. (2013). Study to support and Impact Assessment of Urban Mobility Package - Activity 32: EU Framework for Urban Road User Charging and Access Restriction Schemes. European Commission, DG MOVE;
- CURACAO. (2009). Project CURACAO, Coordination of Urban Road User Charging Organisational Issues, Deliverable D3: Case Study Results Report. Coordinated and edited by ISIS, with contributions by ATAC, BCC, Goudappel Coffeng, NPRA, SESTRAN, SINTEF, TIE, TTR, and WSP; for European Commission. Retrieved from http://www.its-toolkit.eu/2decide/toolkit/files/ITS_TOOLKIT_11_1314874486.pdf;
- DEFRA. (2009). Practice Guidance to Local Authorities on Low Emissions Zones (No. Practice Guidance 2). Department for Environment, Food and Rural Affairs. http://archive.defra.gov.uk/environment/quality/air/airquality/local/guidance/documents/practice-guidance2.pdf;
- DEFRA. (2011). A Low Emissions Zone framework for inclusion in the Time Extension Notification for compliance with the EU limit value for NO_2. http://www.archive.defra.gov.uk/environment/quality/air/airquality/docs/ia-no2.pdf;
- Ecorys, & CE Delft. (2012). Study on Urban Aspects of the Internalisation of External Costs - MOVE/B4/310-1/2011, Final Report. Ecorys, CE Delft, for European Commission, DG MOVE. Retrieved from http://ec.europa.eu/transport/themes/urban/studies/doc/2012-study-on-urban-aspects-of-the-internalisation-of-external-costs.pdf;
- Goudappel Coffieng, & Buck Consultants International. (2010). Landelijke effectstudie milieuzones vrachtverkeer 2010, Effecten op de luchtkwaliteit [National impact assessment environmental zones freight traffic, impact on air quality]. Retrieved from http://www.rijksoverheid.nl/bestanden/documenten-en-publicaties/rapporten/2010/11/18/landelijke-effectstudie-milieuzones-vrachtverkeer-2010/kl-2010029719a-bijlage-effectstudie-luchtkwaliteit-milieuzones.pdf;
- ISIS, & pwc. (2010). Study on Urban Access Restrictions, Final Report (No. TREN/A4/103-2/2009). European Commission, DG MOVE. Retrieved from http://ec.europa.eu/transport/themes/urban/studies/doc/2010_12_ars_final_report.pdf;
- Malina, C., & Fischer, F. (2012). The impact of low emission zones on PM_{10} levels in urban areas in Germany (No. CAWM Discussion Paper No. 58). University of Muenster, Germany.

http://www.wiwi.uni-muenster.de/cawm/forschen/Download/The-impact-of-low-emission-zones-on-PM10-levels-in-urban-areas-in-Germany.pdf;

- Sadler Consultants. (2006). Assessment of the impact on costs and emissions of technical measures on existing heavy duty vehicles and captive fleets, ENV.C.1/SER/2006/0013r, Final Report. Sadler Consultants, for European Commission, DG Environment. Retrieved from http://ec.europa.eu/environment/urban/pdf/final_eu_tm_report.pdf;
- Wolff, H. (2013). Keep your Clunker in the suburb: Low emission zones and adoption of green vehicles. The Economic Journal. doi:10.1111/ecoj.12091. http://faculty.washington.edu/hgwolff/REEP.pdf.

9 Observations and Recommendations

The following observations and recommendations are made to support the harmonisation and efficient implementation of low emission zones.

Implementation of the City Pass system of harmonised LEZ

The voluntary standards proposed in Chapter 2 of the Standards and Guidance Document (Annex A) are the result of a desk analysis, relying on the results of all the tasks of this project, literature, Commission guidance and reports from stakeholder consultations carried out by other projects. This project has not had a stakeholder consultation component in which the proposed standards for harmonisation were openly discussed. Thus the next logical step is to share the LEZ Standards and Guidance Document with interested Member States and stakeholders, and seek consensus on the standards and the further roadmap for their implementation.

Recommendation 1: The Commission should consider inviting interested Member States and stakeholders to discuss and refine the proposed voluntary standards for LEZ presented in Chapter 2 of the Standards and Guidance Document (Annex A).

Impact assessment and programme monitoring

It will be helpful for local authorities planning and implementing LEZ to be able to base local environmental, health and social impact assessments on national impact assessments, as described in the Standards and Guidance Document (Annex A).

Recommendation 2: Member States should prepare national environmental, health and social impact assessments for the implementation of LEZ to achieve the PM_{10}, $PM_{2.5}$ and NO_2 limit values, focusing on inter-city and cross-border impacts and development of national emission, health and cost-benefit parameters.

Recommendation 3: Member States should prepare templates for development of local LEZ impact assessments by municipalities, based on the national impact assessment.

Vehicle registration documents and data exchange

The Euro emission category of a vehicle is not recorded on vehicle registration certificates by all Member States. The Registration Documents Directive (1999/37/EC as amended[75]) provides for presentation and harmonised encoding of the Euro type approval category[76], as optional data on registration certificates or smart cards. Having the Euro category available on registration certificates would simplify processing of applications for LEZ stickers and exemptions, and facilitate manual enforcement. This would also ensure that "early adopter" vehicles meeting a Euro emission category before the date specified in the Directives would be properly recognised.

Recommendation 4: Member States should include the optional Euro environmental category data item on all vehicle registration certificates and smart cards, consistent with the Registration Documents Directive (1999/37/EC).

[75] EU (1999). Council Directive 1999/37/EC of 29 April 1999 on the registration documents for vehicles, as amended by 2003/127EC and 2006/103/EC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0037:EN:NOT.

[76] Annex I of 1999/37/EC, Part II.6 optional data, harmonised Community code (V.9), and Part III.11 Table 3 (optional data objects) Tag 'B0' '9F31'.

Recommendation 5: that the Commission consider making the Euro environmental category a mandatory data item on vehicle registration certificates or smart cards, through amendment of the Registration Documents Directive (1999/37/EC).

Cross-border exchange of vehicle registration data

Administration and enforcement of foreign vehicles in LEZ would be more efficient if cross-border access to vehicle registration data was available. This would facilitate verification of foreign vehicle Euro classification for sale and verification of stickers, recognition of foreign vehicles by ANPR systems, and obtaining foreign vehicle owner information for the purpose of billing and collection of LEZ access charges or penalties. This is important to facilitate the equal treatment of foreign vehicles.

EUCARIS[77] (EUropean CAR and driving license Information System) is EU's data exchange mechanism for Member States' vehicle registration and driver licensing authorities. EUCARIS can also be used by governmental organisations responsible for tracing stolen vehicles, theft and fraud prevention, as well as police, customs and tax authorities. Directive 2011/82/EU[78] on cross-border exchange of information on road safety related traffic offences provides for exchange number plate data between member states to allow for cross-border enforcement of safety-related traffic offences, such as speeding, not stopping for red light, and drunk driving.

Recommendation 6: that the Commission consider extension of Directive 2011/82/EU to include fines related to LEZ (and other access restriction schemes), and

Recommendation 7: that the Commission support the development and expansion of bi-lateral and multi-lateral agreements on exchange of vehicle registration data.

Other relevant legislation may include:
- Council Framework Directive 2005/214/JHA[79] on mutual recognition of financial penalties;
- Council Decisions 2008/615/JHA[80] and 2008/616/JHA[81] on cross-border cooperation may also be relevant, regarding provisions for conducting automated cross-border searching of vehicle registration data via EUCARIS software.

Retrofit Emission Control Devices

Retrofit emission control devices (REC) are in many cases cost-effective to reduce emissions of existing vehicles so they can comply with LEZ entry requirements, where permitted. The UNECE 2013 Regulation on type approval of REC devices provides a basis for harmonisation of REC requirements and certification procedures, and mutual recognition of REC installed on foreign vehicles, for entry into LEZ. There are at present no standards for documentation of installed REC, their Euro emission equivalence, cross-border exchange of data on installed REC, nor for recognition of REC in electronic vehicle identification and toll systems (i.e. EETS). Harmonisation of documentation and data on installed REC would significantly facilitate the acceptance of REC in LEZ implementation and enforcement.

---

77 www.eucaris.net.

78 Directive 2011/82/EU of the European Parliament and of the Council of 25 October 2011 facilitating the cross-border exchange of information on road safety related traffic offences. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0082:EN:NOT.

79 Council Framework Directive 2005/214/JHA of 24 February 2005 on the application of the principle of mutual recognition to financial penalties. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005F0214:EN:NOT.

80 Council Decision 2008/615/JHA of 23 June 2008 on the stepping up of cross-border cooperation, particularly in combating terrorism and cross-border crime. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008D0615:EN:NOT.

81 Council Decision 2008/616/JHA of 23 June 2008 on the implementation of Decision 2008/615/JHA on the stepping up of cross-border cooperation, particularly in combating terrorism and cross-border crime. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008D0616:EN:NOT.

Recommendation 8: Participating Member States should adopt the UNECE 2013 Regulation on REC, and adopt (or amend) national legislation for type-approval and certification of retrofit devices.

Recommendation 9: The Commission should consider developing guidelines for national certificates of installed retrofit emission control devices and the mutual recognition of such certificates, consistent with the UNECE Regulation on Retrofit Emission Control Devices and the EU Registration Documents Directive (1999/37/EC). The information on certificates would identify the device type approval number, installer, and for each regulated air pollutant, the Euro class limit value equivalence achieved by the device and the (minimum) emission reduction percentage. The guidelines should including definitions and harmonised EU codes for data elements regarding retrofit devices.

Recommendation 10: Member States should establish national certificates for retrofit emission control devices installed in vehicles, based on guidelines developed by the Commission.

Recommendation 11: The Commission should consider development of a voluntary standard for cross-border exchange of data on retrofit emission control devices installed in vehicles registered within the EU, for proposed implementation within the EUCARIS[82] information exchange system and consistent with the EUCARIS data exchange standards[83]. This would be optional data for Member States participating in EUCARIS.

Recommendation 12: The Commission should consider extension of data specifications for electronic toll service systems to include data on installed retrofit emission control devices, consistent with the EETS Directive (2004/62/EC) and its associated implementing provisions and standards[84].

Recommendation 13: The Commission should consider requesting UN ECE to develop standards for inspection and testing of installed retrofit devices, as part of normal periodic vehicle inspections.

---

[82] EUCARIS, EUropean CAR and driving license Information System, https://www.eucaris.net/.

[83] EC ISA. (2013). EUCARIS XML messages 4.1 https://joinup.ec.europa.eu/catalogue/asset_release/eucaris-xml-messages?lang=en.

[84] such as EN 15509:2007 - Road transport and traffic telematics - Electronic fee collection - Interoperability application profile for DSRC. and EN 16312:2013 - Intelligent transport systems. Automatic Vehicle and Equipment Registration (AVI/AEI). Interoperable application profile for AVI/AEI and Electronic Register Identification using dedicated short range communication; EN ISO 24534-3:2010 Automatic vehicle and equipment identification. Electronic registration identification (ERI) for vehicles - Vehicle data.

Annex A – Standards and Guidance for European Low Emission Zones

P.O. Box 4175
3006 AD Rotterdam
The Netherlands

Watermanweg 44
3067 GG Rotterdam
The Netherlands

T +31 (0)10 453 88 00
F +31 (0)10 453 07 68
E netherlands@ecorys.com

www.ecorys.nl

BUILDING A BETTER WORLD

Avenue Reine Astrid 92
1310 La Hulpe
Belgium

T +32 (0) 2 655 22 30

P.O. Box 4175
3006 AD Rotterdam
The Netherlands

Watermanweg 44
3067 GG Rotterdam
The Netherlands

T +31 (0)10 453 88 00
F +31 (0)10 453 07 68
E netherlands@ecorys.com

W www.ecorys.nl

Sound analysis, inspiring ideas