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Module 6: Air Quality Local Assessment

Surface Access Demand Management Literature Review

Prepared for the Airports Commission

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Jacobs U.K. Limited

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Contents

Executive Summary

In 2013, the Airports Commission received submissions on potential options for airport expansion for the UK. Following an assessment of these options, three airport schemes were shortlisted to be taken and considered in more detail. These were:

- Gatwick Airport Second Runway (Gatwick R2) promoted by Gatwick Airport Ltd (GAL);
- Heathrow Airport Northwest Runway (NWR) promoted by Heathrow Airport Ltd (HAL); and,
- Heathrow Airport Extended Northern Runway (ENR) promoted by Heathrow Hub Limited (HH).

This report has been prepared to consider the relevance of low emission zones (LEZ) and congestion charging zone (CCZ) in addressing potential air quality implications arising from an airport expansion, with particular attention to traffic emissions.

The review considers the evidence that is available regarding the effectiveness of a sample of schemes in improving air quality in the UK and internationally. The case studies include London, San Francisco, Seattle, Miami/Fort Lauderdale, Minneapolis, Chicago, Singapore, Stockholm, Milan and Berlin. Table A provides a summary of the UK case studies.

Table A – Summary of UK case studies

Location	Measures Implemented	Impacts
London	LEZ: Applicable to a variety of vehicles. Must meet Euro standards. Implemented in phases. Retro-fitting. Purchasing new vehicles	Predicted 39.6% NO_X and 31.1% PM_{10} reductions (2008-2015). CO_2 reduced by 20,600 tonnes/yr.
	Congestion zone: Fixed peak-hour pricing.	Reduction in NO_X, CO_2, and PM_{10}. Reduced traffic volume. Increase in congestion. Increase in public transport ridership.
Norwich	LEZ: Applicable to buses. Must meet Euro standards. Retro-fitting. Purchasing new vehicles. No idle engine policy. Eco-driving training.	Unknown.
Oxford	LEZ: Applicable to buses. Must meet Euro standards. Retro-fitting. No idle engine policy.	Predicted 11% NO_X and 7% PM_{10} reductions (2011-2025).
Brighton	LEZ: Applicable to buses. Must meet Euro standards. Retro-fitting. Purchasing new vehicles. No idle engine policy.	Unknown.

Location	Measures Implemented	Impacts
	Eco-driving training. Electronic ticket purchases.	
Nottingham	LEZ: Applicable to buses. Must meet Euro standards. New bus lanes for congestion control. Bus shelter improvements.	Unknown.
York	LEZ - Not yet implemented.	Unknown.
Bradford	LEZ - Not yet implemented.	3.8-46.4 tonnes of NO_X reduction is expected. CO_2 is not expected to increase.
Leeds	LEZ - Not yet implemented.	178.9-926.7 tonnes of NO_X reduction is expected (2016-2021). CO_2 is not expected to increase.

Effectiveness of Low Emissions Zone

The majority of LEZs presented in the review focused on limiting bus emissions, as buses have been identified by the majority of the cities as the primary vehicles that contribute to PM_{10} and NO_X pollution.

With the exception of London, Local Authorities are not particularly stringent on vehicles that are not part of public transportation services, although several schemes allow for the expansion of LEZ restrictions to private cars and HGVs. As the majority of UK LEZ schemes have just been implemented (or are in the process of being implemented), it is not yet possible to determine their effectiveness in improving air quality.

The lack of quantitative data regarding LEZ success makes it difficult to determine the applicability of an LEZ to Gatwick and Heathrow expansion options. London has already identified that it plans to expand its LEZ into an Ultra Low Emission Zone, (ULEZ) to meet future air quality objectives.

Effectiveness of Congestion Strategies

The majority of the congestion charging case studies presented in the review show an overall beneficial impact, although the impacts vary depending on the type of strategy implemented and the measures it uses.

It is apparent that technology, enforcement, and public transport improvements are all vital components in the effectiveness of congestion charging.

Technological components include;

- Installation of monitoring and management systems such as automated cameras and car number plate recognition.
- Fees can be paid automatically using electronic passes, manually via toll booths, or 'pay by mail' through the use of cameras and databases.
- Use of real-time data to provide updates on traffic conditions and public transit information.

Public transport enhancements are an important complimentary measure to congestion charging and the revenues from congestion charging can provide funding to promote and enhance public transport services.

The London CCZ has experienced a series of successes in terms of reducing traffic volume and emissions and increasing usage of public transport. PM_{10}, NO_2, and NO_X emissions have also been reduced. However, as an increasing amount of road space within the zone has been turned over to other modes (for example through the expansion of bus lanes, the introduction of cycle superhighways, and enhancements to pedestrian and cycle facilities through urban realm improvement schemes), the level of congestion within the zone has been increasing and approaching pre-charging levels despite the traffic volume reductions.

In comparison, the American congestion schemes have been more invasive in terms of infrastructure requirements to create/expand lanes, install toll booths, and introduce smart technology.

Though implementation costs of congestion projects are relatively high, reducing traffic congestion and traffic volume has shown to reduce pollutant emissions (London, San Francisco, Chicago, Milan, and Stockholm) and provide other social benefits such as travel reliability and shorter travel times.

Unlike LEZs, congestion pricing generates steady revenue that can be invested to further improve transportation and air quality.

Potential application at Heathrow and Gatwick

With regard to the expansion options for Heathrow and Gatwick, the literature review has highlighted a number of common themes which may be applicable. These are as follows:

- Voluntary LEZ participation from taxi, coach, and bus operators.
- Mixture of hard and soft measures for emission reduction in LEZs.
- There is uncertainty on which types of vehicles should be included in the LEZ restrictions.
- It is more cost effective to establish LEZ than to pay non-compliance fees.
- There is a lack of transparency on actual LEZ costs and emission reductions.
- Reducing congestion can lead to reduced emissions and other social benefits.
- A variety of restrictions can be placed on express/toll lanes and car parks.
- Automated charges further reduce congestion and promote continuous flow.

Following the airport expansion, for ease of public transition the LEZ/congestion charge should correlate in terms of application, charging and compliance to the existing London LEZ/CCZ and future ULEZ, if introduced. Due to the close proximity of both airports to Greater London and public familiarity with the London LEZ/CCZ requirements, it would be of benefit to use similar operating mechanisms such as number plate recognition to avoid public confusion. Emissions standards should be the same to avoid the possibility of conflicting standards and ensure that if a vehicle is compliant it is compliant for both the existing London LEZ and any future airport LEZ. However, charges under a congestion charging could, and to be effective should be different from the London CCZ in terms of hours of operation and charging levels.

In the context of airport expansion, although referred to by the promoters as a congestion charge, this would be an access charge that would be applied to a zone or zones as yet undefined around an airport scheme, with the purpose of supporting modal shift and managing traffic flows into and out of the airport and their impacts (e.g. air quality) rather than a congestion charge as applied in central London.

The case studies demonstrate that the effectiveness of CCZ and LEZ is difficult to evaluate and may vary over time as the scheme developers and users change their habits. In addition, the information available on the effectiveness of the measures focuses on the impact within the charging zone or LEZ. For the application to an airport the impact on air quality around the edge of the zone will be a key consideration in defining and implementing the scheme and would require monitoring during the operation of any scheme.

1 Introduction

1.1 Background

The Airports Commission is considering the case for, and best means of, providing additional airport capacity within the UK.

In 2013, the Airports Commission received submissions on potential options for airport expansion for the UK. Following an assessment of these options, three airport schemes were shortlisted to be taken and considered in more detail. These were:

- Gatwick Airport Second Runway (Gatwick R2) promoted by Gatwick Airport Ltd (GAL);
- Heathrow Airport Northwest Runway (NWR) promoted by Heathrow Airport Ltd (HAL); and,
- Heathrow Airport Extended Northern Runway (ENR) promoted by Heathrow Hub Limited (HH).

In April 2014, the Airports Commission published an Appraisal Framework which identified the methodology to further assess the three shortlisted schemes. The framework included an assessment of the potential air quality impacts from the proposed airport expansion options. The assessment was undertaken and published for consultation in November 2014.

This report has been prepared to consider the relevance of low emission zones and congestion charging in addressing potential air quality implications arising from an airport expansion, with particular attention to traffic emissions.

1.2 Aim of the Report

The Airports Commission commissioned Jacobs to undertake a literature review of existing Low Emission Zones (LEZ) and congestion charging schemes.

The review considers the evidence that is available regarding the effectiveness of a sample of schemes in improving air quality in the UK and internationally.

1.3 Low Emissions Zones and Congestion Charging

1.3.1 Low Emission Zones

A LEZ aims to reduce pollutant emissions within a certain area, or ‘zone’, with a pollution control scheme (AA, 2015). Within the zone, polluting vehicles are regulated in some way. Certain vehicles must meet set criteria to be able to drive within the zone. Measures such as retro-fitting emission reducing technology, paying a fee to enter the zone, and eco-driving can be utilised within the zone to reach the Scheme objectives. Vehicles may be banned or in some cases charged if they enter the LEZ when their emissions are over a set level.

1.3.2 Congestion Charging

Traffic restrictions, in terms of congestion charging, aim to, reduce delays/congestion, increase vehicle speeds, promote carpooling and public transport services, and control peak traffic flows.

Various measures such as electronic payments, express ways, and passenger limits can be implemented to reduce congestion. These measures can result in improvements in air quality within the zones.

1.4 Spatial Extent

The review has focused on LEZs in the following areas of the United Kingdom (UK):

- London;
- Norwich;
- Oxford;
- Brighton;
- Nottingham;
- York;
- Bradford; and
- Leeds.

The review also covers international congestion schemes in the following countries:

- United States of America (USA);
- Singapore;
- Sweden;
- Italy; and
- Germany,

A review of available data has been undertaken, and case studies from the above areas sources. These case studies have been selected on the basis of their relevance to traffic emissions resulting from airport expansion in the UK, and their capacity to assist in the understanding of the potential effectiveness of the implementation of a LEZ and/or congestion zone in the vicinity of Heathrow and Gatwick Airports. The case studies reviewed are considered to be the best practice for LEZs and congestion charging.

Further analysis of congestion charging in relation specifically to traffic management is provided in the *Surface Access: Heathrow Airport Demand Management* report (Jacobs, 2015a). This includes a number of additional case studies focus on managing airport traffic and these are not referred to in this assessment. The *Air Quality: Local Assessment - Detailed Emissions Inventory and Dispersion Modelling* (Jacobs. 2015b) report also provides an overview of mitigation measures suggested by the scheme promoters and their relevance to the air quality assessment. This includes some traffic management measures that in principle could be relevant to the application of a LEZ to future airport expansion.

2 Limitations of the Review

There are two main areas of limitation within this LEZ and congestion charging scheme literature review. The first are data limitations relating to the availability of qualitative and quantitative data provided within documents and reports reviewed. The second relates to source limitations regarding the origins of the sources of the information about the case studies.

2.1 Data Limitations

Of the data available, limited quantitative information has been published on the success of LEZ schemes by Local Authorities or other bodies. This, therefore, limits the knowledge about the effectiveness of LEZ schemes in improving air quality concentrations.

Within the UK, London has the most well-documented information providing emission reductions and costs information of the LEZ. Other cities such as Norwich, Brighton, and Nottingham do not provide information on pollution reduction as a result of the LEZs. This limits further analysis on how applicable these LEZ schemes are to Heathrow and Gatwick.

In a number of instances this means that the only available information regarding the effectiveness of a LEZ is on the predictions made at feasibility stage before the relevant LEZ was implemented.

The limited availability of information means that it has been necessary to rely on a wide variety of sources including a large number of web based sources. This has resulted in source limitations.

2.2 Source Limitations

For this report, a variety of primary and secondary sources have been used to compile information about each case study. To provide a comprehensive review of LEZ/CCZ schemes, the report relies on a variety of internet-based sources. Of those the official articles or peer reviewed/academic sources are considered the most robust. Table 2.1 provides information about the sources used.

Table 2.1 Detailed overview of the sources used for this literature review

Source	Type	Basis of Information
Anne, A. (2014) “Case Study: Cleaner, Greener City Sightseeing Buses on the Road in Oxford”. Low Carbon Oxford. [Online]. [Accessed 26th March 2015]. Available from: http://lowcarbonoxford.org/2014/04/14/case-study-cleaner-greener-city-sightseeing-buses-on-the-road-in-oxford/	Website	Unverified website source
AA (2015) Low Emission Zones in Europe. [Online]. [Accessed 15 March 2015]. Available from: http://www.theaa.com/motoring_advice/fuels-and-environment/european-low-emission-zones.html.	Website	AA official website
AEA Energy & Environment. (2007) Stage 1 Report: Feasibility Study on a Low Emission Zone for Oxford. [Online]. [Accessed 26th March 2015]. Available from: http://repairshandbook.oxford.gov.uk/Direct/78443Item5part2.pdf	Report	Official AEA Energy & Environment report
Air Quality News. (2015). “Brighton Low Emission Zone comes into Force”. [Online]. [Accessed 26 March 2015]. Available from: http://www.airqualitynews.com/2015/01/23/brighton-low-emission-zone-comes-into-force/	Website	Official Air Quality News article
Bay Area Toll Authority. (2015). Toll & Traffic. [Online]. [Accessed 30 March 2015]. Available from: http://bata.mtc.ca.gov/index.htm	Website	Official Bay Area Toll Authority Website
BBC. (2013). “Oxford City Centre to become Low Emission Zone on 1 January”. [Online]. [Accessed 26th March 2015]. Available from: http://www.bbc.com/news/uk-england-oxfordshire-25557090	Website	Official BBC article
Beevers S.D, and Carslaw D.C, (2004). The Impact of Congestion Charging on Vehicle Emissions in London. Atmospheric Environment 39(1-50).	Report	Peer-reviewed research report

Source	Type	Basis of Information
Bloodworth, J. (2013). “Ten Years of the Congestion Charge: Fewer Cars, Less Pollution, and a Positive Impact on Business”. [Online]. [Accessed 30 March 2015]. Available from: http://leftfootforward.org/2013/02/ten-years-of-the-congestion-charge/	Website	Unverified website source
Borjesson et al. (2012). The Stockholm Congestion charges – Five Years on. Effects, acceptability, and Lessons Learned. Transport Policy. 20: 1-12.	Journal	Peer-reviewed research report
Brighton & Hove City Council. (2015a). “Brighton & Hove’s Low Emission Zone Starts”. [Online]. [Accessed 26 March 2015]. Available from: http://www.brighton-hove.gov.uk/content/press-release/brighton-hoves-low-emission-zone-starts	Website	Official Brighton & Hove City Council article
Brighton & Hove City Council. (2015b). L”Low Emission Zone”. [Online]. [Accessed 26th March 2015]. Available from: http://www.brighton-hove.gov.uk/content/parking-and-travel/travel-transport-and-road-safety/low-emission-zone	Website	Official Brighton & Hove City Council article
Chicago Parking Meters. (2015). [Online]. [Accessed 31 March 2015]. Available from: http://chicagometers.com/fact-sheet.aspx.	Website	Unverified website source
Christainsen. (2006). Road Pricing in Singapore after 30 years. Cato Journal 26(1): 76-88.	Journal	Peer-reviewed research report
Chudasama, R. (2011). Nottingham Local Transport Plan Strategy 2011 – 2026. [Online]. [Accessed 30 March 2015]. Available from: www.nottinghaminsight.org.uk/d/94332	Report	Official Nottingham City Council report
City of Bradford MDC. (2015). Low Emission Zone Feasibility Study. [Online]. [Accessed 27 March 2015]. Available from: http://councilminutes.bradford.gov.uk/wps/PA_CommitteeMinutes/DisplayDocServlet?docID=13796	Report	Official City of Bradford Metropolitan District Council report

Source	Type	Basis of Information
City of Bradford MDC. (2013). Bradford Low Emission Strategy. [Online]. [Accessed 27 March 2015]. Available from: http://www.iapsc.org.uk/document/0613_S_Jones.pdf	Report	Official Bradford Metropolitan District Council report
City of Bradford MDC. (2013). Bradford MDC Low Emission Strategy. [Online]. [Accessed 27 March 2015]. Available from: http://www.bradford.gov.uk/NR/rdonlyres/C997AE78-0CF7-4160-88DF-95B4B650071D/0/BradfordLowEmissionStrategy2013.pdf	Report	Official Bradford Metropolitan District Council report
City of York Council. (2015). AQAP3 – Executive Summary. [Online]. [Accessed 27 March 2015]. Available from: http://www.york.gov.uk/downloads/200360/air_pollution	Report	Official City of York Council report
City of York Council. (2012). Low Emission Strategy. [Online]. [Accessed 27 March 2015]. Available from: http://www.jorair.co.uk/reports/les/Adopted%20LES%20final.pdf	Report	Official City of York Council report
CIVITAS. (2015) Norwich LEZ. [Online]. [Accessed 26 March 2015]. Available from: http://laqm.defra.gov.uk/documents/Norwich_lez.pdf	Report	Official CIVITAS report
Commune Di Milano. (2015). Area C. [Online]. [Accessed 30 March 2015]. Available from: https://www.comune.milano.it/portale/wps/portal/CDM?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/ContentLibrary/elenco+siti+tematici/elenco+siti+tematici/area+c/english	Website	Unverified website source
Danielis, R., Rotaris, L., Marcucci, E. and Massiani, J. (2011). An economic, environmental and transport evaluation of the Ecopass scheme in Milan: Three years later. SIET Working Papers	Journal	Peer-reviewed research report
Eltis. (2014). Area C in Milan: from Pollution Charge to Congestion Charge. [Online].	Report	Official Eltis website

Source	Type	Basis of Information
[Accessed 30 March 2015]. Available from: http://www.eltis.org/discover/case-studies/area-c-milan-pollution-charge-congestion-charge-italy		
Eminox. (2009). Case Study: Norwich Low Emission Zone. [Online]. [Accessed 26 March 2015]. Available from: http://www.eminox.com/assets/documents-and-downloads/Norwich%20Case%20Study%20LR.pdf	Report	Official Eminox report
Energy Foundation. (2014). International Best Practices of Congestion Charge and Low Emissions Zone. [Online]. [Accessed 09 April 2015]. Available from: http://www.efchina.org/Reports-en/report-20140814-en	Report	Research article
Federal Highway Administration. (2010). "I-35W MnPASS" – I-35W, Minneapolis, MN, HOV to HOT Conversion and Shoulder to HOT Conversion Project. [Online]. [Accessed 31 March 2015]. Available from: http://ops.fhwa.dot.gov/freewaymgmt/publications/documents/nrpc0610/workshop_materials/case_studies/minneapolis_i35.pdf	Report	Officla U.S Department of Transportation report
Florida Department of Transportation. (2013). 95 Express Annual Report: Covering July 1, 2011 through June 30, 2012. [Online]. [Accessed 30 March 2015]. Available from: http://www.sunguide.info/sunguide/index.php/tmc_reports/Report/95X_P1_UPA_Eval_FY_12_Annual_Report__4_19_13__FINAL.pdf/Fiscal%20Year%202011/2012%2095%20Express%20Annual%20Report	Report	Official Florida Department of Transportation report
Florida Department of Transportation. (2015). Project/Construction Update. [Online]. [Accessed 30 March 2015]. Available from: http://www.95express.com/	Website	Official Florida Department of Transportation website
Greater London Authority. (2010). Clearing the Air: Executive Summary – the Mayor's Air Quality Strategy. [Online]. [Accessed 26 March 2015]. Available from: http://www.london.gov.uk/sites/default/files/MAQS%20Executive%20Summary%20FINAL.pdf	Report	Official GLA report

Source	Type	Basis of Information
Greater London Authority. (Undated, a). Low Emission Zone Variation Order to change Phase 3 start date. [Online] [Accessed: 29 April 2008]. Available from: http://www.london.gov.uk/sites/default/files/MD666%20LEZ%20VO%20Phase%203%20(unsigned)%20PDF.pdf	Notice	Official GLA notice (unsigned)
Highways and Transportation Directorate of City Development. (2014). Leeds Low Emission Zone Technical Feasibility Study: Summary Report. [Online]. [Accessed 27 March 2015]. Available form: http://democracy.leeds.gov.uk/documents/s124750/BACKGROUND%20DOCUMENT%20Low%20Emission%20Zone%20Report%20081214.pdf	Report	Official Leeds City Council report.
HJS Technologies. (2014). Low Emission Zone [Online]. [Accessed 02 April 2015] Available from: http://www.londonlowemissionzone.com/hot-to-comply.html.	Website	Unverified website source
Huggoson and Eliasson. (2006). The Stockholm Congestion Charging System- An Overview of the Effects after Six Months. Association for European Transport and Contributors. [Online]. [Accessed 30 March 2015]. Available from: http://web.mit.edu/11.951/oldstuff/albacete/Other_Documents/Europe%20Transport%20Conference/traffic_engineering_an/the_stockholm_cong1720.pdf	Report	Official Association for European Transport and contributors report
IBM. (2011). IBM Global Parking Survey. [Online]. [Accessed 31 March 2015]. Available from: https://www-03.ibm.com/press/us/en/pressrelease/35515.wss.	Website	Official IBM article
Invernizzi *et al*. (2012). The Black Carbon Monitoring Project of ‘Area C’, the New Milan City Centre Traffic Restriction Zone. Agenzia Mobilita Ambiente Territorio	Journal	Peer-reviewed research report
Jacobs. (2015a). Surface Access: Heathrow Airport Demand Management.	Report	Consultants report
Jacobs. (2015b). Air Quality: Local Assessment – Detailed Emissions.	Report	Consultants report

Source	Type	Basis of Information
Jowit, J. (2008). “Q&A: London’s Low Emission Zone (LEZ)”. The Guardian. [Online]. [Accessed 26 March 2015]. Available from: http://www.theguardian.com/environment/2008/feb/04/travelandtransport.carbonemissions	Website	Official The Guardian article
Kary, B. (2015). Urban Partnership Agreement: Success and Lessons Learned.so far. Minnesota Department of Transportation. [Online]. [Accessed 30 March]. Available from: http://www.cts.umn.edu/sites/default/files/files/sessions/11-kary.pdf	Presentation	Unverified website source
Kelly, F. et al. (2011). The London Low Emission Zone Baseline Study. Health Effects Insitute, Boston, MA, Research Report 163	Report	Peer-reviewed research report
Land Transport Authority. (2015). Electronic Road Pricing (ERP). [Online]. [Accessed 30 March 2015]. Available from: http://www.lta.gov.sg/content/ltaweb/en/roads-and-motoring/managing-traffic-and-congestion/electronic-road-pricing-erp.html	Website	Official Land Transport Authority website
Lutz, M. (2009) The low emission zone in berlin – results of a first impact assessment. Workshop on “NOx: Time for Compliance”, Birmingham. [Online] [Accessed: 29 April 2008]. Available from: http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/de/luftreinhalteplan/download/paper_lez_berlin_en.pdf	Website	Official Senate Department for Urban Development and the Environment website
Lutz, M. (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. [Online] [Accessed: 29 April 2008]. Available from: http://www.londonair.org.uk/london/asp/LAQNSeminar/pdf/september2010/Berlin_LEZ_impacts_analysis.pdf	Website	Unverified website source
Lutz, M. (2014) The Low Emission Zone in Berlin: Rationale, Impact and framework conditions. LEZ Workshop Mexico City [Online Presentation] [Accessed: 29 April 2008]. Available from: http://climate.blue/wp-content/uploads/Martin-Lutz_Overview-	Website	Unverified website source

Source	Type	Basis of Information
LEZ-in-Berlin.pdf.		
Mayor of London. (2014). Ultra Low Emission Zone: Update to the London Assembly. Cleaner Air for London. [Online]. [Accessed 01 April 2015]. Available from: https://www.london.gov.uk/sites/default/files/ULEZ%20scrutiny%20briefing%20%E2%80%93%20February%202014.pdf	Report	Official Mayor of London report
Menon and Kian-Keong. (2004). ERP in Singapore – What's been learnt from five years of operation? [Online]. [Accessed 30 March 2015]. Available from: http://www.lta.gov.sg/ltaacademy/doc/ERP%20in%20Singapore%20-%205%20years.pdf	Report	Peer-reviewed research report
Nicholls, P. (2014). Low Emission Zone – Central Brighton. [Online]. [Accessed 26 March 2015]. Available from: http://present.brighton-hove.gov.uk/Published/C00000823/M00004790/AI00036882/$20140106105116_004890_0020833_LowEmissionZoneCentralBrightonSR.doc.pdf	Website	Unverified website source
Norwich City Council. (2011). Report for Information. [Online]. [Accessed 26th March 2015]. Available from: http://www.norwich.gov.uk/CommitteeMeetings/Norwich%20highways%20agency/Document%20Library/60/REPNHAC11AirQualityManagementAreaDeclaration20111124.pdf	Report	Official Norwich City Council report
Nottingham City Council. (2010). SQPS: Statutory Quality Partnership Scheme. [Online]. [Accessed 27 March 2015]. Available from: http://www.nottinghamcity.gov.uk/sqps	Report	Official Nottingham City Council report
Oxford City Council. (2013a). "Oxford Low Emission Zone". [Online]. [Accessed 26th March 2015]. Available from: http://www.oxford.gov.uk/PageRender/decEH/OxfordLowEmissionZone.htm	Report	Official City Council report

Source	Type	Basis of Information
Oxford City Council. (2013b). The Traffic Commissioner for the Western Traffic Area. [Online]. [Accessed 26 March 2015]. Available from: http://www.oxford.gov.uk/Library/Documents/Environmental%20Development/LEZ%20Traffic%20Regulation%20Condition.pdf	Website	Official Oxford City Council article
Oxford City Council. (2013c). Air Quality Action Plan 2013 - 2020. [Online]. [Accessed 26th March 2015]. Available from: http://www.oxford.gov.uk/Library/Documents/Environmental%20Development/Air%20Quality%20Action%20Plan%202013.pdf	Website	Official Oxford City Council article
Oxford City Council (2015). "Air Quality in Oxford Improves as Low Emission Zone Celebrates First Birthday". [Online]. [Accessed 26th March 2015]. Available from: http://www.oxford.gov.uk/PageRender/decN/newsarticle.htm?newsarticle_itemid=56280	Report	Official Oxford City Council report
Paniati, J, F. (2007). US DOT Congestion Initiative Urban Partnership Agreement. I-95 Corridor Coalition EPS Summit. [Online]. [Accessed 30 March 2015]. Available from: http://ops.fhwa.dot.gov/speeches/epssummit07/index.htm	Presentation	Unverified website source
Politics. (2015). "Congestion Charge". [Online]. [Accessed 30 March 2015]. Available from: http://www.politics.co.uk/reference/congestion-charge	Website	Unverified website source
Rauterberg-Wulff, A. (2010) Implementation of the Environmental zone in Berlin [Online Presentation]. [Accessed: 29 April 2008].	Presentation	Unverified website source
Rubstello, P. (2013). SR 520 Tolling: Results and Evaluation. Washington State Department of Transportation, National Congestion Pricing Conference. [Online]. [Accessed 30 March 2015]. Available from: http://www.trb-pricing.org/wp-content/uploads/2013/08/Session-1-Patty-Rubstello.pdf	Presentation	Unverified website source
Senate Department for Health, Environment and Consumer Protection (2008)	Website	Official scheme information.

Source	Type	Basis of Information
Berlin's Environmental Zone: Information for Foreign Tourists [Online leaflet] [Accessed: 29 April 2008]. Available from: http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/umweltzone/en/download.shtml.		
Senate Department for Urban Development and the Environment (2014) Berlin Environmental Zone: Information for vehicle owners [Online leaflet] [Accessed: 29 April 2008]. Available from: http://www.stadtentwicklung.berlin.de/umwelt/luftqualitaet/umweltzone/en/download.shtml.	Website	Official scheme information.
SFCTA. (2013). San Francisco Congestion Management Plan. [Online]. [Accessed 30 March 2015]. Available from: http://www.sfcta.org/documents-and-data/documents/congestion-management-program	Report	Official San Francisco County Transportation Authority Report
SFpark. (2015). About SFpark. [Online]. [Accessed 30 March 2015]. Available from: http://sfpark.org/about-the-project/	Website	Unverified website source
Stanley, M. (2008). Infrastructure Management: The Benefits of Keeping the Horse Before the Cart. Morgan Stanley Infrastructure.	Report	Report
Stokholmforsoket. (2006). [Online]. [Accessed 30 March 2015]. Available from: http://www.stockholmsforsoket.se/templates/page.aspx?id=2431	Website	Unverified website source
TfL. (2015a). Congestion Charge. [Online]. [Accessed 30 March 2015]. Available from: http://www.tfl.gov.uk/modes/driving/congestion-charge	Website	Official TfL website for CCZ
TfL. (2015b). About the LEZ. [Online]. [Accessed 26 March 2015]. Available from: http://www.tfl.gov.uk/modes/driving/low-emission-zone/about-the-lez?intcmp=2263	Website	Official TfL website for LEZ
TfL. (2015c), HGVS, Lorries and Coaches. [Online]. [Accessed 29 April 2015].	Website	Official TfL website for LEZ

Source	Type	Basis of Information
Available from http://www.tfl.gov.uk/modes/driving/low-emission-zone/check-if-your-vehicle-is-affected/hgvs-lorries-buses-and-coaches		
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Transport for London. (2011). Stricter emissions standards for central or inner London: a provisional assessment of potential feasibility and effectiveness [Online] [Accessed: 29 April 2008]. Available from: https://www.london.gov.uk/sites/default/files/Central%20and%20Inner%20London%20LEZ%20Feasibility%20Study.pdf	Website	Official TfL report
Transport for London. (2008). Central London Congestion Charging: Impacts Monitoring. Sixth Annual Report. [Online]. [Accessed 14 March 2015]. Available from: http://www.tfl.gov.uk/cdn/static/cms/documents/central-london-congestion-charging-impacts-monitoring-sixth-annual-report.pdf	Report	Official Mayor of London report
Turnbell, M. (2015). “$10.50 Tolls Fail to Keep I-95 Express Lanes Moving”. Sun Sentinel. [Online]. [Accessed 30 March 2015]. Available from: http://www.sun-sentinel.com/local/broward/fl-95-express-toll-congestion-20150226-story.html	Website	Unverified website source
Turnbull, K. et al. (2013). Minnesota Urban Partnership Agreement: National Evaluation Report. US Department of Transportation. [Online]. [Accessed 30 March 2015]. Available from: http://www.dot.state.mn.us/rtmc/reports/hov/20130419MnUPA_Evaluation_Final_Rpt.pdf	Report	Unverified website source
United States Department of Transport. (2013). Lessons Learned from International Experience in Congestion Charging. [Online]. [Accessed 30 March 2015]. Available from: http://ops.fhwa.dot.gov/publications/fhwahop08047/02summ.htm	Website	Official U.S. Department of Transportation Website

Source	Type	Basis of Information
United States Department of Transportation. (2008). Urban Partnership Agreement and Congestion Reduction Demonstration: National Evaluation Framework. [Online]. [Accessed 31 March 2015]. Available from: http://ntl.bts.gov/lib/30000/30700/30764/14446.pdf	Report	Official U.S. Department of Transportation Report
Urban Access Regulations in Europe (2010) Berlin. [Online] Available from: http://urbanaccessregulations.eu/countries-mainmenu-147/germany-mainmenu-61/berlin. [Accessed: 29 April 2008].	Website	Unverified website source
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Urban Access Report. (2015b). Stockholm – Charging Scheme. [Online]. [Accessed 30 March 2015]. Available from: http://urbanaccessregulations.eu/countries-mainmenu-147/sweden-mainmenu-248/stockholm-charging-scheme	Website	Official European Commission Website
Waguespack et al. (2008). Chicago Metered Parking System Concession Agreement. An Analysis of the Long Term Leasing of the Chicago Parking Meter System. City of Chicago.	Report	Peer-reviewed research report
Washington State Department of Transportation. (2015). SR 520 Bridge Program Toll Financial Statements and Reports. [Online]. [Accessed 30 March 2015]. Available from: http://www.wsdot.wa.gov/Tolling/520/Finance.htm	Report	Official Washington State Department of Transportation Report
Watt, Andy. (2011). CIVITAS Smile: Introduction of a Low Emission Zone in Norwich. Norwich City Council. [Online]. [Accessed 26 March 2015]. Available from: http://www.iapsc.org.uk/document/1211_A_Watt.pdf	Report	Official CIVITAS Report

3 UK Scheme Review

3.1 London, UK

In 2002 the Mayor of London introduced an air quality strategy to reduce pollutants emitted by road traffic within Greater London (Kelly, Frank *et al*, 2011). The strategy set out two air quality goals for the future; the first, to decrease the number of vehicles within Greater London, and the second, to reduce vehicle emissions.

To address these goals, London introduced two schemes as outlined by the Transport for London (TfL) website. In 2003, the Congestion Charge Zone (CCZ) was implemented to reduce vehicle usage and congestion (TfL, 2015a). A LEZ was then introduced in 2008 that limited emissions within central London (TfL, 2015b). To date, it is the largest LEZ in place in the UK.

3.1.1 Emission reducing measures

The primary objective of the London LEZ was to improve the health and quality of life within London, (Kelly, Frank *et al*, 2011). TfL states that as of 2015, the LEZ restricts the most polluting, diesel-powered vehicles such as private cars, lorries, buses, coaches, vans, and minibuses, (TfL, 2015b). The implementation and improvements of the LEZ have been undertaken in Phases as outlined by a 2011 TfL report:

Phase 1 (February 2008):

- Vehicles must have met Euro III standards for Particulate Matter;
- Included vehicles over 12 tonnes (gvw); and
- Examples included HGVs and specialist vehicles (TfL. 2011).

Phase 2 (July 2008):

- Vehicles must have met Euro III standards for Particulate Matter;
- Included vehicles such as HGVs (over 3.5 tonnes (gvw); and
- Buses and coaches over 5 tonnes (gvw) with more than 8 passenger seats) (TfL. 2011).

Phase 3 (2010):

This was proposed and then delayed because of concerns over economic difficulties faced by small businesses. The phase would have seen an extension to phases 1 and 2 and applied to larger vans and minibuses (Greater London Authority, Undated(a).

Phase 4 (2012) – current: (TfL. 2015b, c and d)

- Diesel vehicles registered as new before 1 October 2006, (excluding 'early adopters') and of more than 3.5 tonnes gross vehicle weight. These must meet the Euro IV standards for Particulate Matter and include:
    - Lorries;
    - Motor caravans;
    - Breakdown and recovery vehicles;

  - Refuse collection vehicles;
  - Road sweepers;
  - Concrete mixers; and
  - Fire engines.
- Diesel vehicles registered as new before 1 October 2006, (excluding ‘early adopters’) and of more than 5 tonnes gross vehicle weight. These must meet the Euro IV standards for Particulate Matter and include:
  - Buses
  - Coaches (with 8+ passenger seats)
- Vehicles registered as new before 1 January 2002, (excluding ‘early adopters’) and of between 1.205 tonnes unladen and 3.5 tonnes gross vehicle weight. These must meet the Euro III standards for Particulate Matter:
  - Larger vans
  - Motorised horseboxes
  - 4x4 light utility vehicles
  - Pick-ups
  - Other specialist vehicles
- Vehicles registered as new before 1 January 2002, (excluding ‘early adopters’) which are between 2.5 - 3.5 tonnes gross vehicle weight. These must meet the Euro III standards for Particulate Matter and include:
  - Motor caravans
  - Ambulances
- Vehicles registered as new before 1 January 2002, (excluding ‘early adopters’) and of 5 tonnes or less gross vehicle weight. These must meet the Euro III standards for Particulate Matter and include:
  - Minibuses (with 8+ passenger seats).

Phase 5 (Proposed)

In February 2013, it was announced that Phase 5 of the LEZ (from 2015) would only apply to buses (TfL, 2015b). Previously, it was proposed that all buses, coaches and heavy goods vehicles (HGVs) would need to meet a London-wide standard for emissions of nitrogen oxides (NO_x). TfL have identified that applying this standard only to buses will still deliver 75% of the benefits of the original proposal and save £350 million in avoided clean-up costs (TfL, 2015b).

Subject to the implementation of a national certification and testing scheme for NO_x abatement equipment by the national government, and the Mayor’s confirmation following public consultation of a variation to the LEZ Scheme Order, TfL plans to introduce into the scheme a NO_x emissions standard for HGVs, buses and coaches (Euro IV for NO_x emissions) in 2015.

There are no current plans to further tighten the emissions standards. However, the Mayor’s Transport Strategy (MTS) proposes that the Mayor will consider the tightening of standards beyond 2015, zones with tighter standards and/or the inclusion of other vehicles in order to meet outstanding air quality issues (Tfl, 2011)

Implementation

Compliance with the LEZ has been monitored using cameras which record vehicle registration numbers. To avoid penalty fees (£100-£200 per day), vehicles must achieve Euro emission standards which become more stringent over time (Kelly, Frank *et al*, 2011 and TFL, 2015b). The standards can be achieved by:

- Converting to gas;
- Fitting an approved exhaust filter; and / or
- Replacing the vehicle with one that meets standards or is electric.

On average, 96% of vehicles entering the LEZ are compliant with the regulations according to the 2008 Sixth Annual Report by TfL (TfL, 2008).

Central London is now considered compliant for all European Union (EU) air pollutant legal limits except for nitrogen dioxide (NO_2) and particulate matter (PM_{10}), (TfL, 2015b).

3.1.2 Ultra Low Emission Zone (ULEZ)

Central London is currently considering an Ultra Low Emission Zone (ULEZ). The consultation period for the ULEZ closed on 9th January 2015, and included over 16,000 responses, (TfL, 2015b). Following a public consultation, the Mayor has confirmed the introduction of the Ultra Low Emission Zone (ULEZ) in the Capital on 7 September 2020.

Should the ULEZ proposal be taken forward, according to a 2014 report by the Mayor of London, it will aim to further reduce air pollutant emissions, and stimulate the low emission vehicle market (Mayor of London, 2014). The next steps in the process would be, (2015b):

- 2015: Legal order and policies confirmed;
- 2015-2020: An information campaign would take place to help ensure that drivers and operators are aware of the ULEZ standards and understand their options before they are enforced from 2020;
- Number of hybrid and zero emission buses in the ULEZ increase;
- 2018: All newly licensed taxis and new PHVs would be required to be zero emission capable;
- September 2020: Reduction in the age limit for all non-zero emission capable taxis from 15 to 10 years (irrespective of date of licensing);
- September 2020: ULEZ standards are introduced and all double-deck buses and hybrid / single-deck buses to have zero emissions; and
- September 2023: Residents' discount expires.

3.1.3 Congestion reducing measures

The 2014 Mayor of London report affirms that the objective of the CCZ is to reduce congestion within central London, promote public transportation use, whilst collect revenue to improve public transportation services, (Mayor of London, 2014).

London's CCZ complements the LEZ restrictions by limiting the number of vehicles within the zone. All vehicles driving within central London are obligated to pay the daily levy except for disabled drivers, residents living within the CCZ, emergency services, taxis, and alternative fuel vehicles (Politics, 2015). The charge (£11.50) applies to weekdays only, between 07:00 and 18:00, (Mayor of London, 2014).

3.1.4 Overall success of LEZ strategy

The 2010 Mayor's Air Quality Strategy states that London's air quality has improved significantly in recent years and with Phase 5, London will apply more stringent regulations to reduce NO_2 and PM_{10} concentrations to meet acceptable EU limits (Greater London Authority, 2010).

The LEZ strategy, was predicted by the Mayor's Air Quality Strategy to reduce PM_{10} emissions from 135 tonnes in 2008 to 93 tonnes in 2015. NO_X emissions in 2008 were 50,500 tonnes, and these were predicted to have been reduced to 30,500 tonnes in 2015 as a result of the LEZ strategy. NO_X converts to NO_2 in the atmosphere; hence, a reduction in NO_X contributes to a reduction in NO_2.

TfL have begun retrofitting 900 older Euro III buses with Selective Catalyst Reduction (SCR) systems to reduce their NO_2 emissions. Another 900 were replaced with the newest, ultra-low-emission Euro VI buses. However, the Strategy noted that Euro IV and V vehicles emit more NO_2 in urban environments than estimated. Over the next four years, TfL will introduce 600 hybrid New Routemasters in an attempt to reduce CO_2 emissions in central London by around 20,600 tonnes a year, (TfL, 2015a).

3.1.5 Overall success of congestion strategy

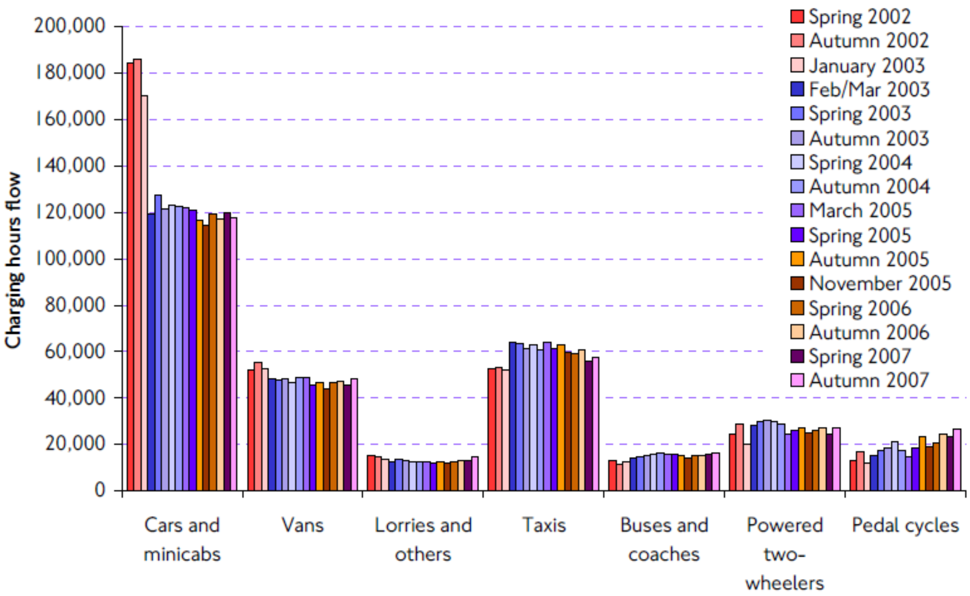
The London congestion charge has been beneficial in terms of transportation and environmental impacts, according to a number of sources such as TfL's own reports and the Bloodworth's report, (TfL, 2008 and Bloodworth, 2013).

Official monitoring reports on the congestion charge are no longer published by the Mayor. The most recent report dates to 2008 (for the 2007 year) and provided the following conclusions, (TfL, 2008):

- Annualised results for 2007 compared with pre charging conditions in 2002 reveal reductions of 16 percent in total vehicles entering the congestion zone
- 21 percent reduction in vehicles with four or more wheels;
- 29 percent reduction in potentially-chargeable vehicles;
- The biggest reduction in cars and minicabs occurred in the first couple of years of the scheme;
- Traffic has been relatively stable across most vehicle types in all post charging years; and
- Some modes of transport such as buses and cycling have seen an increase in this same period.

This is evidenced in Figure 3.1, repeated from the 2008 Sixth Annual Report by TfL (TfL, 2008).

Figure 3.1 Traffic entering the central London charging zone (across all inbound roads). Charging hours, 07:00-18:00, 2002 to 2007.



Additional conclusions from this study report include, (TfL, 2008):

- The effect of the change of charging hours is also evident in terms of a clear shift in traffic entering the zone during the 18:00-18:30 period;
- The majority of the reduction in traffic entering the central London charging zone has decreased more significantly in the inter-peak hours between peak AM and PM periods;
- The level of traffic entering the zone during the morning peak had not reduced as much as at other times; and
- There are further nuances when looking in more detail at effects such as radial roads, intra-zone traffic, traffic on selected roads, etc.

In the first year of the charge, the number of non-exempt vehicles dropped by 30%. Moreover, a 2004 case study by Beevers and Carslaw found that NO_X levels dropped by 13.4% after the first year, and PM10 and CO_2 also decreased by 11.9% and 19.5% respectively (Beevers and Carslaw, 2004).

Overall, these conclusions are substantiated by other reports such as that by the Energy Foundation in 2014, which stated that traffic within the CCZ has steadily decreased between 2002 and 2011 (Energy Foundation, 2014).

The Energy Foundation (2014) report refers to research published in 2005, using 2002/2003 data, which identified that with the CCZ in place, average traffic speed has increased which led to further reductions in emissions in the order of 8%.

However, Bloodworth’s (2013) report finds that though traffic volume has declined, evidence suggests that since the introduction of the CCZ, congestion within the zone has actually increased. Three reasons have contributed to the increase in congestion (Beever and Carslaw, 2004). First, retiming of traffic signals within the zone reallocated ‘green’ time from vehicles to pedestrians. Second, modal shift projects aimed at encouraging sustainable modes of transport, have reduced highway capacity. Third, large scale utility works by several London companies have restricted street access within the zone.

The CCZ scheme has raised over £1 billion since its implementation, with a yearly (2012-2013) total net revenue of £181 million (Bloodworth, 2013). The money has been invested towards bus network improvements, roads and bridges, road safety, walking and cycling, and funding borough transport plans.

3.2 Norwich, UK

Norfolk County Council and Norwich City Council jointly created the Norwich Low Emission Zone in July 2008 according to Eminox (2009). The LEZ strategy aimed for 70% of city buses to meet specified NO_X emission levels that comply with the Euro III emission standards.

Norwich has used a mixture of soft measures aimed at changing attitudes and behaviours, and hard measures, which are legally required. A Norwich LEZ summary by CIVITAS states that a Traffic Regulation Condition (TRC) has been introduced as the main tool to meet the emission standards (CIVITAS 2015). The LEZ is also utilising a Traffic Regulation Order (TRO) and eco-driving.

3.2.1 Emission reducing measures

Watt (2011) explains that the TRC, a hard measure, aims to reduce NO_2 and PM_{10} emissions to Euro III standards. Buses manufactured after 2001 already meet this standard, however, older buses will be fitted with SCR equipment (which can reduce NOX can be reduced by up to 64%) to control exhaust emissions. with the SCR.

Norfolk County Council offers grants of up to 65% to retro-fit buses (Eminox, 2009). As part of the retro-fitting, Exhaust Gas Recirculation (EGR) technology has been introduced, this recirculates exhaust emissions back through the engine. The EGR is capable of reducing NO_X emissions by 40-50%.

The TRO, a soft measure, aims to encourage bus drivers to switch off engines when stationary for a prolonged period of time (CIVITAS 2015), and applies to any vehicle except for when passengers are boarding.

Norfolk County Council offers training sessions on eco-driving to promote driving habits that reduce fuel consumption and vehicle emissions (CIVITAS 2015). Eco-driving is expected to reduce fuel consumption by 16%, lead to associated cost savings, reduce air and noise pollution, as well as maintenance costs (Watt, 2011).

3.2.2 Overall success of LEZ strategy

There are no sources available that specify whether emissions have reduced as a result of the LEZ strategy. A Norwich City Council report (2011) states that the LEZ shows encouraging results, and that it is considered within best practice for transport planning and air quality management.

3.3 Oxford, UK

In 2013, Oxford was awarded £6 million by the DfT's Clean Bus Technology fund to progress its LEZ initiative (Anne, 2014). The City Council introduced a similar approach to the Norwich LEZ by introducing a TRC on 1st January 2014 (BBC, 2013). The LEZ only applies to buses, which according to the Energy Foundation report accounts for up to 80% of air pollution in the Oxford city centre (Anne, 2014). The Oxford City Council affirmed in 2013 that all buses must meet Euro V emission standards for NO_X and PM_{10} (Oxford City Council, 2013a).

3.3.1 Emission reducing measures

The Oxford LEZ states that buses not meeting the engine requirements of the Euro V standard must be retro-fitted to control emissions (Oxford City Council, 2013b). Exhaust treatment devices may also be attached to reduce NO_X. Temporary exemptions (until June 2016) have been established for engines that meet Euro IV requirements.

The Oxford LEZ also requires all buses to turn their engines off when expected to stay stationary for more than 60 seconds. Unlike Norwich, this condition also applies when passengers are boarding.

3.3.2 Overall success of LEZ strategy

Preliminary results from the first year of Oxford's initiative show that NO_2 emissions did not exceed the short-term hourly target threshold of 200µg/m^3 in St Aldate's at any point in 2014 (Oxford City Council, 2015). St Aldate's is one of a number of NO_2 emission hotspots across the city due to congestion and the high volume of buses.

In comparison, before the LEZ was introduced, this target was exceeded 58 times (2012). This reduced to 12 instances during 2013, as local bus companies introduced their lower emission vehicles in time for the new legislation.

The City Council's 2013 Air Quality Action Plan sets out further actions to tackle air pollution in Oxford up to 2020, and looks to build upon the bus LEZ, including options for a freight scheme to reduce emissions from light and heavy goods vehicles (Oxford City Council, 2013c).

Though no recent information is available on emission reductions as a result of the LEZ, a 2007 feasibility study of the Oxford LEZ provided estimates of the expected reductions (AEA Energy & Environment, 2007). By 2025, NO_X and PM_{10} are expected to be reduced by 110 (11%) and 1.9 (7%) tonnes, respectively, in the city centre.

3.4 Brighton, UK

On 1 January 2015, Brighton introduced a LEZ in the city centre aimed at reducing NO_2 emissions (Brighton & Hove City Council, 2015a). The LEZ only applies to buses (Brighton & Hove City Council, 2015b), as 98% of bus movements pass through the zone. As a result, several bus companies operating within the LEZ have invested in retro-fitting and purchasing buses to meet Euro V and VI standards.

3.4.1 Emission reducing measures

An Air Quality News (2015) article detailed that bus operators had five years to update their buses by retro-fitting current buses in use and/or purchasing new buses that meet the emission standards. Buses that idle for more than 60 seconds are required to turn off engines. An exemption to this is when passenger comfort (i.e. air conditioning or heating) would be compromised during adverse weather.

A Council report by Nicholls (2014) specifies that soft measures include eco-driver training and the use of mobile phone apps and online ticketing to reduce passenger boarding times. Furthermore, taxis within the zone have volunteered to participate in the engine idling policy.

HGVs and private vehicles have also been considered as part of the scheme (Nicholls, 2014). However, it was determined that most HGVs are already compliant and that private vehicles are already heavily restricted within the zone through other measures.

The financial implications of this scheme are covered by the existing transport revenue budgets (Nicholls, 2014). Operational costs are mostly made-up of additional transport officer time, which is funded by existing revenue budgets. The scheme also reduced the chances of EU/UK non-compliance fees regarding air quality standards.

3.4.2 Overall success of LEZ strategy

There is no quantitative data available regarding the costs of running the scheme and the expected emission reductions, due to how recently the LEZ strategy has been implemented.

3.5 Nottingham, UK

The city of Nottingham has implemented the Statutory Quality Partnership Scheme (SQPS) which began in May 2010 (Passenger Focus, 2010). This scheme combines emission and congestion reductions into one strategy.

Nottingham has the second highest bus to person ratio in the UK, according to the Nottingham City Council 2010 SQPS document, which greatly attributes to congestion, emissions, delays, and space. SQPS aims to improve the quality of local services operating in the scheme area (Nottingham City Council, 2010). The City Council is satisfied that the provision of the facilities and the provision of local services to the required standard will achieve this aim.

The SQPS objectives are to:

- Increase bus ridership to achieve sustainability objectives;
- Provide additional bus infrastructure;
- Improve transport information communication to customers;
- Improve the range of bus routes;
- Reduce pressure on congested streets and bus stops;
- Achieve better environmental conditions and improve pedestrian and cycling amenities on bus priority streets; and
- Maximize bus capacity, whilst maintaining high environmental standards.

3.5.1 Emission reducing measures

Local services operating within the scheme area must meet Euro III standards or higher (Nottingham City Council, 2010). Bus operators are subject to fines if they do not meet the minimum standards after 1st April 2013. This builds upon the 'Clear Zone Area' that was put in place in 2004.

3.5.2 Congestion reducing measures

The SQPS has introduced a number of measures to reduce congestion within the scheme area, (Nottingham City Council, 2010 and Chudasama, 2011):

- New bus lanes have been introduced on key congestion routes to give priority to public transit and cyclists.
- Several streets have been closed to certain vehicle types, other than buses, cycles, and wheelchair accessible carriages, to reduce the number of through vehicles.
- Bus Stand Clearways are allowed a maximum of 10 minutes for stopping and Bus Stop Clearways have a maximum of 2 minutes.
- Bus shelters are being improved with timetables and route planners based on local services.
- Bus shelters within the scheme area will also be upgraded with real-time electronic displays to broadcast schedule information.

3.5.3 Overall success of strategy

There is no quantitative data available on the effectiveness of the scheme. However, in a report on the Local Transport Plan Strategy it is mentioned that the SQPS is under continuous improvement to further improve on the reliability and punctuality of buses, (Chudasama, 2011).

3.6 Elsewhere in the UK

While London considers the adoption of an ULEZ, other UK cities are considering the feasibility of LEZs, including Bradford, York and Leeds, who are currently carrying out LEZ feasibility studies.

3.6.1 York

Following local air quality assessments and research, the City of York Council is targeting emissions from HGVs, buses, coaches and idling diesel cars as stated in a 2015 executive summary (City of York Council, 2015). The City's Air Quality Action Plan is currently undergoing public consultation. The Plan requires the development and implementation of a Clean Air Zone (CAZ) by 2021 (City of York Council, 2015).

3.6.2 Bradford

The Bradford LEZ feasibility study (2013) was submitted to the Council's Executive in November 2014. The report concluded that:

- There are substantial health burden related to the emissions from vehicles in the Bradford District;
- Health burden is born disproportionately by the most deprived in Bradford and contributes to health inequalities;
- Passenger cars, in particular, the proportion of diesel cars, are the most significant contributor to elevated levels of NO_X within the Bradford outer ring road;
- Within the inner ring road buses are the most significant single contributor of NO_X; and
- From the vehicle km driven by each vehicle type buses and HGVs provide a disproportionate contribution to NO_2 concentrations.

A report produced following a meeting of the Council's Executive (City of Bradford MDC, 2015), recommended that further work was required following the study conclusions. It suggested the development of policies that would deliver improved air quality and health improvements through reductions in the following areas:

- Bus emissions;
- HGV emissions;
- Proportion of diesel cars within the Districts passenger car fleet, including the taxi fleet within the District; and
- Overall number of passenger vehicles by increasing levels of active travel and public transport uptake.

3.6.3 Leeds

According to the Highways and Transportation Directorate of City Development (2014) summary report, the Leeds LEZ feasibility study has carried out baseline studies of emissions and pollutant concentrations to assess a variety of LEZ scenarios.

The LEZ modelling showed:

- A reduction in PM_{10} and NO_X emissions with minimal impact on CO_2.
- The predicted NO_X emission reductions range from 5.8 to 235.1 tonnes, depending on the scenario.
- Abatement costs avoided for the different LEZ models ranges from £163,353 to £25,625,858 from 2016 to 2021.

Leeds will need to invest further funding to implement the LEZ, to replace and retro-fit vehicles, as well as provide enforcement.

The Leeds feasibility study (Highways and Transportation Directorate of City Development, 2014) concluded that:

- Passenger cars, in particular the proportion of diesel cars, are the most significant contributor of particulates and elevated levels of NO_2 within the Leeds Outer Ring Road.
- Buses and cars are the most significant contributors within the Inner Ring Road area.
- Buses and HGVs provide a disproportionately higher contribution to NO_2 concentrations than their VKM driven. These observations also correlate with emissions of fine particulates ($PM_{2.5}$).
- Total NO_X emissions from LGVs are marginally less than HGVs, however, total emissions of both primary NO_2 and $PM_{2.5}$ are greater than for HGVs.

Furthermore, the study concluded that no single intervention can deliver compliance with the air quality objectives; therefore, it is necessary to use a combination of measures to reduce emissions (Highways and Transportation Directorate of City Development, 2014). PM_{10} values do not breach EU limits within the city of Leeds.

4 International Scheme Review

4.1 San Francisco, USA

The San Francisco Municipal Transport Authority (SFMTA), together with the San Francisco Country Transportation Authority (SFCTA), have taken an innovative approach to tackling problems relating to traffic congestion and poor air quality standards. Consequently, San Francisco is often championed as a world leader when it comes to sustainable transport.

The city has schemes that use financial incentives, or deterrents, in an attempt to affect drivers' behaviour. As part of the US Department of Transportation (DOT) Congestion Initiative Urban Partnership, San Francisco has introduced an innovative parking plan and congestion pricing within certain areas of the city.

4.1.1 Emission and congestion reducing measures

The 'SFpark' scheme uses an online parking information map for drivers to quickly find open spaces, (SFpark, 2015). To help achieve the right level of parking availability, SFpark periodically adjusts meter and garage pricing to match demand. Demand-responsive pricing encourages drivers to park in underused areas and garages, reducing demand in overused areas.

The scheme was piloted in 2014, followed by a Pilot Evaluation. The evaluation found that greenhouse gas emissions decreased, vehicle miles travelled decreased, and congestion was reduced. It would appear that the main reason for these benefits was down to a decrease in the number of drivers circling and double-parking (SFpark, 2015).

SFpark (2015) also claims that the scheme has created safer streets, by reducing distracted drivers (looking for parking), which in turn protected cyclists and pedestrians. Less double-parking also means that roads are kept clear and emergency vehicles can pass through faster and more reliably.

SFMTA's main focus is to encourage the use of public transport while reducing the emissions from the city's municipal vehicles (SFpark, 2015). The city has achieved a reduction in emissions from its railway and bus fleets, heavy duty vehicles, taxis and fire trucks, as a result of a change to low emission vehicles implemented by a Mayoral directive. This set minimum quotas of alternative energy vehicles.

The SFMTA also work with land-use agencies on schemes to shape travel demand and reduce emissions (SFpark, 2015). The schemes often aim to minimise the need for individuals to use cars by minimising distances between jobs, homes and services and improve the viability of high quality transit, bicycle and walking opportunities.

The SFCTA is the designated Congestion Management Agency (CMA) for San Francisco. It is obligated to produce a Congestion Management Program (CMP) for the city. The 2013 SFCTA CMP details the 2010 initiative of introducing a congestion management plan and pricing for the core congested areas within the city (SFCTA, 2013).

Elements of the plan include:

- Private vehicles entering the Northeast Cordon area are legally obligated to pay $2.50 - $6.00, depending on the vehicle type, number of passengers and entry time;
- The peak-hours are weekdays 05:00-10:00, and 15:00-19:00 at weekends.
- It was predicted that the congestion toll would reduce peak-hour vehicle trips by 12%, congestion delays by 30%, greenhouse gas emission by 16%, and $PM_{2.5}$ pollutants by 17%; and
- It is predicted that the annual social benefit will be around $350million with net annual revenue of $60-$80million.

4.1.2 Overall success of LEZ strategy

The estimated financial saving of setting minimum quotas of alternative energy vehicles in municipal fleets was over $150,000/year in fuel and maintenance costs in 2014. The LEZ measures adopted in San Francisco have allowed for a reduction in overall greenhouse gas emissions associated with the city. In 2010 a 12% drop was recorded against 1990 levels, from 6.2million tCO_2 to 5.6million tCO_2.

There is no quantitative data available on air quality impacts as a result of the SFpark scheme.

As previously stated, the SFpark scheme has been a success, with the Pilot Evaluation declaring numerous environmental, economic and social benefits. Consequently, the SFMTA are proposing to expand the scheme across the City. It should be noted that local enthusiasm for these measures tends to be higher here than in other cities. Local investment in emissions reduction is also high.

4.1.3 Overall success of congestion strategy

A congestion charge has been implemented on Oakland Bay Bridge, within the congestion charging area, which led to 44,036,844 toll paying vehicles in 2013 to 2014 according to the Bay Area Toll Authority (2015) data. The total toll revenue was $232,240,275.

The data showed that in the first 6 months of the congestion tolls, commute delays dropped by 15%. Due to the success of the congestion charge, SFCTA is planning to expand the congestion zone following the end of the 2015 trial period.

4.2 Seattle, USA

In the Seattle area, the Lake Washington CMP was granted $154.5 million, as reported by Rubstello (2013), as part of the US DOT Urban Partnership, to improve congestion on the State Route (SR) 520 corridor. The report details that de-congestion measures have included:

- Variable tolling on the SR 520 bridge;
- Electronic travel time signs on I-405, SR 520 and SR 522 direct drivers to the best route across Lake Washington;
- Smarter Highways on SR 520 and I-90 provided drivers with variable speed limits and real-time driver information;
- King County Metro and Sound Transit added 140 daily bus trips across the SR 520 bridge; and
- Van-pool and car-pool programs to encourage people to commute together.

The Washington State Department of Transportation (DOT) (2015) has reported that the SR 520 tolling has been implemented to reduce congestion, and raise money for a new bridge. The toll began in December 2011. SR 520 is a collaborative effort between the Washington State (DOT), King County, the Puget Sound Regional Council, and the Federal Highway Administration to reduce congestion and to raise money for a new bridge. The bridge toll began on December 2011.

4.2.1 Congestion reducing measures

The SR 520 toll rates apply to all motor vehicles, except registered vanpools and emergency response vehicles during an emergency situation, (Washington State Department of Transportation, 2015).

Weekday rates between 05:00-23:00 vary from $1.75 to $5.40 depending on time of day and method of payment. Weekend rates between 05:00-23:00 vary from $1.20 to $4.00. Between the hours of 23:00-05:00 there is no charge.

In total, the SR 520 toll is expected to raise $1.2 billion towards a new floating bridge.

The Washington State DOT (2015) conveyed key messages about the SR 520 bridge toll to the public to ease the transition. Firstly, the toll is fully electronic to make payments easier and to keep traffic moving. Secondly, proceeds will also go towards building a new bridge to further reduce congestion. Thirdly, using an electronic ‘GOOD TO GO!’ pass saves drivers money compared to the ‘pay by mail’ option.

The toll aims to make congestion shorter and lighter during peak-hours, make trips more reliable, and use toll revenue to pay back bonds for SR 520 projects (Washington State Department of Transportation, 2015).

4.2.2 Overall success of congestion strategy

Between 2010 and 2013, the Washington State DOT (2015) reports that the use of public transport increased by 34%, and region-wide usage increased by 5%.

The SR 520 toll influenced 30% of bus users to rely more on bus transportation, while 19% of current bus users began taking using public transport after the toll was introduced. There were also an additional 140 daily bus trips to encourage public transport use. 76% of the SR 520 bridge users remained unaffected, 8% changed their driving route to avoid the toll, 3% changed to public transport, 6% changed their time of driving, 1% began to carpool, and 5% changed their destination.

The Washington State DOT (2015) further reports that for the 2014 fiscal year, there were a total of 20,959,574 toll transactions, 84% using the GOOD TO GO! pass and 16% pay by mail. The net revenue was $50,931,202.

The available data suggests that although congestion and vehicle reductions are linked to lower traffic emissions, the SR 520 toll has had a minimal effect on air quality.

4.3 Miami/Fort Lauderdale, USA

The Interstate 95 (I-95) corridor between Miami and Ft. Lauderdale was granted expansion under the Urban Partnership, according to a US DOT document, to create 21 miles of high-occupancy toll lanes, to raise high-occupancy vehicles limit from 2 to 3+ passengers, and to expand from 10 lanes to 12 lanes (Paniati, 2007).The additional two lanes will serve as expressways, 95 Express, that extend between Miami-Dade and Broward Counties (Florida Department of Transportation, 2015). The project will cost approximately $112million.

Since 2008, there had been a 7 mile expressway within Miami-Dade County only; however, due to congestion between Ft. Lauderdale and Miami, the expressway will be expanded. The 95 Express lanes are subject to tolls.

4.3.1 Congestion reducing measures

As explained in the Florida DOT (2015) project update, the 95 Express lanes are separated from general I-95 traffic lanes (which are free of charge), and the toll is electronically collected via the SunPass. Toll rates are dependent on congestion, and fluctuate depending on how many vehicles enter the lanes at a time. Overhead electronic sign display up-to-date toll rates. Rates vary from $0.50 to $10.50.

Vehicles exempt from the congestion rates are registered carpools with 3+ passengers, registered hybrid vehicles, Miami-Dade/Broward County transit, registered South Florida vanpools, motorcycles, emergency vehicles, and registered over-the-road motor coach vehicles (Florida Department of Transportation, 2015).

4.3.2 Overall success of congestion strategy

The 2013 Florida DOT (2013) annual report specifies that the 95 Express project has been considered successful as average speeds have increased during peak hours (06:00-09:00 and 16:00-19:00). Speeds have increased from 20 mph (prior to express lanes) to 63mph (southbound) and 56mph (northbound).

As a result of traffic shifting to the express lanes, the general lanes have also experienced increased speeds from 15mph (southbound) and 20mph (northbound) to 50mph and 42mph, respectively. The express lanes have also improved travel time reliability during peak-hours, with 33% total peak-time traffic using the express lanes (Turnbell, 2015).

The average monthly maximum toll rate for southbound was $5.50 and for northbound $6.50.During 2012, the express lanes have serviced 20.4 million vehicle trips, with total revenue of $16.8million (Turnbell, 2015).

Public transport usage has also increased compared to pre-95 Express (Turnbell, 2015). In 2008, the average amount of people boarding daily was 1,746, while in 2012, this had increased to 4,718.

However, at the time of this report, there is no quantitative data available on associated emission reductions.

Recently, as published by Turnbell (2015), 95 Express has experienced increased congestion within the express lanes as driver demand has increased. This is partly due to drivers disregarding the lane closure signs, which results in traffic jams. There are no physical means of closing off the express lanes. Another reason for congestion is that the maximum toll rate of $10.50 no longer deters as many drivers. To resolve the problem, officials are currently investigating the feasibility of installing gates and increasing the maximum toll to $14.00.

4.4 Minnesota, USA

A Minnesota DOT document by Kary (2015) reports, that the Minnesota Urban Partnership programme was granted $133 million in federal funds with a further $50.2 million in state funds to implement 24 projects that addressed congestion, transit, telecommuting, and technology. The major program focus was to reduce congestion on Interstate 35W (I-35W), which affects traffic on Highway 77 and downtown Minneapolis, with a designated project budget of $65.7 million.

The Minnesota Urban Partnership projects included intelligent transportation systems (ITS), similar to the 95 Express in Florida, to manage tolling, and real-time traffic and transit information, according to Turnbull et al (2013). Furthermore, projects also included high-occupancy toll (HOT) lanes and park-and-ride schemes.

The overall objective of the I-35W project was to create a congestion free express lane from Brunsville Parkway to downtown Minneapolis and commuter choices to avoid congestion (Federal Highway Administration, 2010).

4.4.1 Congestion reducing measures

The I-35W project was split into three segments (Federal Highway Administration, 2010);

- The first segment (9 miles) consisted of converting the existing high-occupancy vehicle (HOV) lane into a widened and extended HOT lane.
- The second segment (4 miles) required the construction of a HOT lane.
- The third segment (3 miles) involved the construction of a priced dynamic shoulder lane (PDSL).

During periods of high congestion, solitary drivers now have the option to use the new lanes reserved for buses, motorcycles, and car-poolers during high-traffic periods, for a fee (Turnbull et al, 2013). All three segments make use of the electronic MnPass to pay toll fees. Similar to 95 Express, the tolls are based on dynamic pricing that is dependent on the amount of vehicles within the lanes. MnPass operating hours vary with direction and segment (Turnbull et al, 2013). Morning peak-hours are 06:00-10:00 and afternoon peak-hours are 14:00-19:00.

To further reduce congestion, 174 intelligent lane control signals were installed to harmonise speed and inform drivers of any incidents (Turnbull et al, 2013).

According to the Federal Highway Administration (2010), operational MnPass costs for I-35W and I-394 are approximately $2 million per year. The revenue for I-35W is approximately $1 million per year, however, in combination with I-394 revenue the total revenue ranges from $2 - $4 million per year.

4.4.2 Overall success of congestion strategy

The 2013 evaluation report claims that since the introduction of the HOT lanes, MnPass users have increased, resulting in a steady growth in the use of the HOT lanes (Federal Highway Administration, 2010). Monthly MnPass revenue in October

2009 was $19,609, which increased to $94,619 in November 2011. The 2011 breakdown of vehicle HOT lane usage is:

- 48% vanpools/carpools;
- 38% MnPass drivers;
- 2% buses; and
- 5% toll violators/single-occupant vehicles.

Compared to 2008 statistics, vanpool/carpool usage has declined from 83% to 48%, leading to an increase in MnPass usage. Toll violators have also declined from 15% to 5%.

Public transport services have increased with the implementation of park-and-ride throughout Minneapolis (Federal Highway Administration, 2010). Bus speeds have also increased, improving transport times and reliability.

Overall, the Urban Partnership Agreement projects have helped reduce congestion levels, though it is not possible to evaluate the influence of each project, individually (Federal Highway Administration, 2010). Certain segments have seen a positive impact on air quality; however, other sections are inconclusive. Net social costs and benefits are estimated to be around $422,701,558.

4.5 Chicago, USA

In December 2008, Chicago City Council approved a 75 year concession agreement to lease the city’s metered parking system to Chicago Parking Meters LLC. The concession agreement was for a one off payment of $1.157 billion to the city, and under the agreement, the concessionaire is entitled to all revenue from the parking meters for the term of the contract. The concessionaire is also responsible for upgrading and maintaining the system.

Waguespack’s (2008) report about the metered parking system states that the City and City Council maintain their rights to revise parking meter fares, collect and retain enforcement revenue, choose location and operating hours of the meters, and add additional or remove existing on-street parking spaces. The concessionaire’s investment is protected in the contract, and the City is financially responsible for any loss in revenue.

4.5.1 Congestion reducing measures

The US DOT Urban Partnership Agreement (2008) report asserts that projects under the Agreement aimed to reduce congestion consist of the following:

- Dedicated Bus Rapid Transit (BRT) service along four downtown corridors;
- Pay-for-use charges in the City of Chicago’s on-street loading zones, with prices varying by time of day or level of demand;
- Peak period surcharge on off-street non-residential parking; and
- A system for variably pricing downtown on-street metered parking.

The parking meter system is comprised of approximately 36,000 metered parking spaces served by 4,700 automated electronic pay stations, predominantly located in the city’s business areas. This system replaced the 36,000 individual space coin operated parking meters that the City previously used. The Chicago Parking Meters factsheet (2015) explains that a three tier pricing structure is in place with 3% of the total spaces charging the highest price of $6.50/hour; 16% of all spaces charged at $4/hour; and 81% of spaces charged at $2/hour.

4.5.2 Overall success of congestion strategy

It was estimated that the reduction of maintenance vehicles (as a result of the system upgrade) would result in 310,000 less miles driven annually, as reported by Stanley (2008). It was also expected that CO_2 emissions would be reduced as a result of reduced vehicle cruising. However, there is no current data available to confirm this.

The IBM (2011) survey of 8,000 commuters in 20 different cities worldwide, suggested Chicago drivers required the least amount of time to locate a parking space.

Although no data is currently available for CO_2 reductions in Chicago, IBM (2011) reported that a similar scheme in Manhattan resulted in a CO_2 reduction of 1.34million kg per year.

There is currently no available data on the impact of the scheme on other air quality pollutants.

4.6 Singapore

Singapore's Electronic Road Pricing (ERP) was introduced in 1998 to replace the previous manual road pricing system. The system works by having In-vehicle Units (IUs) with pre-paid smartcards (CashCards) installed. When these vehicles pass through gantries, located in the city's restricted zone, congested expressways and ring road, money is automatically deducted from the vehicle's smartcard. An article written by Menon and Kian-Keaong (2004) states that the objective of the scheme is to charge vehicle users for using the busiest roads at the busiest times and to encourage uses of the city's other transport networks.

4.6.1 Congestion reducing measures

The Energy Foundation reports that prices for the ERP are based on a speed range of 45-65km/h on expressways, and 20-30km/h on arterial roads. The price is dependent on the vehicle's Passenger Car Unit (PCU) equivalent, which is as follows:

- Cars, taxis and light good vehicles – 1PCU;
- Motorcycles – 0.5 PCU;
- HGVs and small buses – 1.5PCU; and
- Large HGVs and big buses – 2PCU.

The price is also dependent on the time that a vehicle enters a restricted zone, with charges at peak times changing every half hour to take into account traffic volumes. This spreads out traffic flow conditions. The Singaporean Land Transport Authority (2015) stipulates that if vehicles pass through without an IU or CashCard with insufficient monetary value, vehicle owners will receive a letter detailing that they must pay the charge plus a S$10 administrative fee within 2 weeks (Land Transport Authority, 2015).

Furthermore, the Energy Foundation states that to mitigate the impact of the ERP on business, the ERP rates were phased for certain vehicles that made multiple trips throughout the city (Energy Foundation, 2014). Gradually over a number of years, rates increased for taxis, goods vehicles, buses, and commercial vehicles until they were paying the full charge.

Foreign vehicles have the option to rent a temporary IU or permanently install one of they make frequent trips on ERP priced roads (Energy Foundation, 2014).

4.6.2 Overall success of congestion strategy

A case study by Christainsen (2006) reports that the initial cost of setting up the system was approximately S$200 million, with operational costs (as of 2004) of approximately S$16 million. The annual revenues have recently been approximately S$80 million.

The Land Transport Authority has reported that road traffic decreased by nearly 25,000 vehicles during peak hours, with average road speeds increasing by about 20%.

Within the restricted zone itself, traffic has gone down by about 13% during ERP operational hours, with vehicle numbers dropping from 270,000 to 235,000. The Land Transport Authority observed that car-pooling has increased, while the hours of peak vehicular traffic has also gradually eased and spread into off-peak hours, suggesting a more productive use of road space.

In addition, Christainsen (2006) noted that average road speeds for expressways and major roads remained the same, despite rising traffic volumes over the years.

There is no quantitative data available that provides a link between the ERP to improvements in air quality.

4.7 Stockholm, Sweden

Congestion charges were introduced in the city centre of Stockholm in January 2006, first as a trial followed by a referendum, then permanently from August 2007 onwards. Stokholmforsoket (2006) states that the aims of this congestion charge are to:

- Reduce traffic volumes on the busiest roads;
- Reduce emissions of CO_2 and harmful pollutants;
- Improve the flow of traffic on roads;
- Improve the urban environment for Stockholm residents; and
- Provide more resources for public transport.

An environmental zone is also in operation, which restricts HGVs and other large vehicles based on their Euro standards.

4.7.1 Emission reducing measures

An Urban Access Report (2015a) explains that the environmental zone places restrictions on HGVs and buses with a total weight over 3.5 tonnes. Regardless of the country of registration, all vehicles over this weight are permitted to be driven in the zone for 6 years from when the vehicle was first measured. This means that:

- Euro II vehicles are now longer permitted to enter;
- Euro III vehicles can only enter up until 2015 (if registered in 2007);

- Euro IV vehicles can be driven until 2016;
- Euro V vehicles can be driven up until 2020 or 8 years from when the vehicle was first registered; and
- Euro VI vehicles and better have no time limit.

4.7.2 Congestion reducing measures

The city also operates a congestion tax. The automated charging system consists of 18 charging points around the city centre, which act to direct traffic through bottlenecks at the main roads leading into the city. The charge to drivers varies according to the time of day, but with a range generally between €1.10 - €2.20, with a maximum daily charge of €6.60 (Urban Access Report, 2015b). The report details that automatic camera identification is used to identify vehicles and invoices are sent by mail on a monthly basis.

The report states that, initially, alternative-fuel cars were exempt from the congestion fees to try and stimulate environmental awareness on energy consumption; however, in 2012 the exemption was abolished for all vehicles (Energy Foundation, 2014)

To alleviate the expected increased demand in public transportation, Stockholm extended its public transit system (Energy Foundation, 2014).

4.7.3 Overall success of LEZ strategy

During the trial period it was estimated, in a 6 month case study by Huggoson and Eliasson (2006), that there was a decrease in exhaust emissions of 2-3% in Stockholm County, and approximately 14% in the inner city. Furthermore, particulate pollution was estimated to decrease by 5% in the county, and 10% in the inner city. Energy Foundation (2014) confirms that NO_X has declined by 8.5% within the inner city.

4.7.4 Overall success of congestion strategy

In an evaluation report (2012), Boriesson *et al*. state that during the trial period, the immediate effect was a 28% reduction in traffic across the cordon (compared to a 2005 reference), which stabilised at around 20-22% for the rest of the trial period.

In the year between the trial and permanent charges (i.e. the year where no congestion tax was in place), traffic across the cordon increased, but was still 5-10% lower than 2005. In August 2007, the permanent charges were introduced, and there were 21% fewer vehicles crossing the cordon compared to 2005: this decreased to 18% in 2008-2009, and 19% and 20% in 2010 and 2011 respectively (Borjesson *et al*, 2012).

With the permanent introduction of the scheme, the Energy Foundation (2014) reports that traffic levels have remained roughly constant. Congestion has also significantly declined since the reintroduction of congestion charging.

Public transport usage rose by 4% - 5% (Energy Foundation, 2014) The punctuality and speed of bus services has increased in response to reduced congestion. This led to reduced travel times.

The initial capital investment for the congestion tax was $410 million, with operating costs an average of $30 million per annum. The yearly revenue from charges, according to a 2013 US Department of Transport (2013) report, is approximately \$100million.

4.8 Milan, Italy

In January 2012, the city of Milan implemented Area C, a congestion charging scheme that combined road pricing with banning the most polluting vehicles (Energy Foundation, 2014). The Area C system was put into operation to replace the previous road charging scheme (ECOPASS), which was launched in 2008 and lasted until 2011. Whereas ECOPASS was a system put into place as a pollution charge (with the main objective being the reduction of PM_{10} levels), Area C is considered to be an upgrade to a congestion charge with stricter measures in place to regulate traffic. In a 2014 article, Eltis (2014) details the aims of Area C:

- Decrease vehicular access to the city centre and traffic congestion;
- Improve public transport networks;
- Reduce pollutant emissions caused by traffic and reduce health risks related to air pollution; and
- Increase the amount of sustainable travel nodes and raise funds for its further development.

4.8.1 Congestion reducing measures

Area C covers an area of 8.2km^2, and is enforced every working day between 07:30-19:30. All vehicles entering the area must pay a fee of €5, with the exception of residents (reduced fee of €2), and bicycles, scooters, electric cars, vehicles for disabled people, hybrid, methane powered, LPG and biofuel cars (admitted for free).

The Commune Di Milano (2015) stipulates that entrance is prohibited for petrol pre-Euro standard and diesel pre-Euro, Euro I and Euro II vehicles. Entry is regulated by use of 43 electronic gates with surveillance cameras, 7 of which are reserved for public transport, and cars monitored by use of Automatic Number Plate Recognition technology. Data on environmental pollution is obtained from Environmental Monitoring Stations positioned in the city.

4.8.2 Overall success of congestion strategy

Before the introduction of Area C, the ECOPASS congestion strategy had a degree of success in reducing congestion as well as pollution levels. In 2010, the number of days exceeding the PM_{10} threshold of 50μgm^{-3} was 86, compared to 166 in 2002.

However, it should be noted that this still fell short of the 35 days recommended in European Directive 2008/50/CE. In 2010, there was only one day where the hourly limit of NO_2 (200 μgm^{-3}) was exceeded, the lowest amount of days in 9 years. However, the annual concentrations of NO_2 were 61 μgm^{-3}; higher than the 42 μgm^{-3} recommended by European Directive 2008/50/CE (Danielis and Rotaris *et al*, 2011). Measurements of black carbon are being taken as an indicator of particulate matter. In terms of traffic, the amount of vehicles entering the ECOPASS area was reduced by 21% in the first year. This effect levelled off however, with there being an increase between 2009 and 2010 (Danielis and Rotaris *et al*, 2011).

The Black Carbon Monitoring Project (Invernizzi *et al*, 2012) report concludes that measurements indicate that black carbon is 28% lower in the Area C controlled zone, than outside (Invernizzi et al, 2012). Overall, traffic emissions have been reduced by 18% for PM_{10}, 42% for ammonia, 18% for NO_X, and 35% for CO_2 since the introduction of Area C (Energy Foundation, 2014).

The implementation of Area C had the aim of reducing the volume of vehicles as the ECOPASS was not as affective. Comparing Area C with ECOPASS there are 39,864 less vehicles entering the zone which has decreased traffic congestion by 30.2% (Energy Foundation, 2014). Public transport speeds have increased by 9.3% for buses and 5.4% for trams.

Based on the first 6 months data, the net revenue was estimated at about €23.5million in 2012, which has been reinvested by the city authorities in projects for sustainable mobility (Invernizzi et al, 2012).

4.9 Berlin, Germany

EU limit values for particulate matter (PM_{10}) were regularly exceeded along one third of Berlin's 1500 kilometres of main road network (Lutz, 2009).

According to Lutz (2009), two source apportionment studies revealed that road traffic is the predominant source for PM_{10}, $PM_{2.5}$ and NO_2 pollution. So, any abatement measures in Berlin needed to focus on the transport sector.

An Environmental Zone or Low Emission Zone (LEZ) was consequently created in Berlin on 1st January 2008 to aim to achieve European air quality standards (Senate Department for Health, Environment and Consumer Protection, 2008).

4.9.1 Emission reducing measures

The LEZ is an area where only those vehicles that meet certain exhaust emission standards are allowed to enter. The LEZ covers a central city area of 85 km^2 (surrounded by the local railway ring) within which more than 1 Million people live (Senate Department for Health, Environment and Consumer Protection, 2008).

The exhaust emission standards were implemented using a vehicle labelling scheme in the form of different coloured windscreen stickers as shown in table 4.9 below:

Table 4.9: Berlin exhausts emission standards

Emission standard (Euro norm)	Polluant Class	Initial vehicle registration passenger cars	Sticker
Diesel engine			
Euro 1 or older	1	before 01.01.1997	**none**
Euro 2/ Euro 1 + filter	2	from 01.01.1997 to 31.12.2000	
Euro 3/ Euro 2 + filter	3	from 01.01.2001 to 31.12.2005	
Euro 4/ Euro 3 + filter	4	from 01.01.2006	
Petrol engine			
Before Euro 1	1	before 01.01.1993	**none**
Euro 1 and better	4	from 01.011.1993	

(Senate Department for Health, Environment and Consumer Protection, 2008)

The LEZ was introduced in two stages; from 1st January 2008 until 31st December 2009, diesel vehicles with a red, yellow or green sticker were allowed to drive in the LEZ, but from 1st January 2010 only those with green stickers were allowed (Lutz, 2010). Stickers were not issued for vehicles in pollutant class 1 as these have a particularly high level of air pollutant emissions and were therefore not permitted to enter the LEZ at all (Senate Department for Health, Environment and Consumer Protection, 2008).

Diesel vehicles can be reclassified in a higher pollutant class if they are retrofitted with a particulate filter and some vehicles, such as: vintage cars, police, fire brigade and emergency vehicles were initially exempted from the scheme (Senate Department for Health, Environment and Consumer Protection, 2008). However, the 2011-2017 clean air plan adopted by the Berlin Senate in June 2013 called for an end to most of the exemptions in 2015 (Senate Department for Urban Development and the Environment, 2014).

Penalties are enforced if vehicles in the LEZ do not have the appropriate sticker or meet the emissions standards required (Urban Access Regulations in Europe, 2010).

4.9.2 Overall success of LEZ strategy

According to Lutz, (2009 and 2010) the impact of the LEZ on traffic flows, emission characteristics of registered vehicles and air quality within and outside of the LEZ has been analysed (from 2007 to 2010 and some parameters in 2012) using:

- Traffic data;
- Berlin's vehicle registration data base;
- Extra video recordings at representative spots of the main road network and
- Evaluating air quality monitoring data (including black and organic carbon).

All impact analysis reports (Lutz, 2009, 2010 and 2012 and Rauterberg-Wulff, 2010) have concluded that the LEZ has had no measurable impact on traffic flows, as traffic volume data recorded both in and outside of the LEZ revealed a decrease. In 2008, there was a larger drop of vehicle numbers outside of the LEZ (6%) than within it (4%).

An increase in the number of cleaner vehicles (more green stickers) has however been identified year on year as a result of the LEZ. For example, in 2007, 34% of diesel cars in the LEZ fell into pollutant class 4 (green stickers), 36% in pollutant class 3, 24% in pollutant class 2 and 6% pollutant class 1. In 2010, this changed to 91% in pollutant class 4, 7% in pollutant class 3, 2% in pollutant class 2 and 0% in pollutant class 1. In the absence of the LEZ, it was estimated that the renewal trend of vehicles would be below 50% (Lutz, 2012).

The total number of Diesel vehicles in Berlin which have been retrofitted with Diesel Particle Filters (DPF) has increased from 11,132 in 2008 to 55,541 in 2010 (Lutz, 2012).

Overall, the scheme has resulted in a decrease of both particle exhaust emissions and NO_x emissions. Particle exhaust emissions have decreased from 379 tonnes / year in 2007 to 92 tonnes / year in 2012 (a 63% larger reduction than what would have been expected had the LEZ not been implemented). NOx emissions have decreased from 8730 tonnes / year in 2007 to 5675 tonnes per year in 2012 (a 19% larger reduction than what would have been expected without the LEZ in place) (Lutz, 2012).

However, to better understand the net benefit of the LEZ from the air quality data, Lutz (2009) implies that the decrease in particle exhaust emission should treated with caution as concentrations of pollutants are strongly depend on the meteorological conditions and other pollution sources such as non-transport emissions, which cannot be mitigated by the LEZ and are likely to have influenced the results.

5 LEZ and Congestion Charging – costs and benefits

The following Tables 4.1 and 4.2, provides a summary overview of all of the case studies reviewed in Section 2 and 3. Table 4.3 provides a summary and suggestion for how the different congestion and emission reducing measures can be applied to Heathrow and Gatwick airports.

Table 5.1 Summary of Emission and Congestion Reducing Schemes – UK

Location	Measures Implemented	Revenue	Cost	Impacts
London	LEZ: Applicable to a variety of vehicles Must meet Euro standards Implemented in phases Retro-fitting Purchasing new vehicles	£5 - £11 m/yr (Jowit, 2008)	£57 million to start-up £10.7 million operate/yr	Predicted 39.6% NO_X and 31.1% PM_{10} reductions (2008-2015) CO_2 reduced by 20,600 tonnes/yr
	Congestion zone: Fixed peak-hour pricing	Net Total/yr: £181 million	Unknown	Reduction in NO_X, CO_2, and PM_{10} Reduced traffic volume Increase in congestion Increase in public transport ridership
Norwich	LEZ: Applicable to buses Must meet Euro standards Retro-fitting Purchasing new vehicles No idle engine policy Eco-driving training	Unknown	Unknown	Unknown
Oxford	LEZ: Applicable to buses Must meet Euro standards Retro-fitting No idle engine policy	Unknown	£437,000 to start-up £259,474 operate/yr	Predicted 11% NO_X and 7% PM_{10} reductions (2011-2025)
Brighton	LEZ: Applicable to buses Must meet Euro standards Retro-fitting Purchasing new vehicles No idle engine policy Eco-driving training Electronic ticket purchases	Unknown	Unknown	Unknown

Location	Measures Implemented	Revenue	Cost	Impacts
Nottingham	LEZ: Applicable to buses Must meet Euro standards New bus lanes for congestion control Bus shelter improvements	Unknown	Unknown	Unknown
York	LEZ - Not yet implemented	Unknown	£40,000 - £100,000+ (City of York Council, 2012)	Unknown
Bradford	LEZ - Not yet implemented	Unknown	Awarded £252,000 (City of Bradford MDC, 2013) Abatement costs saved: £0.04 – £6.2 million[23]	3.8-46.4 tonnes of NO_X reduction is expected CO_2 is not expected to increase
Leeds	LEZ - Not yet implemented	Unknown	2016 – 2021 £0.16 - £25.6 million of abatement costs avoided	178.9-926.7 tonnes of NO_X reduction is expected (2016-2021) CO_2 is not expected to increase

Table 5.2 Summary of Emission and Congestion Reducing Schemes – International

Location	Measures Implemented	Revenue	Cost	Impacts
San Francisco	SFpark scheme Congestion tolling w/in the city	Net Total/yr: $60 - $80 million	Unknown	Reduction in CO_2 and other pollutants Savings on fuel and maintenance Reduced travel delays
Seattle	GOOD TO GO! Variable tolling Smart highways Increased bus trips	Total/yr: $50.9 million	Construction: $154.5 million	Increased ridership on public transit Increased carpooling Increased off-peak driving Reduced congestion
Miami/Fort Lauderdale	SunPass Express (HOT) lanes Increase HOV passengers Fixed pricing	Total/yr: $16.8 million	Construction: $112 million	Increased ridership on public transit Increased speeds Reduced congestion
Minneapolis	MnPass Express (HOT) lanes Priced dynamic shoulder lane Dynamic pricing	Total/yr: $2 - $4 million	Construction: $183.2 million Operational: $2 million	Decline in carpooling/vanpooling Increase in HOT lane use Transit times shorter and more reliable Somewhat positive impact on air quality
Chicago	Variable parking prices Improve public transit Pay-for-use zones	Total/yr: $22.9 million	Concession purchase: $1.157 billion	Reduced driving Decrease in CO_2 emissions
Singapore	Electronic road pricing Dynamic pricing	Total/yr: S$80 million	Construction: S$200 million Operational S$16 million (as of 2004)	Increase in road speed Reduction in traffic Increase in carpooling
Stockholm	Restricted zones to buses/lorries Congestion charges	Total/yr: $100 million	Construction: $410 million Operational: $30 million	14% reduction in CO_2 (2-3% in county) 10% reduction in PM_{10} (5% in county) Reduction in traffic flow
Milan	Fixed congestion fee in Area C Fuel type restrictions base on Euro standards	Total/yr: €23.5 million	Unknown	NO_2 limit exceeded in 2010 Decrease in PM_{10}, NO_X, and CO_2, Black carbon concentrations decreased by 28%
Berlin	Exhaust emission standards implemented using a vehicle labelling scheme in the form of different coloured windscreen stickers	Unknown	Unknown	Overall, decrease in both particle exhaust emissions and Nox emissions Particle exhaust emissions have decreased from 379 tonnes / year in 2007 to 92 tonnes / year in 2012 Nox emissions have decreased from 8730 tonnes / year in 2007 to 5675 tonnes per year in 2012

Table 4.3 Summary of congestion charge and LEZ measures and their application to future airport expansion

Policy	Measures	Measures Applied to a Heathrow expansion scheme	Measures Applied to a Gatwick expansion scheme	Likely Impact	Notes
Congestion Charge	Vehicles paying charge between certain hours in controlled zones.	Congestion zones during peak times on M25. (Localised tolling may also be possible see Surface Access: Heathrow Airport Demand Management report for further details) Use London system of camera monitoring and registering.	Congestion zones during peak times on M23. Use London system of camera monitoring and registering.	Reduction in NO_X, CO_2, and PM_{10}. Increase in use of public transportation. Reduction in traffic.	Geographical scale and implications of matters such as parking will be key issues. Need to determine which vehicles will be charged. (See Surface Access: Heathrow Airport Demand Management report for further details)
	Congestion price strategies; - Dynamic fees based on time, type of vehicle, and number of vehicles within zone - Fixed fees for designated times that differ based on vehicle type	Congestion zones along M25. Update traffic/road technology to implement and monitor fees.	Congestion zones along M23. Update traffic/road technology to implement and monitor fees.	Reduction in number of vehicles on the relevant motorways, travel delays, and drivers using alternative routes.	Geographical scale and implications of matters such as parking will be key issues. Could affect traffic patterns in the surrounding area. Type of price system applied will depend on resources and means of monitoring. (See Surface Access: Heathrow Airport Demand Management report for further details)
	Improvements to public transport: - New bus lanes to encourage public transport and cyclists - Prohibiting private vehicles in certain streets - Improving bus shelters and timetables	Give priority to public transport: - Improve/expand bus lanes. - Promote public transport. - Reduce waiting times. - Reduce travel time with more direct routes/less stops.	Give priority to public transport: - Improve/expand bus lanes. - Promote public transport. - Reduce waiting times. - Reduce travel time with more direct routes/less	Increased use of public transport. Increased reliability of public transport.	New infrastructure / changes to layout of existing infrastructure. Good public transport alternatives are key to a successful CCZ.

Policy	Measures	Measures Applied to a Heathrow expansion scheme	Measures Applied to a Gatwick expansion scheme	Likely Impact	Notes
			stops.		It is not certain that high public transport usage strategies can be delivered. **(**See Air Quality: National and Local Impacts: Assessment Addendum: Detailed Emissions Inventory & Dispersion Modelling and Surface Access report for further details).
	Use of online/real-world information to reduce journey times, delays, and improve reliability	This could be made available through a website/app.	This could be made available through a website/app.	Reduced rider dissatisfaction and increased travel confidence	Collaboration with already existing travel websites/apps (Citymapper etc.) may be more efficient
	Variable parking charges to encourage drivers to park in less congested areas	Not likely to be applicable for an airport.	Not likely to be applicable for an airport.	N/A	N/A
	Use of smart/automated toll systems to increase efficiency Expressways and High Occupancy Toll (HOT) lanes with smart toll system	Use cameras/DVLA database to identify vehicles to charge congestion fee. Designate an already existing lane as a priority express/HOT lane.	Use cameras/DVLA database to identify vehicles to charge congestion fee. Designate an already existing lane as a priority express/HOT lane.	Increased speeds. Reduced traffic volume.	May be difficult to justify an express way exclusively for the airport. (See Surface Access: Heathrow Airport Demand Management report for further details on local application to Heathrow)
	Prohibit single occupancy vehicles Increase High Occupancy Vehicle (HOV) passenger limits	Establish enforcement measures (cameras/officers) to assure compliance along the M25. Build physical barriers (tolls).	Establish enforcement measures (cameras/officers) to assure compliance along the M23. Build physical barriers (tolls).	Increased carpooling. Reduced traffic volume.	May be difficult to implement and enforce for an airport alone. High initial investment costs for enforcement/barriers.
	Park–and-ride scheme	Hub locations on M25 / M4 / M3.	Hub locations on M23.	Increased use of	Improvements to public

Policy	Measures	Measures Applied to a Heathrow expansion scheme	Measures Applied to a Gatwick expansion scheme	Likely Impact	Notes
		Provide economic incentive to park further away from airport.	Provide economic incentive to park further away from airport.	public transport. Reduced parking delays/traffic jams.	transport should coincide with park-and-ride scheme.
	Pay-for-use scheme on loading zones in congested areas	N/A – unless freight vehicles identified as a significant source of air quality emissions	N/A – unless freight vehicles identified as a significant source of air quality emissions	N/A	N/A
Low Emission Zone	Vehicles to meet Euro emission standards. Either fines or outright bans can be in place for vehicles under a certain standard	Controlled zones along the M25. Update emission level standards regularly. Phase in what types of vehicles need to meet standards (similar to London).	Controlled zones along the M23. Update emission level standards regularly. Phase in what types of vehicles need to meet standards (similar to London).	Improve pollution emission levels.	Can coincide with London (U)LEZ requirements as public is already used to them. Emission standards should become increasingly stringent with technological improvements and updated Euro standards.
	Grants and incentives to encourage bus operators to retrofit/replace their buses to meet Euro standards.	Applicable to bus service providers to airport. Find sponsors/donors for grants.	Applicable to bus service providers to airport. Find sponsors/donors for grants.	Insufficient information to make a determination, but expected to reduce pollution emissions.	Work with Department of Transport and TfL.
	LEZ in operation at all times	Establish 24/7 monitoring and enforcement.	Establish 24/7 monitoring and enforcement.	Insufficient information to make a determination.	Based on case studies this is considered best practice.
	'No idling engine' policies	Make mandatory bus service providers to airport. Encourage voluntary participation from other motorists with public promotion.	Make mandatory bus service providers to airport. Encourage voluntary participation from other motorists with public promotion.	Insufficient information to make a determination, but expected to reduce pollution emissions.	Difficult to monitor and enforce.
	Eco-driving training	Promote to bus service providers to airport.	Promote to bus service providers to airport.	Insufficient information to make a determination, but expected to reduce pollution emissions.	
	Use of mobile apps and online ticketing to reduce passenger boarding times.	This could be made available through a website/app.	This could be made available through a website/app.	Insufficient information to make	This is already in place with TfL buses via the

Policy	Measures	Measures Applied to a Heathrow expansion scheme	Measures Applied to a Gatwick expansion scheme	Likely Impact	Notes
		Extend to coaches and non-TfL buses.	Extend to coaches and non-TfL buses.	a determination.	Oyster card and no more cash payments on buses.

6 Conclusion

A review of available research and information into Low Emission Zones, both within the UK, and internationally has been undertaken.

6.1 Effectiveness of LEZs

The majority of LEZs presented in the review focused on limiting bus emissions, as buses have been identified by the majority of the cities as the primary vehicles that contribute to PM_{10} and NO_X pollution.

The schemes also apply mixed soft and hard methods to alleviate emissions. Hard measures include the replacement of out-dated vehicles that do not meet current Euro standards regarding the legal limits of emission allowance. As replacements are typically costly, Local Authorities opt to retro-fit out-dated vehicles with emission reducing technologies. Examples include SCRs to control exhausts emissions and EGR to recirculate exhaust. Soft measures include eco-driving lessons, reducing road traffic, and policies to reduce engine idling.

With the exception of London, Local Authorities are not particularly stringent on vehicles that are not part of public transportation services, although several schemes allow for the expansion of LEZ restrictions to private cars and HGVs. As the majority of UK LEZ schemes have just been implemented (or are in the process of being implemented), it is not yet possible to determine their effectiveness in improving air quality.

The lack of quantitative data regarding LEZ success makes it difficult to determine the applicability of an LEZ to Gatwick and Heathrow expansion options. London has already identified that under its current scheme it will not achieve its future air quality objectives, thus, it plans to expand its LEZ into an ULEZ.

6.2 Effectiveness of Congestion Strategies

The majority of the congestion charging case studies presented in the review show an overall beneficial impact, although the impacts vary depending on the type of strategy implemented and the measures it uses.

It is apparent that technology, enforcement, and public transport improvements are all vital components in the effectiveness of congestion charging.

Technological components include;

- Installation of monitoring and management systems such as automated cameras and car number plate recognition.
- Fees can be paid automatically using electronic passes, manually via toll booths, or ‘pay by mail’ through the use of cameras and databases.
- Use of real-time data to provide updates on traffic conditions and public transit information.

Strong enforcement is essential in catching violators. It can be done automatically through the use of cameras to register license plates. Officials such as toll operators and law enforcement are used to enforce lane use regulations, speeds, and vehicle occupancy requirements throughout the designated congestion area.

Public transport enhancements are an important complimentary measure to congestion charging and the revenues from congestion charging can provide funding to promote and enhance public transport services. Typical measures include expanding service catchment and capacity, increasing frequency, and enhancing priority measures (for example bus lanes) in order to reduce travel time. The provision of real-time information on services is also important to make public transport more attractive and encourage an increase in patronage.

The London CCZ has experienced a series of successes in terms of reducing traffic volume and emissions and increasing usage of public transport. PM_{10}, NO_2, and NO_X emissions have also been reduced. However, as an increasing amount of road space within the zone has been turned over to other modes (for example through the expansion of bus lanes, the introduction of cycle superhighways, and enhancements to pedestrian and cycle facilities through urban realm improvement schemes), the level of congestion within the zone has been increasing and approaching pre-charging levels despite the traffic volume reductions.

In comparison, the American congestion schemes have been more invasive in terms of infrastructure requirements to create/expand lanes, install toll booths, and introduce smart technology.

San Francisco and Seattle built toll booths on key bridges to deter driving in the city centre during peak times, while Miami/Fort Lauderdale and Minneapolis built HOT express lanes to give drivers the option to use faster lanes for a fee.

Moreover, Chicago and San Francisco developed parking schemes to deter driving into the city centre and reduce parking congestion, respectively. The USA schemes have been successful in reducing traffic volume as well as increasing air quality, speeds, and public transport usage. However, the schemes need improvements, as seen with Miami/Fort Lauderdale, to maintain congestion charge objectives.

The Singapore, Stockholm, and Milan schemes have been successful in reducing traffic volume within the established areas. Furthermore, Stockholm and Milan have experienced significant improvements in air quality since the implementation of their schemes.

Though implementation costs of congestion projects are relatively high, reducing traffic congestion and traffic volume has shown to reduce pollutant emissions (London, San Francisco, Chicago, Milan, and Stockholm) and provide other social benefits such as travel reliability and shorter travel times.

Unlike LEZs, congestion pricing generates steady revenue that can be invested to further improve transportation and air quality.

6.3 Potential application at Heathrow and Gatwick

With regard to the expansion options for Heathrow and Gatwick, the literature review has highlighted a number of common themes which may be applicable. These are as follows:

- Voluntary LEZ participation from taxi, coach, and bus operators.
- Mixture of hard and soft measures for emission reduction in LEZs.
- There is uncertainty on which types of vehicles should be included in the LEZ restrictions.

- It is more cost effective to establish LEZ than to pay non-compliance fees.
- There is a lack of transparency on actual LEZ costs and emission reductions.
- Reducing congestion can lead to reduced emissions and other social benefits.
- A variety of restrictions can be placed on express/toll lanes and car parks.
- Automated charges further reduce congestion and promote continuous flow.

Following the airport expansion, for ease of public transition the LEZ/congestion charge should correlate in terms of application, charging and compliance to the existing London LEZ/CCZ and future ULEZ, if introduced. Due to the close proximity of both airports to Greater London and public familiarity with the London LEZ/CCZ requirements, it would be of benefit to use similar operating mechanisms such as number plate recognition to avoid public confusion. Emissions standards should be the same to avoid the possibility of conflicting standards and ensure that if a vehicle is compliant it is compliant for both the existing London LEZ and any future airport LEZ. However, charges under a congestion charging could, and to be effective should be different from the London CCZ in terms of hours of operation and charging levels.

In the context of airport expansion, although referred to by the promoters as a congestion charge, this would be an access charge that would be applied to a zone or zones as yet undefined around an airport scheme, with the purpose of supporting modal shift and managing traffic flows into and out of the airport and their impacts (e.g. air quality) rather than a congestion charge as applied in central London.

Jacobs' Surface Access: Heathrow Airport Demand Management report, (Jacobs, 2015a) provides a more detailed assessment of the potential application of congestion charging to the management of airport traffic for Heathrow, and identifies pros and cons with a number of different strategies for implementing a charge. A scheme implemented by the airport operator would for example have no impact on the public purse and would be relatively straight-forward from a regulatory standpoint, but commercial pressures and the terms of the airport's economic regulation licence may prevent the operator from levying a charge of a sufficient level to encourage a significant reduction in traffic generated by the airport. In contrast, a public sector-led initiative would allow more flexibility to set charges to achieve wider transport objectives around the airport but is more complex from a regulatory and political standpoint, particularly with regard to the motorway spurs serving the airport.

Similarly, there are pros and cons in terms of the geographic extent of the zone. A local scheme covering the airport road network would face less opposition from local residents and businesses and would result in lower capital costs but there would be no impact in terms of encouraging a reduction in background non-airport traffic around Heathrow, nor would airport users who park remotely from the site be affected. In fact, the implementation of a scheme that only covered the roads in the immediate vicinity of the terminals would likely lead to increasing pressure on remote parking areas and also add an incentive for private operators seeking to increase remote parking capacity, which would need to be controlled by local authorities. In addition, it would also likely lead to an increase in pick-up/drop-off and informal parking activity at transport interchanges in the vicinity of the airport, the control of which would have knock-on costs and implications for traffic authorities.

Wider area charging would conversely be more effective at capturing remote parking activity for example, and could also be designed to reduce background traffic on roads around the airport, but would also be more costly to implement and is likely to create more strategic re-routing of traffic, potentially increasing the scope and costs of ancillary traffic management measures. For example, the potential impact on the M25/M4 would need to be carefully assessed if these routes were not included within a wider area zone, as would the impact on strategic routes into London such as the M3/A316 and the M40/A40 and more local distributors such as the A3063 around Hounslow town centre.

The case studies demonstrate that the effectiveness of CCZ and LEZ is difficult to evaluate and may vary over time as the scheme developers and users change their habits. In addition, the information available on the effectiveness of the measures focuses on the impact within the charging zone or LEZ. For the application to an airport the impact on air quality around the edge of the zone will be a key consideration in defining and implementing the scheme and would require monitoring during the operation of any scheme.

7 Acronyms

ULEZ	Ultra Low Emission Zone
LEZ	Low Emission Zone
UK	United Kingdom
USA	United States of America
HGV	Heavy Goods Vehicle
NO_X	Oxides of nitrogen
TfL	Transport for London
NO_2	Nitrogen dioxide
PM_{10}	Particulate matter
CCZ	Congestion Charge Zone
SCR	Selective Catalyst Reduction
TRC	Traffic Regulation Condition
TRO	Traffic Regulation Order
EGR	Exhaust Gas Recirculation
DfT	Department for Transport
EU	European Union
SQPS	Statutory Quality Partnership Scheme
CAZ	Clean Air Zone
CO_2	Carbon Dioxide
$PM_{2.5}$	Fine particulates
SFMTA	San Francisco Municipal Transport Authority
SFCTA	San Francisco Country Transportation Authority
US DOT	US Department of Transportation
CMA	Congestion Management Agency
CMP	Congestion Management Program
ITS	Intelligent Transportation Systems
HOV	High-occupancy Vehicle

HOT	High-occupancy Toll
PDSL	Priced Dynamic Shoulder Lane
BRT	Bus Rapid Transit
ERP	Electronic Road Pricing
IU	In-vehicle Unit
PCU	Passenger Car Unit

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