Evaluation of Directive 2002/49/EC relating to the assessment and management of environmental noise

Appendices

Second Implementation Review and Evaluation of the Environmental Noise Directive

The Centre for Strategy & Evaluation Services LLP
April – *2016*

EUROPEAN COMMISSION

Directorate-General for Environment
Directorate F
Unit ENV F.3
Knowledge, Risks and Urban Environment

E-mail: ENV-END-REVIEW@ec.europa.eu

European Commission
B-1049 Brussels

EUROPEAN COMMISSION

Evaluation of Directive 2002/49/EC relating to the assessment and management of environmental noise

Appendices

Second Implementation Review and Evaluation of the Environmental Noise Directive

Directorate-General for Environment
Knowledge, Risks and Urban Environment

2016

CONTENTS

APPENDIX A – LIST OF COMPLETED INTERVIEWS

No.	MS	Name	Organisation	Position	Organisation type
1	EU	Michael Dodds	DG GROW - Outdoor noise equipment mobile machinery	Policy officer	European Commission - Community legislation on noise at source
2	EU	Piotr RAPACZ	DG MOVE, railway noise	Policy officer	European Commission – Community legislation on noise at source
3	EU	Stylianos Kephalopoulos	DG JRC	Policy officer	European Commission, JRC
4	EU	Tobias BAHR	European Automobile Manufacturer's Association (ACEA)	Environmental Policy Director	Industry association
5	EU	Erwin KIRSCHNER	European Automobile Manufacturer's Association (ACEA)	Technical Affairs Director	Industry association
6	EU	Hans-Martin Gerhard	Porsche AG	Policy officer	Industry
7	EU	Chrystelle Damar	ACI EUROPE (Airports Council International)	Head of Environmental Strategy & Intermodality	EU – industry association
8	EU	Ethem Pekin	Community of European Railways	Policy officer	EU – industry association
9	CY	Joanna CONSTANTINIDOU	Ministry of Agriculture, Natural Resources and Environment	Policy officer	Public authority
10	DK	Lisette Mortensen (LIMO)'	Danish Railways (LIMO)		Public authority (rail)
11	DK	Jakob Fryd	Danish Road Directorate		Public authority
12	DK	Jens Jensen	COWI	Acoustics consultant	Consultancy
13	EL	Kyriakos Psychas	Ministry of Environment	Policy officer	Public authority
14	EL	Prof. Kostas Vogiatzis	University of Thessaly Laboratory of Transportation	Director	Academic Expert responsible for strategic noise maps and actions plans in Greece and

No.	MS	Name	Organisation	Position	Organisation type
			Environmental Acoustics		Cyprus Representative of Greece in EU working groups
15	IE	Willie Pearce	Irish Rail/ Iarnród Éireann	Manager, Energy & Environment	Public authority (rail)
16	IE	Mark Conroy	Irish Rail/ Iarnród Éireann	Manager, Energy & Environment	Public authority (rail)
17	IE	Dr. Vincent O'Malley	Irish Roads Authority	Environmental Manager, Environment Unit.	Public authority (roads)
18	IE	Tony Dolan	Environmental Protection Agency	Head of Competent Authority, noise division	Competent authority (national)
19	IE	Brian McManus	Dublin City Council.	Head of Traffic Noise & Air Quality Unit, Environment & Transportation Dept,	Public authority (agglomeration)
20	INT	Nick Craven	International Union of Railways		Industry association
21	LT	Valdas Uscila	Ministry of the Environment, Republic of Lithuania	Policy official, environmental noise	Competent authority (national)
22	LV	Oskars Beikulis	SIA Estonian, Latvian & Lithuanian Environment Skolas	Environmental consultant (SNM)	Consultancy
23	NL	Annemarie van Beek	RIVM		Competent authority
24	PT	Maria Leite	AP Ambiente		Competent authority
25	UK	Colette Clarke	Department for Environment, Food and Rural Affairs (DEFRA)	Head of Noise & Statutory Nuisance Policy Team	Competent authority
26	UK	Hilary NOTLEY	Department for Environment, Food and Rural Affairs (DEFRA)	Senior Technical Advisor, Noise and Nuisance	Competent authority

No.	MS	Name	Organisation	Position	Organisation type
				Team	
27	UK	Anna Hunt	Department for Environment, Food and Rural Affairs (DEFRA)	Policy Advisor, Resource, Sustainable Development, Noise and Nuisance	Competent authority
28	UK	Linda Story	Scottish government	Policy Advisor, Environmental Quality Division	Competent authority
29	UK	Martin McVay	Welsh government	Policy Advisor (Environmental Noise and Chemicals)	Competent authority
30	UK	Amy Holmes	Northern Ireland	Policy Advisor	Competent authority
31	UK	Rick Jones	Rail Safety and Standards Board (RSSB)	Acoustic Expert	Public authority (rail)
32	UK	Tim Johnson	Aviation Environment Federation	Director	Civil society organisation
33	UK	John Stewart	HACAN	Director	Civil society organisation
34	UK	Simon Shilton	ACUSTICA	Senior Consultant	Consultancy
35	UK	Brendon Sewill	Gatwick Area Conservation Campaign (GACC)	Chairman	Civil society organisation
36	UK	John Bryant	Gatwick Area Conservation Campaign (GACC)	Director	Civil society organisation
37	BE	Jean-Pierre LANNOY	DPA - Walloon Region, Belgium (Service Public de Wallonie, Département de l'Environnement et de l'Eau)		Competent Authority
38	BE	Mme Marie Poupé	Institut Bruxellois pour la Gestion de l'Environnement - Dpt Bruit – Service Plan Bruit - Bruxelles Environnement, Bruxelles-Capitale		Competent Authority
39	BE	Mrs Sandra Geerts	Flemish government, Department Environment, Nature		Competent Authority

No.	MS	Name	Organisation	Position	Organisation type
			and Energy		
40	MT	Christopher Camilleri	Environment Protection Directorate (MEPA)		Competent Authority
41	SE	Johanna Bengtsson Ryberg Moa Ek Per Andersson (Written input from Marta Misterewicz and Tor Borinder) interview undertaken 20 May	Swedish Environmental Protection Agency	Coordinator	Public authority
42	UK	Anna Hunt	Resource, Sustainable Development, Noise and Nuisance	Policy Advisor	Consultancy
43	PL	Piotr Ochnio	General Directorate of National Roads and Motorway in Poland (GDDKiA)	Head of Department Environmental Assessment and Monitoring Department of the Environment	Public authority (roads)
44	PL	Beata Telega-Królikowska	General Directorate of National Roads and Motorways in Poland (GDDKiA)	Vice Head of Department Environmental Assessment and Monitoring Department of the Environment	Public authority (roads)
45	PL	Łukasz Dudzikowski	Polish Railways (PKP PLK)	Project Director Environmental noise measurements	Public authority (rail)
46	PL	Piotr Kokowski	Adam Mickiewicz University in Poznań, Institute of Acoustic, Poland	Academic Expert responsible for noise monitoring, measurements, strategic noise maps and actions plans	Competent Authority
47	PL	Tomasz Kaczmarek	AkustiX Sp. Z o.o.	Director	Consultancy
48	EE	Reet PRUUL	Ministry of Environment	In charge of	Competent

No.	MS	Name	Organisation	Position	Organisation type
				road mapping	authority
49	BG	Maria KOSTOVA	Industrial Pollution Prevention at Ministry of Environment and Water		Competent authority
50	IE	Willie Pierce	Manager, Energy and E nvironment, national rail authority		Public authority and mapping body
51	SE	Kerstin Hannrup Magnus Lindqvist Agreed 20 May	Boverket	National coordinator	Competent authority
52	SE	Marie Hankanen Agreed 22 May	Transportstyrelsen	National coordinator	Competent authority
53	SE	Lars Dahlbom Karin Blidberg 13 May	Trafikverket	National coordinator	Competent authority (roads)
54	NL	Miriam Weber	Ministry of Infrastructure and Environment	Policy expert	Competent authority
55	IT	Emilio Lucadamo	Rete Ferroviaria Italiana S.p.A.	Technical manager	Competent authority (rail)
56	IT	Lorenzo Lombardi	Ministry for the Environment, Land and Sea - Sezione Inquinamento Acustico ed Elettromagnetico	Policy officer	Competent authority (national)
57	IT	Dr. Giorgio Galassi	Regione Toscana	Environmental noise specialist	Competent authority (regional)
58	UK	Stephen Turner	Consultant	Previous Head of Defra Technical Noise Team, member of EU END working groups	Independent expert

No.	MS	Name	Organisation	Position	Organisation type
59	UK	Nigel Jones	Consultant	Undertaken most of noise mapping in England and Wales, member of EU END working groups	Independent expert
60	UK	Howard Price	CIEH, NGO	Professional body responsible for LA noise experts	NGO
61	UK	Ben Fenech	Public Health England, government agency	Responsible for noise & health policies in UK	Competent Authority
62	UK	Graeme Willis	CPRE, NGO	Specialist in quiet areas and tranquillity	NGO
63	ES	Núria Blanes Guàrdia	Barcelona University of Technology European Topic Centre on Air Pollution and Climate Mitigation (ETC/ACM)	Assists the EEA with the EIONET reporting system)	Other
64	EU	Mrs. Fazilet Cinaralp	ETRMA - European Tyre & Rubber Manufacturers Association	Secretary General	EU industry association
65	EU	Jean-Pierre Taverne	ETRMA - European Tyre & Rubber Manufacturers Association	Coordinator Environment & ELT Technical Support	EU industry association
66	NL	Henk Wolfert	Euronoise conference organiser and Eurocities	European Policy Officer	Other
67	DK	Frank Pedersen	Environmental Protection Agency		National Competent Authority
68	FI	Larri Liikonen	Centre for Economic Development, Transport and the Environment	Coordinator	Competent Authority
69	BG	Antonia Danailova	Plovdiv city municipality administration	Chief expert “Ecology and waste management” Department	Public authority
70	BG	Maria Galabova	MINISTRY OF ENVIRONMENT AND WATER	Director of Preventive Activities Directorate	National Competent Authority

No.	MS	Name	Organisation	Position	Organisation type
71	BG	Boris Mihaylov	Consultant at SPECTRI Ltd.	Consultant	Independent expert
72	HU	Attila JAKAB	CENTRE FOR TRANSPORT IT (KTI)	Head of Centre	Competent authority (rail)
73	HU	Mihaly Berndt	OPAKFI	Environmental noise specialist	NGO
74	HU	Milán Kara	Ministry of Agriculture Department of Environmental Preservation Hungary	Lead Counsellor	National Competent Authority
75	DE	Dr. Michael Gerke	Bayerisches Landesamt für Umwelt (Federal Environment Agency Bavaria)	Director of Construction	Federal Competent Authority
76	DE	Jens Krüsmann	Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft Brandenburg (Federal Environment Agency Brandenburg)	Consultant Noise, Light, Vibration	Federal Competent Authority
77	DE	Matthias Hintzsche	Umweltbundesamt (Federal Environment Agency)	Resort "Noise Reduction for plants and products, effects of noise"	National Competent Authority
78	DK	Karen Forsting	Municipality of Copenhagen		Public authority
79	HR	Valerija Golub	Ministry of Health		Competent authority
80	HR	Sandra Hamin	City of Zagreb		Public authority
81	LU	David GLOD	Ministry of Sustainable Development and Infrastructure, Administration de l'Environnement	Noise department	National Competent Authority
82	LU	Luc Buttel	Administration de l'Environnement	Noise department	National Competent Authority
83	FR	Pascal Valentin.	Ministry of Ecology, Sustainable Development and Energy Direction	Head of noise department	National Competent Authority

No.	MS	Name	Organisation	Position	Organisation type
			Générale de la Prévention des Risques (DGPR) Service de la prévention des risques et de la qualité de l'environnement, (SPNQE)		
84	FR	Lory WAKS	Ministry of Ecology, Sustainable Development and Energy.	Noise department	National Competent Authority
85	IE	Chris Dilworth	AWN Consulting	Head of Acoustics team	Consultancy
86	FR	Piotr Gaudibert	Bruitparc	Noise observatory of the Ile-de-France region, European projects manager	Noise monitoring body
87	FR	Guillaume DUTILLEUX	CEREMA (Centre for expertise and engineering on risks, urban and country planning, environment and mobility).	Head of the Acoustics Group PCI Acoustics and Vibrations	
88	LV	Dace Šatrovska	Ministry of Environmental Protection and Regional Development	Deputy Head of Environmental Protection Department, Head of Environmental Quality and Waste Management Division	
89	LV	Jānis Dundurs	Riga Stradina University	Academic in public health	
90	EE	Villu Lükk	Estonian Road Administration	Public authority	
91	HU	Mihaly Berndt	OPAKFI	Consultancy	
92	HU	Attila Jakab	KTI	Public authority	
93	HU	Milan Kara		Competent authority	
94	BG	Maria Galabova	KOSTOVA	Wider stakeholder	
95	BG	Antonia Danailova		Public authority	

No.	MS	Name	Organisation	Position	Organisation type
96	BG	Boris Mihaylov	BM1	Consultancy	
97	SE	Christin Zackrisson	Malmö Stad	Environmental Inspector	Public authority
98	FI	Jenni Kuja-Aro	City of Helsinki Environment Centre	Environmental Inspector	Public authority Notes: detailed response in writing
99	FI	Anu Haahla	City of Helsinki Environment Centre	Environmental Inspector	Public authority Notes: detailed response in writing
100	UK	Ian Holmes	Highways England	Principal Noise Advisor	Public authority (roads)
101	UK	David Foote and Tim Walmsley	Manchester Airport	Environment Advisor	
102	PT	Margarida Guedes	Portuguese Environmental Agency (APA)		National Competent authority
103	PT	Maria Joao Leite	Portuguese Environmental Agency (APA)		National Competent authority
104	SE	Jarmo Riihinen	Orebro County, Sweden	Traffic engineer	Public authority
105	ES	Miguel Garcia	lyCSA	Consultant	Consultancy
106	ES	Jose Manuel Sanz			National Competent authority

APPENDIX B - BIBLIOGRAPHY

No.	The legal text of the END, EC Communications, EEA reports and reporting information on END implementation
1	Directive 2002/49/EC
2	2004 Report from the Commission concerning existing Community measures relating to sources of environmental noise, pursuant to Art.10.1 of Directive 2002/49/EC
3	Reporting information communicated by the Member States to the Commission under Articles 4(2), 5(4), 7, 8 and 10 of the Directive, including the two last set of noise maps/data submitted by Member States under the Directive. See the EIONET and CIRCA links in table above.
4	First implementation report (COM(2011) 321 final of 1 June 2011) and the report prepared under Service contract No 070307/2008/510980/SER/C3: Preparation of Commission review on the implementation of the Directive 2002/49/EC, both available at http://ec.europa.eu/environment/noise/milieu.htm
5	Confidential information on the quality of reporting produced by the EEA on Round 1 / 2 implementation.
6	The EEA's Noise in Europe report, 2014
7	The Environmental Noise Directive at a turning point", Euronoise conference paper, Ivana Juraga, Marco Paviotti and Bernhard Berger, Directorate-General for the Environment, European Commission, June 2015
Good practice documents	
8	Good practice guide on noise exposure and potential health effects, EEA Technical report No. 11/2010 - http://www.eea.europa.eu/publications/good-practice-guide-on-noise/at_download/file
9	Good practice guide on quiet areas, EEA Technical report No. 4/2014
10	Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure, European Commission Working Group Assessment of Exposure to Noise (WG-AEN), August 2007 http://www.lfu.bayern.de/laerm/eg_umgebungslaermrichtlinie/doc/good_practice_guide_2007.pdf
11	National guidance documents on SNM and action planning such as Guidance for Possible Measures to Manage Noise from Road and Rail (Scottish Government), Noise Mapping and Action Planning in Northern Ireland[1], Danish guidelines (http://mst.dk/service/publikationer/publikationsarkiv/2006/aug/stoejkortlaegning-og-stoejhandlingsplaner/) etc. Guidance Note by the EPA Ireland for Strategic Noise Mapping for the Environmental Noise Regulations 2006.
12	International Union of Railways. 2010. Railway Noise in Europe. A 2020 report on the state of the art.

[1] http://www.noiseni.co.uk/airports_noise_mapping_and_action_planning_technical_guidance_2013.pdf

No.	The legal text of the END, EC Communications, EEA reports and reporting information on END implementation
Common noise assessment methods and the development of CNOSSOS-EU	
13	European Commission. 2012. JRC Reference Reports. Common Noise Assessment Methods in Europe (CNOSSOS-EU) - http://ec.europa.eu/environment/noise/cnossos.htm
14	Advances in the development of common noise assessment methods in Europe: The CNOSSOS-EU framework for strategic environmental noise mapping, Stylianos Kephalopoulos, Marco Paviotti, Fabienne Anfosso-Lédé, Dirk Van Maercke, Simon Shilton and Nigel Jones. http://ac.els-cdn.com/S0048969714001934/1-s2.0-S0048969714001934-main.pdf?_tid=787bda36-4b19-11e5-904a-00000aacb360&acdnat=1440501027_c8d4f497bf7f0f8f4b0205f99b7f9b27
15	Conversion of existing road source data to use CNOSSOS-EU. Simon Shilton, Acustica Ltd, Fabienne Anfosso Lédée, Ifsttar, Nantes, France, Hans van Leeuwen, DGMR, the Hague, Netherlands. http://dgmr.nl/uploads/files/Euronoise%20Conversion%20of%20existing%20road%20source%20data%20to%20use%20CNOSSOS-EU%20-%20000564.pdf
16	COMMISSION DIRECTIVE (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council.
17	FP6 - HARMONOISE (Harmanised Accurate and Reliable Methods for the EU Directive on the Assessment and Management of Environmental Noise).
18	FP6 - the IMAGINE project (Improved Methods for the Assessment of the Generic Impact of Noise in the Environment - https://ec.europa.eu/research/fp6/ssp/imagine_en.htm
Methodological guidance on estimating the costs, benefits and health impacts of environmental noise.	
19	Methodological guidance for estimating the burden of disease from environmental noise, Edition: World Health Organization and European Commission, Joint Research Centre, Chapter: Usefulness of strategic noise maps as exposure data for estimating the environmental burden of disease from environmental noise, Publisher: World Health Organization, Editors: Tomas Hellmuth, Thomas Classen, Rokho Kim, Stylianos Kephalopoulos, pp.39-45
20	Position Paper on Dose-Effect Relationships for Night Time Noise, European Commission Working Group on Health and Socio-Economic Aspects, 11 November 2004
21	Methodological guidance for estimating the burden of disease from environmental noise, Edited by: Tomas Hellmuth, Thomas Classen, Rokho Kim and Stylianos Kephalopoulos. WHO Regional Office, World Health Organization / JRC 2012[2]
22	Report "Burden of disease from environmental noise" (WHO, JRC 2011). http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf

[2] http://www.euro.who.int/__data/assets/pdf_file/0008/179117/Methodological-guidance-for-estimating-the-burden-of-disease-from-environmental-noise-ver-2.pdf

No.	The legal text of the END, EC Communications, EEA reports and reporting information on END implementation
23	The Environmental Burden of Disease in Europe project http://en.opasnet.org/w/Ebode. This ranked noise as second environmental stressor. It introduced a general methodology to quantify the impact of environmental noise based on measuring disability-adjusted life years, DALY.
24	WHO - Night noise guidelines for Europe - http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf
25	WHO and the JRC - Burden of disease from environmental noise - quantification of healthy life years lost in Europe, 2011. http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf
26	The 'Valuation of noise' (EC, 2004) which is based on the willingness-to-pay principle, drawing upon data from Navrud (2002). See study below.
27	State-of-the-Art in the Economic Valuation of Noise Final Report to European Commission DG Environment, April 2002, Ståle Navrud, Department of Economics and Social Sciences, Agricultural University of Norway.
28	Conference of European Directors of Roads. 2013. National Road Authorities' practice and experiences with preparation of noise action plans.
29	Conference of European Directors of Roads. 2013. The European Noise Directive and NRAs: Final Summary Report CEDR Road Noise 2009-2013.
30	National Road Authority (Ireland). 2014. Good Practice Guidance for the Treatment of Noise during the Planning of National Road Schemes.
31	International Union of Railways. 2012. On the END Consultation. Noise limits and trigger values.
32	Royal HaskoningDHV. 2013. The real cost of railway noise mitigation. A risk assessment.
33	Craven, Nick et al. 2012. Responding to the Environmental Noise Directive by demonstrating the benefits of rail grinding on the GB railway network. RRUKA Annual Conference
National guidance on END implementation and methodological guidelines -	
34	UK - Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet. Defra, November 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/380852/environmental-noise-valuing-imapcts-PB14227.pdf
35	Hardy, AEJ and RRK Jones. 2004. Rail and wheel roughness - implications for noise mapping based on the Calculation of Railway Noise procedure.
36	EU funded research projects relevant to environmental noise and END implementation (e.g. EU RTD FPs – FP6, FP7, the LIFE + programme).
37	FP6 – the HEATCO project - "Developing Harmonised European Approaches for Transport Costing and Project Assessment", in particular Deliverables 4 and 5 (including Annex E) http://heatco.ier.uni-stuttgart.de/deliverables.html
38	FP7 – the CITYHUSH Project. Acoustic Central et al.. 2012. Acoustically Green Road Vehicles and City Areas. FP7 project 233655

No.	The legal text of the END, EC Communications, EEA reports and reporting information on END implementation
39	Weber, Miriam. 2012. Quiet Urban Areas: repositioning local noise policy approaches – questioning visitors on soundscape and environmental quality.
40	LIFE + Programme – the QUADMAP project. Gezer, Sevgi. Silence & the City. WPA2: Data collection and analysis in The Netherlands, Belgium, Norway and United Kingdom.
Other studies	
41	Towards A Comprehensive Noise Strategy, Policy Department A: Economic and Scientific Policy (IPOL-ENVI_ET(2012)492459_EN)
	National implementation documents • Strategic noise maps across EU28 • Noise Action Plans across EU28
42	• National implementation reports and research papers. Examples include: – Consultancy and field surveys to implement the END in Malta. June 2011, Acustica Ltd.). – Implementation of the EU Environmental Noise Directive: Lessons from the first phase of strategic noise mapping and action planning in Ireland – E. A. Kinga, E. Murphyb, H.J. Ricea, Department of Mechanical and Manufacturing Engineering, Parson's Building, Trinity College Dublin, Ireland & the School of Geography, Planning and Environmental Policy, University College Dublin, Ireland. – Make some noise. Shadow report on implementation of the Environmental Noise Directive in Austria, Czech Republic, Estonia, Hungary, Slovakia and Slovenia (European Network of Environmental Law Organizations.

APPENDIX C – LIST OF RELEVANT LEGISLATION

This Appendix provides a list of all relevant EU legislation on noise. The list is especially relevant to the following evaluation questions:

- How far is the Directive coherent and consistent with other EU legislation on noise? (coherence)
- What progress has been made towards the second objective of the END - "to provide a basis for developing Community measures" to reduce noise at source (Article 1(2))?

Article 1(2) of the Directive sets out the second objective of the END which is to "provide a basis for developing Community measures[3] to reduce noise emitted by the major sources, in particular road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery". The Directive states that "to this end, the Commission shall submit to the European Parliament and the Council, no later than 18 July 2006, appropriate legislative proposals. Those proposals should take into account the results of the report referred to in Article 10(1)".

In order to meet this requirement in the Directive, the EC produced a report in 2004 "concerning existing Community measures relating to sources of environmental noise, pursuant to Article 10.1 of Directive 2002/49/EC relating to the assessment and management of environmental noise"[4]. This document points out links between the END and development of existing EU measures relating to sources of environmental noise as part of an **integrated approach to noise management**. The document states that "there is scope for better cooperation throughout the Community to improve the availability and comparability of data on information relating to exposure to environmental noise. There is also scope for the Community to help Member States share noise abatement experiences".

The report also describes EU measures relating to sources of environmental noise and highlights the relevant legal basis for EU intervention. The legal articles of the Treaty have changed since the END came into force due to the adoption of the Lisbon Treaty (TFEU), which came into effect in December 2009. The legal competences remain but simply, the relevant Articles have changed numbers. A table updating the articles of the legal base to reflect the Lisbon Treaty is provided below:

Table 1: The legal basis for EU intervention – Community measures to tackle noise at source.

Provision of the Lisbon Treaty (TFEU)	Scope
Article 90 - 100 (Common transport policy)	• Aircraft noise
Article 114 (Internal market – Approximation of the laws of Member States):	• Road vehicles • Tyres • Outdoor equipment and tractors • Recreational craft
Article 170 (Trans-European networks)	• Railway interoperability

[3] It should be pointed out that whereas in 2002, the correct terminology was Community legislation and Community measures, post the Lisbon Treaty (TFEU), we refer to EU legislation and EU measures.
[4] COM(2004) 160 final

Provision of the Lisbon Treaty (TFEU)	Scope
Article 192 (Environment)	• Environmental assessment[5] • Assessment and management of environmental noise • Integrated Pollution Prevention and Control

Source: CSES / ACCON update of legal basis for Community noise at source measures

The report then details the different transport modes where the EC has competence for Community measures on noise at source legislation. This includes legislation to tackle noise from motor vehicles (4 wheels, 2 and 3 wheels), rolling noise between tyres and road surfaces, railway noise at source through Directives on railway interoperability, and technical standards for interoperability (e.g. TSI on high-speed rolling stock), and aircraft noise.

In the following table, an overview of relevant EU noise at source legislation is provided. This gives an update on the 2004 report produced by the European Commission and is reasonably comprehensive as at November 2015.

Table 2: EU legislation tackling noise at source

Legislation	Description	References to END and other relevant references
Road traffic noise (Directorate General GROW – formerly Enterprise)		
Automotive Regulation 540/2014 on the sound level of motor vehicles and of replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC	The Regulation aims to improve environmental protection public safety, and quality of life by reducing major sources of noise caused by motor vehicles. To this end, it sets out the administrative and technical requirements for the EU approval of all new vehicles of certain categories with regard to their sound level and for the EU approval of replacement silencing systems and related components. The regulation sets noise-limit values for the different vehicle categories and a timeframe for implementation.	Recital 1 refers to providing for a high level of environmental protection and to a better quality of life and health. Recital 3 states that traffic noise harms health in numerous ways. "The effects of traffic noise should be further researched in the same manner as provided for in Directive 2002/49/EC". Recital 13 points out that noise is a multifaceted issue with multiple sources and factors that influence the sound perceived by people and the impact of that sound upon them. Vehicle sound levels are partially dependent on the environment in which the vehicles are used, in particular the quality of the road infrastructure, and therefore a more integrated approach is required. Directive 2002/49/EC requires strategic noise maps to be drawn up periodically as regards, inter alia, major roads.

[5] Two types of procedure are provided for in Community legislation, Strategic Environmental Assessment (Directive 2001/42/EC) and Environmental Impact Assessment (Directive 85/337/EEC).

Legislation	Description	References to END and other relevant references
		The information presented in maps could form the basis of future research work regarding environmental noise in general, and road surface noise in particular, as well as best practice guides on technological road quality development and a classification of road surface types, if appropriate. Also references the objective in the 6th EAP of substantially reducing the number of people regularly affected by long-term average levels of noise, particularly from traffic.
Motor Cycles Directive 97/24/EC – Motor Cycles	The Directive provides that Member States can grant tax incentives to vehicles which meet specified requirements concerning atmospheric pollution and noise pollution set out in the Directive.	
Mopeds Directive 2002/51/EC on the reduction of the level of pollutant emissions from two- and three-wheel motor vehicles and amending Directive 97/24/EC	This Directive aims at reducing the level of pollutant emissions from two or three-wheel motor vehicles by tightening the limit values for such emissions allowed in the type approval procedures for these vehicles.	
Automotive The European Tyre Labelling Regulation (EC/1222/2009)	The Regulation introduced labelling requirements for tyres. The external rolling noise of tyres is one of three types of information that must be displayed.	
Aircraft noise (Directorate MOVE)		
Communication on air transport and environment (1999)	The Communication sets out an EU strategy to put in place a coherent and environmentally friendly policy in the field of air transport. Inter alia, this includes improvement of technical environmental standards on noise and gaseous emissions as well as various actions proposed to assist airports in limiting noise.	
Regulation 1592/2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, repealing Directive 80/51/EEC	Establishes a safety agency to ensure the uniform implementation within Europe of harmonised safety standards and regulations.	

Legislation	Description	References to END and other relevant references
Directive 89/629/EEC – Subsonic Jet Aeroplanes	This Directive sets limits for noise emission from civil subsonic jet aeroplanes.	
Directive 92/14/EEC – Limitation of the Operations of Aeroplanes	This Directive sets noise certification standards for civil subsonic jet aeroplanes.	
Directive 1999/28/EC amending the Annex to Council Directive 92/14/EEC on the limitation of the operation of aeroplanes covered by Part II, Chapter 2, Volume 1 of Annex 16 to the Convention on International Civil Aviation, second edition		
Directive 2002/30/EC – Operating restrictions at Community airports	This Directive aims to promote the sustainable development of air transport through the reduction of noise pollution from aircraft at airports. The use of aircraft with a better environmental performance can contribute to a more effective use of the available airport capacity and facilitate the development of airport infrastructure in line with market requirements. The directive lays down common rules for prohibiting the noisiest aircraft from European airports and repeals Regulation (EC) No 925/1999, the 'Hushkit' Regulation, which was intended to prohibit the registration in Europe of aircraft fitted with noise-reducing devices.	
Directive 2006/93/EC on the regulation of chapter 3 civil subsonic aeroplanes	A consolidated Directive of obligations contained in 3 earlier Directives. Prohibits Chapter 2 aircraft (the oldest and noisiest aircraft) from operating in Europe.	
Regulation 598/2014 on operating restrictions at community airports	The new Regulation aims to ensure the consistent application in the EU of the ICAO (International Civil Aviation Organization) set of principles and guidance known as the "Balanced Approach" for the introduction of noise-related operating restrictions at airports. It will establish uniform procedures for the assessment and management of noise around airports.	

Legislation	Description	References to END and other relevant references
Railway noise (DG MOVE)		
Directive 2008/57/EC on Railway Interoperability, repealing Directive 96/48/EC	The Directive sets out the conditions to be met to achieve interoperability within the Union rail system. These conditions concern the design, construction, placing in service, upgrading, renewal, operation and maintenance of the parts of this system as well as the professional qualifications and health and safety conditions of the staff who contribute to its operation and maintenance.	
Commission Decision 2002/735/EC – Technical specification for interoperability (TSI) relating to high-speed rolling stock	The Decision defines technical standards for the interoperability of the High-Speed Trans-European Rail network. It imposes statutory levels of exterior and interior noise.	
Directive 2001/16/EC on Interoperability of the conventional Trans-European rail system	Provides that the operation of the trans-European conventional rail system must respect existing regulations on noise pollution.	
Commission Decision 2004/446/EC	Specifies the basic parameters of the 'Noise', 'Freight Wagons' and 'Telematic applications for freight' Technical Specifications for Interoperability referred to in Directive 2001/16/EC.	
Directive 2004/50/EC on Railway Safety	This Directive harmonises safety principles, including procedures for granting safety approval to railway operators and infrastructure owners.	
Directive 2012/34/EC establishing a single European railway area	Consolidates EU railway legislation and provides the basis for Regulation 2015/429 and the measures setting out the modalities to be followed for the application of the charging for the cost of noise effects.	
Regulation 1304/2014 on the technical specification for interoperability relating to the subsystem rolling stock noise amending Decision 2008/232/EC and repealing Decision 2011/229/EU2	Sets technical specifications for interoperability of rolling stock of the trans-European conventional rail system, including requirements relating to noise emission limits.	
Regulation (EU) 2015/429 setting out the modalities to be followed for the application of the charging for the cost of noise effects	Sets out the modalities to be followed for the charging of cost of noise effects caused by freight rolling stock whereas charges are commensurate with noise levels.	

Legislation	Description	References to END and other relevant references
Other		
Directive 2000/14/EC of the European Parliament and the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors	The Directive replaces a wide range of individual pieces of legislation associated with acoustic noise emission in the various member states of the EU. It attempts to make it easier for manufacturers to sell their products across the whole community by ensuring that the noise performance requirements for the machines within its scope are the same in all member states. The Directive also introduces a downward pressure on noise emissions by placing limits on certain types of equipment in two stages, the limits for stage 2, which came into force in 2006, being quieter than those for stage 1.	
Directive 2005/88/EC amending Directive 2000/14/EC	This Directive amended Directive 2000/14/EC by making the Stage 2 limits indicative for some types of equipment where the new limits were not going to be technically feasible in time for the deadline.	
Directive 2003/44/EC – Recreational Craft Directive, amending Directive 94/25/EC	This Directive sets out minimum technical, safety and environmental standards for the trade of boats, personal watercraft, marine engines and components and ensures their suitability for sale and operation in Europe. The Directive also introduced new noise limits for marine and propulsion engines.	

APPENDIX D – METHODOLOGY FOR COST-BENEFIT ASSESSMENT

1.1 Introduction

The purpose of the CBA is to provide a structured framework for identifying, quantifying, and comparing the monetary and non-monetary **costs and benefits of the implementation of the END** to date. The CBA was developed on the basis of data collected through 19 test cases covering agglomerations, major roads, major railways and major airports. This information has then been used to assess the efficiency of the END at EU level.

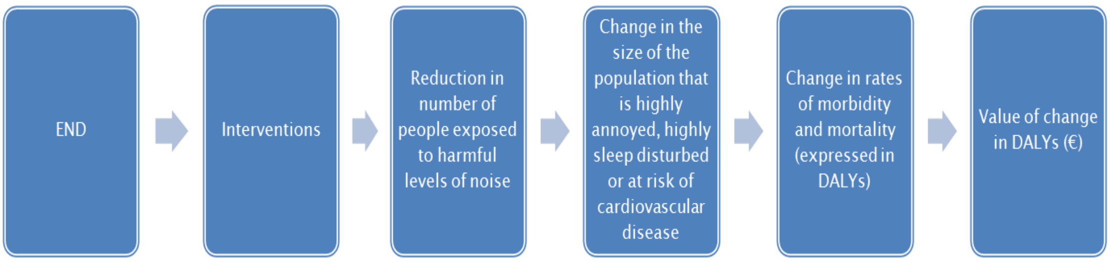
1.2 Overall approach

The approach to the CBA was informed by a review of the relevant literature and good practice guidance relating to the quantification and valuation of environmental noise. Key sources of information include:

- WHO (2011) Burden of Disease from Environmental Noise;
- EEA (2010) Good Practice Guide on Noise Exposure and Potential Health Effects;
- Defra (2014) Environmental Noise: Valuing impacts on sleep disturbance, annoyance, hypertension, productivity and quiet;
- HEATCO FP6 Project - Developing Harmonised European Approaches for Transport Costing and project assessment;
- Houthuijs et al (2014) Health implication of road, railway and aircraft noise in the European Union. Provisional results based on the 2nd round of noise mapping, RIVM Report 2014-0130;
- CE Delft, INFRAS and Fraunhofer ISI (2011) External Costs of Transport in Europe;
- JRC (2013) Final Report ENNAH – European Network on Noise and Health.

In order to help define the scope of the CBA and the associated data requirements, an impact pathway or logic chain was developed (see Figure 1). This provides a structured and transparent way of linking the sequence of events between implementation of the END and the outcomes or impacts that can be valued in monetary terms, and the assumptions that may be implicit within that.

Figure 1: The impact pathway



Thus, it is assumed that the introduction of the END has supported a number of activities or interventions including strategic noise mapping, noise action planning (both compliance activities) and, following these, the implementation of a range of measures to reduce harmful levels of noise. While the implementation of measures is not specifically mandated by the END, there is an implicit assumption or reasonable expectation that the measures identified in the Noise Action Plans (NAPs) will be implemented. Indeed, the implementation of many of these measures is already underway and some have already been completed.

The implementation of these measures in turn contributes to a reduction in the number of people exposed to harmful levels of noise. The benefits are considered in terms of a reduction in the burden of disease caused by environmental noise which can be quantified using the concept of disability-adjusted life years (DALYs) and valued using the concept of a value of a life year (VOLY).

The efficiency of measures has then been assessed using typical decision criteria – in this case, net present value (NPV) and cost-benefit ratios. Ultimately, the CBA seeks to identify and quantify the net benefits (i.e. the difference between costs and benefits) both with and without the END in place.

More simply, the general form of the equation for the calculation of impacts is:

Impact = Noise level x population at risk x Response function

The specific steps undertaken to quantify the costs and benefits and the overall net present value (NPV) of typical measures implemented as a result of the END are described in detail in Section 3.

1.3 Limitations

The extent to which it is possible to produce an assessment at an EU-level of the aggregate costs and benefits of the full implementation of measures identified in NAPs is limited by a number of factors. These are summarised in the table below together with a description of the implications for the analysis and the interpretation of findings.

Table 3: Factors that limit an EU-level assessment of the aggregate costs and benefits of the full implementation of measures identified in NAPs

Limitation / Issue	Description	Implications for analysis and interpretation of findings
Data gaps	In many instances, it was not possible to obtain reliable data on the costs of END implementation (both administrative costs and costs of measures). In most cases, only partial information was available on the costs of measures (i.e. it was only possible to obtain comparable information on costs and benefits for a selection of measures in each test case). This makes it difficult to compare costs and benefits across test cases or calculate an average cost or benefit per person or per area or per length (e.g. of road or railway). For the purposes of extrapolation, average (or median) costs are calculated using the test case data, supplemented with information from other published sources (e.g. NAPs) where available, or from interviews with relevant stakeholders. Where no such data was made available, estimates were made on the basis of cost factors (e.g. €2 / person for END implementation over 25 years) that have been established on the basis of secondary data sources and professional experience.	Estimates of net present value and cost-benefit ratio are indicative only

Limitation / Issue	Description	Implications for analysis and interpretation of findings
Differences in the types of measures implemented	The range and type of noise reduction measures implemented (or planned) varies significantly between agglomerations and the major infrastructure types. The choice of measures depends on, *inter alia*, the size of the infrastructure, the number of affected people and general maturity in addressing noise issues. The costs and benefits for each test case are in turn influenced by *inter alia* the choice of measures implemented (which may in turn reflect their affordability), the timing of interventions, the size of the infrastructure (e.g. in terms of number of vehicle movements) and population density in agglomerations or around major infrastructure	The test case studies are not necessarily representative of other situations and the relatively small sample of test cases makes it difficult to confidently extrapolate across the EU. For the purposes of the CBA, the costs and benefits are assessed drawing on information about implemented measures identified in the NAPs and applying assumptions around the typical measures adopted by agglomerations and major infrastructure schemes of similar scope and scale. Sensitivity analyses have also been undertaken to determine the range within which the actual costs and benefits (and hence NPV) are likely to lie.
Differences in the effect of measures implemented and gaps in information	While in some cases it was possible to obtain the costs of individual measures, it was not possible to determine the level of noise reduction that can be attributed to each measure or to different combinations of measures. The effects of implemented measures vary depending on factors such as the boundary conditions, e.g. the number of affected persons by noise from each of road, rail and air (within and outside of agglomerations) and source-specific factors (e.g. background noise, composition of traffic or geometrical considerations).	For the purposes of extrapolation, and in the absence of more refined data on the local context, the simplifying assumption is made that similar packages of measures are implemented to reduce noise associated with major infrastructure of similar sizes and types and that these measures are similar in terms of the overall noise reductions they achieve. It is not possible, however, to determine the effectiveness of measures with regards to the actual number of people benefiting as this requires detailed information on population densities within agglomerations and within the vicinity of major infrastructure schemes. The EU-wide CBA therefore makes use of median population densities (i.e. the median size of the population exposed to noise across groups of airports, agglomerations, roads or railways) based on information in the European Environment Agency Noise Observation and Information Service for Europe (NOISE) and the associated EIONET Forum Noise Database and other relevant sources.

Limitation / Issue	Description	Implications for analysis and interpretation of findings
Differences in the timing of implementation of measures and in which measures in the NAPs have been implemented to date	There are differences in the times at which the measures were introduced or their implementation was completed. Some measures were implemented before the NAPs were published (and should not therefore directly be attributed to the END) while other measures identified in the NAPs have not yet been implemented. Moreover, from the interviews, it became clear that some Member States report on all possible measures that could potentially be implemented (some of which have already been implemented, some of which may be underway and some of which may or may not be implemented in future) while other Member States only report measures for which there already is a dedicated budget. For the purposes of the test cases, it is assumed that the measures identified in the NAPs are implemented at some point during the 25 year assessment period, and thus the benefits (in terms of changes in the size of the population exposed to harmful levels of noise) correspond to a situation in which these measures are implemented, even though in some cases (e.g. major rail, Slovakia) the measures may be under discussion but have not yet been implemented and may not yet have a specific budget allocation. Where possible, the distribution of costs and benefits over the 25-year assessment period has been considered in the CBA, particularly for those measures that have already been implemented or that are underway.	Both the costs and benefits may be overstated in cases where these measures are not finally implemented.
Lack of information on the population exposed to noise levels below 55 dB L_{den} and 50 dB L_{night}.	The END requires Member States to report on the size of the population exposed to noise levels above 55 dB L_{den} and 50 dB L_{night}. However, epidemiological studies have shown that adverse health impacts begin to occur below these levels. For hypertension, coronary heart disease and stroke it is suggested that the threshold for the onset of these health effects starts at 50 dB L_{den}; for annoyance the threshold is less than 40 dB L_{den} and for sleep disturbance less than 40 dB L_{night}. Given that there is no readily available information across all Member States for all agglomerations and major infrastructure on the size of the population affected by noise below these thresholds, the health impact assessment has only been carried out for levels equal	The reported numbers and percentages are only relevant for the populations living at levels equal to or above 55 dB L_{den} and 50 dB L_{night} which underestimates the total impact of environmental noise in Europe.

Limitation / Issue	Description	Implications for analysis and interpretation of findings
	to or above 55 dB L_{den} and 50 dB L_{night} unless additional information on noise exposure below these levels was available in the NAPs investigated for the test cases.	
Incompatibility of approaches to the benefit estimation	The benefits of END implementation have been estimated by considering the reduction in the burden of disease from environmental noise. While dose-response relationships can provide estimates of the total number of people who are annoyed or sleep disturbed, the effects of annoyance and sleep disturbance in terms of morbidity and mortality can only be quantified for the highly annoyed and highly sleep disturbed populations (see step 4 in Section 1.4.1). An alternative approach would be to use estimates of willingness to pay (WTP) for a reduction in noise levels as reflected in differences in property value. While such an approach may capture the benefits of noise across the whole of the sleep disturbed and annoyed population, it is not possible to determine the effects of noise separately on the sleep disturbed and annoyed populations or on the incidence of cardiovascular diseases. The approach is therefore not compatible with the health-savings approach as to do so, would result in double-counting of the effects on the highly annoyed and highly sleep disturbed populations (which is larger than the effects on the moderately and highly annoyed and sleep disturbed populations).	The effects of the END on the annoyed and sleep disturbed populations are not quantified in the CBA and therefore the benefits are likely to be under-stated.
Attribution	Related to the above, it is also difficult to ascertain which benefits (reductions in noise levels) may be attributed directly to the END and which would have occurred anyway. As noted above, some of the measures that have been included in the analysis began to be implemented before the first round of NAPs were published and there may also be other reasons (unrelated to the END) why noise levels have diminished in certain areas (e.g. changes in the road network, or infrastructure upgrades). Indeed, as discussed in Section 3.2.5.1 of the main report, the findings of the online survey[6] showed that 61% of respondents agreed and a further 12% strongly agreed that	In the absence of any quantitative evidence relating to the effects of other (non-END) interventions, various assumptions have been made around the extent to which the costs and benefits of measures can be attributed to the END. In particular, the analysis assumes that the degree of attribution is lower in those Member States in which noise legislation was in existence prior to the introduction of the END (assumes only 50% attribution in the base case) and that the benefits are highest in situations where no previous noise legislation existed but where a

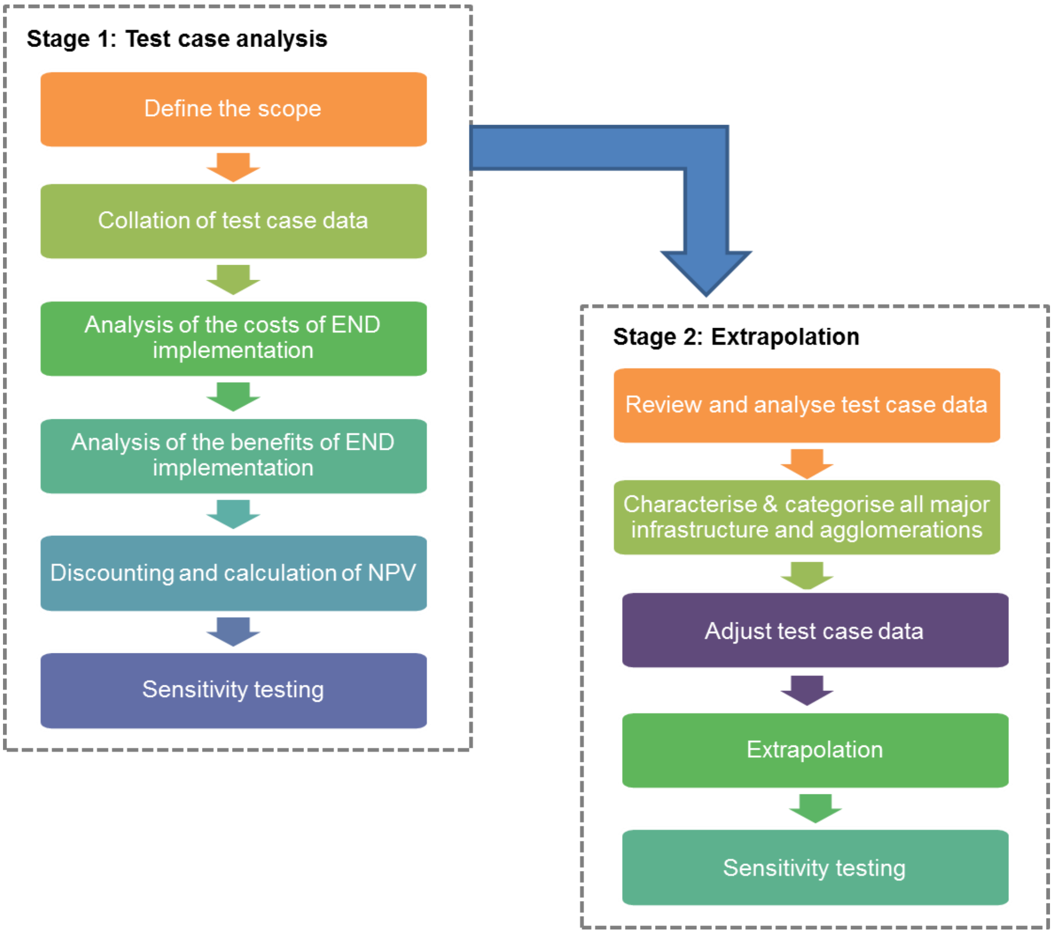
[6] The online survey was carried out with different categories of stakeholders. 73 valid questionnaire responses were received from public authorities, 7 from consultancies involved in strategic noise mapping, and 10 from NGOs/community groups

Limitation / Issue	Description	Implications for analysis and interpretation of findings
	progress in noise reduction was the result of national legislation. However, a similarly high percentage acknowledged that the END had at least partially contributed to noise reduction and positive developments in noise reduction would not have happened without the END.	NAP has been produced. The specific levels of attribution that have been applied in the analyses are set out in the sections relating to each of airports, roads, railways and agglomerations that follow. Sensitivity analyses have also been conducted to test how the outcomes may differ under a range of different assumptions regarding the extent (from 25-100%) to which the measures can be attributed to END.

1.4 Methodology

The cost-benefit analysis was conducted in two stages. These are set out in Figure 2 and described in more detail in the paragraphs that follow.

Figure 2: Overview of the methodology



1.4.1 Stage 1 – Test cases

1) The scope of the CBA

The scope of the CBA was determined based on a review of the guidance documents listed in Section 1.2, a wider review of the literature, discussions with relevant stakeholders and the availability of necessary data. It is necessarily limited to costs and benefits:

- that can be reasonably or reliably quantified, e.g. where there are established relationships between changes in noise levels and health or other outcomes;
- for which the necessary data exists to support the assessment; and
- that can be included without resulting in double counting.

In this light, the CBA includes:

- Direct **administrative compliance costs** relating to the implementation of the END, such as the preparation of strategic noise maps and the development of noise action plans (including making provision for public information and consultation);
- The **substantive compliance costs** associated with implementing the measures identified in the Noise Action Plans; and
- The benefits to those experiencing a reduction in noise levels expressed in relation to **improvements in three health endpoints** (described in more detail in a later section). It is important to note, however, that the **CBA is only able to consider the value of changes in the highly annoyed and highly sleep disturbed populations** as there are no published disability weights applicable to the low and moderately annoyed and sleep disturbed populations. While the use of willingness to pay (WTP) estimates was considered for valuing annoyance and sleep disturbance alongside the DALY estimates for highly annoyed and highly sleep disturbed), there are few studies that distinguish between the WTP amongst populations that are annoyed and highly annoyed, or sleep disturbed and highly sleep disturbed and therefore combining them with the DALY measures would in effect be double counting. As we are concerned with noise as a health endpoint, then it is only high levels of annoyance that have this effect.

It is important to note that there are a number of potentially important effects that the CBA does <u>not</u> consider. There are various reasons for this including difficulties in establishing reliable estimates of the impacts[7] and the potential for double counting. Some of these effects include:

- The influence of the END on **land use planning and residential development.** This is because it is not possible to place a monetary value on the contribution of the END to land use planning in such a way that it could be incorporated into the CBA. There is nevertheless evidence to suggest that noise concerns, driven by the END, are relevant to the siting and design of new developments. For example, Planning Practice Guidance and Planning Advice Notes issued by the Governments of England and Scotland respectively promote the appropriate location of new potentially noisy development, and a pragmatic approach to the location of new development within the vicinity of existing noise generating uses, to ensure that quality of life is not unreasonably affected and that new development continues to support sustainable economic growth.
- Changes in **property values.** It is nevertheless acknowledged that this means that a significant portion of the benefits of END implementation (i.e. those accruing to the moderately annoyed and sleep disturbed populations) are not captured (see Box 1).
- The effects of the END on direct, indirect or induced **employment.** Again, it is not straightforward to quantify the contribution of END to employment in monetary terms. It is nevertheless likely that there will have been some employment gains in terms of the specific requirements of the END in relation to preparation of strategic noise maps and action plans, as well as in the design and implementation of noise-reduction measures.

[7] In this case, the effort applied was proportionate to the estimated magnitude of the impact, outcomes at stake and resources available. Impacts were excluded from the analysis in cases where the level of effort required to generate quantified estimates was considered disproportionate to the importance of the impact relative to other impacts.

- The impacts of measures such as changes in flight paths, ascent/descent rates and scheduling on **greenhouse gas emissions and air quality**). While it is theoretically possible to calculate the additional air miles (and hence emissions and impacts) accrued as a result of changes in flight paths and scheduling, this would necessitate the collection and analysis of a number of additional datasets from across the test cases. This was not considered proportionate to the outcomes at stake and the time available.

The quantitative analysis also does not consider other relevant benefits of the END in relation to:

- **Raising awareness of and stimulating discussions around environmental noise as an issue**. Data from noise mapping has supported assessments of the effects of changes in environmental noise on health, productivity and ecosystem services which in turn have been used to influence decision-makers.
- **Generating large and consistent datasets on noise** (through SNMs) that have been invaluable in advancing research on the effects of noise on health and productivity.
- **Supporting actions in other areas** (e.g. development of technical standards, emission levels and other Directives) that have a positive effect on noise levels, unless these can be explicitly linked to the END.

2) Collation of test case data

A comprehensive data collection and analysis template was developed to capture information on the costs and the benefits of END implementation across each of the 19 test cases (see Table 4).

Table 4: Test cases

	Agglomerations	Airports	Major roads	Major railways
1	Athens, Greece	Athens, Greece	Austria	Austria
2	Augsburg, Germany	Frankfurt, Germany	Greece	Slovakia
3	Bratislava, Slovakia	Glasgow, UK		
4	Bucharest, Romania	Stuttgart, Germany		
5	Düsseldorf, Germany	Vienna, Austria		
6	Essen, Germany			
7	Helsinki, Finland			
8	Malmö, Sweden			
9	Munich, Germany			
10	Nuremberg, Germany			

The information necessary to support the CBA comes from:

- a review of the relevant NAPs;
- interviews with the relevant implementing authorities in each Member State;
- a review of the wider literature; and
- estimations based on specialist expertise and professional judgement.

The sources of data and basis for any estimations (including any underlying assumptions) are set out in more detail in the input data sheets filed in Appendix L.

The information collected includes:

- **Projections (based on strategic noise mapping[8]) of the size of the population exposed to noise** (in 5 dB intervals) with and without measures implemented under the END. This information in turn supports the assessment (using established dose-response relationships) of the value of noise reductions in terms of changes in levels of annoyance, sleep disturbance, and cardiovascular diseases. Where population data was not available in the NAPs, this was estimated based on other available sources.
- The specific data sources used for each test case are described in Appendix L and the process for classifying the size of the exposed population in each noise band is described in the test case summary reports available in Appendix F. The size of the population exposed to harmful levels of noise (i.e. in excess of 50 dB L_{night} and 55 dB L_{den}) *before the implementation of measures* is taken either from the Round 1 Strategic Noise Mapping or from detailed analysis within the noise action planning procedure of the responsible authority. The population exposed *after the implementation of measures* is taken from Round 2 Strategic Noise Mapping (where appropriate given changes in the approach to noise mapping between Round 1 and Round 2) or is estimated using either detailed analysis of the noise action planning procedure of the responsible authority or the established techniques and professional judgement, assuming the full implementation of selected measures or combinations of measures.
- Data on the **administrative or compliance costs** associated with implementation of the END. In most cases, this information has been extracted from the relevant Noise Action Plans (see Appendix L) and includes information on:
  - **Human resource costs** – the costs incurred by national competent authorities and other public authorities at local, regional and national level for strategic noise mapping, the development of NAPs, the identification of suitable noise reduction/ mitigation measures and monitoring their implementation; and meeting EU reporting obligations under the END. Note that these costs are additional to the human resource costs that would otherwise have been incurred in the absence of the END.
  - **Financial costs** - in implementing the END, implementing authorities may also bear direct costs in relation to the procurement of external consultancy support to assist in strategic noise mapping, the development of NAPs and the costs associated with the implementation of noise mitigation or noise reduction measures (e.g. quieter road surfaces)[9].
  - Data on the **actual or estimated costs of implementation of both fully implemented and planned measures**. Where possible, this information has been obtained from the published Noise Action Plans but in other instances has been estimated on the basis of secondary information. The specific sources used in each case are detailed in the input data sheets in Appendix L.

In collating the costs of END implementation, the distinction between **one-off and recurring costs** (linked to the five year cycle) and the **incidence of costs** (i.e. in which year(s) they have been incurred) has also been considered.

---

[8] The Noise Observation and Information Service for Europe (NOISE) contains data related to strategic noise maps delivered in accordance with the END. NOISE is maintained by the European Environment Agency (EEA) and the European Topic Centre for Air Pollution and Climate Change Mitigation (ETC-ACM) on behalf of the European Commission.

[9] It is arguable as to whether the costs of measures should be considered as direct or indirect costs since the END does not explicitly mandate the Member States to incur expenditure on noise reduction measures. However, it does imply that provision should be made for appropriate measures within in Article 1(1c) since Action Plans are required in order to reduce noise and preserve environmental noise quality where it is good.

In the majority of cases, the costs represent the total costs to completion for the selected measures, even if the measures have not yet been fully implemented. This is to allow for a like-for-like comparison of the costs and benefits given that, where information on beneficiaries is provided in the NAP, the number of beneficiaries corresponds to a situation in which the measure(s) has been fully implemented. Where it was not possible or not appropriate to use the costs to completion, this has been explicitly noted in the input data summaries (Appendix L).

Note that complete data for all test cases was not available and therefore in some instances costs have had to be estimated based on knowledge of similar agglomerations and major infrastructure elsewhere across the EU-28 countries (EU-28) and expert judgement. The specific sources of all costs (actual and estimates) are identified for each test case in Appendix L (input data sheets). The number of people to which the measures apply is determined by the number of persons affected by daytime noise levels > 55 L_{den} dB(A) or by night-time noise levels > 50 L_{night} dB(A). This information, in turn, is obtained from the NAPs or calculated (see Appendices L and E).

3) Analysis of the costs of END implementation

For each test case, the costs of END implementation are considered in terms of:

- The administrative costs incurred by the implementing authority in relation to Noise Action Planning and the END;
- The costs of measures; and
- The present value of the total costs discounted over a 25 year assessment period. A social discount rate of 4%[10] has been applied.

Note that costs are only included for those measures for which information on costs and number of people affected is available (from the NAPs, personal communications, other secondary sources or professional judgment) <u>and</u> for which it is possible to determine the number of beneficiaries (i.e. the number of people who benefit from reduced noise as a result of the measure or a package of measures). While estimates of beneficiaries can be made for individual measures, it is not possible where cost information is only provided for groups of measures (unless specifically stated in the NAP).

[10] This is the rate recommended by the European Commission. A social discount rate is used to convert all costs and benefits to "present values" so that they can be compared. This discount rate is a correction factor applied to costs and benefits expressed in constant prices. See: http://ec.europa.eu/smart-regulation/guidelines/tool_54_en.htm

4) Analysis of the benefits of END implementation

A number of adverse health impacts, both direct and indirect, have been linked to exposure to persistent or high levels of noise[11]. These include:

- Annoyance;
- Sleep disturbance;
- Cardiovascular diseases
- Tinnitus; and
- Cognitive impairment.

The health implications of environmental noise can be described as the number of people with (severe) annoyance and (severe) sleep disturbance and the number of residents with hypertension, hospital admissions due to cardiovascular disease and premature mortality related to noise exposure. These health effects are the most investigated non-auditory health endpoints of noise exposure.

Figure 3 illustrates the extent to which exposure to noise affects different elements of health and well-being. Within a proportion of a population exposed to elevated levels of noise, stress reactions, sleep-stage changes, and other biological and biophysical effects may occur. For some people, these may in turn lead to a worsening of various health risk factors such as blood pressure. For a relatively small part of the exposed population (as shown towards the top of the pyramid in Figure 3), the subsequent changes may then develop into clinical symptoms like insomnia and cardiovascular diseases that, as a consequence, can increase rates of premature mortality.

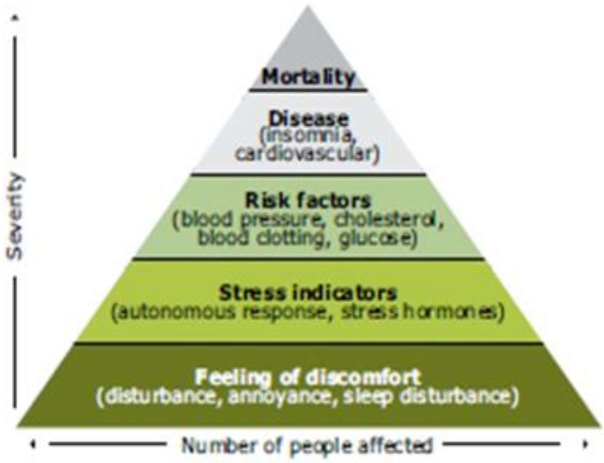
Sleep disturbance, cardiovascular diseases and annoyance, mostly related to road traffic noise, comprise the main burden of environmental noise. In 2007, CE Delft estimated (on the basis of several earlier studies) the social costs of traffic, rail and road noise across 22 countries in Europe at about €40 billion a year (about 0.4% of total EU GDP, in 2006 prices) of which 90% is related to passenger cars and goods vehicles[12]. However, it should be noted that this takes into account only effects related to noise levels above 55 dB(A) and is therefore likely to underestimate the actual costs as annoyance values have been shown to set in at around 40 dB(A)[13]. The Commission's Green Paper "Fair and Efficient Pricing in Transport" (albeit published almost a decade earlier and therefore potentially drawing on a more limited evidence base) had a somewhat lower estimate of 0.2% of GDP, which is within the same order of magnitude.

[11] WHO (2011) *Burden of disease from environmental noise. Quantification of healthy life years lost in Europe*, World Health Organization Regional Office for Europe, Copenhagen [online] available at http://www.who.int/entity/quantifying_ehimpacts/publications/e94888.pdf?ua=1

[12] CE Delft (2007) Traffic noise reduction in Europe. Health effects, social costs and technical and policy options to reduce road and rail traffic noise [online] available at http://www.transportenvironment.org/sites/te/files/media/2008-02_traffic_noise_ce_delft_report.pdf (last accessed 21/12/2015).

[13] CE Delft (2007) Traffic noise reduction in Europe. Health effects, social costs and technical and policy options to reduce road and rail traffic noise [online] available at http://www.transportenvironment.org/sites/te/files/media/2008-02_traffic_noise_ce_delft_report.pdf (last accessed 21/12/2015).

Figure 3: Pyramid of noise effects



Source: Babisch, 2002, based on WHO, 1972.

In addition, there is increasing scientific evidence regarding the harmful effects of noise on wildlife[14]. The CBA is, however, limited to those health end-points of environmental noise for which reliable dose-response relationships exist, i.e.:

- Annoyance (road, rail and air);
- Sleep disturbance (road, rail and air); and
- Cardiovascular disease (acute myocardial infarction for road only and hypertension for road and air)

Although dose-response relationships have been formulated for tinnitus and cognitive development in children, these are not used in the CBA. In the case of tinnitus, studies have suggested that environmental noise exposure with a $L_{Aeq,24h}$ of 70 dB(A) or below will not cause hearing impairment in the vast majority of people, even after a lifetime of exposure[15]. As such, social/leisure noise (such as personal music players, gun shooting events, music concerts, sporting events and the use of firecrackers) is likely to be the most relevant source of exposure in Europe although it is acknowledged that traffic noise may exceed 85 dB(A) in some urban settings. The extent to which noise impairs cognitive development, particularly in children, has been investigated using both experimental and epidemiological studies. These have generated sufficiently reliable evidence to indicate the adverse effects of chronic noise exposure on children's cognition, particularly in relation to aircraft noise. However, there is no generally accepted criterion for quantification of the degree of cognitive impairment into a disability weight.

[14] Dutilleux, G., 2012, *Anthropogenic outdoor sound and wildlife: it's not just bioacoustics!*, Proceedings Acoustics, 2301–2306, Nantes [online] available at https://hal.archives-ouvertes.fr/docs/00/81/07/95/PDF/hal-00810795.pdf

[15] WHO (2011) *Burden of disease from environmental noise. Quantification of healthy life years lost in Europe*, World Health Organization Regional Office for Europe, Copenhagen [online] available at http://www.who.int/entity/quantifying_ehimpacts/publications/e94888.pdf?ua=1

The benefits of END implementation are expressed in terms of the reduction in the number of people exposed to harmful noise levels, the corresponding decrease in morbidity and mortality (measured in terms of disability-adjusted life-years, or DALYs) and the value of these DALYs (measured using estimates of the value of a statistical life).

In order to estimate the benefits of reduced noise levels as a result of END, a quantitative risk assessment approach has been used. This is in line with guidance produced by the EEA (2009)[16], the WHO (2011)[17] and Defra (2014)[18]. There are nevertheless alternative approaches to valuing noise including both revealed and stated preference methods (see Box 1).

Box 1: Approaches to valuing noise nuisance

Revealed preference approaches

Noise nuisance has commonly been valued using hedonic pricing (HP), a revealed preference approach which uses the market for a particular good, in this case the housing market, to estimate the value of the different components of the good. The value of noise obtained is usually expressed in the form of a Noise Depreciation Index (NDI) or Noise Sensitivity Depreciation Index (NSDI) which indicates the percentage change in house prices that results from a 1 dB change in noise levels. The number of HP studies on aircraft noise is such that a number of meta-analyses have been carried out. Wadud (2013)[19] identified 65 NDI values ranging from 0 to 2.3% and included 53 estimates in a meta-analysis concluding that a 1 dB increase in aircraft noise levels leads to a fall in house prices of between 0.45% and 0.64%. This estimate is broadly consistent with meta-analysis by Nelson (2004)[20] and the earlier review by Nelson (1980)[21] though somewhat lower than the estimates of Schipper et al. (1998)[22] of 0.9% to 1.3%. Comparison of studies is difficult due to differences: in functional form, the quality and scope of data, definitions of variables and the level of discrimination of the impact being valued. There are fewer HP studies of road traffic noise, Bateman et al. (2001)[23] reviewed 18 studies mostly from North America finding a range from 0.08% to 2.22% and an average NSDI of 0.55%. More recent European studies fall within this range and tend to be reasonably consistent with this average[24]. Although the HP approach is broadly accepted and underpins many values used in public sector appraisals, the range of values is nonetheless large and, moreover, this variation is largely unexplained.

Furthermore, the revealed preference approach is based on the assumption that there is perfect labour and personal mobility and that individuals are well-informed about the risks they face in exposure to noise.

---

[16] EEA (2010) Good Practice Guide on Noise Exposure and Potential Health Effects

[17] WHO (2011) *Burden of disease from environmental noise. Quantification of healthy life years lost in Europe*, World Health Organization Regional Office for Europe, Copenhagen [online] available at http://www.who.int/entity/quantifying_ehimpacts/publications/e94888.pdf?ua=1

[18] Defra (2014) Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet

[19] Wadud Z. (2013) Using meta-regression to determine Noise Depreciation Indices for Asian airports. Asian Geographer, 30(2) 127-141.

[20] Nelson J.P. (2004) Meta-analysis of Airport Noise and Hedonic Property Values: Problems and Prospects. Journal of Transport Economics and Policy 38(1), 1-28.

[21] Nelson J.P. (1980) Airports and Property Values, Journal of Transport Economics and Policy 14(1) 37-52.

[22] Schipper Y., Nijkamp P. and Rietveld P. (1998) Why do aircraft noise value estimates differ? A meta-analysis. Journal of Air Transport Management 4(2), 117-124

[23] Bateman I., Day B., Lake I. and Lovett A. (2001) The effect of road traffic on residential property values: a literature review and hedonic pricing study. Report to the Scottish Executive.

[24] Bristow A.L. (2010) Valuing Noise Nuisance, paper to INTER-NOISE 2010, the 39th International Congress and Exposition on Noise Control Engineering, 13th -16th June, Lisbon.

Box 1: Approaches to valuing noise nuisance

The difficulty in fulfilling these requirements is thought to explain the variation in estimates produced by revealed preference studies[25].

The HP method is attractive because it has a basis in real decisions in the market place and underpins many values used in transport appraisals in Europe. However, the approach may be criticised in that purchasers may not have perfect knowledge of all the attributes of the different houses they choose between; the housing market is susceptible to other imperfections most notably transaction costs; explanatory variables suffer from correlation and it is difficult to measure some intangible influences and perceptions of them. HP is also limited in that it can only give a value of disturbance as experienced at home. Meta-analysis suggests that this cost may be capitalised through a house price discount of about 0.5% to 0.6% per dB (A). However, this cannot tell us what people might be willing to pay now for changes in the noise level experienced or how this might vary by time of day, day of week or season[26].

Stated preference approaches

Given the difficulties posed to the revealed preference approach by imperfect markets and a lack of data, economists have turned to stated preference approaches to value non-market goods. Within the class of stated preference methods, there are two alternative groups of techniques: **choice modelling** (CM) and **contingent valuation** (CV). In general, contingent valuation concentrates on the non-market good or service as a whole (e.g. WTP for a defined change in noise levels), while choice modelling seeks people's preferences for the individual characteristics or attributes of these goods and services (e.g. preferences for aircraft vs road noise or different levels or durations of noise, etc.). The advantage of contingent valuation questions is their ability to elicit exactly the information that is required.

The main challenge is the necessary assumption that individuals have a coherent set of preferences. A number of phenomena have been identified as evidence that such coherent preference may not be observed in practice, including: substitution effects; endowment effects; hypothetical bias; the influence of irrelevant cues, where respondents are influenced by the elicitation procedure, such as start-point bias, anchoring effects, focusing effects, embedding effects, and range bias[27]. CM techniques have been developed largely to take account of some of the shortcomings of CV and have been increasingly applied in this context.

This approach has grown in importance, especially in Europe, in part due to the still influential review by Navrud in 2002[28] which suggested a range of €2-€32 per household per decibel per year for road noise based on six studies. This led to the recommendation of a value of €25 per household per year by the EU Working Group on Health and Socio-economic aspects[29].

---

[25] Dolan, P. and Metcalfe, R. (2007), Valuing non-market goods: A comparison of preference-based and experience-based approaches.

[26] Bristow, A.L. and Wardman, M. (2015) Comparing noise nuisance valuation estimates across methods, meta-analyses, time and space. Paper presented at The 22nd International Congress on Sound and Vibration, Florence (Italy) 12-16 July 2015.

[27] Dolan, P. and Metcalfe, R. (2007), Valuing non-market goods: A comparison of preference-based and experience-based approaches

[28] Navrud S. (2002) The State-of-the-Art on Economic Valuation of Noise. Final Report to European Commission DG Environment.

[29] EU Working Group on Health and Socio-economic Aspects, Valuation of Noise – Position Paper. http://ec.europa.eu/environment/noise/pdf/valuatio_final_12_2003.pdf (2003).

Box 1: Approaches to valuing noise nuisance

More recent work by Bristow et al (2015)[30] identified 62 SP studies of transportation noise extracting 258 comparable values from 49 of these to conduct the first meta-analysis of such data.

As might be expected, the SP valuations of noise nuisance assembled exhibit a wide range. This variation may be explained by variations in data type and survey method, the systematic influence of study and country specific factors and, importantly, intertemporal effects. Values per unit dB change in aircraft noise exceed those for road and rail reflecting evidence in the noise annoyance literature[31]. Moreover, those who experience higher noise levels or report high levels of annoyance have higher values. The study found an inter-temporal income elasticity close to one, somewhat larger than the cross-sectional income elasticity typically obtained from individual studies. The meta-analysis revealed a significant range in WTP depending on level of income, noise source, noise exposure and perceived annoyance. For road traffic noise, for example, those who are highly annoyed report values nearly nine times higher than those who are not annoyed.

Value of a life year

There is an increasing focus on the health effects of noise with growing evidence relating to hypertension and coronary heart disease[32]. Some efforts have been made to incorporate health effects into values used in the appraisal of transport schemes, for example, the values used in Sweden are based on local HP studies with the addition of 'a 42% mark-up is made to capture the value of "un-conscious" health effects, i.e. the effects of noise on residents' health that they are not aware of and hence are not reflected in house prices' (Eliasson, 2013, p6)[33]. A more formalised approach would be to use Disability Adjusted Life Years (DALY) and Quality Adjusted Life Year (QALY) to apply a health impact pathway to noise, as has been done in this CBA.

The Department for Environment, Food and Rural Affairs (Defra)[34] recommend this approach for the valuation of noise in UK economic appraisal including annoyance and sleep disturbance, and health effects associated with cardiovascular disease, strokes and dementia. Defra argues that estimating annoyance values on the same basis as the health values should avoid risks of double counting.

Although it may be argued that the inclusion of annoyance in this way may introduce a risk of double counting if, in health terms, it is simply a precursor to other health impacts., annoyance from noise clearly impacts on well-being and thus its inclusion is wholly compatible with the WHO 1946 definition of health as "… a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." (WHO, 1946)[35].

---

[30] Bristow, A.L., M. Wardman and Chintakayala V.P.K. (2015) International Meta-analysis of Stated Preference Studies of Transportation Noise Nuisance, Transportation, January 2015, 42(1) 71-100.

[31] Miedema, H.M.E. and Oudshoorn C.G.M. (2010), Annoyance from transportation noise: relation-ships with noise exposure metrics DNL and DENL and their confidence intervals, Environmental Health Perspectives, 109 (4) 409-416

[32] Babisch, W. (2014), Updated exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis, Noise and Health, 16 (68) 1-9.

[33] Eliasson J. (2013) International Comparison of Transport Appraisal Practice: Annex 4 Sweden Country Report, University of Leeds. Available at https://www.gov.uk/government/publications/international-comparisons-of-transport-appraisal-practice.

[34] Department for Environment, Food and Rural Affairs, Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet. November 2014. Available from:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/380852/environmental-noise-valuing-imapcts-PB14227.pdf

[35]

Box 1: Approaches to valuing noise nuisance

Values derived from hedonic pricing studies may reflect annoyance and sleep disturbance but do not reflect current preferences of residents. Values derived from stated preference studies are likely to include the combined perceived amenity effects of annoyance and sleep disturbance.

It is less likely that the values from these approaches would include the more serious health effects as the relationships between noise and health are not widely understood, partly because the evidence base is still developing.

The implications of this that the approach adopted for this study, using DALYs, understates the benefits of reduced noise levels to the noise-affected population. The value of the benefits that have not been included will depend largely on the distribution of the population affected by noise at various levels - annoyance and hence WTP is higher at higher levels of noise.

The benefits relating to each health end-point are estimated using the following data:

- The distribution of environmental noise exposure within the population (and how this changes as a result of END implementation);
- The dose-response relationships for each health end-point;
- A population-based estimate of the incidence or prevalence of cardiovascular disease from surveys or routinely reported statistics; and
- The value of the disability weight (DW) for each health end-point. The DW is associated with each health condition and lies on a scale between 0 (indicating the health condition is equivalent to full health) and 1 (indicating the health condition is equivalent to death).
- The value of a life year (VOLY).

Each of these steps is briefly described below.

a) Estimate the prevalence of noise exposure within the population with and without/in absence of measures

The first step in the benefits estimation process is to identify the change in the size of the population exposed to harmful levels of noise. Data was therefore collected on the size of the population exposed to noise levels in 5dB increments (from 45 dB(A) to 80 dB(A) and using both L_{den} and L_{night} measures) under both the 'with END measures' and 'without END measures' scenarios. The difference between the two scenarios is then used to estimate the change in the size of the population affected by each of annoyance, sleep disturbance and cardiovascular disease.

As noted above, the size of the population affected by harmful levels of noise both before and after the implementation of measures and at each noise interval, is taken from the published NAPs or Strategic Noise Maps wherever possible. Where information on the distribution (across noise intervals) of the affected population after measures was not available in the NAP, this was estimated by applying widely accepted average noise reduction levels for each of the measures identified in the NAP (see Appendix E) and combining this with standard reference distributions used to determine the size of the population (before measures). Further details of the approach used for each of roads, railways and agglomerations are set out in Appendix F.

b) Estimate the incidence (or prevalence) of annoyance and sleep disturbance as a result of noise exposure using relevant dose-response relationships

Once the size of the population exposed to various noise levels has been established, the next step is to determine the proportion of that population that is moderately or highly annoyed, moderately or highly sleep disturbed or at risk of hypertension or cardiovascular disease (acute myocardial infarction and ischaemic heart disease) as a result of noise. For this, we make use of established dose-response relationships obtained from epidemiological studies. The derivation of these relationships is described in detail in WHO (2011)[36]

Annoyance and sleep disturbance

The specific dose-response functions used for each of sleep disturbance and annoyance are set out in the table below.

Table 5: Dose-response relationships for health effects of noise

Sleep disturbance	Roads	Moderate	$\%SD = 13.8 - 0.85L_{night} + 0.01670L_{night}^2$
		High	$\%HSD=20.8-1.05(L_{night})+0.01486(L_{night})^2$
	Rail	Moderate	$\%SD = 12.5 - 0.66L_{night} + 0.01121L_{night}^2$
		High	$\%HSD=11.3-0.55(L_{night})+0.00759(L_{night})^2$
	Air	Moderate	$\%SD = 13.714 - 0.807L_{night} + 0.01555 (L_{night})^2$
		High	$\%HSD=18.147-0.956(L_{night})+0.01482 (L_{night})^2$
Annoyance	Roads	Moderate	$\%A=1.795*10^{-4}(L_{den}-37)^3+2.110*10^{-2}(L_{den}-37)^2+0.5353(L_{den}-37)$
		High	$\%HA=9.868*10^{-4}(L_{den}-42)^3-1.436*10^{-2}(L_{den}-42)^2+0.5118(L_{den}-42)$
	Rail	Moderate	$\%A=4.538*10^{-4}(L_{den}-37)^3+9.482*10^{-3}(L_{den}-37)^2+0.2129(L_{den}-37)$
		High	$\%HA=7.239*10^{-4}(L_{den}-42)^3-7.851*10^{-3}(L_{den}-42)^2+0.1695(L_{den}-42)$
	Air	Moderate	$\%A=8.588*10^{-6}(L_{den}-37)^3+1.777*10^{-2}(L_{den}-37)^2+1.221(L_{den}-37)$
		High	$\%HA=-9.199*10^{-5}(L_{den}-42)^3+3.932*10^{-2}(L_{den}-42)^2+0.2939(L_{den}-42)$

[36] WHO (2011) *Burden of disease from environmental noise. Quantification of healthy life years lost in Europe*, World Health Organization Regional Office for Europe, Copenhagen [online] available at http://www.who.int/entity/quantifying_ehimpacts/publications/e94888.pdf?ua=1

Hypertension and cardiovascular diseases

Epidemiological studies on the relationship between transportation noise (particularly road traffic and aircraft noise) and cardiovascular effects have been carried out on adults and on children, focusing on mean blood pressure, hypertension and ischaemic heart diseases as cardiovascular end-points. While there is evidence that road traffic noise increases the risk of ischaemic heart disease, including myocardial infarction, there is less evidence for such an association with aircraft noise because of a lack of studies. However, there is increasing evidence that both road traffic noise and aircraft noise increase the risk of hypertension. Very few studies on the cardiovascular effects of other environmental noise sources, including rail traffic, are known and are, therefore, not considered further here.

Two meta-analyses (Van Kempen, (2002)[37] and Babisch (2006)[38]) combined a number of suitable primary studies to estimate exposure-response functions based upon the best available evidence at the time. These were then applied to population level data on noise exposure to estimate the health impacts of noise in the Netherlands and Germany. The exposure-response relationships that each of these studies derived have since been recommended for use by the WHO, Defra and EEA guidance. This earlier work has since been supplemented by a more recent meta-analysis (Babisch, 2014)[39] based on a more substantial body of evidence on the association between road traffic noise and coronary heart diseases. This more recent analysis concluded that studies of the associations between road traffic noise and the risk of coronary heart diseases show a significant increase in risk with increasing noise level. In particular, the meta-analysis revealed an 8% increase in risk per increase of the weighted day-night noise level L_{DN} of 10 dB (A) within the range of approximately 52-77 dB (A).

The WHO and EEA set out approaches to valuing hypertension and ischaemic heart disease separately while Defra recommends that, in order to reduce the risk of double counting, hypertension is not directly valued, but that instead its impacts are valued in terms of consequential health outcomes, namely strokes and dementia.

Defra therefore recommends a two-stage approach to valuing hypertension. Firstly, quantifying the impact of noise exposure and hypertension (using odds ratios derived by Babisch and Van Kamp (2009) and in accordance with the WHO and EEA guidance) and then between hypertension and dementia and strokes. The second stage values the expected incidents of hypertension by quantifying consequential changes in incidents of both dementia and strokes and then valuing these in terms of DALYs. The key steps in this approach are presented in detail in the Defra guidance.

For the purposes of the present CBA, hypertension has been valued using the odds ratios presented in WHO (2011) and established on the basis of a review by Berry et al (2009)[40] of the link between environmental noise and hypertension.

[37] Van Kempen, E et al (2002), The Association Between Noise Exposure and Blood Pressure and Ischaemic Heart Disease: a Meta-analysis.

[38] Babisch, W (2006) Transportation Noise and Cardiovascular Risk: Review and Synthesis of Epidemiological Studies [online] available at http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/2997.pdf

[39] Babisch, W., 2014. Updated exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis. Noise and Health, 16(68), p.1.

[40] Berry, B. (forthcoming) Review of recent research on noise and hypertension. Berry Environmental Ltd.

For aircraft noise, the odds ratio was derived using the results of five studies on the relationship between aircraft noise and high blood pressure. When the coefficients of a linear trend from the five studies were taken together, the pooled estimate of the relative risk was 1.13 (95% CI 1.00–1.28) per 10 dB(A) for aircraft noise levels ranging between approximately 47 and 67 dB(A)[41].

Owing to the results of more recent studies, this pooled effect estimate was smaller than that obtained from an earlier meta-analysis where the estimate of the relative risk was 1.59 (95% CI 1.30–1.93) per 10-dB(A) increase in the noise level [42].

For road traffic noise, we have used the value recommended by Defra (2014)[43]. The Defra value is derived from evidence collated by Berry (forthcoming, cited in Defra, 2014)[44] and is set at 1.07 for a 10 dB increase above 50 dB.

The WHO and EEA guidance concur on the use of the Babisch (2006) polynomial for estimating the increase in risk of ischaemic heart disease (using acute myocardial infarction as a marker) for each unit increment in noise level:

$$OR = 1.629657 - 0.000613 * (L_{day,16h})^2 + 0.000007357 * (L_{day,16h})^3,\ R^2 = 0.96$$

c) Conversion to DALYs using disability weights

The impacts on each of the health end-points were then converted into a standard health metric using disability weights (DWs) and expressed in terms of deaths and/or duration of disability (in years) (see Box 2).

Box 2: DALYs

DALYs indicate the estimated number of healthy life years lost in a population from premature mortality or morbidity, i.e. the health burden.

The DALY is calculated as the sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability. It can be calculated as follows:

DALY = YLL + YLD

Where YLL = ND (number of deaths) x DW (disability weight) x LD (standard life expectancy at age of death in years); and

YLD = NI (number of incident cases) x DW (disability weight) x LI (average duration of disability in years)

There are previous studies available that provide benchmark data on DWs, such as the WHO study on *the Burden of Disease from Environmental Noise.* This data has been used in the present CBA.

[41] Babisch, W. and van Kamp I. Exposure–response relationship of the association between aircraft noise and the risk of hypertension. *Noise & Health*, 2009, 11(44):161–168.

[42] van Kempen EEMM. et al. The association between noise exposure and blood pressure and ischaemic heart disease: a meta-analysis. *Environmental Health Perspectives*, 2002, 110:307–317.

[43] Defra (2014) Defra (2014) Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet.

[44] Berry, B., (forthcoming) 'Review of recent research on noise and hypertension' Berry Environmental Ltd.

Disability weights allow time lived in various non-fatal health states and death to be measured using a common unit using a scale that takes societal preferences into account. The recommended values for DWs for various disease states are set out in WHO (2011) and have been used to support this CBA. The specific values that have been used in the analysis for sleep disturbance and annoyance are shown in Table 6.

Table 6: Disability weights used in the analysis

Health endpoint	Recommended Value	Low	High	Notes
Sleep disturbance	0.07	0.04	0.10	Following the *Night noise guidelines for Europe*[45], 0.07 was chosen as the DW of noise-related sleep disturbance in the calculation of DALYs. This value takes into account both the medians and means of the DWs observed in various epidemiological studies. Given the skewed distribution of the DWs reported across the studies, the median of the study with the lowest DW was chosen as the low estimate, whereas the highest observed mean value (0.10) was chosen as a high estimate yielding the uncertainty interval 0.04-0.10.
Annoyance	0.02	0.01	0.12	Given the limited number of studies on a DW for annoyance, and the sensitivity of the environmental burden attributed to noise annoyance for small chances in DW, the WHO proposes a tentative DW of 0.02 with a relatively large uncertainty interval (0.01-0.12).

Note, however, that there are no published disability weights applicable to the low and moderately annoyed and sleep disturbed populations. As a result, the CBA only considers the value of changes in the highly annoyed and highly sleep disturbed populations.

In line with the approach presented in WHO (2011), we make use of WHO health statistics[46] for estimates of the DALYs relating to cardiovascular disease (acute myocardial infarction and hypertension) in each Member State. As DALYs for myocardial infarction are not published, we applied the values relating to ischaemic heart disease. Thus, for the sake of DALY calculation, we assume that road traffic noise has a similar impact on all ischaemic heart disease as on myocardial infarction.

Combining the data on noise exposure, the incidence of health outcomes as a result of noise and the appropriate disability weights, we are then able to provide an estimate of the health impact of sleep disturbance and annoyance (for the highly sleep disturbed and highly annoyed populations respectively) and cardiovascular disease expressed in terms of DALYs.

[45] WHO (2009) Night noise guidelines for Europe. Copenhagen, WHO Regional Office for Europe [online] available at http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

[46] WHO (2014) Health Statistics - Environmental Burden of Disease (2012). Online at http://www.who.int/healthinfo/global_burden_disease/estimates/en/index2.html

d) Estimate the health value

The value of these outcomes is then estimated by applying a derived value of a life year (VOLY). The derivation of the estimates the VOLY used in this analysis is described in more detail below.

The cost-savings through a reduction in the number of hospital admissions (and hence healthcare costs) and lost productive days at work (particularly relating to the incidence of acute myocardial infarction) should ideally be included in the analysis but it was not possible to do so with the available evidence. While it was possible to obtain marginal values for healthcare costs and absenteeism, more detailed research is required to determine the incidence rate of acute myocardial infarction across the population (which varies by age, gender, ethnicity) and how this changes in response to changes in exposure to noise. This is required in order to derive estimates of the total number of avoided hospital admissions and lost work days. The derivation of the marginal estimates for healthcare costs and absenteeism are nevertheless reported below.

Morbidity and Mortality

Opinion is divided on whether one should use the Value of a Statistical Life (VSL) or VOLY for mortality valuation. Some argue that the VOLY approach links more naturally to the quantified health impact. Others, however, argue that the VOLY concept lacks the strong empirical base developed by VSL estimates made over many years. A 2004 report for European Commission, DG Research, Technological Development and Demonstration (RTD) on an Assessment of External Costs from Energy Technologies (New EXT)[47] compares the Value of Statistical Life (VSL) and VOLY approaches for valuing the incidence of premature death (in this instance by air pollution) in different contexts and concludes that there is strong support for using VOLYs in cases where "the impact of air pollution is not instantaneous but the cumulative result after years of exposure, so that the number of deaths is not observable".

There is nevertheless some debate in the literature on what the most appropriate monetary value should be. In the absence of European studies directly focussing on the VOLY, the New EXT project carried out a study to provide an empirical basis for valuing mortality impacts. This made use of a relationship, established in Rabl (2003)[48], between changes in probabilities of death and changes to life expectancy. In essence, the relationship presents the equivalent change in life expectancy associated with a 5 in 1000 change in risk of premature death for different ages and sex, based on EU population statistics. Based on their calculations, the authors suggest that the implied mean and median values of a statistical life-year (VOLY) are €125,250 and €55,800 (in 2000 prices) respectively but that, "… given the uncertainties, this might safely be rounded to €50,000".

[47] IER (2004) New Elements for the Assessment of External Costs from Energy Technologies. Final Report to the European Commission, DG Research, Technological Development and Demonstration (RTD) [online] available at http://www.ier.uni-stuttgart.de/forschung/projektwebsites/newext/newext_final.pdf

[48] Rabl, A. (2003). Interpretation of air pollution mortality: number of deaths or years of life lost?. *Journal of the air & waste management association*, *53*(1), 41-50.

In 2005, AEA Technology[49] led a CBA of air quality related issues, in particular in the Clean Air for Europe (CAFE) Programme. The methodological report reviewed the available evidence relating to the valuation of morbidity and mortality effects, including those used in the new EXT study and estimates from a Defra study on WTP for a reduction in air pollution that would bring about a range of health benefits. The authors concluded that the newEXT median and mean values were most appropriate since they are more representative of the EU population and made use of a larger sample size.

A more recent report by EMRC on the CBA of the Air Quality Package for Europe[50] also makes use of the newEXT values. While these were challenged by stakeholders[51], the authors of the EMRC study argue that the newEXT values are representative of the broader literature in the area, including work by Desaigues *et al* (2011)[52] who argue that "[*for the EU] the VOLY is at least €25,000 and at the most €100,000"* and a more recent paper by Chanel and Luchini (2014)[53] which provides a further peer reviewed estimate for the VOLY based on analysis performed in France, of €140,000.

For the purpose of this CBA, a value in accordance with the recent CBA of the Air Quality Package for Europe[54], adjusted to 2014 prices using the Eurostat GDP deflator, of €110,987 has been used. This value has been applied across all Member States as it was considered neither practically possible nor politically appropriate to use different values and also because there is also the practical challenge of getting such values from Member States. For instance, a WTP for increasing life expectancy has been derived only for a couple of Member States. Furthermore, data requirements would weigh against pursuing a Member State by Member State approach. Finally, as the analysis is carried out at the EU level, it is justified to use the same average WTP values across all Member States. Sensitivity tests were also run using the lower - and upper-bound estimates provided by the Commission as having been used in other impact assessments with a range from €67,163 to €155,000.

Hospital admission costs

Ready et al (2004) reported generic unit costs for hospital health care in various EU Member States including both outpatient / emergency room and inpatient care. The CAFE CBA uses these values as a starting point to calculate mean values suitable for use as a first proxy for EU countries for which specific values do not exist. Generic hospital costs are taken as the average costs of a wide variety of specialist treatments, for use when precise information about the nature of the individual's hospital contact is not known. The mean inpatient costs were estimated at €620 per day and the outpatient costs as €35 per visit (both in 2000 prices).

---

[49] AEAT (2005) Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme Methodology for the Cost-Benefit analysis for CAFE:

Volume 2: Health Impact Assessment [online] available at http://ec.europa.eu/environment/archives/cafe/pdf/cba_methodology_vol2.pdf

[50] EMRC (2014) Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package Version 2 Corresponding to IIASA TSAP Report 11, Version 1 March 2014 [online] available at http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP_CBA_corresponding_to_IIASA11_v2.pdf

[51] See, for example, Concawe (2013) CONCAWE Comments on the Key Submissions Associated with 5th Stakeholder Expert Group of the Air Quality Policy Review held in Brussels, 3rd April 2013. Cost Benefit Analysis under the Microscope.

[52] Desaigues, B., et al (2011) Economic valuation of air pollution mortality: A 9-country contingent valuation survey of value of a life year (VOLY). *Ecological Indicators* 11 (2011) 902–910.

[53] Chanel and Luchini (2014)

[54] EMRC (2014) Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package Version 2 Corresponding to IIASA TSAP Report 11, Version 1 March 2014 [online] available at http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/TSAP_CBA_corresponding_to_IIASA11_v2.pdf

The EMRC (2014) study, however, uses information from the WHO's CHOICE database[55] which indicates that that the 'hotel' costs of hospitalisation are on average in the region of €280/day (2008 prices) for the EU. These estimates represent only the 'hotel' component of hospital costs, i.e. excluding the costs of drugs and diagnostic tests but including costs such as personnel, capital and food costs. WHO's Hospital Morbidity Database indicates 8.6 days for cardiovascular admissions as an average for EU countries. Combining these figures provides the total cost of a hospital stay.

For the purposes of this CBA, we have used the WHO estimates adjusted to 2014 prices. The average cost of admission to hospital is thus taken to be around €2,600. It can be further assumed that each episode of myocardial infarction results in a hospital admission. However, as explained above, it was not possible to obtain information on the absolute number of hospital admissions relating specifically to noise-induced illness in the baseline (i.e. before the introduction of noise-reduction measures), and therefore it is not possible to determine the change in the number of AMI admissions related to noise disturbance. From the information available, it is only possible to determine the change in the number of people at risk of myocardial infarction as a result of the implementation of noise-reduction measures under the END. The cost-savings from a reduction in the number of hospitalisations has therefore not been included in the cost-benefit analysis.

Employer costs (costs of absenteeism)

The costs of absenteeism adopted in this analysis are based on surveys conducted by the Confederation of British Industry (CBI, 2013)[56] and the CIPD (2013)[57]. This report is the outcome of a survey on absence conducted by the CBI. The direct cost of absence is based on information from a survey across a range of organisations from various sectors which seeks to establish the levels, causes and costs of absence in the UK. Direct costs include the salary costs of absent individuals, replacement costs (i.e. the employment of temporary staff or additional overtime), and lost service or production time. The indirect costs of absence (i.e. those relating to lower customer satisfaction and poorer quality of products or services leading to a loss of future business) are not included as there is insufficient information to provide a representative estimate.

The CBI reports a mean direct cost to business per employee as £975 (€1,209) in 2012 prices. However, the mean cost estimates are skewed (increased by the fact that a small number of employers have very high costs and therefore the median estimate (£622 or €771) is likely to be a better indicator of average costs. The survey also notes that the average absence level per employee is 5.3 days per year. Based on the median, the average cost per employee per day is therefore £117.36 (or €145.56 in 2012 prices). The CIPD survey reports an average of 7.6 days absence (trimmed mean) and median cost of absence of £595 (€738 in 2012 prices) giving an implied cost per day of £78.29 (or €97.10), somewhat below the CBI estimate. For the purposes of this CBA, we have used the average of the CBI and CIPD figures and adjusted these to 2014 prices.

[55] See http://www.who.int/choice/cost-effectiveness/inputs/health_service/en/

[56] CBI (2013) Fit for purpose: Absence and workplace health survey 2013 [online] available at http://www.cbi.org.uk/media/2150120/cbi-pfizer_absence___workplace_health_2013.pdf

[57] CIPD (2013) Absence Management, Annual Survey Report 2013 [online] available at https://www.cipd.co.uk/binaries/absence-management_2013.pdf

In order to derive country-specific estimates of the direct costs presented for the UK, we have used a EUROSTAT index of purchasing power parity[58] to scale the UK estimate up or down for each Member State and to derive a mean estimate that is then applied across the EU-28. The mean EU estimate is €111.82 per day (2014 prices). This figure is then multiplied by the average number of days absent from work for each person that suffers from noise-induced myocardial infarction.

This is equated to the length of hospital stay (8.6 days) plus the time spent at home recovering (15 days). The total cost to the employer for each incidence of myocardial infarction is therefore estimated to be €2,856 (2014 prices). For an EU-wide estimate, the costs per absent person then need to be applied to the average proportion of the working age population (65.9%) across the EU28 in each of part- and full-time employment (20.4% and 79.6% respectively)[59].

However, as noted above, the employer costs are not included in the analysis as it was not possible to obtain information on the change in the number of people that suffer from noise-related cardiovascular disease relative to the baseline.

It is only possible to derive estimates of the change in relative risk.

The following costs have also been excluded from the analysis as it was not possible (within the confines of the present study) to obtain estimates of the baseline values and hence cost-savings as a result of noise reduction measures: Emergency room visits

- General Practitioner (GP) visits
- Daily medication (e.g. for sleeplessness, hypertension, heart conditions, etc.)
- The opportunity cost of lost leisure (i.e. non-work) time

The value of cost-savings in relation to each of the items below is nevertheless considered small relative to the total benefits.

A summary of the relevant cost savings to be considered in the CBA is provided in Table 7 below. However, due to limited information from the literature, it was only possible to include those impacts which are shown in bold. Table 8 provides a summary of the base case estimates derived for each of VOLYs, hospital admissions and employer costs. It can be seen that hospital admissions and employer costs together constitute only around 5% of the value of mortality as measured by the VOLY.

Table 7: Health impact summary

	Road	Rail	Air	Health impacts
Annoyance	✓	✓	✓	• **Mortality from life years lost**
Sleep Disturbance	✓	✓	✓	• **Mortality from life years lost or premature death** • Costs of medication • GP visits • Lost productive time (employer costs)
Myocardial Infarction	✓			• **Mortality from life years lost or premature death** • Cardiac hospital admissions • Lost productive time (employer costs) • Emergency room visits • GP visits

[58] http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00114&plugin=1
[59] http://ec.europa.eu/eurostat/data/database

	Road	Rail	Air	Health impacts
Hypertension	✓		✓	• Costs of medication • **Mortality from life years lost or premature death** • GP visits • Costs of medication

Table 8: Valuation basis and central value for each of the health impacts included in the analysis

Health impact	Valuation basis	Central Value (2014 prices)
Hospital admission for acute myocardial infarction	WHO databases on inpatient costs and average length of hospital stay for cardiovascular conditions	€2,600 per stay
Mortality / morbidity	VOLY (from EMRC, 2014)	€110,987
Employer costs	CBI and CIPD surveys on workplace absence	€2,639 per incidence of myocardial infarction

e) Wider benefits

In addition to measures identified in individual NAPs, the analysis has also considered the influence of the END on other EU Regulations, Directives and Communications. These are also complemented by a whole host of national and local regulations and policies relevant to noise. It is, however, very difficult to precisely quantify the degree to which the END has influenced these national and local initiatives and therefore their individual effects have not been considered directly in the assessment. They are, however, at least partly accounted for through sensitivity tests around the degree to which the benefits can be attributed to the END.

The relevant Directives investigated are set out in the table below.

Table 9: Other relevant Directives and Regulations

Directive / Regulation	Entry into force
Roads	
EC regulation No 1222/2009 on the **labelling of tyres** with respect to fuel efficiency	1 November 2012
Regulation (EC) No 661/2009 concerning type-approval requirements for the **general safety of motor vehicles**, their trailers and systems, components and separate technical units intended therefor.	20 August 2009
Regulation 540/2014 on the sound level of motor vehicles and of replacement silencing systems	June 2015
Airports	
Directive 2002/30/EC on **noise management at airports** (and subsequent Regulation No. 1137/2008 relating to Article 6)	28 March 2002
Regulation 598/2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC	13 June 2016

Directive / Regulation	Entry into force
Railways	
Directive 2006/38 (revised) Charging heavy goods vehicles on motor- and freeways for infrastructure use. Basis: Allocated infrastructure costs plus mark-ups for noise and air pollution. This was the precondition set in Dir. 2001/14 for including noise costs in the rail track charging scheme.	
COM 2006/66 Technical Specifications for Interoperability related to the subsystem 'rolling stock-noise'. Functional and technical specification of the sub-system. Limits for pass-by and stationary noise. Limits for locomotives, multiple units and coaches. Measurement, assessment, application to new and existing rolling stock.	June 2006

5) Calculate the present value of benefits

The benefits of a reduction in noise levels are assumed to be persistent, i.e. they endure for as long as the noise levels remain below those that would have been experienced in absence of the END (i.e. the counterfactual scenario). For the purpose of this CBA, the benefits are assumed to be constant over the assessment period although in reality, these may be eroded over time as general noise levels increase. Consequently, even if individuals may continue to experience noise levels lower than without the intervention, they may end up back in the highly annoyed group. The analysis could therefore potentially overstate the size of the benefits. However, we also considered a counterargument put forward in this regard, namely the fact that if general noise levels increase over time, this would equally increase the adverse effects in the absence of the END. It is possible that the "gap" between the adverse effects experienced both under the END and in a counterfactual situation in the absence of the END would remain the same no matter what the general noise levels trends are.

The stream of benefits was assessed over a 25-year assessment period and discounted using the EC's recommended social discount rate of 4% to obtain a measure of the present value.

The estimate of the size of the benefits calculated has also taken into account, as far as possible and on the basis of contextual information provided during interviews, the extent to which the benefits linked to the implementation of measures in the NAPs (i.e. a reduction in environmental noise in decibels) can be attributed to the END, or would have happened anyway as a result of other policies and legislation and general pre-planned infrastructure upgrades.

6) Apply decision criteria

Net present values and cost-benefit ratios are then calculated for each measure by comparing the present value of costs and benefits.

7) Sensitivity testing

The sensitivity of the results to the underlying assumptions (e.g. around the value of disability weights, VOLYs or the extent to which the change in the size of the population exposed to noise can be attributed to the implementation of the END) were also systematically tested to reflect the confidence intervals (i.e. using the low and high points of ranges in, for example, disability weights and QALYs). More specifically, the parameters shown in Table 10 were tested.

Table 10: Parameters for sensitivity testing

	Base case	Test 1 (Low scenario)	Test 2 (High scenario)
Disability weight for annoyance	0.02	0.01	0.12
Disability weight for sleep disturbance	0.07	0.04	0.1
VOLY	€110.987	€67,163	€154,812

1.4.2 Stage 2 – Extrapolation to the EU level

The test case results were then aggregated and extrapolated to inform an indicative assessment of the costs and benefits of the END at the EU-wide level. To this end, the individual test case costs and benefit estimates were considered in light of:

- Their **representativeness** (i.e. are there factors that make the agglomeration, airport or other major infrastructure unique in terms of the selection of measures implemented and the associated costs and benefits or can it be considered broadly representative of other agglomerations or major infrastructure?)
- The **reliability** of the test case data (i.e. is the test case data complete and reliable or to what extent is it based on estimates).

Where considered necessary, the values applied across the EU-28 were adjusted to take account of:

- The **local context** (e.g. rural vs urban, largely to reflect the differences in population densities in these areas);
- The **size** of the agglomeration or airport, or length of road or railway in relation to that to which the values are being applied;
- The relative maturity of the implementing authority in terms of the noise measures that have been implemented (i.e. is the implementing authority in the test case likely to be ahead, or behind of the curve in relation to other implementing authorities). This is relevant as some authorities may already have implemented the most cost-effective measures and thus any further expenditure will result in lower net benefits;
- The **reliability of the information** on the costs of measures in the test cases when benchmarked against other agglomerations and infrastructure with similar characteristics.

The process of extrapolating the test case data for each of major airports, roads, railways and agglomerations, including any adjustments, is described in more detail in the following section. Various sensitivity tests were then applied using the same parameters as identified in Table 10, as well as an additional one that considered the degree of completeness of NAPs across the EU28 by only considering those Member States for which NAPs exist.

1.5 Aggregate assessment of the costs and benefits of END

1.5.1 Major airports

1.5.1.1. Context

Under the END, there is a requirement for noise exposure levels to be reported for all airports with more than 50,000 aircraft movements per year. According to the EEA Noise database[60], a total of 93 airports fulfil this criterion. These range in size (in terms of annual traffic movements) from 22,000 movements per year (Turku Airport, Finland) to almost 500,000 movements per year (London Heathrow, United Kingdom and Paris Charles de Gaulle Airport, France).

Based on European Environment Agency (EEA) data from 2013[61], it is estimated that around 0.66 million people in Europe are exposed to harmful levels of noise (L_{den}) from major airports.

In recent years there have been a number of policy and technological advances that have sought to reduce aircraft noise. In the past 15 years, a 75% reduction in aircraft noise (equivalent to a 6dB reduction) at source has been achieved, reflecting investment by manufacturers in R&D to reduce aircraft noise at source through a combination of improvements in aircraft design (e.g. advanced aerodynamics, lighter aircraft etc.) and engine design (e.g. next generation engines). This development has been supported by the increasingly stringent standards for noise at source set by the ICAO which date back to the 1970s. In addition, procedural operating efficiencies, such as Continuous Descent Approaches and Continuous Climb Operations reduce noise by flying aircraft higher, routing aircraft differently within the airspace and/or optimising the use of engine thrust). It is, however, challenging to separate out those improvements that have been at least influenced by the END and those which would have happened anyway. Other possible influences on noise reduction around airports include:

- The European Parliament and Council approved on April 16, 2014 **new aviation noise rules** (Regulation 598) that repeal a 2002 Directive on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports[62]. The new regulation, which is due to take effect on June 13, 2016, puts the EU in line with the International Civil Aviation Organization’s ‘**balanced approach**’ to noise. This approach calls for cutting noise levels through the deployment of modern aircraft, land-use planning, quieter ground-control operations and restrictions on nighttime flying.
- **Advances in jet engine technology**. It is estimated that new generation jet engines are on average 75% quieter than their 20th century predecessors.

However, critics argue that these are likely to make little difference to noise levels as they are accompanied by an increase in the total number of flights and a demand for larger passenger planes[63] and because of a lack of a binding noise target[64]. It is nevertheless possible to attribute at least some of the reduction in noise to the END.

[60]Accessed at http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/index_html

[61] See http://www.eea.europa.eu/data-and-maps/indicators/exposure-to-and-annoyance-by-1/assessment

[62] Directive 2002/30/EC of the European Parliament and of the Council of 26 March 2002 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports (OJ L 85, 28.3.2002, p. 40).

[63] See http://www.euractiv.com/sections/aviation/aircraft-become-quieter-health-concerns-about-noise-grow-louder-303449

1.5.1.2. Methodology: Summary overview

The analysis that follows considers a number of test cases from which an indicative estimate of the costs and benefits across the EU28 was made.

The test cases covered five airports:

- Glasgow (United Kingdom)
- Stuttgart (Germany)
- Athens International (Greece)
- Vienna International (Austria)
- Frankfurt (Germany)

The figure and table below show the size of the test case airports in terms of annual number of aircraft movements in relation to all airports that are required to report under the END.

Figure 4: Distribution of airport sizes by number of aircraft movements across EU Member States

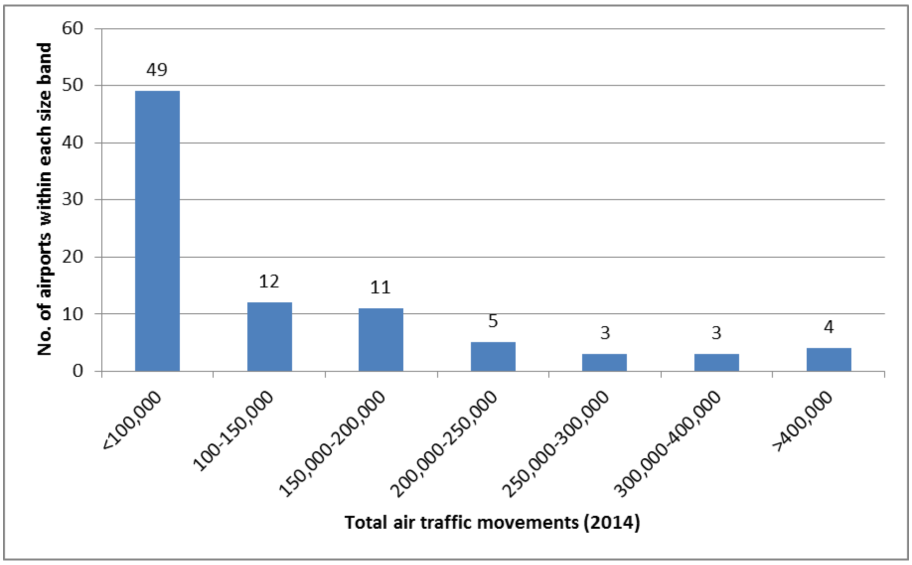


Table 11: Test case airports by size

Airport	Movements per year
Glasgow	83,999
Stuttgart	127,678
Athens	154,530
Vienna	249,989
Frankfurt	469,026

[64] See http://www.euractiv.com/sections/aviation/new-eu-rules-seen-too-timid-reduce-airport-noise-303427

This shows that the test case airports are larger (in terms of total air traffic movements, ATMs) than most of the major airports across the EU. Almost half (at least 29) of the 62 airports for which data is available, are smaller than Glasgow airport.

The test case data was then extrapolated to inform an assessment of the costs and benefits across the EU-28. For each test case, the number of people exposed above 55 dB L_{den} is used to derive per person estimates of costs and benefits. It is important to note that this cost or benefit per person is not the cost or benefit per single beneficiary of the noise reduction measures; rather, it is an averaged cost or benefit that considers both those people that benefited from the noise reduction measures and those that did not. The average benefit per person is therefore simply an indicator of the performance at airport level. It is not an assessment of the effectiveness of specific measures (i.e. the value of the benefit derived by those that directly benefit from the measure), as the beneficiary population is a subset of the total population affected by noise.

The size of the population exposed to noise levels greater than 50 dB L_{night} is also reported but not used for calculations.

Costs

Costs are divided into a) compliance/administrative costs, and b) costs of implementing the measures. Costs reported here are the total costs incurred (or planned) to date, discounted (at 4% per year) over a 25-year assessment period, and expressed in 2014 prices.

Costs are then averaged per person affected by more than 55 L_{den}, by dividing the present value costs (i.e. the sum of the discounted costs over 25 years) by the number of people exposed to noise levels higher than 55 dB L_{den}.

Benefits

Benefits are considered as the difference between the existing situation and the situation after the implementation of all the measures. They are monetised by means of the methodology of valuation of health effect described in Section 1.4.1. The benefits are assessed over a 25-year period, discounted at 4% per year and expressed in 2014 prices.

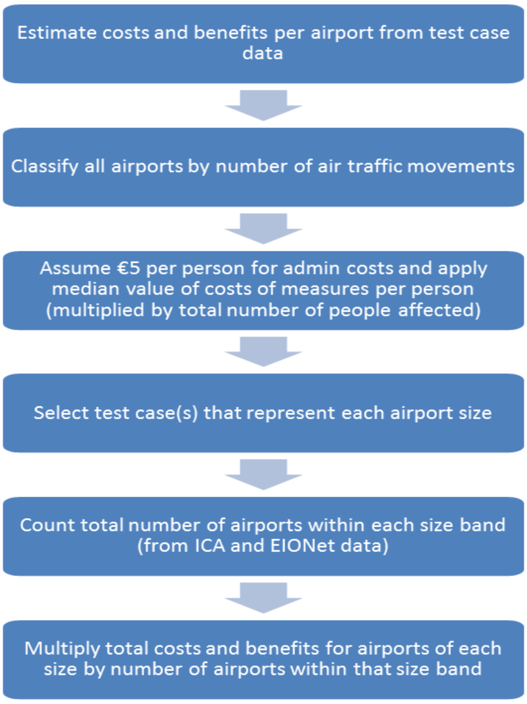
Benefits and benefits per person are then adjusted to consider the effect of measures that result in changes indoor noise levels (i.e., noise insulating windows/sound-proofing measures) that are not reflected in strategic noise mapping but which nevertheless result in a reduction in environmental noise levels.

Net present value

The net present value (NPV) is then calculated as the difference between the benefits (typically higher than costs) and the costs (both the compliance/administrative and the costs of measures) over the 25 year assessment period. The cost-benefit ratio is also presented to provide an idea of the overall value for money.

Figure 5 shows, in simplified form, the approach to extrapolating the test case findings across the EU-28 airports for which noise exposure data was available. A more detailed analysis of the test case findings and description of the extrapolation across the EU-28 is provided below.

Figure 5: Approach to extrapolation for major airports



1.5.1.3. Test case findings

A summary of the test case findings is provided in Table 12 overleaf. More detailed descriptions of each of the test cases and key findings are provided in Appendix F. Sources of information on costs and noise exposure are described in a series of input data sheets in Appendix L. The discounted cost and benefit estimates are calculated in a series of Excel workbooks which are available as separate files. The summary output pages for each test case are shown in Appendix G.

Table 12: Major airport test case summary

	Glasgow	Stuttgart	Athens	Vienna	Frankfurt
Key characteristics					
Location (urban / rural)	Peri-urban	Rural	Rural	Rural	Urban
Characteristics	Regional	Single runway	Dual runway; located near sea	Minor hub	Major hub
Size (ATMs, 2014)	83,999	127,678	154,530	249,989	469,026
Noise exposure					
Population exposed to noise > 55 dB L_{den}	68,800	44,200	14,970	12,300	238,700
Population exposed to noise > 50 dB L_{night}	22,700	5,700	4,710	1,100	107,500
Costs					
Compliance/administrative costs (€), discounted @4% p.a. over 25 years	101,127	120,362	51,776	70,367	2,600,849
Costs of measures (€), discounted @4% p.a over 25 years	287,759	54,366	523,979	21,965,699	12,449,063

	Glasgow	Stuttgart	Athens	Vienna	Frankfurt
Notes on costs	Costs of measures have been estimated using information contained in the Glasgow Airport Draft Masterplan (2011). The Masterplan notes that £60m has been spent on improvements since 2006 and over £200m will be spent over next 10 years. This covers all improvements. Improvements specifically aimed at reducing noise levels have been assumed to be 0.5% of the total value	Costs of measures are based on information from Stuttgart Airport. Costs are reimbursements for windows / ventilation systems only and do not cover other measures that may have been identified in the NAP and implemented	Cost information was requested but not provided. Administrative costs are therefore estimated €3 / affected person for SNM + €2/affected person for NAP. Costs of measures are taken as 10% of costs of measures at Frankfurt airport	Compliance costs are very low because the NAP is a short document written by a single person and with little or no public participation. The total cost of measures was obtained from the Noise Action Plans for 2008 and 2013	Compliance costs are significant because of the highly participatory process through which the NAP was developed Costs only available for soundproofing measures; have estimated costs of additional measures
Average total cost per person (€)	5.65	3.95	8.95	1,791.55	63.05
Benefits (assuming 100% attribution)					
Benefits (€)	339,878,384	2,530,786	98,278,030	8,752,186	1,045,671,376
Average benefit per person (€)	4,940	57	1,527	712	4,381

	Glasgow	Stuttgart	Athens	Vienna	Frankfurt
Adjusted Benefits (€). These take account of the effects of sound-proofing measures on indoor noise levels and hence sleep disturbance	340,298,823	37,003,009	107,003,800	54,485,999	1,045,671,376
Average benefit per person - adjusted (€)	4,946	837	1,662	4,430	4,381
Net Present Value (€)	339,909,937	36,828,281	106,428,044	32,449,933	1,030,621,463
Cost-Benefit Ratio	1:58	1:212	1:185	1:2	1:69
Sensitivity Testing					
Benefits: central estimates, 25% attribution (€, million)	84.97	0.63	24.57	2.19	261.42
Benefits: central estimates, 50% attribution (€, million)	169.94	1.27	49.14	4.38	522.84
Benefits: central estimates, 75% attribution (€, million)	254.91	1.90	73.71	6.56	784.25
High scenario - high values, 100% attribution (€, million)	1,371	8	236	49	2,702
Low scenario - low values, 100% attribution (€, million)	121	1	50	3	431
Low scenario - low values, 25% attribution (€, million)	30	0.31	13	1	108

For the purposes of extrapolating the test case data across all major airports, the costs and benefits of each of the test cases have been applied to other airports across the EU using information on both the airport size (total annual air traffic movements and size of the population exposed to harmful levels of noise (> 55 dB L_{den}). All EU-28 airports that are required to report and for which data exists have been classified into one of the size bands shown in Table 13. The table also shows which of the test cases correspond to each class. So, for example, Glasgow is taken to be broadly representative of all airports with fewer than 100,000 air traffic movements per year although, where considered necessary, further adjustments have been made to the test case data prior to extrapolation to account for any known anomalies (e.g. maturity in addressing noise issues or location) that may determine whether or not the test case estimates can be considered representative of other airports of that size.

Table 13: Classification of test case airports by size

Airport	Representative of airports with annual air traffic movements
Glasgow	<100,000
Stuttgart	100-150,000
Athens	150-200,000
Vienna	200-250,000
Frankfurt	>250,000

Costs of END implementation for major airports

On the basis of the test case data, the discounted **administrative costs** of END implementation (noise mapping, consultants, etc.) vary between €52,000 (at Athens airport) and almost €3 million (at Frankfurt airport). The variation in costs can be explained, at least partly, by the level of effort (including extent of public consultation) invested in preparing the NAPs. For Vienna airport, for example, the NAP is a relatively simple document prepared by a single person over a short period of time. However, in other cases (e.g. Frankfurt), the process of preparing a NAP is an extensive exercise involving multiple people (which may include consultants) and public consultation. The cost per affected person has also been calculated using information on the total population exposed to noise levels in excess of 55 dB L_{den} before the implementation of measures.

The range of measures implemented across airports is quite similar and includes a mix of operational changes, flight time restrictions and noise insulation measures (sound proofing and ventilation). However, the costs of measures published in the NAPs vary significantly. There are a number of possible explanations for this. First, as noted earlier, in some Member States the costs of measures are estimated on the basis of all measures that could potentially be implemented while in others the costs relate only to those measures for which a specific budget has already been allocated. Second, the costs are likely to vary by the size of the population affected: the larger the total number of households affected, the greater expenditure is to be on sound-proofing measures (one of the most commonly applied measures to reduce noise from airports). And third, some airports (more than 15) will have introduced noise reduction measures some time ago in response to national legislation and can now only make marginal improvements while others will be starting from a completely different base.

Moreover, the costs presented in the test cases are not directly comparable because they cover different measures (e.g. Stuttgart only includes costs of soundproofing measures) while in others (e.g. Vienna) they are relatively complete. The actual costs of measures were not available for Glasgow or Athens and therefore these costs were estimated using secondary information (e.g. the Glasgow Airport Master Plan) and assumptions made on the basis of professional judgement (e.g. it is assumed that only 0.5% of the total costs of improvements at Glasgow Airport are related to measures to reduce noise levels) (see Table 12).

Table 14 provides a summary of the total costs as well as costs per person for each of the test case airports.

Table 14: Summary of costs from major airport test cases

	Glasgow	Stuttgart	Athens	Vienna	Frankfurt	Source
Size (ATMs, 2014)	83,999	127,678	154,530	249,989	469,026	From ICA (2015)
Representative class	< 100,000	100-150,000	150-200,000	200-250,000	>250,000	
Population exposed to noise > 55 dB L_{den}	68,800	44,200	14,970	12,300	238,700	Strategic Noise Mapping data
Costs of END implementation (administrative costs)						
Total costs of implementation (€)	101,127	120,362	51,776	70,367	2,600,849	Based on published or estimated costs, discounted at 4% over 25 year assessment period
Cost per affected person (€)	1.47	2.72	0.80	5.72	10.90	Total costs of implementation divided by the population exposed to noise > 55 dB L_{den}
Costs of measures						
Total costs of measures (€)	287,759	54,366	523,979	21,965,699	12,449,063	Based on published or estimated costs, discounted at 4% over 25 year assessment period
Cost per affected person (€)	4.18	1.23	8.14	1,785.83	52.15	Total costs of measures divided by the population exposed to noise > 55 dB L_{den}
Total costs (€)	**388,886**	**174,728**	**575,755**	**22,036,066**	**15,049,912**	Sum of administrative costs and costs of measures
Total costs per person (€)	**6**	**4**	**9**	**1,792**	**63**	Total costs divided by the population exposed to noise > 55 dB L_{den}

For the purposes of extrapolation, the test case estimates have therefore been adjusted to take account of:

- The reliability and completeness of the data in the test case (e.g. whether the costs have been obtained from primary sources, published information or estimated using secondary data and whether they cover the costs of all measures are only a selection of measures);
- The relative size (in terms of aircraft movements per year) of each of the test case airports in relation to other airports within that size band;
- The characteristics of the test case airport to which they apply (e.g. number of runways and density of surrounding population) relative to a 'typical' airport within the corresponding size band; and
- The extent to which the public was consulted in the development of the NAPs for each of the test case airports (where known) as this has a bearing on the administrative costs.

The administrative costs of END implementation are assumed to be the same for all airports and are estimated to be around €5 per noise-affected person. This is slightly higher than the median of the test case values but accounts for the fact that the per person costs at Glasgow and Stuttgart Airports are likely to be lower than at other airports as the total costs are spread across a much larger population while the opposite is true of Frankfurt airport.

For the costs of measures, the average (€919) of the estimates from the Vienna (€1,785) and Frankfurt (€52) test cases has been used. The Vienna and Frankfurt costs estimates are considered to be the most reliable as they are based on published information and cover a range of typical measures implemented at airports. The costs of measures for all the other airports are either incomplete (they cover only selected measures) or have been derived from secondary information. The per person estimates have then been scaled up to provide estimates of the total costs of measures based on the median size of the population exposed to noise levels exceeding 55 dB L_{den} for all airports in each size band.

A further distinction is then made between those airports that had noise legislation prior to the introduction of the END and those that did not. For those airports with pre-existing legislation, it is assumed that some of the costs of measures would have been incurred anyway in order to comply with domestic regulatory requirements. It is thus assumed that only 50% of the total costs can be attributed to END for airports within countries that had noise legislation prior to the introduction of the END.

The resulting costs used for the purposes of extrapolation are shown in Table 15.

Table 15: Total adjusted costs (used for extrapolation to the EU28) by size of airport

	< 100,000	100-150,000	150-200,000	200-250,000	>250,000
Size (TATMs, 2014)	83,999	127,678	154,530	249,989	469,026
Model	Glasgow	Stuttgart	Athens	Vienna	Frankfurt
Population exposed to noise > 55 dB L_{den}	68,800	44,200	64,364	12,300	238,700
Median population exposed to noise > 55 dB L_{den} for each size airport in Member States without pre-existing legislation, before measures	11,600	4,500	5,150	8,800	7,800
Median population exposed to noise > 55 dB L_{den} for each size airport in Member States with pre-existing legislation, before measures	1,100	12,500	15,000	2,000	34,400
Costs of END implementation (administrative costs)					
Cost per affected person (€)	5.00	5.00	5.00	5.00	5.00
Total costs of END implementation for airports in Member States without pre-existing legislation (€)	58,000	22,500	25,750	44,000	39,000
Total costs of END implementation for airports in Member States with pre-existing legislation (€)	5,500	62,500	75,000	10,000	172,000
Costs of measures					
Cost per affected person (€)	918.99	918.99	918.99	918.99	918.99
Total costs of measures in Member States without pre-existing legislation (€)	10,660,300	4,135,461	4,732,806	21,965,699.11	7,168,133
Total costs of measures in Member States with pre-existing legislation (€)	505,445	5,743,696	6,892,435	918,991	15,806,652
Total costs for a typical airport in a Member State without pre-existing legislation (€, millions)	**10.72**	**4.16**	**4.76**	**22.01**	**7.21**

	< 100,000	100-150,000	150-200,000	200-250,000	>250,000
Total costs for a typical airport in a Member State with pre-existing legislation (€, millions)	**0.51**	**5.81**	**6.97**	**0.93**	**15.98**
Total costs per person (€)	**924**	**924**	**924**	**924**	**924**

Finally, the total costs shown in Table 15 are extrapolated across all EU28 airports by assuming that all the airports within each size band will incur the same costs as the model or representative airport. So, for example, the total costs of END implementation (administrative costs plus costs of measures) at a 'typical' airport with fewer than 100,000 traffic movements will be €10.72 million for airports in Member States without pre-existing noise legislation or €0.51 million for airports in Member States with pre-existing noise legislation.

The total cost for the representative airport (for each of without and with pre-existing noise legislation) is then multiplied by the total number of airports within that size band to provide an indicative cost across the EU-28 major airports for which exposure data was available (see Table 16 below).

Table 16: Extrapolation of costs across the EU-28 major airports

Airport size	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000	Total
No. of airports within class without pre-existing legislation	10	2	2	2	3	19
Total costs for all airports **without** pre-existing legislation (€, millions)	107	8	10	44	22	190.66
No. of airports within class **with** pre-existing legislation	27	9	9	3	7	55
Total costs for all airports with pre-existing legislation (€, millions)	14	52	63	3	112	243.40
GRAND TOTAL (€, millions)	**121**	**61**	**72**	**47**	**133**	**434.05**

The analysis was then further refined to take account of the status of NAPs for each of the major airports. It is assumed, for example, that in the case where an airport has not produced a NAP, then it should also be attributed a lower level of costs (and benefits). Similarly, for airports in Member States with no pre-existing noise legislation but where a NAP has been produced, then it is assumed that 100% of the costs (and benefits) can be attributed to the introduction of the END. The specific factors that have been used to attribute costs to END for each major airport type within each band are shown in Table 17.

Table 17: Factors used to attribute costs to major airports

Status	%
No legislation, NAP	100
No legislation, no NAP	25
Legislation, NAP	50
Legislation, no NAP	50

Similar to the approach described above, the costs for each model/representative airport are then multiplied by the number of airports within that category, (taking account of both NAP status and whether or not the airport is within a Member State with pre-existing noise legislation. More specifically, the total cost per person (€924 for airports with fewer than 100,000 movements) is multiplied by (a) the median value of the population exposed to noise levels higher than 55 dB L_{den} across all airports within that size band, and depending on whether or not they have a NAP and whether or not they are located within a Member State with pre-existing noise legislation (b) the number of airports within that category and (c) the proportion of costs that is assumed to be attributable to END (from Table 17). The resulting estimates are shown in Table 18.

Table 18: Median exposure across major airports in each category

Status (legislation and NAPs)	Size	Median exposure (L_{den})	No. of airports within category
None; NAP	<100,000	3,000	1
None; No NAP	<100,000	11,600	9
Pre-existing; NAP	<100,000	600	9
Pre-existing; No NAP	<100,000	3,000	18
None; NAP	100-150,000		
None; No NAP	100-150,000	4,500	2
Pre-existing; NAP	100-150,000	12,500	5
Pre-existing; No NAP	100-150,000	18,450	4
None; NAP	150,000-200,000	10,200	1
None; No NAP	150,000-200,000	100	1
Pre-existing; NAP	150,000-200,000	9,300	5
Pre-existing; No NAP	150,000-200,000	44,150	4
None; NAP	200,000-250,000	8,800	1
None; No NAP	200,000-250,000	49,700	1
Pre-existing; NAP	200,000-250,000	1,700	2
Pre-existing; No NAP	200,000-250,000	30,900	1
None; NAP	>250,000	1,000	1
None; No NAP	>250,000	25,550	2
Pre-existing; NAP	250,000-300,000	59,450	4
Pre-existing; No NAP	250,000-300,000	34,400	3

Table 19: Total costs of END implementation for major airports across the EU

Airport size	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000	Total
No. of airports within class without pre-existing legislation and with a NAP	1	-	1	1	1	4
Total costs (€, millions)	2.77	-	9.42	8.13	1	21.25
No. of airports within class without pre-existing legislation and with no NAP	9	2	1	1	2	15.00
Total costs (€, millions)	24	2	0.0	11	12	49.50
No. of airports within class with pre-existing legislation and with a NAP	9	5	5	2	4	25
Total costs (€, millions)	2	29	21	2	110	164.29
No. of airports within class with pre-existing legislation and with no NAP	18	4	4	1	3	30
Total costs (€, millions)	25	34	82	14	48	202.59
GRAND TOTAL	**54.33**	**65.05**	**112.52**	**35.46**	**170.27**	**437.63**

Benefits of END implementation

The benefits associated with the implementation of noise reduction measures are driven largely by the change in the size of the exposed population and will therefore be more significant for those airports that have higher populations exposed to higher levels of noise and where measures to reduce harmful levels of noise have been introduced under the END. As noted in Section 4.1.1, the benefits of noise reduction at major airports relate to changes in welfare as a result of reductions in the population affected by annoyance, sleep disturbance and hypertension. The change in welfare is only valued for those populations that are highly annoyed, highly sleep disturbed or at risk of noise-related hypertension.

It is important to note that data from Strategic Noise Mapping (SNM) does not reflect the effects of sound-proofing measures. This is because noise measurements are taken at the external façade of buildings and thus do not take account of the reduction in indoor noise levels that would be obtained as a result of sound-proofing. Where necessary (i.e. where the change in the size of the exposed population is based on SNM data, the benefit estimates have been adjusted (by setting the population exposed to night-time levels in excess of 50 dB L_{night} after measures to zero) to take account of the reduction in indoor noise levels and thus sleep disturbance results. The original and adjusted values are shown in Table 12.

On this basis, the discounted total benefits over a 25-year assessment period range from €37 million at Stuttgart Airport to €1,046 million at Frankfurt airport – see Table 21. On a per person basis, and using the available test case data, the benefits range from €84 at Stuttgart to €495 at Glasgow. The per person estimates are calculated by dividing the total benefits at each test case airport by the population exposed to harmful levels of noise (without measures in place) at that airport. The central, low and high values refer to the corresponding estimates for VOLYs and disability weights defined in Table 21.

Table 20: Summary of test case benefits for major airports

	Glasgow	Stuttgart	Athens	Vienna	Frankfurt
Size (TATMs, 2014)	83,999	127,678	154,530	249,989	469,026
Representative class	< 100,000	100-150,000	150-200,000	200-250,000	>250,000
Population exposed to noise > 55 dB L_{den}	68,800	44,200	64,364	12,300	238,700
Health benefits of END implementation					
Total benefits - central values; 100% attribution	340	37	107	54	1,046
Benefit per person - central values; 100% attribution	494.62	83.72	166.25	442.98	438.07
Total benefits - low values; 100% attribution	121	1	50	3	431
Benefit per person - low values; 100% attribution	1,763.08	27.92	783.38	230.51	1,807.24
Total benefits - high values; 100% attribution)	1,371	8	236	49	2,702
Benefit per person - high values; 100% attribution	19,920.48	183.74	3,668.93	4,007.73	11,321.07

For the purposes of extrapolation, we have used the median value of the central, low and high values (€4,380.69, €783 and €4,008 respectively) of the benefits per person across the five test case airports. This is considered reasonable given that the values for Athens, Vienna and Frankfurt are quite similar and is not too different from the median or the mean when the per person benefits at Glasgow and Stuttgart are excluded. Note, however, that the median of the central values (€4,380.69) is higher than the median of the high values (€4,007.73). This is because the median rather than mean was used.

Similar to the approach used for the cost estimates, the per person benefit estimates are then scaled up to derive an estimate of total benefits based on the size of the median population exposed to noise levels in excess of 55 dB L_{den} for all airports within that size band (and for which data was available) and taking account of whether or not airports are located in Member States with pre-existing noise legislation.

The attribution factors applied within each of the scenarios are set out in Table 21.

Table 21: Attribution factors for estimating benefits from major airports

	Scenario		
	Low (% attribution)	**Base Case (% attribution)**	**High (% attribution)**
No pre-existing noise legislation	50	50	100
Pre-existing noise legislation	25	50	100
Values	Low	Central	High

Note that the median exposure values for airports with more than 250,000 air traffic movements (ATMs) are likely to be skewed heavily by the presence of Heathrow Airport within this class. More people are affected by noise at Heathrow than at any other major European airport. More than three times as many people fall within Heathrow's 55 L_{den} contour than at Frankfurt, which has the second highest number of people exposed to noise at this level[65]. The total benefits for airports within the > 250,000 size band may thus be somewhat exaggerated, particularly for those airports within fewer than 400,000 air traffic movements per year.

The total benefits per airport by size of airport and taking into account whether or not airports are in Member States with pre-existing noise legislation are shown in Table 22.

Table 22: Total benefits by size of airport (data for extrapolation)

	< 100,000	**100-150,000**	**150-200,000**	**200-250,000**	**> 250,000**
Size (TATMs, 2014)	83,999	127,678	154,530	249,989	469,026
Model	Glasgow	Stuttgart	Athens	Vienna	Frankfurt
Population exposed to noise > 55 dB L_{den}	68,800	44,200	64,364	12,300	238,700
Median population exposed to noise > 55 dB L_{den} for each size airport in Member States without pre-existing legislation, before measures	11,600	4,500	5,150	8,800	7,800
Median population exposed to noise > 55 dB L_{den} for each size airport in Member States with pre-existing legislation, before measures	1,100	12,500	15,000	2,000	34,400
Benefit per person -central values (median of central values from Table 17)	4,380.69	4,380.69	4,380.69	4,380.69	4,380.69
Benefit per person - low values (median of low values from Table 17)	783.38	783.38	783.38	783.38	783.38
Benefit per person -high values (median of high values from Table 17)	4,007.73	4,007.73	4,007.73	4,007.73	4,007.73
Health benefits of END implementation for a typical major airport in a Member State with no pre-existing noise legislation					
	€, millions	*€, millions*	*€, millions*	*€, millions*	*€, millions*
Total benefits - base case (central values; 100% attribution)	50.82	19.71	22.56	38.55	34.17
Total benefits - low scenario (low values; 50% attribution)	4.54	1.76	2.02	3.45	3.06
Total benefits - high scenario (high values; 100% attribution)	46.49	18.03	20.64	35.27	31.26

[65] http://www.aef.org.uk/issues/aircraft-noise/

	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000
Health benefits of END implementation for a typical major airport in a Member State with pre-existing noise legislation					
	€, millions	*€, millions*	*€, millions*	*€, millions*	*€, millions*
Total benefits - base case (central values; 50% attribution)	2.41	27.38	32.86	4.38	75.35
Total benefits - low scenario (low values; 25% attribution)	0.22	2.45	2.94	0.39	6.74
Total benefits - high scenario (high values; 100% attribution)	4.41	50.10	60.12	8.02	137.87

The benefits per airport in each size category (from Table 22) are then extrapolated across all EU28 airports by multiplying the total benefits in each size band and under each scenario by the total number of airports in each category. So, for example, in the base case, the total benefits across all airports with fewer than 100,000 movements and where no noise legislation previously existed are calculated as €50.82 million multiplied by 10. The total benefits under each scenario and for all major airports across the EU for which data were available are shown in Table 23.

Table 23: **Extrapolation of benefits across the EU28**

Airport size	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000	Total
Health benefits of END implementation for major airports in Member States with no pre-existing noise legislation						
No. of airports within class without pre-existing noise legislation	10	2	2	2	3	19
Total benefits (€, millions) - base case (central values; 100% attribution)	508.16	39.43	45.12	77.10	102.51	772.32
Total benefits (€, millions) - low scenario (low values; 50% attribution)	45.44	3.53	4.03	6.89	9.17	69.06
Total benefits (€, millions) - high scenario (high values; 100% attribution)	464.90	36.07	41.28	70.54	93.78	706.56
Health benefits of END implementation for major airports in Member States with pre-existing noise legislation						
No. of airports within class with pre-existing noise legislation	27	9	9	3	7	55
Total benefits (€, millions) - base case (central values; 50% attribution)	65.05	246.41	295.70	13.14	527.44	1,147.74
Total benefits (€, millions) - low scenario (low values; 25% attribution)	5.82	22.03	26.44	1.18	47.16	102.62
Total benefits (€, millions) - high scenario (high values; 100% attribution)	119.03	450.87	541.04	24.05	965.06	2,100.05

Airport size	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000	Total
Total health benefits of END implementation for major airports in Member States						
Total benefits (€, millions) - base case	573.21	285.84	340.82	90.24	629.94	629.94
Total benefits (€, millions) - low scenario	51.25	25.56	30.47	8.07	56.33	56.33
Total benefits (€, millions) - high scenario	583.93	486.94	582.32	94.58	1,058.84	1,058.84

In the final step, and using the same approach as applied to estimating the costs, consideration has been given to whether or not each of the major airports had NAPs in place. As noted earlier, it is assumed that where a major airport is located in a Member State that had no pre-existing noise legislation and the airport has produced a NAP, then 100% of the benefits can be attributed to END. In contrast, where there is no pre-existing legislation and no NAP, then only 25% of the benefits are attributed to the END. This is considered a conservative assumption as it is possible that no measures have been implemented at airports for which neither domestic noise legislation nor NAPs exist.

The specific factors that have been used to attribute costs to END for each major airport type within each band are the same as those shown in Table 17. The benefits for each model/representative airport (from Table 20) are then multiplied by the number of airports within that category, (taking account of both NAP status and whether or not the airport is within a Member State with pre-existing noise legislation. More specifically, the benefit per person (e.g., €4,380.69 in the base case) is multiplied by (a) the median value of the population exposed to noise levels higher than 55 dB Lden across all airports within that size band, and depending on whether or not they have a NAP and whether or not they are located within a Member State with pre-existing noise legislation (see Table 21) (b) the number of airports within that category and (c) the proportion of benefits that are assumed to be attributable to END. The resulting estimates are shown in Table 24.

Table 24: Total benefits for major airports across the EU, taking NAP status and prior existence of noise legislation into account

Airport size	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000	Total
Health benefits of END implementation for major airports in Member States with no pre-existing noise legislation and a NAP						
No. of airports within class	1	0	1	1	1	4.0
Total benefits (€, millions) - base case (central values; 100% attribution)	13.14	-	44.68	38.55	4.38	100.8
Total benefits (€, millions) - low scenario (low values; 50% attribution)	1.18	-	4.00	3.45	0.39	9.0
Total benefits (€, millions) - high scenario (high values; 100% attribution)	12.02	-	40.88	35.27	4.01	92.2
Health benefits of END implementation for major airports in Member States with no pre-existing noise legislation and no NAP						
No. of airports within class	9.00	2.00	1.00	1.00	2.00	15.0
Total benefits (€, millions) - base case (central	114.34	9.86	0.11	54.43	55.96	234.7

Airport size	< 100,000	100-150,000	150-200,000	200-250,000	> 250,000	Total
values; 25% attribution)						
Total benefits (€, millions) - low scenario (low values; 25% attribution)	20.45	1.76	0.02	9.73	10.01	42.0
Total benefits (€, millions) - high scenario (high values; 25% attribution)	104.60	9.02	0.10	49.80	51.20	214.7
Health benefits of END implementation for major airports in Member States with pre-existing noise legislation and a NAP-						
No. of airports within class	9.00	5.00	5.00	2.00	4.00	25.0
Total benefits (€, millions) - base case (central values; 50% attribution)	11.83	136.90	101.85	7.45	520.86	778.9
Total benefits (€, millions) - low scenario (low values; 25% attribution)	1.06	12.24	9.11	0.67	46.57	69.6
Total benefits (€, millions) - high scenario (high values; 100% attribution)	21.64	250.48	186.36	13.63	953.04	1,425.1
Health benefits of END implementation for major airports in Member States with pre-existing noise legislation and no NAP-						
No. of airports within class	18.00	4.00	4.00	1.00	3.00	30.0
Total benefits (€, millions) - base case (central values; 50% attribution)	118.28	161.65	386.82	67.68	226.04	960.5
Total benefits (€, millions) - low scenario (low values; 25% attribution)	10.58	14.45	34.59	6.05	20.21	85.9
Total benefits (€, millions) - high scenario (high values; 100% attribution)	216.42	295.77	707.76	123.84	413.60	1,757.4
Total health benefits of END implementation for major airports in Member States						
Total benefits (€, millions) - base case	269.41	445.30	635.31	175.56	1,328.12	2,853.7
Total benefits (€, millions) - low scenario	34.31	40.70	56.81	20.56	123.75	276.1
Total benefits (€, millions) - high scenario	376.33	805.75	1,121.46	236.16	2,374.88	4,914.6

The total costs and benefits for all EU28 airports for which data exists are shown in Table 25. This suggests that total benefits from END implementation at major airports lie within the range of €276 million to €4.9 billion. The Net Present Values (NPV) and cost-benefit ratios for the base case and high scenario are positive but negative under the low scenario. However, conservative assumptions have been applied in all cases such that the costs are likely to be somewhat overstated and the benefits somewhat understated. This implies that the cost-benefit ratio is possibly closer to 1 in the low scenario.

Table 25: Summary of costs, benefits and NPV for all EU28 airports

	Low Scenario (Worst Case)	Base Case	High Scenario (Best Case)
Total costs (€, million) – from Table 16)	437.63	437.63	437.63
Total benefits (€, million) – from Table 21	276.14	2,853.69	4,914.58
Net Present Value (€, million)	-161.48	2,416.07	4,476.95
Cost-Benefit Ratio	1:0.6	1:7	1:11

1.5.2 Major roads

The EEA's 2014 Noise in Europe Report notes that road traffic noise is the most significant source of transport noise "with an estimated 125 million people affected by noise levels greater than 55 decibels (dB) L_{den} (day‑evening‑night level)". This equates to one in four EU citizens. This is confirmed in WHO guidance[66], which notes that road traffic noise is the principal source of environmental noise.

According to the WHO[67], "results from epidemiological studies performed in past few years consistently indicate significant increases in the risk of myocardial infarction and elevated blood pressures among the population exposed to road or aircraft traffic noise". The WHO also notes in the same study that "one in three individuals is annoyed during the daytime and one in five has disturbed sleep at night because of traffic noise".

A report[68] by CE Delft in the Netherlands has sought to assess the health effects and social costs of environmental noise. Among the findings were that traffic noise is especially harmful to vulnerable groups, such as children, the elderly and the poor, who are disproportionately affected, being more likely than average to live in close proximity to major roads. The study also found that in the 22 countries covered by the research, the social costs of traffic noise were estimated at over EUR 40 billion a year.

The study estimated that "road and rail traffic noise are responsible for around 50,000 premature deaths per year in Europe".

Under the END, there is a requirement for Member States to report noise exposure levels for all major roads (regional, national or international) with more than three million vehicle passages per year.

According to the EEA Noise database[69], a total of 203,833km of roads across the EU28 fulfil this criterion. It was not possible to obtain information on the number of vehicle movements for each of the major roads reported but the lengths vary from 75 km in Greece to 48,585 km in Germany.

---

[66] Burden of disease from environmental noise (quantification of healthy life years lost in Europe), WHO/JRC, 2011

[67] Burden of disease from environmental noise: Report on WG meeting, 14–15 October 2010

[68] Traffic noise reduction in Europe - Health effects, social costs and technical and policy options to reduce road and rail traffic noise, CE Delft, the Netherlands, 2007, Eelco den Boer, Arno Schroten.

[69] Accessed at http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/index_html (last updated June 2015)

1.5.2.1. Methodology: Summary overview

Data was collated from two test cases to provide an indication of the costs and benefits associated with changes in noise levels along major roads as a result of the implementation of the END.

Similar to the approach used for airports, the costs and benefits of END implementation within each of the test cases was used to estimate the average costs and benefits per person for the population exposed to noise levels higher than 55 dB L_{den}. As noted previously, the per person costs and benefits are calculated as the total costs and benefits divided by the whole of the population affected by noise levels greater than 55 dB L_{den} and not just the beneficiaries of noise reduction measures.

Costs

Costs are divided into a) compliance/administrative costs, and b) costs of implementing the measures. Costs reported here are the total costs incurred (or planned) to date, discounted (at 4% per year) over a 25-year assessment period and expressed in 2014 prices. Costs are then averaged per person affected by more than 55 L_{den}, by dividing the present value costs (i.e. the sum of the discounted costs over 25 years) by the number of people exposed to noise levels higher than 55 dB L_{den}.

Benefits

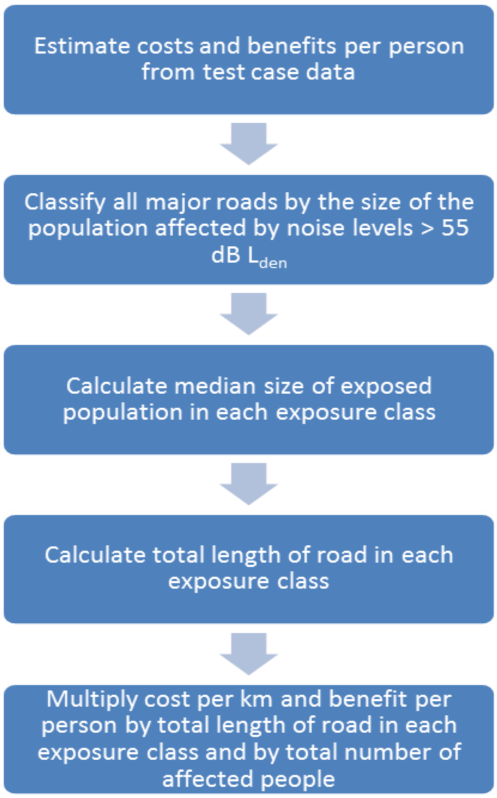
Benefits are considered as the difference between the existing situation and the situation after the implementation of all the measures. They are monetised by means of the methodology of valuation of health effect described in Section 1.4.1. The benefits are assessed over a 25-year period, discounted at 4% per year and expressed in 2014 prices.

Net present value

The net present value is then calculated as the difference between the benefits (typically higher than costs) and the costs (both the compliance/administrative and the costs of measures) over the 25 year assessment period. The cost-benefit ratio is also presented to provide an idea of the overall value for money.

A summary of the approach to the extrapolation is shown in Figure 6. A more detailed analysis of the test case findings and description of the extrapolation across the EU-28 follows.

Figure 6: Approach to extrapolation for major roads



1.5.2.2. Test case data

The test cases covered major roads in two countries:

Austria (2,500km)[70]

Greece (75km – the Attica Tollway)

The Attica Tollway serves as a ringroad for the greater metropolitan area of Athens and, as such, the population density along the road is relatively high. By contrast, the major roads in Austria traverse much of the country and pass through both highly populated and less populated areas. Where available, additional information on the costs of END implementation in Member States has been used to supplement the test case findings and to provide additional data points from which to extrapolate. In particular, the test case data was supplemented by information obtained from published information and through interviews with relevant stakeholders in England, France and Spain.

A summary of the test case findings is provided in Table 26 overleaf. More detailed descriptions of each of the test cases and key findings are provided in Appendix F.

[70] Note that although the total length of major roads reported in the EIONet Database is over 5,000 km, the test case only considers those roads that fall under the responsibility of the national authority. Roads that fall under the responsibility of federal authorities were not included in the test case.

Table 26: Test case summary – major roads

Test case	1	2
Country	**Austria**	**Greece**
Key characteristics		
Context	All motorways and highways	The Attica Tollway serves as a ringroad for the greater metropolitan area of Athens. It functions as a bypass and connects 30 municipalities of the Attica basin. The volume of traffic along the route has been declining since 2007 and is expected to continue this trajectory in reflection of the macroeconomic situation in the country.
Population along length of road network	714,000	28,000
Length of road network (km)	2,500	70
Population density (persons/km)	286	400
Noise exposure	-	-
Population exposed to noise > 55 dB L_{den} before measures	591,001	28,000
Population exposed to noise > 50 dB L_{night} before measures	713,329	28,000
Costs	-	-
Compliance/administrative costs (€), discounted @4% p.a. over 25 years	1,004,838	40,938
Costs of measures (€), discounted @4% p.a over 25 years	146,579,116	63,602,648
Notes on costs	There is no information available on the administrative costs of END implementation but given the simple design of the NAP and the simple public participation and discussion of measures, the costs of have been estimated on the basis of professional judgement as €2 per affected inhabitant	It was not possible to obtain detailed costs of noise reduction measures. The CBA thus only considers the costs and benefits associated with noise barriers. These have been constructed in 138 different sections of the motorway and covering a total area of 87,000 m^2.
Average cost per km (€)	59,034	909,194

Test case	1	2
Country	**Austria**	**Greece**
Ave cost per person (€)	207	2,273
Benefits (assuming 100% attribution)		
Benefits (€, million)	1,267	176
Average benefit per person (€)	1,775	6,303
Net Present Value (€, million)	1,120	113
Cost Benefit Ratio	1:9	1:3
Sensitivity testing		
Benefits: central values, 25% attribution (€, million)	317	44
Benefits: central values, 50% attribution (€, million)	634	88
Benefits: central values, 75% attribution (€, million)	950	132
Benefits: central estimates, 100% attribution (€, million)	1,267	176
High scenario - high values, 100% attribution (€, million)	5,238	409
Low scenario - low values, 100% attribution (€, million)	426	93
Low scenario - low values, 25% attribution (€, million)	107	23

Costs of END implementation for major roads

The total costs of END implementation (administrative costs plus costs of measures) vary substantially, ranging from €59,000 per km in Austria to over €900,000 per km in Greece. When considering the average population density along major roads, the costs range from around €250 per person per km in Austria to over €2,200 per person per km in Greece.

These costs are not, however, strictly comparable as they:

- cover different packages of measures. The Greek test case considers only the costs of a noise barrier while the Austrian test case considers a range of measures including implementation of barriers, walls and/or passive noise protection.
- apply to different lengths of railways and population densities along the railway. The average number of people per km of railtrack is almost twice as high in Greece as it is in Austria.

For the purposes of comparison, we have supplemented the test case data with information that was available (or could reliably be estimated) for Spain, France and England. These show an even higher degree of variability, with the total costs of END implementation ranging from approximately €2,457 per km in England to over €909,194 per km in Greece. This is likely to reflect the different stages that these countries are at in terms of addressing road traffic noise and therefore what levels of expenditure are still required to reduce exposure of the population to harmful levels of noise.

The cost estimates per km have been adjusted to make them more comparable with the benefit estimates by taking account of average population density in each case. On this basis, the costs per person are €11 in England and €2,273 in Greece. A comparison of costs between the two case studies, as well as some additional information from Spain, France and England, is shown in Table 27.

Table 27: Costs of END implementation along major roads

	Austria	Greece	Spain	France	England
Total length of road	2,500	70	19,552	24,972	25,472
Total population affected by noise (before measures)	591,001	28,000	1,243,600	3,492,200	5,704,000
Average population density (people per km)	236	400	64	140	224
Costs of END implementation (administrative costs)					
Total costs of implementation (€)	1,004,838	40,938	3,739,906	4,000,000	117,720.60
Total implementation costs per km (€)	401.94	584.83	191.28	160.18	4.62
Cost per affected person (€)	1.70	1.46	3.01	1.15	0.02
Costs of measures					
Total costs of measures (€)	146,579,116	63,602,648	178,335,906	178,335,906	62,470,750
Total costs of measures per km (€)	58,632	908,609	9,121	7,141	2,453
Cost per affected person (€)	248.02	2271.52	143.40	51.07	10.95

	Austria	Greece	Spain	France	England
Total costs (€)	**147,583,954**	**63,643,586**	**182,075,812**	**182,335,906**	**62,588,471**
Total costs per km (€)	**59,034**	**909,194**	**9,312**	**7,302**	**2,457**
Total costs per person (€)	**250**	**2,273**	**146**	**52**	**11**

The test case cost data was then scaled up to an EU level taking account of:

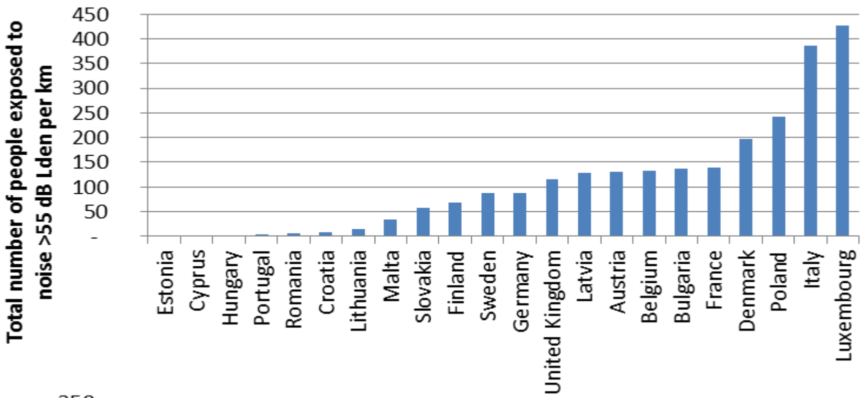
- The total length of major roads in EU Member States with more than 3 million vehicle movements per year;
- The availability of information on road noise exposure in those Member States that are required to report on road noise.

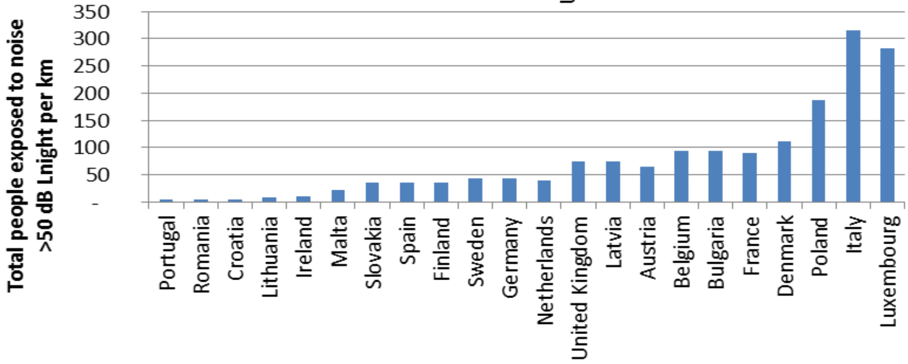
Based on information on major roads in the EIONET Noise Database[71], around 22 of the 28 Member States required to report on exposure to road traffic noise had actually done so. Non-EU Member States have been excluded from the analysis.

Member States were then classified into four broad groups according to the number of people exposed to noise levels in excess of 55 dB L_{den} or 50 dB L_{night}

The figure below shows the average number of people exposed to harmful levels of noise along major roads by day (> 55 dB L_{den}) and by night (>50 dB L_{night}) per kilometre for each Member State.

Figure 7: Average number of people exposed to harmful levels of noise along major roads in Member States for which exposure data was available.





[71] http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/end_df4_df8_results_2012_150630

The total length of road in each exposure class, as well as the median exposure to harmful levels of noise for each of Lden and Lnight and for all Member States within each class is set out in Table 28. Median exposure to noise is calculated as the median value of the size of the population exposed to noise greater than 55 dB L_{den} or 50 dB L_{night} across all the Member States in each class.

Table 28: Classification of major roads in Member States by population density per km

Density	Member States	Total km	Median exposure per km (L_{den})	Median exposure per km (L_{night})
0-50	Portugal, Romania, Croatia, Lithuania, Ireland, Malta	24,489	12	6
50-150	Slovakia, Spain, Finland, Sweden, Germany, Netherlands, United Kingdom, Latvia, Austria, Belgium, Bulgaria, France	146,436	103	54
150-350	Denmark, Poland	439	219	148
>350	Italy, Luxembourg	812	406	299

Note that estimates are for those countries that reported data only and exclude non-EU Member States

Using the costs per person from the test cases as a guide, the costs of END implementation, including both administrative costs and costs of measures, are extrapolated across the relevant EU Member States according to the approximate population exposed to harmful levels of noise along the total length of roads in each category shown in Table 28.

Low, central and high cost estimates per person are calculated using the three test case estimates shown in Table 29. (England = low, median of Austria, France, Spain and England = central; Greece = high).

Each density class is further subdivided according to whether or not each of the Member States within that class had pre-existing noise legislation. It is assumed that those Member States that had noise legislation prior to the introduction of the END[72] would most likely have incurred at least some of the costs associated with the implementation of measures irrespective of whether or not the END was introduced. For the purposes of this analysis, it is assumed that in the base case (central) scenario, only 50% of the total estimated costs in those Member States with pre-existing noise legislation can be attributed to the END. This is considered a conservative assumption given that in several of these Member States, many of the most cost-effective measures had already been implemented (or budgeted) prior to the END and thus the costs attributed solely to the END are likely to be relatively small. For those Member States that did not have any noise legislation prior to the END, it is assumed that 100% of the costs can be attributed to END in the base case (central) scenario.

[72] These are Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Portugal, Slovakia, Sweden and UK. On the basis of the available information, it is inferred that the other 13 Member States had no noise legislation prior to the END.

For the purposes of sensitivity testing, low and high scenarios have also been defined. The low scenario uses the lowest of the test case cost estimates per person (from Table 29) and assumes that only 25% and 50% of the total costs can be attributed to END implementation in Members with and without pre-existing noise legislation respectively. The high scenario uses the highest of the test case cost estimates per person (from Table 29) and assumes that 100% of the total costs can be attributed to END regardless of whether or not Member States had pre-existing noise legislation.

The parameters used to define each of the cost scenarios are summarised in Table 29 and the resulting cost estimates under each scenario are shown in Table 30.

Table 29: Parameters for estimating total costs within each class

Existence of noise legislation prior to END	Low		Central		High	
	Attribution (% of total costs)	Cost estimate	Attribution (% of total costs	Cost estimate	Attribution (% of total costs	Cost estimate
Pre-existing	25	Low	50	Central	100	High
None	50	Low	100	Central	100	High

Table 30: Costs of END implementation for major roads across the EU

			LOW		CENTRAL		HIGH	
Existence of noise legislation prior to END	Density	Total length of road (km)	Ave costs per person(€)	Total costs (€, millions)	Ave costs per person (€)	Total costs (€, millions)	Ave costs per person (€)	Total costs (€, millions)
Pre-existing	0-50	18,839	10.97	0.54	99	9.81	2,272.99	448.97
None	0-50	5,650	10.97	0.37	99	6.63	2,272.99	151.82
Pre-existing	50-150	109,507	10.97	26.57	99	480.97	2,272.99	22,016.18
None	50-150	36,929	10.97	26.06	99	471.80	2,272.99	10,798.41
Pre-existing	150-350	1,043	10.97	0.56	99	10.17	2,272.99	465.73
None	150-350	9,822	10.97	13.06	99	236.39	2,272.99	5,410.39
Pre-existing	> 350	-	10.97	0.00	99	-	2,272.99	-
None	> 350	13,687	10.97	30.47	99	551.63	2,272.99	12,625.47
	TOTAL	**195,477**		**98**		**1,767**		**51,917**

Benefits of END implementation for major roads

The benefits of END implementation along major roads are estimated in respect of changes in the number of people exposed to harmful levels of noise as a result of the implementation of noise abatement measures and the associated improvements in health. In particular, the benefits are expressed in terms of the reduction in DALYs relating to the decline in noise-related annoyance and sleep disturbance.

For each test case, the total benefits have been estimated for a central (most likely) scenario and by varying the parameters to provide the extent of the range in which the value of benefits could potentially lie. The benefit estimates for each of the low, central and high scenarios for each of the test cases are shown in Table 31, together with estimates derived from averaging the test case values assuming that 100%, 50% and 25% respectively of the benefits can be attributed to the END. The numbers shown in bold represent the high, central and low estimates that are used to derive an estimate of the benefits of END implementation for major roads across the EU. The assumptions and parameters used to estimate the outcomes in each scenario are the same as those defined earlier (in Section 1.4.1) and repeated in Table 32 for ease of reference.

Table 31: Benefits of END implementation along major roads

		LOW (€)	CENTRAL (€)	HIGH (€)
Austria (100% attribution)	Total benefits	426,322,840.20	1,267,129,476.57	5,237,855,851.12
	Total benefits per km	170,529.14	506,851.79	2,095,142.34
	Total benefits per person	721.36	2,144.04	8,862.69
Greece (100% attribution)	Total benefits	92,652,769.89	176,476,819.12	408,858,146.76
	Total benefits per km	1,323,611.00	2,521,097.42	5,840,830.67
	Total benefits per person	3,309.03	6,302.74	14,602.08
Average (100% attribution)	Total benefits	259,487,805.05	721,803,147.84	2,823,356,998.94
	Total benefits per km	747,070.07	1,513,974.60	3,967,986.50
	Total benefits per person	2,015.19	**4,223.39**	**11,732.38**
Average (50% attribution)	Total benefits	129,743,902.52	360,901,573.92	1,411,678,499.47
	Total benefits per km	373,535.03	756,987.30	1,983,993.25
	Total benefits per person	**1,007.60**	**2,111.70**	5,866.19
Average (25% attribution)	Total benefits	64,871,951.26	180,450,786.96	705,839,249.73
	Total benefits per km	186,767.52	378,493.65	991,996.63
	Total benefits per person	**503.80**	1,055.85	2,933.10

Table 32: Parameters used to define scenarios

	Low	Central	High
Value of a QALY	€ 67,163	€ 110,987	€ 154,812
Disability Weight for Sleep Disturbance	0.04	0.07	0.1
Disability Weight for Annoyance	0.01	0.02	0.12

The test case data has then been used to derive an estimate of the average present value of benefits per person (per km) over a 25-year assessment period. Using the same approach as for the cost estimates, the test case benefit estimates have been scaled up on the basis of the total length of major roads across the Member States for which exposure data was available[73], and accounting for both differences in average population density along major roads in different Member States and whether or not each Member State had pre-existing noise legislation. The resulting benefits estimates under each of a low, central and high scenario are shown in Table 33. The scenarios (low, central, high) are defined using the same parameters as described in Table 32.

Table 33: Total benefits of END implementation for major roads

			LOW		CENTRAL		HIGH	
Existence of noise legislation prior to END	**Density**	**Total length of road (km)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**
None	0-50	5,650	1,007.60	67.30	4,223.39	282.09	11,732.38	783.63
Pre-existing	0-50	18,839	503.80	99.51	2,111.70	417.12	11,732.38	2,317.46
None	50-150	36,929	1,007.60	4,786.85	4,223.39	20,064.33	11,732.38	55,737.75
Pre-existing	50-150	109,507	503.80	4,879.80	2,111.70	20,453.93	11,732.38	113,640.10
None	150-350	9,822	1,007.60	2,398.38	4,223.39	10,052.94	11,732.38	27,926.59
Pre-existing	150-350	1,043	503.80	103.23	2,111.70	432.69	11,732.38	2,403.96
None	> 350	13,687	1,007.60	5,596.77	4,223.39	23,459.15	11,732.38	65,168.41
Pre-existing	> 350	-	503.80	-	2,111.70	-	11,732.38	-
	TOTAL	**195,477**		**17,932**		**75,162**		**267,978**

[73] The estimate does not include Estonia, Cyprus, Slovenia, Hungary and Czech Republic as there was no data available for these Member States.

Combining the costs and benefits of END implementation for major roads, the net present value and cost-benefit ratios under each scenario are estimated as shown in Table 34.

Table 34: Cost-benefit summary – major roads (for all Member States for which data was available)

	Low	Central	High	High cost, low benefit
Total Present Value Costs (€, millions)	98	1,767	51,917	51,917
Total Present Value Benefits (€, millions)	17,932	75,162	267,978	17,932
Total Net Present Value (€, millions)	17,834	73,395	216,061	-33,985
Cost-Benefit Ratio	1:184	1:43	1:5	1:0.3

These findings suggest that the costs of END implementation justify the benefits for major roads in most cases, with cost-benefit ratios ranging from 1:5 (in cases where it assumed that 100% of benefits can be attributed to END and using high values for the VOLY and disability weights) to 1:184 (where between 25% and 50% of the benefits can be attributed to END depending on whether or not each Member State had pre-existing noise legislation, and using the low values). However, when combining the highest estimate of costs with the lowest estimate of benefits, the cost-benefit ratio is less than 1 (i.e. costs exceed benefits).

Further sensitivity tests were then applied to assess how the outcomes would change at an EU-wide level given the status of NAP implementation (i.e. differentiating between those Member States who have completed, or at least partially completed their NAPs and those who have not)[74]. The assumptions governing the level (%) of attribution of the total estimated costs and benefits in each scenario are set out in Table 35.

Table 35: Percentage of costs and benefits attributed to END in each scenario for major roads given Member States' status in terms of pre-existing noise legislation and NAP completion

	% costs and benefits attributed to END		
	Low scenario	Central scenario	High scenario
No pre-existing legislation; NAP submitted/underway	50	100	100
No pre-existing legislation; no NAP	25	25	25
Pre-existing legislation; NAP submitted/underway	25	50	100
Pre-existing legislation; no NAP	25	50	100
Cost / benefit values	Low	Central	High

[74] Based on information provided by DG Environment.

Tables 34 and 35 show the extrapolation and distribution of costs and benefits respectively across each density class for Member States with and without pre-existing noise legislation and NAPs. The average costs per person under each scenario are simply the low, central or high costs per person (from Table 29). These are then multiplied by the total length of road, the median number of people exposed to noise levels greater than 55 dB Lden and the applicable percentage attribution (from Table 35) to provide an estimate of total costs for the total length of road in each category. The average benefits per person in each category are determined according to pre-existing legislation and NAP status using the information from Tables 31 and 35.

The summary findings in terms of present value costs, present value benefits, NPV and cost-benefit ratio are shown in Table 36.

Table 36: Net Present Value and Cost Benefit Ratio for END implementation for major roads in Member States taking account of NAP status)

	Low	Central	High	HIGH COST LOW BENEFIT
Total Present Value Costs (€, millions)	356	1,202	8,545	8,545
Total Present Value Benefits (€, millions)	609	2,554	8,179	609
Total Net Present Value (€, millions)	254	1,351	-366	-7,935
Cost-Benefit Ratio	1:71	1:2	1:0.9	1:0.7

From the table above, it can be seen that the cost-benefit ratios become slightly less favourable when Member States' NAP status is also taken into account. This may, at least in part, be attributed to the fact that some of the Member States with relatively long lengths of major roads have (a) not yet submitted action plans (e.g. Belgium, Romania) and thus were attributed a lower level (25%) of both costs and, more importantly, benefits (compared to 50% attribution in Table 34 or (b) their NAPs only cover a small percentage of total segments (e.g. Spain, Poland); in the latter case the estimates of costs and benefits are determined in relation to the percentage of NAP completion (and whether or not the Member State had pre-existing noise legislation).

Note that these findings do need to be treated with caution as the estimates are based on a very limited sample and are based on a number of underlying assumptions. In particular, the costs of measures are known to be incomplete as these were only available for a limited selection of measures.

Table 37: Extrapolation of costs across major roads in the EU-28 taking account of existing legislation and NAP status

			LOW		CENTRAL		HIGH	
Pre-existing legislation & NAP status	**Density**	**Total length of road (km)**	**Ave costs per person (€)**	**Total costs (€, millions)**	**Ave costs per person (€)**	**Total costs (€, millions)**	**Ave costs per person (€)**	**Total costs (€, millions)**
None; NAP	0-50	1,275.97	10.97	0.10	99.31	1.89	2,272.99	43.20
None; No NAP	0-50	3,270.00	10.97	0.05	99.31	0.46	2,272.99	10.46
Pre-existing; NAP	0-50	17,799.50	10.97	0.48	99.31	8.72	2,272.99	398.98
Pre-existing; No NAP	0-50	-	10.97	-	99.31	-	2,272.99	-
None; NAP	50-150	5,361.03	10.97	2.71	99.31	48.97	2,272.99	1120.87
None; No NAP	50-150	5,406.00	10.97	1.98	99.31	17.91	2,272.99	409.93
Pre-existing; NAP	50-150	60,255.60	10.97	16.76	99.31	303.36	2,272.99	13,886.06
Pre-existing; No NAP	50-150	-	10.97	-	99.31	-	2,272.99	-
None; NAP	150-350	39.29	10.97	0.001	99.31	0.003	2,272.99	0.09
None; No NAP	150-350	-	10.97	-	99.31	-	2,272.99	-
Pre-existing; NAP	150-350	1,043.00	10.97	0.56	99.31	10.17	2,272.99	465.73
Pre-existing; No NAP	150-350	-	10.97	-	99.31	-	2,272.99	-
None; NAP	>350	-	10.97	-	99.31	-	2,272.99	-
None; No NAP	>350	-	10.97	-	99.31	-	2,272.99	-
Pre-existing; NAP	>350	-	10.97	-	99.31	-	2,272.99	-
Pre-existing; No NAP	>350	13,687.00	10.97	15.24	99.31	275.82	2,272.99	12625.47
	TOTAL	**108,137.39**		**37.88**		**667.29**		**28,960.80**

Table 38: Extrapolation of benefits across major roads in the EU-28 taking account of existing legislation and NAP status

			LOW		CENTRAL		HIGH	
Status	**Density**	**Total length of road (km)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**
NAP	0-50	1,276	1,007.60	19.15	4,223.39	80.27	11,732.38	223.00
No NAP	0-50	3,270	503.80	9.27	1,055.85	19.43	2,933.10	53.97
NAP	50-150	5,361	1,007.60	496.87	4,223.39	2,082.67	11,732.38	5,785.56
No NAP	50-150	5,406	503.80	363.44	1,055.85	761.69	2,933.10	2,115.93
NAP	150-350	39	1,007.60	0.04	4,223.39	0.16	11,732.38	0.45
No NAP	150-350	-	503.80	-	1,055.85	-	2,933.10	-
NAP	> 350	-	1,007.60	-	4,223.39	-	11,732.38	-
No NAP	> 350	-	503.80	-	1,055.85	-	2,933.10	-
Pre-existing legislation		129,389	503.80	5,082.54	2,111.70	21,303.73	11,732.38	118,361.52
	TOTAL	**144,741**		**5,971**		**24,248**		**126,540**

1.5.3 Major railways

1.5.3.1. Context

Under the END, there is a requirement for Member States to report noise exposure levels for all major railways (regional, national or international) with more than 60,000 train passages per year. According to the EEA Noise database[75], a total of 46,667 km of railways across the EU28 fulfil this criterion.

Member State reports compiled by the European Environment Agency (EEA) in 2010 show that railway noise affects about 12 million EU inhabitants at day time, with a noise exposure above 55 dB(A), and about 9 million at night time, with a noise exposure above 50 dB(A). The actual figures are, however, likely to be higher since the EEA's European noise mapping initiative concentrates on agglomerations with over 250,000 inhabitants and on main railway lines with over 60,000 trains per year.

According to EEA data from the first round of noise mapping, the following states in Europe are most affected by railway noise in terms of the share of their population that is exposed to railway noise in excess of 55 dB(A) L_{den}: Austria (9.3%), Slovakia (9.0%), Switzerland (7.5%), France (5.5%), Germany (4.3%), Czech Republic (3.8%), the Netherlands (3.8%) and Latvia (3.0%). It is further estimated that about 85% of people affected by railway noise (over 55 dB(A) L_{den} or 50 dB(A) L_{night}) are located in the following six countries in Europe: Germany, France, UK, Austria, Poland and Switzerland. About 60% are located in Germany and France.

If only areas outside agglomerations are considered, the figures change significantly. In this case the six countries mentioned above represent 89% of affected people. The share of people affected in agglomerations and outside agglomerations differ very much between the countries. In Germany about 75% of affected people live outside agglomerations whereas in Poland this share is 0 (Switzerland: 15%, Austria: 59%, the UK: 17%, France: 44%).

In 2012, a study by the European Parliament investigated a range of measures, funding and regulations to reduce rail noise and concluded that the introduction of modern rolling stock would lower noise most significantly but that, in the short run, the replacement of cast iron by composite brake blocks on rail freight cars was most important[76]. Rail grinding has also been shown to have a significant effect (see Box 3).

[75] Accessed at http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/index_html (last updated June 2015)

[76] European Parliament (2012) Reducing railway noise pollution. Directorate-General for Internal Policies; Policy Department B: Structural and Cohesion Policies [online] available at http://www.europarl.europa.eu/RegData/etudes/etudes/join/2012/474533/IPOL-TRAN_ET(2012)474533_EN.pdf?bcsi_scan_ab11caa0e2721250=0&bcsi_scan_filename=IPOL-TRAN_ET(2012)474533_EN.pdf (last accessed 21/12/2015).

Box 3: Reducing noise through improved track maintenance: Case Study

Rolling noise is currently the most important noise source associated with the railways in Great Britain (GB). It is generated by roughness of the wheel and rail. The combined roughness excites both the wheel and track, which then radiate noise. Wheel roughness tends to stabilise at a level determined by the vehicle braking system. Typical GB rolling stock has relatively smooth wheels due to the preference for composite brake blocks and disc brakes over cast iron brake blocks. Rail roughness tends to increase over time in proportion to the gross tonnage and can be controlled by grinding.

Between 2002 and 2004, Network Rail, the authority charged with running, maintaining and developing Britain's rail tracks, signalling, bridges, tunnels, level crossings and many key stations, developed a new preventative maintenance grinding strategy to address rolling contact fatigue.

This strategy is applied to lines carrying more than five million tonnes of traffic per year. From 2003 grinding was carried out based on curvature and tonnage and originally was carried out at every 15 Equivalent Million Gross Tonnes (EMGT) on curves <2500m radius and every 25 to 30 EMGT on curves and straight track > 2500m radius. This frequency was reviewed in 2007 and the frequencies of grinding changed to better reflect measured rail wear rates on straight track. From 2009, grinding of straight track was revised so that it was planned to be carried out every 45 EMGT with curves continuing to be ground every 15 EMGT.

A typical section of main line track might therefore be ground every one or two years on straight sections and every six months on curves. No cyclic grinding was undertaken on the network for the 10 year period prior to 2002. Grinding was limited to the use of small machines on a site-specific basis. While the purpose of the grinding is not to reduce noise, rail grinding is proven to reduce wayside rolling noise levels generated by the railway. It can therefore be expected that the grinding strategy introduced between 2002 and 2004 would have an effect of reducing wayside noise levels on main lines.

Based on measurements at three locations along the East Coast and West Coast Mainline routes, there is strong evidence to suggest that it has resulted in a significant improvement in Acoustic Track Quality (ATQ) across the GB network. In particular, the measurements have shown a large reduction of 8dB relative to 2004.

Source: Craven, N., Bewes, O., Fenech, B. and Jones, R. (2015) Investigating the Effects of a Network-Wide Rail Grinding Strategy on Wayside Noise Levels. N*oise and Vibration Mitigation for Rail Transportation Systems*. Proceedings of the 11th International Workshop on Railway Noise, Uddevalla, Sweden, 9–13 September 2013, pp369-376.

The European Parliament study distinguishes between three different sources of railway noise:

- **Engine noise** - largely generated by freight trains and trains containing older wagons or engines, and is particularly problematic during the night. Most relevant at lower speeds up to about 30 km/h.
- **Rolling noise** - generally higher from poorly maintained rail vehicles, and from trains running on poorly maintained infrastructure. Most relevant above speeds of 30km/h.
- **Aerodynamic noise -** particularly relevant for high speed lines where, in most cases, noise limiting measures like noise barriers are implemented; noise barriers reduce the impact of rolling noise, but are usually too low to have any effect on noise originating at the pantograph. Dominates above 200km/h.

The most important noise source is rolling noise, which affects all kinds of train.

To reduce railway noise pollution, passive measures at the place of disturbance can be distinguished from active measures at the noise source. The most important passive methods used to reduce the impact of railway noise on the environment are noise protection walls and insulating windows, and for the most part action plans and investments of the Member States concentrate on these methods. However, they are only locally effective, requiring huge investments to protect wider parts of railway networks. In contrast, source-driven measures lower noise across the whole railway system if they are widely introduced. As an example, the problem of noisy rail freight cars can be reduced by the replacement of cast iron brake blocks by composite brake blocks. This is currently being investigated by the railway industry and would affect about 370,000 old freight wagons. Also, wheel absorbers, aerodynamic design of pantographs and noise insulation of traction equipment (e.g., locomotive engines) are measures to reduce noise at source.

According to the current Technical Standard for Interoperability (TSI Noise), rolling stock introduced since the year 2000 (including engines and passenger coaches or passenger power cars) are required to lower noise emissions by about 10 dB(A) compared to the equipment of the 1960s and 1970s.

1.5.3.2. Methodology: Summary overview

Data was collated from two test cases to provide an indication of the costs and benefits associated with changes in noise levels along major railways as a result of the implementation of the END.

Similar to the approach used for airports, the costs and benefits of END implementation within each of the test cases was used to estimate the average costs and benefits per person for the population exposed to noise levels higher than 55 dB L_{den}. As noted previously, the per person costs and benefits are calculated as the total costs and benefits divided by the whole of the population affected by noise levels greater than 55 dB L_{den} and not just the beneficiaries of noise reduction measures.

Costs

Costs are divided into a) compliance/administrative costs, and b) costs of implementing the measures. Costs reported here are the total costs incurred (or planned) to date, discounted (at 4% per year) over a 25-year assessment period and expressed in 2014 prices.

Costs are then averaged per person affected by more than 55 L_{den}, by dividing the present value costs (i.e. the sum of the discounted costs over 25 years) by the number of people exposed to noise levels higher than 55 dB L_{den}.

Benefits

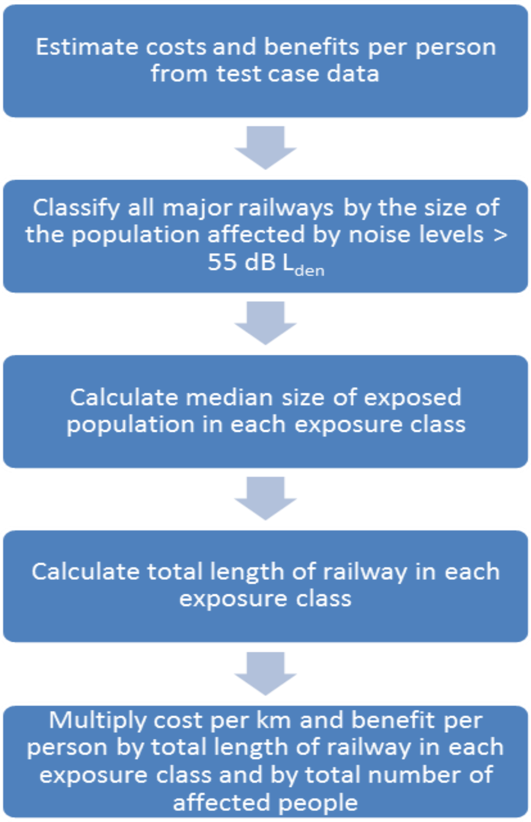
Benefits are considered as the difference between the existing situation and the situation after the implementation of all the measures. They are monetised by means of the methodology of valuation of health effect described in Section 1.4.1. The benefits are assessed over a 25-year period, discounted at 4% per year and expressed in 2014 prices.

Net present value

The net present value is then calculated as the difference between the benefits (typically higher than costs) and the costs (both the compliance/administrative and the costs of measures) over the 25 year assessment period. The cost-benefit ratio is also presented to provide an idea of the overall value for money.

A summary of the approach to extrapolation is shown in Figure 8. A more detailed analysis of the test case findings and description of the extrapolation across the EU-28 follows.

Figure 8: Approach to extrapolation for major railways



1.5.3.3. Test case data

For the purposes of the evaluation, two major railways were selected as test cases for analysis. These were selected on the basis that information on costs and benefits (in terms of changes in the number of people exposed to noise from rail traffic) was available.

The two test cases were:

- Austria (2,218 km)
- Slovakia (506 km)

Where available, additional information on the costs of END implementation in Member States has been used to supplement the test case findings and to provide additional data points from which to extrapolate.

A summary of the test case information and benefits estimates are provided in Table 39 overleaf. More detailed descriptions of each of the test cases and key findings are provided in Appendix F.

Table 39: Test case summary – major railways

Test case	Austria	Slovakia
Key characteristics		
Context	National rail network covering 2,218km.	Malacky is an important regional transport hub connected to a highway and national road that services the Bratislava agglomeration. The main train line connecting Bratislava and the Czech Republic traverses the city.
Population along length of railway	968,877	16,400
Length of railway (km)	2,218	506
Population density (persons/km)	436.82	32.41
Noise exposure		
Population exposed to noise > 55 dB L_{den}	420,045	16,400
Population exposed to noise > 50 dB L_{night}	598,952	15,600
Costs		
Compliance/administrative costs (€), discounted @4% p.a. over 25 years	487,155	22,689
Costs of measures (€), discounted @4% p.a over 25 years	19,350,869	3,331,587
Notes on costs	• Costs published in the NAPs include costs of planning and implementation of measures. • Costs relate to a range of measures including rehabilitation of existing tracks by implementation of barriers, walls and/or passive noise protection	• Costs of measures are based on estimates prepared for the authorities by a consultant; they are not published. The only noise abatement measure considered is a noise barrier.
Average cost per km (€)	8,944	6,629

Test case	Austria	Slovakia
Ave cost per person (€)	20	205
Benefits (assuming 100% attribution)		
Benefits (€, million)	116.35	47.55
Average benefit per person (€)	120	2,899
Net Present Value (€, million)	97	44
Cost Benefit Ratio	1:4	1:10
Sensitivity testing		
Benefits: 25% attribution (€, million)	29.09	11.89
Benefits: 50% attribution (€, million)	58.18	23.77
Benefits: 75% attribution (€, million)	87.27	35.66
High scenario – high values, 100% attribution (€, million)	625.70	199.39
Low scenario – low values, 100% attribution (€, million)	37.56	15.73
Low scenario – low values, 25% attribution (€, million)	9.39	3.93

Costs of END implementation for major railways

The total costs (i.e. costs of compliance plus costs of measures) of END implementation per kilometre are broadly similar: Slovakia (€6,629 per km) and Austria (€8,944 per km). They are not, however, strictly comparable as they:

- cover different packages of measures. The Slovakian test case considers only the costs of a noise barrier while the Austrian test case considers a range of measures including implementation of barriers, walls and/or passive noise protection.
- apply to different lengths of railways and population densities along the railway. The average number of people per km of railtrack is approximately 14 times higher in Austria (437) than it is in Austria (32) and the number of people per kilometre exposed to noise levels in excess of 55 dB L_{den} is 26 times higher in Austria than it is in Slovakia.

The cost estimates per km have therefore been adjusted to make them more comparable with the benefit estimates by taking account of average population density in each case. On this basis, the costs per person are €20 in Austria and €205 in Slovakia. A comparison of costs between the two case studies, as well as some additional information made available from France, is shown in Table 40.

Table 40: Costs of END implementation along major railways

	Austria	Slovakia	France
Total length of railway (km)	2,218	506	7,239
Total population along length of railway	968,877	16,400	1,018,800
Average population density (noise-affected people per km)	437	32	141
Costs of END implementation (administrative costs)			
Total costs of implementation (€)	487,155	22,689	672,408
Total implementation costs per km (€)	219.64	44.84	92.89
Cost per affected person (€)	0.5	1.38	0.66
Costs of measures			
Total costs of measures (€)	19,350,869	3,331,587	700,000
Total costs of measures per km (€)	8,724	6,584	97
Cost per affected person (€)	20	203	0.69
Total costs (€)	**19,838,024**	**3,354,276**	**1,372,408**
Total costs per km (€)	**8,944**	**6,629**	**190**
Total costs per person (€)	**20**	**205**	**1.35**

The test case cost data was then scaled up to an EU level taking account of:

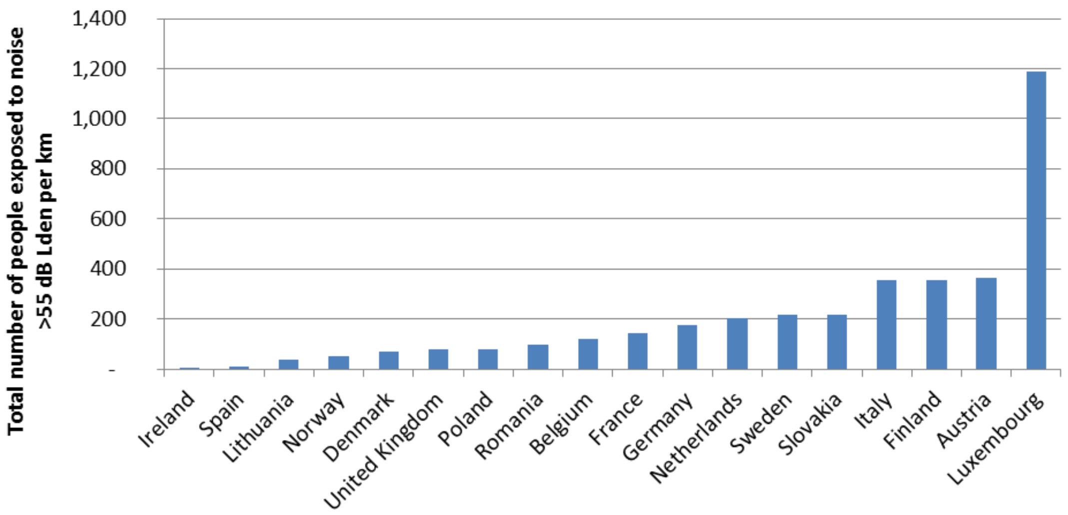
- The total length of railways in EU Member States with more than 60,000 passages a year;
- The availability of information on railways and noise exposure in those Member States that are required to report on railway noise.

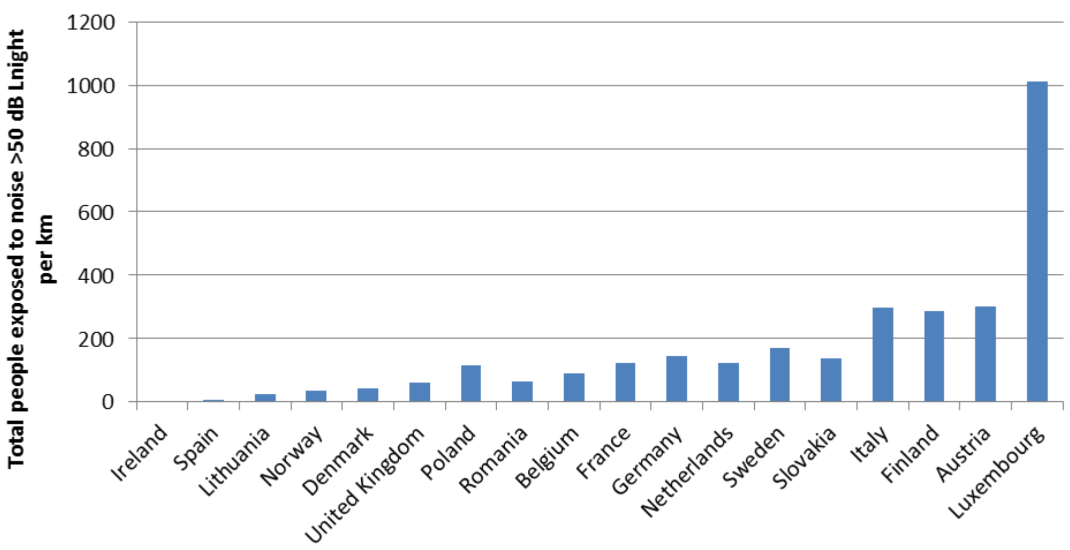
Based on information on major railways in the EIONET Noise Database[77], around 17 of the 23 Member States required to report on exposure to railway noise had actually done so. Non-EU Member States have been excluded from the analysis.

[77] http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/end_df4_df8_results_2012_150630

Member States were then classified into three broad exposure density groups according to the number of people exposed to noise levels in excess of 55 dB L_{den} or 50 dB L_{night}. The figure below shows the average number of people exposed to harmful levels of noise along major railways by day (> 50 dB L_{den}) and by night (>50 dB L_{night}) per kilometre for each Member State.

Figure 9: Average number of people exposed to harmful levels of noise along major railways in Member States for which exposure data was available.





The total length of railway in each class, as well as the median exposure to harmful levels of noise for each of L_{den} and L_{night} and for all Member States within each class is set out in Table 41. Median exposure to noise is calculated as the median value of the size of the population exposed to noise greater than 55 dB Lden or 50 dB Lnight across all the Member States in each class.

Table 41: Classification of major railways in Member States by population density per km

Density	Member States	Total km	Median exposure per km (L_{den})	Median exposure per km (L_{night})
0-150	Ireland, Spain, Lithuania, Denmark, United Kingdom, Poland, Romania, Belgium, France	18,537	78	60
150-300	Germany, Netherlands, Sweden, Slovakia,	19,631	209	141
>300	Italy, Finland, Austria Luxembourg	5,475	358	300
Total		43,643		
Note that estimates are for those countries that reported data only and exclude non-EU Member States				

Using the costs per person from the test cases as a guide, the costs of END implementation, including both administrative costs and costs of measures, are extrapolated across the relevant EU Member States according to the approximate population exposed to harmful levels of noise along the total length of railways in each category shown in Table 41.

Low, central and high cost estimates per person are calculated using the three test case estimates shown in Table 40 (France = low, Austria = central, Slovakia = high).

Using the same approach as that applied to major roads, each density class for major railways is further subdivided according to whether or not each of the Member States within that class had pre-existing noise legislation. It is assumed that those Member States that had noise legislation prior to the introduction of the END[78] would most likely have incurred at least some of the costs associated with the implementation of measures irrespective of whether or not the END was introduced. For the purposes of this analysis, it is assumed that in the base case (central) scenario, only 50% of the total estimated costs in those Member States with pre-existing noise legislation can be attributed to the END. This is considered a conservative assumption given that in several of these Member States, many of the most cost-effective measures had already been implemented (or budgeted) prior to the END and thus the costs attributed solely to the END are likely to be relatively small. For those Member States that did not have any noise legislation prior to the END, it is assumed that 100% of the costs can be attributed to END in the base case (central) scenario.

For the purposes of sensitivity testing, low and high scenarios have also been defined. The low scenario uses the lowest of the test case cost estimates per person (from Table 37) and assumes that only 25% and 50% of the total costs can be attributed to END implementation in Members with and without pre-existing noise legislation respectively. The high scenario uses the highest of the test case cost estimates per person and assumes that 100% of the total costs can be attributed to END regardless of whether or not Member States had pre-existing noise legislation.

The parameters used to define each of the cost scenarios are summarised in Table 42 and the resulting cost estimates under each scenario are shown in Table 43.

[78] These are Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Portugal, Slovakia, Sweden and UK. On the basis of the available information, it is inferred that the other 13 Member States had no noise legislation prior to the END.

Table 42: Parameters for estimating total costs within each class

Existence of noise legislation prior to END	Low		Central		High	
	Attribution (% of total costs)	Cost estimate	Attribution (% of total costs	Cost estimate	Attribution (% of total costs	Cost estimate
Pre-existing	25	Low	50	Central	100	High
None	50	Low	100	Central	100	High

Table 43: Costs of END implementation for major railways across the EU

			LOW		CENTRAL		HIGH	
Existence of noise legislation prior to END	Density	Total length of railway (km)	Ave costs per person (€)	Total costs (€, millions)	Ave costs per person (€)	Total costs (€ millions)	Ave costs per person (€)	Total costs (€, millions)
Pre-existing	0-150	14,254	1.35	0.35	20.48	10.61	204.53	211.88
None	0-150	4,283	1.35	0.23	20.48	6.96	204.53	69.56
Pre-existing	150-300	18,777	1.35	1.36	20.48	41.37	204.53	826.41
None	150-300	854	1.35	0.12	20.48	3.54	204.53	35.34
Pre-existing	>300	3,231	1.35	0.84	20.48	25.52	204.53	509.88
None	>300	2,244	1.35	0.54	20.48	16.43	204.53	164.14
	TOTAL	**43,643**		**3**		**104**		**1,817**

Benefits of END implementation for environmental noise along major railways

As with major airports and roads, the benefits of END implementation along major railways are estimated in respect of changes in the number of people exposed to harmful levels of noise as a result of the implementation of noise abatement measures and the associated improvements in health. In particular, the benefits are expressed in terms of the reduction in QALYs relating to the decline in noise-related annoyance and sleep disturbance. There are no reliable dose-response relationships for cardiovascular diseases (acute myocardial infarction and hypertension) for railway noise.

For each test case, the total benefits have been estimated for a central (most likely) scenario and by varying the parameters to provide the extent of the range in which the value of benefits could potentially lie. The benefit estimates for each of the low, central and high scenarios for each of the test cases are shown in Table 44, together with estimates derived from averaging the test case values under assuming that 100%, 70% and 25% respectively of the benefits can be attributed to the END. The numbers shown in bold represent the high, central and low estimates that are used to derive an estimate of the benefits of END implementation for major railways across the EU. The assumptions and parameters used to estimate the outcomes in each scenario are the same as those defined earlier (in Section 1.4.1) and repeated in Table 45 for ease of reference.

Table 44: Benefits of END implementation along major railways

		Low	Central	High
Austria (100% attribution)	Total benefits (€)	37,564,616.42	116,353,698.65	625,700,440.99
	Total benefits per km (€)	16,936.26	52,458.84	282,101.19
	Total benefits per person per km (€)	38.77	120.09	645.80
Slovakia (100% attribution)	Total benefits (€)	15,732,021.85	47,546,769.30	199,389,129.28
	Total benefits per km (€)	31,090.95	93,965.95	394,049.66
	Total benefits per person per km (€)	959.27	2,899.19	12,157.87
Average (*100% attribution*)	Total benefits (€)	26,648,319.14	81,950,233.98	412,544,785.13
	Total benefits per km (€)	24,013.60	73,212.39	338,075.43
	Total benefits per person per km (€)	499.02	**1,509.64**	**6,401.84**
Average (*50% attribution*)	Total benefits (€)	13,324,159.57	40,975,116.99	206,272,392.57
	Total benefits per km (€)	12,006.80	36,606.20	169,037.71
	Total benefits per person per km (€)	**249.51**	**754.82**	3,200.92
Average (*25% attribution*)	Total benefits (€)	6,662,079.78	20,487,558.49	103,136,196.28
	Total benefits per km (€)	6,003.40	18,303.10	84,518.86
	Total benefits per person per km (€)	**124.76**	377.41	1,600.46

Table 45: Parameters used to define scenarios

	Low	Central	High
Value of a QALY	€ 67,163	€ 110,987	€ 154,812
Disability Weight for Sleep Disturbance	0.04	0.07	0.1
Disability Weight for Annoyance	0.01	0.02	0.12

The test case data have then been used to derive an estimate of the average present value of benefits per person (per km) over a 25-year assessment period. Using the same approach as for the cost estimates, the test case benefit estimates have been scaled up on the basis of the total length of major railways across the Member States for which exposure data was available[79], and accounting for both differences in average population density along major railways in different Member States and whether or not each Member State had pre-existing noise legislation.

[79] The estimate does not include Estonia, Cyprus, Slovenia, Hungary and Czech Republic as there was no data available for these Member States.

The resulting benefits estimates under each of a low, central and high scenario are shown in Table 46. The scenarios (low, central, high) are defined using the same parameters as described in Table 42.

Table 46: Total benefits of END implementation for major railways

			LOW		CENTRAL		HIGH	
Existence of noise legislation prior to END	**Density**	**Total length of railway (km)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**	**Ave benefits per person (€)**	**Total benefits (€, millions)**
None	0-150	4,283	249.51	84.86	1,509.64	513.43	6,401.84	2,177.26
Pre-existing legislation	0-150	14,254	124.76	129.24	754.82	781.95	6,401.84	6,631.88
None	150-300	854	249.51	43.12	1,509.64	260.87	6,401.84	1,106.24
Pre-existing legislation	150-300	18,777	124.76	504.08	754.82	3,049.89	6,401.84	25,866.96
None	>300	2,244	249.51	200.23	1,509.64	1,211.50	6,401.84	5,137.51
Pre-existing legislation	>300	3,231	124.76	311.01	754.82	1,881.74	6,401.84	15,959.57
	TOTAL	**43,643**		**1,273**		**7,699**		**56,879**

Combining the costs and benefits of END implementation for major roads, the net present value and cost-benefit ratios under each scenario are estimated as shown in Table 47.

Table 47: Cost-benefit summary – major railways (for all Member States for which data was available)

	Low	Central	High	High cost, low benefit
Total Present Value Costs (€, millions)	3	104	1,817	1,817
Total Present Value Benefits (€, millions)	1,273	7,699	56,879	1,273
Total Net Present Value (€, millions)	1,269	7,595	55,062	-545
Cost-Benefit Ratio	1:370	1:74	1:31	1:0.7

These findings suggest that the costs of END implementation justify the benefits for major railways in most cases, with cost-benefit ratios ranging from 1:31(in cases where it assumed that 100% of benefits can be attributed to END and using high values for the VOLY and disability weights) to 1:370 (where between 25% and 50% of the benefits can be attributed to END depending on whether or not each Member State had pre-existing noise legislation, and using the low values). However, when combining the highest estimate of costs with the lowest estimate of benefits, the cost-benefit ratio is less than 1 (i.e. costs exceed benefits).

Further sensitivity tests were then applied to assess how the outcomes would change at an EU-wide level given the status of NAP implementation (i.e. differentiating between those Member States who have completed, or at least partially completed their NAPs and those who have not)[80]. The assumptions governing the level (%) of attribution of the total estimated costs and benefits in each scenario are set out in Table 48.

Table 48: Percentage of costs and benefits attributed to END in each scenario for major railways given Member States' status in terms of pre-existing noise legislation and NAP completion

% costs and benefits attributed to END			
	Low scenario	Central scenario	High scenario
No pre-existing legislation; NAP submitted/underway	50	100	100
No pre-existing legislation; no NAP	25	25	25
Pre-existing legislation; NAP submitted/underway	25	50	100
Pre-existing legislation; no NAP	25	50	100
Cost / benefit values	Low	Central	High

Tables 50 and 51 show the extrapolation and distribution of costs and benefits respectively across each density class for Member States with and without pre-existing noise legislation and NAPs. The average costs per person under each scenario are simply the low, central or high costs per person (from Table 40). These are then multiplied by the total length of railway, the median number of people exposed to noise levels greater than 55 dB L_{den} and the applicable percentage attribution (from Table 48) to provide an estimate of total costs for the total length of road in each category. The average benefits per person in each category are determined according to pre-existing legislation and NAP status using the information from Tables 44 and 47.

The summary findings in terms of present value costs, present value benefits, NPV and cost-benefit ratio are shown in Table 49.

Table 49: Net Present Value and Cost Benefit Ratio for END implementation for major railways in Member States taking account of NAP status)

	Low	Central	High	HIGH COST LOW BENEFIT
Total Present Value Costs (€, millions)	3	82	1,417	1,417
Total Present Value Benefits (€, millions)	2,238	7,317	26,004	2,238
Total Net Present Value (€, millions)	2,235	7,235	24,586	820
Cost-Benefit Ratio	1:815	1:89	1:18	1:1.6

80 Based on information provided by DG Environment.

From the table above, it can be seen that the cost-benefit ratios become more favourable in the low and central scenarios and less favourable in the high scenario when Member States' NAP status is also taken into account. This is largely due to the fact that half (8) of the Member States for which exposure data was available had no noise legislation prior to the introduction of the END but five of these had produced NAPs and therefore at least 50% of the benefits (and costs) were attributed to the implementation of the END in the low scenario (compared to 25% in Table 47) and 100% in the central and high scenarios (compared to 50% and 100% for the central and high scenarios in Table 47). Since the benefits are typically higher than the costs, the net present value and cost-benefit ratio is correspondingly higher.

Note that these findings do need to be treated with caution as the estimates are based on a very limited sample and are based on a number of underlying assumptions. In particular, the costs of measures are known to be incomplete as these were only available for a limited selection of measures.

Table 50: Extrapolation of costs across major railways in the EU-28 taking account of existing legislation and NAP status

			LOW		CENTRAL		HIGH	
Pre-existing legislation & NAP status	**Density**	**Total length of railway (km)**	**Ave costs per person (€)**	**Total costs (€, millions)**	**Ave costs per person (€)**	**Total costs (€, millions)**	**Ave costs per person (€)**	**Total costs (€, millions)**
None; NAP	0-150	82	1.35	0.001	20.48	0.03	204.53	0.34
None; No NAP	**0-150**	4,088	1.35	0.11	20.48	1.66	204.53	16.60
Pre-existing; NAP	0-150	14,254	1.35	0.35	20.48	10.61	204.53	211.88
Pre-existing; No NAP	0-150	-	1.35	-	20.48	-	204.53	-
None; NAP	150-300	854	1.35	0.12	20.48	3.54	204.53	35.34
None; No NAP	**150-300**	-	1.35	-	20.48	-	204.53	-
Pre-existing; NAP	150-300	18,271	1.35	1.20	20.48	36.55	204.53	730.10
Pre-existing; No NAP	150-300	506	1.35	0.04	20.48	1.12	204.53	22.36
None; NAP	>300	2,244	1.35	0.54	20.48	16.43	204.53	164.14
None; No NAP	**>300**	-	1.35	-	20.48	-	204.53	-
Pre-existing; NAP	>300	3,210	1.35	0.38	20.48	11.59	204.53	231.55
Pre-existing; No NAP	>300	21	1.35	0.01	20.48	0.26	204.53	5.11
		43,529.95		**2.74**		**81.78**		**1,417.41**

Table 51: Extrapolation of benefits across major railways in the EU-28 taking account of existing legislation and NAP status

			LOW		CENTRAL		HIGH	
Status	**Density**	**Total length of railway (km)**	**Ave benefits per person**	**Total benefits (€, millions)**	**Ave benefits per person**	**Total benefits (€, millions)**	**Ave benefits per person**	**Total benefits (€, millions)**
NAP	0-150	82	249.51	1.36	1,509.64	8.23	6,401.84	34.89
No NAP	0-150	4,088	124.76	40.50	377.41	122.51	1,600.46	519.53
NAP	150-300	854	249.51	43.12	1,509.64	260.87	6,401.84	1,106.24
No NAP	150-300	-	124.76	-	377.41	-	3,200.92	-
NAP	>300	2,244	249.51	200.23	1,509.64	1,211.50	6,401.84	5,137.51
No NAP	>300	-	124.76	-	377.41	-	3,200.92	-
Pre-existing legislation		36,262	124.76	1,952.49	754.82	5,713.58	6,401.84	19,205.51
	TOTAL	**43,530**		**2,238**		**7,317**		**26,004**

1.5.4 Agglomerations

Under the END, there is a requirement for Member States to report noise exposure levels for all agglomerations. Agglomerations are defined by the END as "part of a territory, delimited by the Member State, having a population in excess of 100 000 persons and a population density such that the Member State considers it to be an urbanised area" (*Article 3k).*

According to the EEA Noise database[81], there are 471 agglomerations across Europe, 466 of which are within the EU-28. Of the 471 agglomerations required to prepare SNMs, all of them are required to report on road traffic noise, 460 on rail noise and 381 on aircraft noise. By 2012, only 62% had reported on road traffic noise and 57% and 44% on rail and aircraft noise respectively.

1.5.4.1. Methodology: Summary overview

For the purposes of the evaluation, 10 agglomerations were selected as test cases for analysis. These were selected on the understanding that information on costs and benefits (in terms of changes in the number of people exposed to noise from all transportation sources within agglomerations) was readily available, either from the published NAPs or directly from the relevant authorities and other published sources.

The information obtained was, however, incomplete and was not sufficiently comparable across the test cases to support a reliable extrapolation. More specifically, the test cases vary widely with respect to:

- The **types of measures implemented** (see Table 50), the degree of implementation of measures and the number of affected persons exceeding limit values (which are country specific);
- The **sources of environmental noise** (some are affected by road, railway and airport noise while others only by one or two principal sources of noise).
- The **extent to which cost and benefit information was available** for the principal noise sources. For instance, while Nuremberg is affected by noise from roads, railways and airports, it was not possible to determine the combined effects (costs and benefits) of measures to address noise from these sources. Separate analyses were conducted for individual measures implemented in each of the test case agglomerations.

This is compounded by further challenges in that the agglomerations that are required to report under the END, all differ with respect to:

- **Population size and density**. This has a bearing on the cost-effectiveness of measures, particularly measures of a 'public good' nature. (i.e. where the benefits of a measure extend beyond the specific population for which the measure was intended (non-excludable) and where there is no incremental cost of providing the measure to others (non-rivalrous);
- **The principal sources of environmental noise**. While road traffic noise is common to all agglomerations; noise from railways and airports does not apply to all agglomerations;
- The **completeness of information** on the size of the population exposed to harmful levels of noise (> 55 dB L_{den} or 50 dB L_{night}), particularly in relation to noise from airports.

[81]Accessed at http://forum.eionet.europa.eu/etc-sia-consortium/library/noise_database/index_html (last updated June 2015)

The costs and benefits of measures relating to each noise source (roads, railways, airports) ought to be treated separately in order to avoid the risk of double counting. This is because a number of households could potentially be exposed to noise from more than one source. Moreover, the benefits that households or individuals derive from the measures aimed at achieving a reduction in noise from each source are not additive (i.e. the cumulative effect will be less than the sum of the change in noise reduction from each source). However, it can also be argued that households are primarily affected by only one source. For example, people living on a main street are not normally affected by rail or airport noise at the same intensity and the dose-response relationships show an increasing share of annoyed persons at high noise levels.

Although the test cases have estimated the benefits for the single noise source situation (not total noise), it is nevertheless possible to add the benefits of measures relating to different noise sources with a relatively small risk of double counting. However, as Table 50 shows, no two test cases are the same in terms of the types of measures included and the scale at which they are implemented also varies widely. This limits the ability to reliably extrapolate the test case findings to the EU level.

For this reason, rather than extrapolating from the agglomeration test cases, an indicative assessment of the efficiency of END implementation within agglomerations is made by considering the cost-benefit ratios associated with specific measures that were identified in the NAPs for each of the test cases and for which cost and benefit data exists. The process for calculating costs and benefits of individual measures is similar to that described in section 1.4.1 (and repeated below for ease of reference) but differs with respect to the way in which costs and benefits per person are calculated.

Costs

Costs are divided into a) compliance/administrative costs, and b) costs of implementing the measures. Costs reported here are the total costs incurred (or planned) to date, discounted (at 4% per year) over a 25-year assessment period, and expressed in 2014 prices.

The costs per person are then calculated as the present value costs (i.e. the sum of the discounted costs over 25 years) divided by the number of people who benefited from the measure. This differs from the approach used for estimating the costs (and benefits) for groups of measures where costs per person were calculated as using the total number of people affected by noise levels higher than 55 dB L_{den}.

Benefits

Benefits are considered as the difference between the existing situation and the situation after the implementation of all the measures. They are monetised by means of the methodology of valuation of health effects described in Section 1.4.1. The benefits are assessed over a 25-year period, discounted at 4% per year and expressed in 2014 prices. Similar to the approach used for costs, the per person benefits for individual measures are calculated using the estimated number of beneficiaries of each measure rather than the total size of the population affected by noise levels exceeding 55 dB L_{den}.

Cost-benefit ratio

The cost-benefit ratio is then calculated to provide an overall indication of value for money of each of the measures. Where the ratio is greater than 1, this implies that the benefits exceed the costs and the measure is thus cost-efficient. Where the ratio is less than 1, the costs exceed the benefits and the measure.

A more detailed analysis of the test case findings and cost-benefit ratios of individual measures is provided below.

1.5.4.2. Test case data

The table below shows the test cases that were investigated, as well as their status with respect to completeness of data.

Table 52: Test case agglomerations

Test case	Noise sources covered	Completeness of data
Nuremberg, Germany	Road	• Incomplete data on the costs of measures, including rail grinding • Costs and benefits relate only to roads measures
Dusseldorf, Germany	Road	• No information on administrative costs • Analysis does not include the costs of noise abatement measures implemented by Dusseldorf airport or the national railway authority. While the costs and benefits of these measures are likely to be significant, many of these measures were implemented independently of the NAP. • The costs of measures relate only to city and federal expenditures on road and railway measures • Benefits relate to roads measures only
Essen, Germany	Road, rail	• Data on the costs of measures is largely incomplete. In particular, the costs of noise abatement measures implemented by the federal roads and national rail authorities are not included. The costs and benefits of these measures are likely to be significant • Many measures identified in the NAP have not yet been implemented or are still underway • If all measures identified in the NAP are implemented, the benefits (and costs) are likely to be significantly higher
Munich, Germany	Road, rail	• Cost information is only available for two of the measures, both of which are still underway. • No information on the total size of the population benefitting from the measures with known costs.
Augsburg, Germany	Road, rail	• Incomplete data on the costs of measures • Benefits relate to road and rail • Some measures still underway therefore benefit estimates over-estimate the benefits achieved to date
Athens, Greece	Road, rail	• No information on the costs of measures • Benefits relate to road measures only
Helsinki, Finland	Road, rail	• Costs only available for a selection of the 23 measures identified in the NAP. • The size of the populating benefitting from the measures for which cost data is available is unknown and therefore it is not possible to calculate benefit estimates.
Malmö, Sweden	Road	• Costs only available for a limited number (4) of the 15 measures identified in the NAP. • Benefits therefore only relate to these measures. • All measures are still underway and therefore the level of benefits estimated by the analysis is likely to over-state the actual benefits achieved to date. • If all measures identified in the NAP are

Test case	Noise sources covered	Completeness of data
		implemented, then the costs and benefits will be significantly higher than those in the test case.
Bratislava, Slovakia	Road, rail, air	• No information on the administrative costs of END. • No information available on the costs of measures. • While the Environmental Action Plan provides estimates of the change in the total number of people affected by noise (L_{den}) from measures along the road network, there is no information on the size of the population affected by the other measures identified in the NAP.
Bucharest, Romania	Road, rail, 2 airports	• No information on costs • No reliable information on benefits relating to measures identified in the provisional NAP • The first official NAP has not yet been published (anticipated end 2015). The draft NAP contains details for proposed measures but cost and benefit information is only available for two measures – a noise barrier along the railway and improved road surfacing along the D4 motorway.

A summary of the test case findings is provided in Table 53 overleaf. More detailed descriptions of each of the test cases and key findings are provided in Appendix F.

Table 53: Test case summary - agglomerations

Agglomeration	Nuremberg	Athens	Helsinki	Augsburg	Dusseldorf	Essen	Munich	Bucharest	Malmö	Bratislava
Country	**Germany**	**Greece**	**Finland**	**Germany**	**Germany**	**Germany**	**Germany**	**Romania**	**Sweden**	**Slovakia**
Noise sources	Roads, railways, tramways, airport and industry	Heavy exposure to noise from roads and railways	Road, rail, tram and metro	Inner-city noise; noise from two major motorways that cross the city. Connected to five train lines and a 76km long tram network. Noise from aviation is insignificant.	Road, rail and air	Road, rail and air	Road and rail	Road, rail, air	Road	Road, rail, air and industry
Noise sources covered in test case (costs and benefits)	Roads	Roads	Road (costs only)	Roads	Roads	Road, rail	Road, rail	Road, rail, air	Road	Road, rail
Key characteristics										
Context	Heavy exposure to environmental noise in densely populated area; several autobahn routes pass close to the city and a multi-lane motorway crosses the city	Densely populated area with heavy exposure to traffic noise from all sources.	The commercial port was relocated in 2008 and the old harbour area was developed for residential purposes. This resulted in a decrease in rail and heavy road traffic in the inner city and a correspondin g decrease in	Vibrant industrial city, smaller agglomeratio n	One of 10 largest cities in Germany; the city is an economic hub. Characterised by heavy traffic flows and an extensive road network. Densely populated with nearly as many workplaces as residents.	One of the 10 largest cities in Germany. Dense road network and highly congested expressway cuts across the city. Well-established public transport system, including buses, trams and railways. The	Third largest agglomeratio n in Germany. Dense inner-city road network; functions as a hub for long-distance traffic both on road and rail. Extensive public transport system. City road network connects to	Capital city of Romania. The city is connected to 5 train lines and has an underground network. It is also served by two international airports. Noise is a significant issue with over 3,800 buildings exceeding noise levels	Third largest city in Sweden and most densely populated area in Scandinavia.	Capital of Slovakia. The agglomeratio n is defined to lie within the boundaries of the municipal area whereas the greater metropolitan area includes another 100,000 people. Noise mapping covers roads, railways, industry and

Agglomeration	Nuremberg	Athens	Helsinki	Augsburg	Dusseldorf	Essen	Munich	Bucharest	Malmö	Bratislava
			noise levels.			population is also affected by aircraft noise due to proximity of Essen Mulheim airport.	an outer and an inner circular roads well as to seven motorways in the vicinity of the city. Noise from aviation not relevant as the airport is situated well away from the city.	above 65 dB, around 200 buildings exceeding noise levels above 70 dB and a number of buildings exceeding 75 dB L_{den}.		the international airport which is situated 9km from the city centre.
Population	520,000	701,852	560,905	276,542	598,686	569,884	1,407,836	1,931,000	318,107	460,000
Area (km2)	187	38	215	147	217	210	311	285	156	859
Population density (persons/km)	2,781	18,470	2,609	1,881	2,759	2,714	4,527	6,775	2,039	536
Noise exposure (Road)										
Population exposed to noise > 55 dB L_{den} (before measures)	122,600	701,821	No information	46,900	159,346	182,600	No information	No information	142,500	No information
Population exposed to noise > 50 dB L_{night} (before measures)	77,700	698,401	No information	29,000	113,510	118,400	No information	No information	82,460	No information
Noise exposure (Rail)										
Population exposed to noise > 55 dB L_{den} (before measures)	100,540	702,424	No information	39,060	131,067	75,240	No information	No information	n/a	No information
Population exposed to noise > 50 dB L_{night} (before measures)	80,450	702,424	No information	29,620	100,552	57,110	No information	No information	n/a	No information

Agglomeration	Nuremberg	Athens	Helsinki	Augsburg	Dusseldorf	Essen	Munich	Bucharest	Malmö	Bratislava
Noise exposure (Air)										
Population exposed to noise > 55 dB L_{den} (before measures)	3,400	n/a	n/a	n/a	7,112	n/a	n/a	No information	n/a	No information
Population exposed to noise > 50 dB L_{night} (before measures)	900	n/a	n/a	n/a	1,164	n/a	n/a	No information	n/a	No information
Costs										
Compliance/administrative costs (€), discounted @4% p.a. over 25 years	136,934	-	259,820	19,819	-	790,161	600,000	-	150,022	-
Total costs of measures (€), discounted @4% p.a over 25 years	23,045,738	-	6,508,854	4,710,245	13,125,969	9,271,764	12,242,764	-	18,084,436	-
Notes on costs	Costs only relate to measures to reduce noise from roads. This includes reductions in speed limits, quieter road surfaces and soundproof windows	No information available (or provided) on either the administrative costs associated with END or the costs of measures.		Costs (and benefits) relate to 2 roads measures only	Costs only available for measures within the responsibility of the city of the Dusseldorf and the federal government (state roads)	Costs relate primarily to roads measures; 2 rail measures also included	The total cost of the END implementation cannot be calculated to date, since not all measures are approved. However, the soundproof windows program as well as the action program "Mittlerer Ring" incur high costs and are underway.	No information available (or provided) on either the administrative costs associated with END or the costs of measures.	Cost data only available for a selection of measures - noise-proof windows, noise barriers and other noise-reducing activities in selected locations	Cost (and benefit) information only available for 2 proposed measures (noise barrier and low noise surface on motorway D4) within a single hotspot district (Petrzalka)

Agglomeration	Nuremberg	Athens	Helsinki	Augsburg	Dusseldorf	Essen	Munich	Bucharest	Malmö	Bratislava
							Only the cost of those two measures are included. Also not included are noise abatement measures implemented by the federal state government for federal roads and rail that account for high expenditures and significant effects.			
Ave cost per affected person (€)	189	-	12	101	45.19759278	39			128	
Benefits (assuming 100% attribution)										
Benefits (€)	658,804,377	86,576,856	Total benefit cannot be calculated as the number of residents benefiting from the implementation of measures with known costs cannot be determined	71,159,384	865,480,746	1,644,855,489	Total benefit cannot be calculated as the number of residents benefiting from the implementation of measures with known costs cannot be determined	No reliable information on the benefits relating to the full suite of measures identified in the Environmental Action Plan (2008). Costs and benefits associated with a reduction in L_{den} levels as	529,952,835	No information on benefits from measures applied across the whole of the agglomeration. Benefit estimates only available for the two measures described above and in a single

Agglomeration	Nuremberg	Athens	Helsinki	Augsburg	Dusseldorf	Essen	Munich	Bucharest	Malmö	Bratislava
								a result of improved road surfaces along 50km of the main road network have been estimated but are not included in the analysis because they relate only to a single measure.		hotspot area
Average benefit per person (€)	5,374	123	-	1,517	5,431	9,008	-	-	3,719	-
Net Present Value (€)	635,621,704	-	-	66,429,320	-	1,634,793,564	-	-	511,718,377	-
Cost Benefit Ratio	1:28			1:15		1:231			1:29	
Sensitivity testing										
Benefits: central estimates, 25% attribution	164,701,094	21,644,214	-	17,789,846	216,370,187	411,213,872	-	-	132,488,209	-
Benefits: central estimates, 50% attribution	329,402,188	43,288,428	-	35,579,692	432,740,373	822,427,744	-	-	264,976,417	-
Benefits: central estimates, 75% attribution	494,103,283	64,932,642	-	53,369,538	649,110,560	1,233,641,616	-	-	397,464,626	-
High scenario - high values, 100% attribution (€, million)	2,013,260,463	383,193,544		151,574,257	2,620,319,692	4,688,607,357			1,436,919,099	

Agglomeration	Nuremberg	Athens	Helsinki	Augsburg	Dusseldorf	Essen	Munich	Bucharest	Malmö	Bratislava
Low scenario - low values, 100% attribution (€, million)	289,104,020	31,018,046		38,381,061	442,536,679	789,916,032			191,209,212	
Low scenario - low values, 25% attribution (€, million)	72,276,005	7,754,511		9,595,265	110,634,170	197,479,008			47,802,303	
Measures considered										
Noise proof window campaign	x			x	x	x	x		x	
rehabilitation of roads/low noise road surfaces	x			x	x	x	x	x		x
Speed reduction	x									
Speed control	x			x		x	x			
re-distribution/reduction of number of Heavy trucks						x				
Barriers/walls			x		x		x			x
Embedded tracks for trams	x				x					
Acoustical grinding of tracks	x									
Vegetated tram tracks					x		x			
combination 3,4,5										

1.5.4.3. Efficiency of measures implemented in agglomerations

Noise Action Planning in agglomerations covers a broad range of measures utilised for the objective of the END. Most measures affect a clearly defined case study area in which the measure is implemented. Often more than one measure affects the population in a given case study area. Cumulative effects of packages of measures within test cases are only studied by way of example since the combination of measures varies by agglomeration. Cost-benefit assessments were carried out for 28 measures in 10 agglomerations.

The NAPs analysed contain a large variety of measures. For the CBA, a sample of these measures was selected taking into consideration evidence as to their effectiveness and whether such measures have actually been implemented during R1. Table 54 shows the measures that were selected for the analysis. The measures relevant to each test case agglomeration are identified at the bottom of Table 53.

Table 54: Measures implemented in agglomerations and for which CBAs were conducted

No.	Measure	Comment
1	Noise proof window campaign	Usually only available for affected residents over the threshold value e.g. L_{den}/night >70/60 dB(A).
2	Rehabilitation of roads / Low noise road surfaces	Measure primarily applied for road sections.
3	Speed reduction	Reduction by 20 km/h, e.g. Speed limit reduced from 60km to 40km or from 50km to 30km
4	Speed control	Measure primarily applied for road sections.
5	Re-distribution / Reduction of number of heavy trucks	Requires redesign of traffic flows for road systems within agglomerations.
6	Barriers / Walls	Frequently used for roads and rails but not usually for agglomerations.
7	Embedded tracks for trams	Often only implemented when replacing old tracks.
8	Acoustical grinding of tracks	---
10	Implementing Vegetation Systems in Tram Tracks.	---

Cost of measures

Conclusive information regarding the actual costs incurred of measures was only available for a few selected cases. The costs presented in NAPs are often estimates as only a few of the measures have been fully implemented and thus it is only for these measures that the actual costs are known. Where no detailed cost information was available for a measure, data from similar cases was collated, adjusted where necessary to account for local factors, and applied to the case. This made it possible to develop a generalised cost approach for each measure, as presented in Table 55.

Table 55: General unit cost estimates used for estimating total costs of measures

No.	Measure	Cost
1	SNM / NAP	2 € / resident in agglomeration
2	Noise proof window campaign	1,500 € / flat resp. 750 € / effected resident
3	Rehabilitation of roads / Low noise road surfaces	50 € / m² exchanged surface
4	Speed reduction	50 € / m road
5	Speed control	cost neutral due to revenue from speeding fines
6	Re-distribution / Reduction of number of heavy trucks	requires redesign of traffic concept approx. 250,000 € depending on size of agglomeration
7	Barriers / Walls	1,000 € / m² wall
9	Embedded tracks for trams	500 € /m double track
10	Acoustical grinding of tracks	1 € / m single track
11	Vegetated tram tracks	2,500 € / m double track

The total costs comprise both the SNM/NAP preparation expenditure per resident and the capital and ongoing maintenance costs associated with each measure.

Benefits

The effectiveness of a measure is measured by the reduction of noise level in the case study area. This information is generally provided in the NAPs. Where this is not the case, the degree of noise reduction is estimated using data from similar cases. As a result, generally accepted average noise reduction levels are available for each measure, as presented in Table 56.

Table 56: Reductions in noise levels achieved with each measure

No.	Measure	Effectiveness (reduction of noise level)
2	Noise proof window campaign	L_{den} = no effect L_{night} < 45 dB(A)
3	Rehabilitation of roads / Low noise road surfaces	$L_{den}/_{night}$ = -4 dB(A)
4	Speed reduction	$L_{den}/_{night}$ = -2 dB(A)
5	Speed control	$L_{den}/_{night}$ = -1 dB(A)
6	Re-distribution / Reduction of number of heavy trucks	reduction of effected residents by 20 %
7	Barriers / Walls	$L_{den}/_{night}$ = -3 dB(A)

No.	Measure	Effectiveness (reduction of noise level)
8	Embedded tracks for trams	$L_{den}/_{night}$ = -3 dB(A)
9	Acoustical grinding of tracks	$L_{den}/_{night}$ = -6 dB(A)
10	Vegetated tram tracks	$L_{den}/_{night}$ = -2 dB(A)

The benefits are then calculated based on the change in the number of people affected by noise within each 5 dB noise interval. A more detailed explanation of the process for calculating the change in the size of the population exposed to noise within agglomerations is provided in Appendix E.

Cost-benefit ratios

The resulting cost-benefit ratios for each of the measures in each test case are summarised in Table 57 below.

Table 57: Cost-benefit ratios for individual measures in each test case agglomeration

Overview CB-Ratios	Augsburg	Munich	Nuremberg	Essen	Düsseldorf	Malmö	Athens	Bucharest	Bratislava	Helsinki
Noise proof window campaign	1:11	1:8	1:14	1:25	1:18	1:15	-	-	-	-
rehabilitation of roads/low noise road surfaces	1:4	1:16	1:21	1:10	1:8	-	-	1:3	1:10	-
Speed reduction (speed limits)	1:119	1:335	1:301	1:112	-	-	-	-	-	-
Speed control (enforcement)	1:14,335	-	-	-	-	-	-	-	-	-
re-distribution/reduction of number of heavy trucks	-	-	-	1:6321	-	-	-	-	-	-
Barriers/walls	-	1:0.3	-	-	1:5	-	-	-	1:7	1:1.2
Embedded tracks for trams	-	-	1:6	-	1:3	-	-	-	-	-
Acoustical grinding of tracks	-	-	1:74	-	-	-	-	-	-	-
Vegetated tram tracks	-	1:1	-	-	1: 1	-	-	-	-	-

It is evident from the information presented in Table 54 that there is a wide degree of variation in the cost-benefit ratios for different measures, which is not unexpected. Speed control and re-routing of heavy vehicles are particularly cost-efficient because they involve low levels of capital expenditure yet yield high benefits. The cost estimates do not, however, include estimates of the costs that may be passed on to heavy vehicle users in the form of the opportunity costs of time and additional fuel costs from having to travel longer distances, or to society from the additional greenhouse gas emissions associated with additional fuel use. These are, nevertheless, anticipated to be small relative to the overall benefits associated with noise reductions.

The negative cost-benefit ratio associated with the construction of noise barriers in Munich can be attributed to the relatively low number of people benefitting from the measure (190 people along a length of road of approximately 500m) in comparison to the high costs (€1.8 million, undiscounted).

Assuming that the cost-benefit ratios presented above provide are broadly indicative of the cost-benefit ratios (at least of similar order of magnitude) that would be achieved in other agglomerations across the EU, then it can be concluded that the implementation of the END has been efficient and cost-effective overall in agglomerations.

1.5.5 Administrative costs at EU level

In addition to the costs incurred at Member State level, the costs of administration, reporting, research and evaluation at the supra-national level (i.e. by the European Commission, European Environment Agency and Joint Research Centre) also need to be taken into account.

The costs incurred to date (2002-2015) for each of the implementing authorities at European level are shown in Table 55.

Table 58: Costs of END implementation at supra-national level

	Staffing costs	Other costs (e.g. of meetings, missions, etc.)	Total costs
European Commission	2,112,000	462,000	2,574,000
European Environment Agency	1,815,000	not provided	1,815,000
Joint Research Centre (est.)	100,000	not provided	100,000

*Costs estimated as 0.5 FTEs over 4 years (2009-2012) reflecting time spent on contributing to the development of the CNOSSOS methodology

The administrative costs are then discounted (using the 4% social discount rate) over the 25-year assessment period to allow them to be compared to the benefits (and costs) of implementation at Member State level. The total of the discounted values is shown in Table 56 below.

1.5.6 Aggregate assessment

Combining the information on administrative costs and the outcomes from the analyses for each of airports, roads, railways and agglomerations, it is possible to provide an indicative assessment of the overall efficiency of the implementation of the END. The overall findings in the base case are summarised in Table 56.

Note that the benefits (and costs) are assessed over a 25-year assessment period and the analysis assumes that the same level of benefits will be delivered year-on-year from the time the expenditure on measures was made until the end of the assessment period. Shortening the assessment period, and thus the flow of benefits relative to the costs, will substantially reduce the NPV.

For example, if the assessment period were reduced to 18 years such that the effects of measures only endure for 5 years after the final year of investment, rather than the current 12 years, the NPV for major rail in Austria almost halves. It is likely that, at least in some cases, reducing the flow of benefits would result in negative NPVs and cost-benefit ratios.

The results shown in Tables 59 to 61 are considered indicative of the order-of-magnitude costs and benefits only and should be treated with caution. In particular:

The **cost and benefit estimates are partial.**

- They do not include the costs and benefits associated with measures to reduce harmful levels of noise in agglomerations. Cost-benefit ratios have not been calculated for agglomerations as the test cases did not provide a sufficiently representative sample from which to extrapolate. However, the test case data and the cost-benefit analyses for a range of typical measures employed in agglomerations suggest that the benefits of measures to reduce noise in agglomerations substantially outweigh the costs although the ratios vary significantly between measures.
- They only cover a subset of the total range of measures identified in Member States' NAPs. Only those measures for which reliable and comparable cost and benefit information was available were included.

The **benefit estimates are understated**.

- They only account for the benefits associated with noise reductions amongst the highly annoyed and highly sleep disturbed populations. They do not consider the benefits to those that experience low or moderate levels of sleep disturbance and annoyance.
- They do not include the benefits in the form of cost savings from a reduction in hospital admissions (costs borne by individuals) and lost productive days (costs to employers). These are nevertheless likely to be small in relation to the value of avoided DALYs.
- In contrast, while some of the measures included in the assessment have not yet been fully implemented, the benefits estimates are calculated assuming that the measures have been fully implemented*. The benefits associated with some measures are thus somewhat overstated*.

The **cost estimates, particularly in relation to roads and airports) are understated**.

- The indirect costs of measures (such as increases in transport costs and greenhouse gas emissions as a result of changes to routes, etc.) are not included. These are nevertheless likely to be low relative to the direct costs of measures.
- The **test case costs and benefits are not necessarily representative** of the situation across the EU and the extrapolation was performed using a limited sample.
- **The degree to which costs and benefits can be attributed to the END is unknown**. While different assumptions about the level of attribution have been tested in the sensitivity analyses, the assumptions that have been applied were formulated for the purposes of illustration only using professional judgement and may not accurately reflect the actual situation.

Notwithstanding the limitations, the outcomes suggest that the END is efficient overall. The NPV is positive under all scenarios (base case, best and worst case) and only negative for airports and roads under the worst case scenario (Table 60).

The corollary of this is that if the END did not exist, it can be assumed that some noise mitigation measures would still go ahead anyway because measures identified in NAPs were driven by national regulations or there were other primary regulatory drivers, such as introducing speed limits to help reduce pollution and comply with air quality limits. However, at least some measures would not have been identified and / or already implemented had it not been for the existence of the END. There would therefore have been a higher number of exposed persons to environmental noise, with significant implications for the health and well-being of those affected by noise as a result.

Table 59: Aggregate assessment of costs and benefits at the EU scale

	Total present value costs (€, million)	Total present value benefits (€, million)	Net present value (€, million)	Cost-benefit ratio
EU level	3	-	-	-
Major airports	438	2,854	2,416	1:7
Major roads	667	24,248	23,581	1:36
Major rail	82	7,317	7,235	1:89
TOTAL	1,190	34,418	33,228	1:29

The worst case scenario (Table 60) is modelled using the highest cost estimates and the lowest benefit estimates where the benefit estimates are in turn based upon the low values for the disability weights, VOLY and assuming that only 25% of the benefits can be attributed to the END in the case that noise legislation within the Member State pre-dated the introduction of the END. The benefits are, however, understated (for the reasons cited above) and thus the probability of such a situation actually arising is considered to be low and, for airports at least, the benefits may at least equal the costs.

Table 60: Worst case scenario

	Total present value costs (€, million)	Total present value benefits (€, million)	Net present value (€, million)	Cost-benefit ratio
EU level	3			
Major airports	438	276	-161	2:1
Major roads	28,961	5,971	-22,989	5:1
Major rail	1,417	2,238	820	1:2
TOTAL	30,819	8,485	-22,334	4:1

In contrast, the best case scenario (Table 61) is modelled using the low cost estimates and high benefit estimates and assumes that 100% of the calculated benefits can be attributed to the END except for those Member States in which there was no noise legislation prior to the introduction of the END and where no NAP has been published. As may be expected, under the best case scenario, both the NPV and cost-benefit ratios are positive, with a return on investment of approximately €327 for every €1 spent (excluding agglomerations). However, under a worst case scenario, only expenditure on measures to reduce noise from railways yields a positive NPV and cost-benefit ratio.

Table 61: Best case scenario

	Total present value costs (€, million)	Total present value benefits (€, million)	Net present value (€, million)	Cost-benefit ratio
EU level	3	-	-	-
Major airports	438	4,915	4,477	1:11
Major roads	38	126,540	126,503	1:3341
Major rail	3	26,004	26,001	1:9474
TOTAL	481	157,459	156,977	1:327

APPENDIX E – METHODOLOGY FOR THE CASE STUDIES

The methodology for the case studies by source is now summarised.

E.1 Agglomerations

Noise Action Planning in agglomerations covers a broad range of measures utilised for the objective of the END. Most measures affect a clearly defined explicit "case study area" in which the measure is implemented. Often more than one measure affects the population in a given case study area. Cumulative effects of several measures in one case study area are only studied by way of example since the combination of measures varies by agglomeration. Cost-benefit assessments (CBAs) were carried out for 28 measures in 10 agglomerations.

E.1.1 Evaluated measures

The NAPs analysed contain a large variety of measures. For the CBA, a sample of these measures has been selected taking into consideration evidence as to their effectiveness and whether such measures have actually been implemented during R1. The following table shows the measures that were selected for the analysis.

No.	Measure	Comment
1	Noise proof window campaign	Usually only available for affected residents over the threshold value e.g. L_{den}/L_{night} >70/60 dB(A).
2	Rehabilitation of roads / Low noise road surfaces	Measure primarily applied for road sections.
3	Speed reduction	Reduction by 20 km/h, e.g. Speed limit reduced from 60km to 40km or from 50km to 30km
4	Speed control	Measure primarily applied for road sections.
5	Re-distribution / Reduction of number of heavy trucks	Requires redesign of traffic flows for road systems within agglomerations.
6	Barriers / Walls	Frequently used for roads and rails but not usually for agglomerations.
7	Embedded tracks for trams	Often only implemented when replacing old tracks.
8	Acoustical grinding of tracks	---
10	Implementing Vegetation Systems in Tram Tracks.	---

E.1.2 Cost of measures

Conclusive information regarding the actual costs incurred of measures was only available for a few selected cases. Often, the costs presented in NAPs are estimates, since only a few measures have yet been fully implemented. Where no detailed cost information was available for a measure, data from similar cases was evaluated and applied to the case. This made it possible to develop a generalised cost approach for each measure, as presented in the following table.

No.	Measure	Cost
1	SNM / NAP	2 € / resident in agglomeration
2	Noise proof window campaign	1,500 € / flat resp. 750 € / effected resident
3	Rehabilitation of roads / Low noise road surfaces	50 € / m² exchanged surface
4	Speed reduction	50 € / m road
5	Speed control	cost neutral due to revenue from speeding fines
6	Re-distribution / Reduction of number of heavy trucks	requires redesign of traffic concept approx. 250,000 € depending on size of agglomeration
7	Barriers / Walls	1,000 € / m² wall
9	Embedded tracks for trams	500 € /m double track
10	Acoustical grinding of tracks	1 € / m single track
11	Vegetated tram tracks	2,500 € / m double track

The total cost of a measure is made up of the SNM/NAP preparation expenditure per resident and the costs of implementation and maintenance for the measure.

E.1.3 Effectiveness of measures (agglomerations)

The effectiveness of a measure is measured by the reduction of noise level in the case study area. This information is generally provided in the NAPs. Where this is not the case, the degree of noise reduction is estimated using data from similar cases. As a result, generally accepted average noise reduction levels are available for each measure, as presented in the following table.

No.	Measure	Effectiveness (reduction of noise level)
2	Noise proof window campaign	L_{den} = no effect L_{night} < 45 dB(A)
3	Rehabilitation of roads / Low noise road surfaces	L_{den}/L_{night} = -4 dB(A)
4	Speed reduction	L_{den}/L_{night} = -2 dB(A)

No.	Measure	Effectiveness (reduction of noise level)
5	Speed control	L_{den}/L_{night} = -1 dB(A)
6	Re-distribution / Reduction of number of heavy trucks	reduction of effected residents by 20 %
7	Barriers / Walls	L_{den}/L_{night} = -3 dB(A)
8	Embedded tracks for trams	L_{den}/L_{night} = -3 dB(A)
9	Acoustical grinding of tracks	L_{den}/L_{night} = -6 dB(A)
10	Vegetated tram tracks	L_{den}/L_{night} = -2 dB(A)

E.1.4 Residents in case study area

The number of residents in a case study area is often not clearly specified in the NAP. Where this is the case, the population is estimated based on other sources. The following estimation approaches were applied based on data availability and in order of preference:

1. Number of residents from case study area as explicitly stated in the NAP.
2. Number of residents in the first row of buildings on both sides of the road as retrieved from the noise calculation model.
3. Resident density in case study area multiplied by the case study area (length of road section x 100 m populated corridor).

In the majority of cases, the noise calculation model (2) was used to estimate the number of residents.

E.1.5 Categorising residents into noise level classes

Particulars of the distribution of residents in noise level classes in a specific case study area are usually incomplete. Many NAPs only present the number of residents exposed to noise exceeding a certain threshold value. This threshold may differ from case to case.

As a remedy, standard reference distributions for roads in agglomerations and for agglomerations in general were developed. Based on the noise calculation models of Augsburg and Munich agglomerations, the number of residents in the different noise level classes were determined for the residents in the first row of buildings of roads. This procedure allows to combine road sections with similar characteristics to develop three reference roads. The corresponding reference distributions D-1 to D-3 are therefore based on real road sections in agglomerations taken from NAPs. In order to apply the reference distributions to a certain case, the road characteristics are compared using the data in the following table.

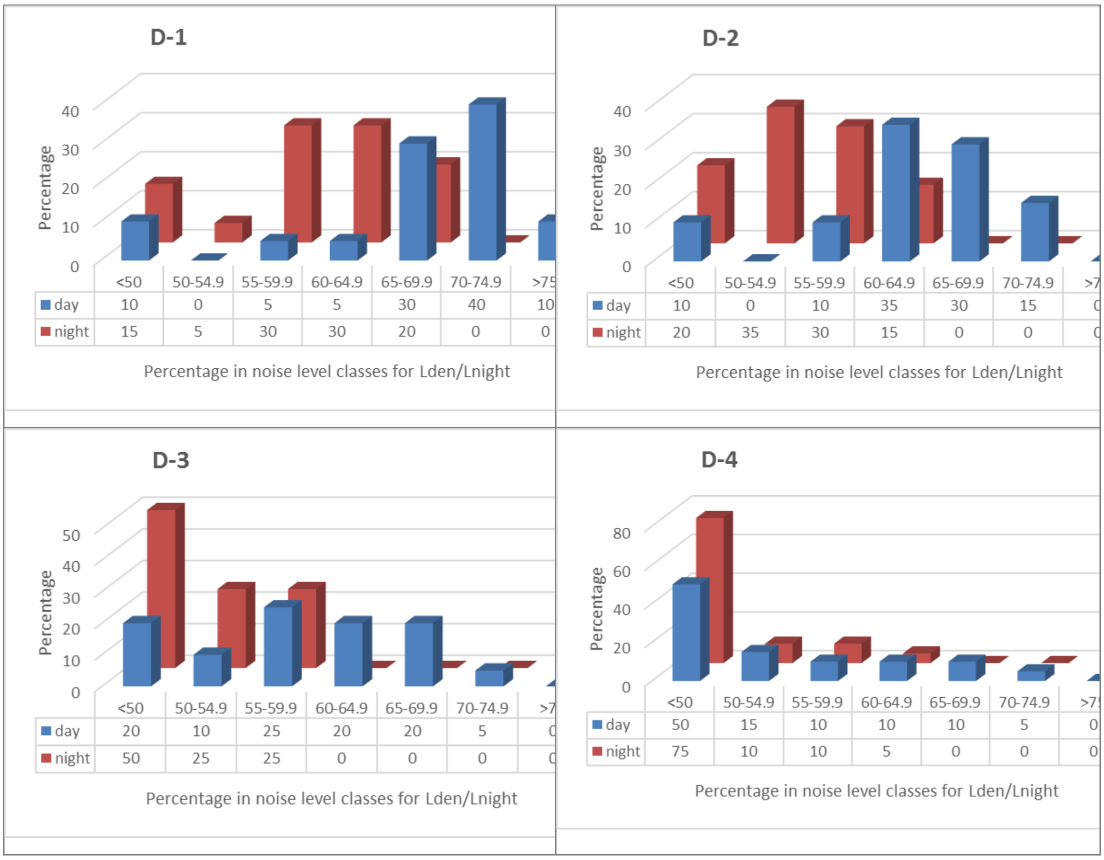
<table>
<tr><th rowspan="2">No. of distribution</th><th colspan="4">Road characteristics</th><th rowspan="2">Based on</th></tr>
<tr><th>Building structure</th><th>Building density</th><th>Distance to buildings</th><th>Building levels</th></tr>
<tr><td>D-1</td><td rowspan="2">buildings on both sides of the road</td><td>highly compacted structure, rare gaps in between the buildings</td><td>+/- 20 metres</td><td>3 to 5</td><td>Landshuter Allee (Munich)
Leopoldstr. (Munich)
Fuerstenrieder Str. (Munich)</td></tr>
<tr><td>D-2</td><td>compact structure with gaps between the buildings</td><td>+/- 35 metres</td><td rowspan="2">1 to 3</td><td>Koenigsbrunner Str. (Augsburg)
Friedberger Str. (Augsburg)</td></tr>
<tr><td>D-3</td><td>buildings on one side of the road / only few buildings on one side</td><td>loosely built, large gaps between the buildings</td><td>+/- 50 metres</td><td>Hans-Boeckler-Str. (Augsburg)</td></tr>
</table>

Following this approach makes it also necessary to compare the theoretical reference distribution with the given threshold values to assure the noise levels lie within the expected range.

In case the study area covers the entire agglomeration (e.g. redistribution of heavy trucks) the following reference distribution D-4 can be applied. However, data regarding the distribution of residents in noise level classes for the entire agglomeration is usually stated in the NAPs.

<table>
<tr><th rowspan="2">No. of distribution</th><th colspan="2">Characteristics of agglomeration</th><th rowspan="2">Based on</th></tr>
<tr><th>Density</th><th>Building structure</th></tr>
<tr><td>D-4</td><td>high</td><td>dense</td><td>Munich/Augsburg agglomerations</td></tr>
</table>

The following graphs visualize the available reference distributions D-1 to D-4.



E.1.6 Establishing the number of residents benefitting from noise mitigation, abatement and reduction measures

Details on the number of residents that stand to benefit from measure(s) are usually only provided for one or two noise level classes above a certain threshold value. In addition to this information, most NAPs state the expected reduction of noise in dB(A). Using this information, the affected residents are reassigned to lower noise classes according to the specific reduction of the measure. The following example shows the approach applied for a reduction of 2.5 dB(A) with distribution D-2 (L_{den}):

Noise level class	Residents without measure	Residents with measure	Comment
<50	1,000	1,000	All residents below level of 50 dB(A).
50-54.9	0	500	Reduction of 2.5 dB(A) results in **shift** of 50 % of the residents to the lower 5 dB(A)-noise-class, whereas the remaining 50 % **stay** in the 5 dB(A)-noise-class.
55-59.9	1,000	1,750 + 500	
60-64.9	3,500	1,500 + 1,750	
65-69.9	3,000	750 + 1,500	
70-74.9	1,500	750	
>75	0	0	No residents in this class.
Total	**10,000**	**10,000**	**All residents benefit from the measure.**

For this example, it was assumed that all residents in the case study area experience an improvement due to the measure. This effect is expected with measures such as speed reduction, noise optimised surface or embedded tracks for trams. In other cases, only a subset of residents from a case study area may benefit from a measure, e.g. in case of noise proofing windows campaigns.

E.2 Road

Noise Action Planning for roads includes active measures such as speed reduction and passive measures such as noise-optimised windows. The measures usually relate to the residents/houses directly adjacent to the road sections with the highest noise levels.

CBAs were carried out for individual measures along a specified road section (Greece) and an entire road network (Austria).

E.2.1 Evaluated measures (roads)

The following table shows the measures evaluated.

No.	Measure	Comment
1	Combination of measures e.g. noise optimised surface, noise barriers	Applied for Action Plans of the entire road network (e.g. Austria).
2	Noise barriers	Single measure primarily selected for noise abatement along highways.

E.2.2 Cost of measures

The total cost of a measure comprises the SNM/NAP preparation expenditure per resident and the cost of implementation and maintenance of the measure.

The cost of the measures analysed is obtained from the NAPs or through an interview with the responsible authorities. A generalised cost approach was not developed.

E.2.3 Effectiveness of measure

The effectiveness of the measures is assessed based on the distribution of effected residents in 5 dB noise level classes. This data is derived either from the NAPs or through an interview with the responsible authorities. A generalized approach was not developed.

E.2.4 Residents in case study area

The number of affected residents is specified in the NAP or stated by the responsible authorities. Further classifications are not necessary.

E.2.5 Distribution of residents by noise level classes

The distribution of residents across the noise level classes is usually known for the entire road network in question. Population exposure data for individual measures was taken from the NAP or based on information provided through contact with the responsible authorities. Further classifications are not necessary.

E.2.6 Determination of the number of residents with reduced noise exposure

The number of residents that benefit from a reduced noise exposure is known for all analysed measures and can be categorised into 5 dB noise level classes from the NAP or other sources. Further classifications are not necessary.

E.3 Rail

Noise Action Planning for railways covers measures relating to the rail tracks, optimising train schedules and passive measures to tackle noise at receptor such as erecting noise barriers. The measures usually benefit the residents living directly adjacent to the tracks who are most affected by railway noise. Typical measures involve noise insulation of houses and residential buildings and installing noise barriers.

CBAs were carried out for an individual measure along a specified railway section (Slovakia) and the entire railway network (Austria).

E.3.1 Evaluated measures

The following table shows the measures evaluated.

No.	Measure	Comment
1	Combination of measures Barriers / Walls and Noise proof window campaign	Applied for Action Plans of the entire rail network (e.g. Austria).
2	Noise barriers / Walls	Single measure primarily selected for noise abatement along railways.

E.3.2 Cost of measures

The total cost of a measure is made up of the cost of preparing SNMs/NAPs per resident and the cost of implementing the measure (including maintenance).

The costs of the measures analysed were obtained either from the NAPs or by interviewing the responsible authorities. It was not therefore necessary to develop a generalised cost approach to estimating the costs of measures.

E.3.3 Effectiveness of measures

The effectiveness of measures is assessed by distributing of affected residents across 5 dB noise level classes. The data needed is derived either from the NAPs or through an interview with the responsible authorities. A generalized approach was not developed.

E.3.4 Residents in case study area

The number of affected residents is specified in the NAP or stated by the responsible authorities. Further classifications are not necessary.

E.3.5 Distribution of residents across noise level classes

The distribution of residents across noise level classes is usually known for the entire track network regarding the individual measure area from the NAP or information from the responsible authorities. Further classifications are not necessary.

E.3.6 Determination of the number of residents with reduced noise exposure

The number of residents that benefit from reduced noise exposure is known for all measures analysed and distributed across 5 dB noise level classes from the NAP or other sources. Further classifications are not necessary.

E.4 Airports

Noise Action Planning for airports covers measures relating to the aircraft fleet, management and organisation of airport structures and passive measures such as noise-optimised windows. The measures usually relate to the entire area affected by air traffic noise. Often, more than one measure has an effect on the case study area. CBAs were carried out for combinations of measures at 5 airports. In addition, a CBA for the most common airport measure, the "Improvement of Windows/façades", was carried out at three airports, using generalised cost and benefit approaches.

E.4.1 Evaluated measures

The following table shows the measures considered in the analysis.

<table>
<tr><th>No.</th><th>Measure</th></tr>
<tr><td>1</td><td>SNM/NAP</td></tr>
<tr><td>2</td><td>Improvement of windows / facades</td></tr>
<tr><td>3</td><td>Combination of measures:
Low noise routing
Flight restriction by night
Engage with communities affected by noise impacts to better understand their concerns and priorities, taking them into account as far as possible in airport noise strategies and communication plans
Influencing planning policy to minimise the number of noise sensitive properties around
airports
Re-organisation to manage noise efficiently and effectively
Achieving complete understanding of aircraft noise to inform priorities, strategies and targets
Adopt the quietest aircraft operations (balanced against other negative effects) as practicable</td></tr>
</table>

E.4.2 Cost of measures

A generalised cost approach is available for measures, as presented in the following table.

No.	Measure	Cost
1	SNM/NAP	2 € / affected person (> 55 dB L_{den})
2	Passive Noise control	2500 € / eligible person

The total cost of a combination of measures comprises the SNM/NAP preparation expenditure per resident and the cost of implementation and maintenance of the measure.

E.4.3 Effectiveness of measures

The effectiveness of measures depends significantly on the density and distribution of inhabitants in the areas immediately surrounding the airport and underneath the existing flight routes. Therefore, the effectiveness (measured as the number of persons less affected by noise) can only be estimated by subtracting the results of Round 2 and Round 1 mapping results. This approach assumes that other factors determining aircraft noise which are not affected by the measures have remained constant during the investigation period. Only in the case of window insulation measures within a "window insulation programme", the effectiveness can be assessed based on the level of reduction in noise in bedrooms (since sleep disturbance is a key health end data point. For this purpose, it can be assumed that measures reduce the average noise levels inside the bedroom to a level which prevents sleep problems. This effect can be simulated by using outdoor levels L_{den} without any effect and L_{night} < 45 dB(A).

E.4.4 Residents in case study area

The number of affected residents is usually specified in the NAP since the entire area affected by air traffic noise is considered for measures. Further classifications are not necessary.

E.4.5 Distribution of residents to noise level classes

The distribution of residents to noise level classes is usually known for the area affected by air traffic noise from the NAP. Further classifications are not necessary.

E.4.6 Determination of the number of residents with reduced noise exposure

The number of residents that have reduced noise exposure is usually known for each noise level class by 5 dB threshold from the NAP. Further classifications are not necessary.

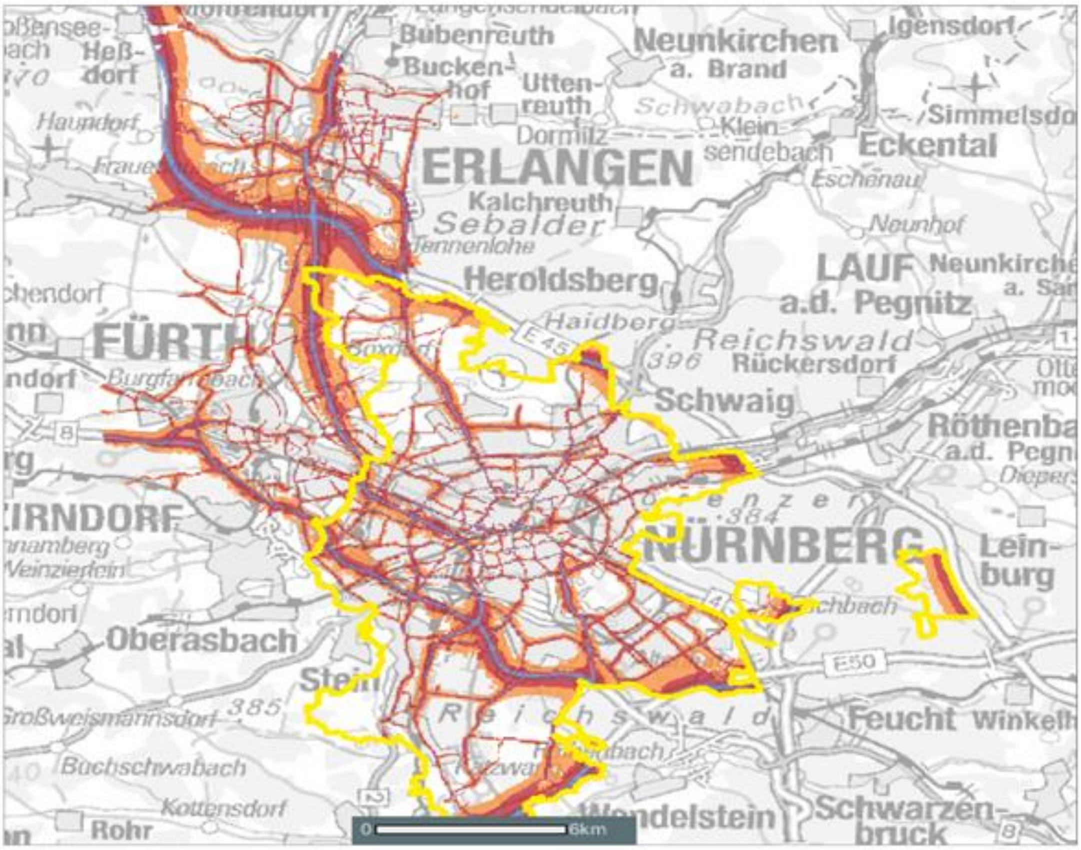
APPENDIX F – TEST CASE SUMMARIES

F.1 AGGLOMERATIONS

F.1.1 Case study – Nuremberg, Germany agglomeration

The city of Nuremberg, Germany is the center of the “European Metropolitan Area Nuremberg” and is a typical agglomeration of the Round 1 mapping with around 520,000 inhabitants. The city was chosen as a case study due to its comprehensive sources of traffic noise from roads, railways, tramways and industry. Besides several Autobahn routes that pass close by the city a multi-lane road, the so called “Frankenschnellweg”, crosses the city. Due to the vicinity to Nuremberg airport the population is also affected by air traffic noise. The city of Nuremberg therefore presents a case study agglomeration heavily exposed to traffic noise of all types in a densely populated area.

Nuremberg was noise mapped in 2007 and 2012. The responsible authority for the development of the NAP is the Office for the Environment Nuremberg. Although the final NAP has not yet been approved, the city council agreed on a number of abatement measures to be implemented independently from the NAP. Measures include test tracks with noise optimized surfaces and speed restrictions in parts of the minor road network. The reconstruction of the Frankenschnellweg to achieve a disruption free traffic flow, is also seen as a noise abatement measure. Although the reason for this measure lies in the existing traffic constraints of the Frankenschnellweg.



L_{den} for roads in Nuremberg agglomeration

1. Costs

The total cost of END implementation incurred from 2010 onwards is presented in the table below. The total costs over a 25-year-assessment period are expected to amount to over € 23m.

Table 62 – Costs

Total costs of END Implementation (€, discounted)[82]	
Additional staff time	81,322.57
Consultants	55,611.90
(Mapping) Software	-
Reporting	-
Costs of measures (€, discounted)[83] over 25 years	
Total discounted capital costs of measures[84]	23,045,737.85
Total discounted maintenance costs of measures[85]	-
GRAND TOTAL COSTS (€, discounted)	23,182,672.32

The following table presents the measures taken outlined in the NAP adopted in 2015.

Table 63 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise-reducing road surfaces in targeted areas	2014	underway	5,535,342.99
Speed reduction (-20km/h) at night in all metropolitan areas	2014	planned	810,810.80
Speed reduction all day in all metropolitan areas	2014	planned	810,810.80
Installation of noise reducing road surfaces under the road renovation programme	2015	planned	-
Installation of noise reducing road surfaces in the ten most polluted areas	2015	planned	6,533,263.98
Passive noise protection (sound insulating windows programme)	2014	planned	810,810.80
Undisturbed traffic flow on the Frankenschnellweg	2014	planned	6,237,006.18
M8a: Speed reduction all day	2014	planned	1,153,846.14

[82] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[83] These are the total costs of measures to reduce or minimise noise levels

[84] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[85] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
in all U- and B – regions with exceptions during the day at particularly significant major roads			
M8a without speed reduction during night period at particularly significant major roads	2014	planned	1,153,846.14
Environmental Noise Adapted beep "close doors" (rail)	2014	planned	-
Elastic embedding / mounting rails	2014	underway	-
Acoustic grinding (rail)	2014	planned	-

Most of the measures outlined have an implementation period of at least 10 years. The implementation has only partly begun. For example, three road sections were equipped with low-noise road surfaces. The installation on another 9 sections is planned shortly. This means that the impact of many of these measures will only materialise in the future, and the benefits presented further below need to be interpreted in that context. However, within the framework of short-term realizable individual measures with an implementation perspective of 5-7 years, a pilot project for a section of the southern city was designed to examine the effectiveness of the measures.

Cost estimates for the measures relating to the inner-city tramway network are not available. The extent and implementation date for those measures is indefinite.

2. Benefits

Through the planned measures, the number of very highly affected inhabitants with L_{den}> 70dB (A) or L_{night}> 60 dB (A) can solely be reduced by installation of noise reducing road surfaces. The other planned measures may bring an additional reduction in the number of people affected.

Using information from the Strategic Noise Maps produced in 2009, it is possible to determine the change in the number of people exposed to noise levels above 55 dB (A) L_{den} and 50 dB (A) L_{night}, as presented in table 3. Since air traffic related noise abatement is responsibility of Nuremberg Airport, this noise type is not included in the table.

Table 64 – Benefits – exposed population[86]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[87]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	0	0
55-59.9 dB(A)	0	14,940
60-64.9 dB(A)	0	15,800
65-69.9 dB(A)	1,990	1,900
70-74.9 dB(A)	17,200	0
75-80 dB(A)	2,700	0

As the table above shows, noise reduction measures did reduce the number of people exposed above 65 dB by about 21,890 overall against a total population of about 500,000 in the agglomeration. The benefits were achieved due to noise reduction measures for roads. Since measures relating to the tramway networks are still in the planning process, the number of households exposed to noise is unchanged. Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 4 and 5).

Table 65 – Benefits – annoyance

Change in size of the annoyed population[88]	Road	Total	DALYs per year
Annoyed[89]	11,882	11,882	
Highly Annoyed[90]	6,796	6,796	136

As the table above illustrates, the number of people annoyed was reduced by about 11,900 due to noise reduction measures, and the number of people highly annoyed was reduced by about 6,800 people, resulting in a decrease in disease-adjusted life years of 136.

[86] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[87] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[88] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[89] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[90] Data below 45dB and above 75dB (Lden) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

Table 66 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	DALYs per year	Present Value (€)
Sleep Disturbed	7,720		
Highly Sleep Disturbed	3,852	270	266,006,585

Another benefit of the noise reduction measures in the Nuremberg agglomeration is that the number of people whose sleep is disturbed could be reduced by over 7,700 and the number of people whose sleep is highly disturbed could be reduced by another 3,900. This corresponds to a decrease in disease-adjusted life years of 270 and is valued at € 266 M over a 25-year assessment period.

The following tables summarise the effects of the noise abatement measures on cardiovascular disease and hypertension. The data available shows that a reduction in road noise has resulted in a reduction of DALYs of about 21,000 (over 25 years) valued at over € 250m.

Table 67 – Benefits - Cardiovascular disease

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[91]	0.744		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[92]	166.972	166.972	18,531,820
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI			225,451,985

Table 68 – Benefits – Hypertension

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from hypertensive heart disease that is attributable to environmental noise[93]	0.601	0.601	
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[94]	24.617	24.617	2,732,197
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease			33,238,998

[91] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

[92] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

[93] The numbers in this row show the change in the proportion of cases of hypertensive heart disease due to noise exposure

[94] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

The benefit of the END implementation for the population of Nuremberg agglomeration amounts to:

Net Present Value (€): 635,621,704.

3. Cost Benefit Analysis of Individual Measures

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Annex D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Annex E.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Chapter D.

3.2 CBA of individual measures

The following tables present the results of the CBA performed for individual measures in Nuremberg agglomeration.

Noise proof window campaign

The city-wide program is available for affected residents with noise levels of L_{den} 67 dB (A) and L_{night} 57 dB (A). With the determined amount of € 100,000 funding per year more than 400 residents/year can be equipped with noise optimized windows. The total cost for the measure aggregates to 1,000 € per resident/year which equals a total of 400,000 €/year. The program is designed for a period of 26 years, in which all remaining 10,400 eligible residents are to be equipped with new windows.

The benefits of the measure exceed the costs of the measure by a factor of 17. The noise proof window campaign of Nuremberg agglomeration therefore rates in the mid-ranges of the CB-ratios of all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
400	€0.24 million	€3.4 million	€601	€8,655	1 : 14

Rehabilitation of roads / Low noise road surfaces

The goal of this measure is to equip all areas with the highest noise levels above L_{den} 75 dB (A) with noise reducing road surfaces. The implementation focuses on eight highly affected areas (more than 50 residents over L_{den} 75 dB (A)). The implementation of this measure is planned to be completed within a period of ten years.

Due to the dense building structure in the relevant road sections, the CB-rate of the measure rates as one of the highest compared to all assessed agglomerations. The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
20,600	6.5million	138 million	317	6,696	1:21

Speed reduction

This measure assigns a speed reduction of 20 km/h during daytime on the roads in 59 study areas. The implementation is planned to be carried out on a medium to long term basis, within 10 to 20 years. Taking into account the total length of the considered road network considered of about 91 km the estimated cost amounts to about 260,000 €/year. Assuming that the reduced speed limit is respected and adhered to by road users, an improvement in the noise level by 2.5 dB (A) can be expected.

The benefits of the measure outweigh the costs by a multiple which is reflected in the high-CB ratio. The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
81,800	0.8 million	244 million	10	2,985	1 : 301

Embedded tracks for trams

The aim of this measure is to minimize the elastic mounting of the rail to minimize ripple formation due to wear, which is responsible for the level of noise emissions between wheel and rail. For operational reasons, exchanges of tram tracks can usually only be carried out during maintenance. Embedded tracks can reduce the noise emissions by approximately 5 dB (A). The measure is to be performed in the defined study areas with high noise levels.

Due to the excellent noise improvement potential, the substantial costs of the measure also face high benefits.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
24,400	7.1 million	42.3 million	293	1,737	1:6

Acoustical grinding of tracks

The aim is to minimize ripple formation through rail grinding during regular driving of the tram and so to reduce the level of noise emissions between wheel and rail.

The measure should particularly be employed in areas with high rail noise levels, but can be expanded at relatively low cost to the entire tram network.

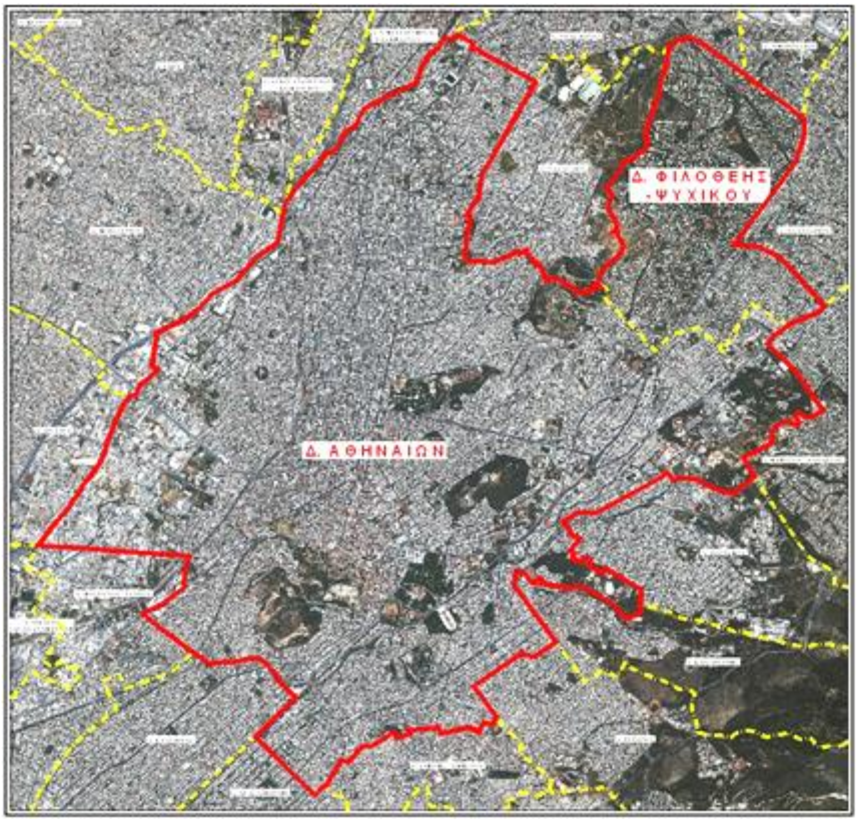
To date, the cost of such abrasive systems are not known. From the fact that these devices can be used in normal daily routine and therefore no additional cost from track closures, safeguards etc. arise, it is assumed that the measure is cost-effective. This is expressed by the high CB-ratio of the measure.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
24,400	0.57 million	42.3 million	23	1,737 €	1:74

F.1.2 Case study – Athens, Greece agglomeration

The city of Athens in the capital of Greece and the largest and most populous city of the country. Covering an area of 39 km² in Athens live nearly 700,000 people. The agglomeration of Athens includes the municipalities of Athens and Filothei. Including other surrounding districts and suburbs about 3.7 million people live in the greater Athens area.



Geographical study area - Municipalities of Athens & Filothei – Psychiko

Source: Environmental Noise Assessment according to Directive 2002/49/EC, Athens Central Area, Final Report (Phase D)

Noise mapping in Athens includes the extensive road network, national railway, metro and tram lines. The city of Athens therefore presents a case study agglomeration heavily exposed to traffic noise of all types in a densely populated area.

1. Costs

It has not been possible to obtain information on costs of implementation of the END or costs of measures for Athens agglomeration. The following table presents the measures taken on the basis of the NAP for Athens. No details of the years of implementation, completion status or costs have been obtained for Athens.

Table 69 – List of measures

Name of measure
The Panepistimiou Street from Avenue Vas. Sofias to Omonia Square and Patission Street from Panepistimiou Street to Marni Str., modified on roads dedicated to pedestrian, bicycle and ground transportation (where appropriate). The movement of vehicles on Patission Rd. will be bidirectional with one lane in each direction, while on the Panepistimiou road will be unidirectional with one lane in each direction.
Aeolou Rd becomes one-way (segment from Panepistimiou Ave to Stadium Rd) towards the Stadium Rd. Permission only for public transport vehicles (PTVs), goods delivery vehicles, taxis and tourist buses.
Change traffic direction on Academias Rd (from Avenue Vas. Sofias to Canningos Rd) and Chalkokondyli street (from Canningos Rd to Marnis Rd). The movement of vehicles on the Academias Rd takes place in 3-lanes plus one bus lane between the Vas. Sofias and Homirou Rds and 2-lanes plus one bus lane between Omirou and Canningos Rds. The movement of vehicles on the Chalkokondyli street is placed in 3-lanes.
Changing the traffic direction from Marnis Rd, where the division between Tritis Septemvriou Str. is bidirectional, while the section between the streets Tritis Septemvriou Str and Nikiforou Rd is one way towards Nikiforou Rd.
The movement of vehicles on Marni Rd is performed in 2-lanes between Tritis Septemvriou and Patission Rd and 3-lane between Tritis Septemvriou and Nikiforou Rds.
One-way system is planned for Carolou Rd (from Nikiforou Rd to Platea Karaiskaki) towards the Platea Karaiskaki. The movement of vehicles on Carolou Str will take place in 3-lanes.
Extension of Omonia Square by removing the connecting portion of Panepistimiou Ave to Tritis Septemvriou Rd.
Changing the direction of Ag. Konstantinou Rd (from Platea Karaiskaki to Tritis Septemvriou). The movement of vehicles on Ag. Konstantinou Rd takes place in 2- lanes in each direction between Karaiskaki Square and Geraniou Str and 3-lane between Tritis Septemvriou and Socratous Rds.
Changing the direction of Socratous Rd (from Pireos Str to the Ag. Konstantinou Rd).
Remove the counter-flow bus lanes Avenue Vas. Amalias reduction of lanes (two lanes and one bus lane between the streets Philellinon and Othonos Str and three traffic lanes and one bus lane road between Othonos Str and Vas. Sofias Ave).
Avenue Vas. Sofias becomes one –way between Panepistimiou Rd and Academias street heading to the Academias Str and prohibition of left turn from Avenue Vas. Sofias to Academias Str. The movement of vehicles on Vas. Sofias Ave will be done in 1-lane and 2 bus lanes (one for the straight movement and one for the left movement).
Change of Benaki Rd direction (between Academias Str. and Stadiou Rd) towards the Stadium Rd.
Changing the direction of Themistocli Rd (between Academias Str and Stadiou Rd) towards Academias Str.
Omirou Street (between Academias street and Stadiou Rd) is turned to bus lane towards the Stadiou Rd, with exclusive use by PTVs, taxis, goods delivery vans and coaches.
Edward Lo Str (between Academy street and Stadiou Rd) is turned to bus lane towards Academias Street, with exclusive use by public transport vehicles, taxis, goods delivery vans and coaches.
Othonos Rd (between Filellinon Rd and Vas. Amalia Ave) is turned to bus lane towards Vas. Amalia Ave, for exclusive use of public transport vehicles, taxis, goods delivery vans and tourist

Name of measure
buses.
Repeal of the counter-flow bus lane on Pireos Str. between Aristotelous and Menandrou Rds.
The roads of : Kriezotou, Riga, Charilaou Trikoupi, Hippocratous, Gennadiou, Feidiou, Nikitara, Gamveta, Themistocleous, Veranzerou, Arsaki and Pesmatzoglou (between Stadiou Rd and Academias street), Ioulianou and Metsovou Rds (between Patision Rd and Mavromichali str) and Xenophontos Street (between the Philellinon Rd and Vas. Amalias Ave) will be turned to calm traffic roads.
Avenue Vas. Olgas will be changed to dedicated pedestrian way and bicycle and public transport (where and when appropriate). The use of delivery goods vans, taxis and tourist buses is permitted. The vehicular traffic is bidirectional with 1- lane in each direction

2. Benefits

Using information from the National Action Plan "Final Report – Phase D" of 2014, it is possible to determine the change in the number of people exposed to noise, as presented in table 3.

Table 70 – Benefits – exposed population[95]

Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures under the END:	L_{den}		
	Road	Rail	Total
45-49.9 dB(A)	90	-173	-83
50-54.9 dB(A)	-681	-237	-918
55-59.9 dB(A)	-5 804	25	-5 779
60-64.9 dB(A)	-5 213	0	-5 213
65-69.9 dB(A)	7 534	0	7 534
70-74.9 dB(A)	2 822	0	2 822
Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures under the END:	L_{night}		
	Road	Rail	Total
45-49.9 dB(A)	-523	-20	-543
50-54.9 dB(A)	-3 439	20	-3 419
55-59.9 dB(A)	-2 842	0	-2 842
60-64.9 dB(A)	4 985	0	4 985
65-69.9 dB(A)	831	0	831
70-74.9 dB(A)	1 439	0	1 439

[95] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 71 and 72).

Table 71 – Benefits – annoyance

Change in size of the annoyed population[96]	Road	Rail	Total	DALYs per year
Annoyed[97]	2,527	-21	2,506	
Highly Annoyed[98]	1,726	-5	1,721	34

As the table above illustrates, the number of people annoyed was reduced by 2,506 due to noise reduction measures, and the number of people highly annoyed was reduced by 1,721 people, resulting in a decrease in disease-adjusted life years of 34.

Table 72 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	Rail	Total	DALYs per year	Present Value (€)
Sleep Disturbed	998	0	999		
Highly Sleep Disturbed	619	0	620	43	42,790,767

Another benefit of the noise reduction measures in the Athens agglomeration is that the number of people whose sleep is disturbed could be reduced by 999, and the number of people whose sleep is highly disturbed could be reduced by another 620, corresponding to a decrease in disease-adjusted life years of 43 valued at € 43 M.

The following tables summarise the effects of the noise abatement measures on cardiovascular disease and hypertension. The data available shows that a reduction in road noise has resulted in a reduction of DALYs of 0.7, valued at € 772 M per year, and a total benefit of more than € 9 M. as a result of avoided DALYs.

---

[96] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[97] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[98] Data below 45dB and above 75dB (Lden) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

Table 73 – Benefits - Cardiovascular disease

	Road	Rail	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[99]	0.166	n/a		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[100]	0.696	n/a	0.696	772,517
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI				9,398,188

Table 74 – Benefits – Hypertension

	Road	Rail	DALYs per year	Present Value (€)
Change in the % of the population suffering from hypertensive heart disease that is attributable to environmental noise[101]	0.118	n/a	0.118	
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[102]	0.317	n/a	0.317	35,135
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease				427,437

<u>Since no costs are available for the measures of the NAP the Net Present Value cannot be calculated for Athens agglomeration</u>. Instead, the total Present Value Benefit from the END implementation for the population of Athens was calculated to be:

Total Present Value Benefit (€): 86,576,856.

[99] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

[100] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

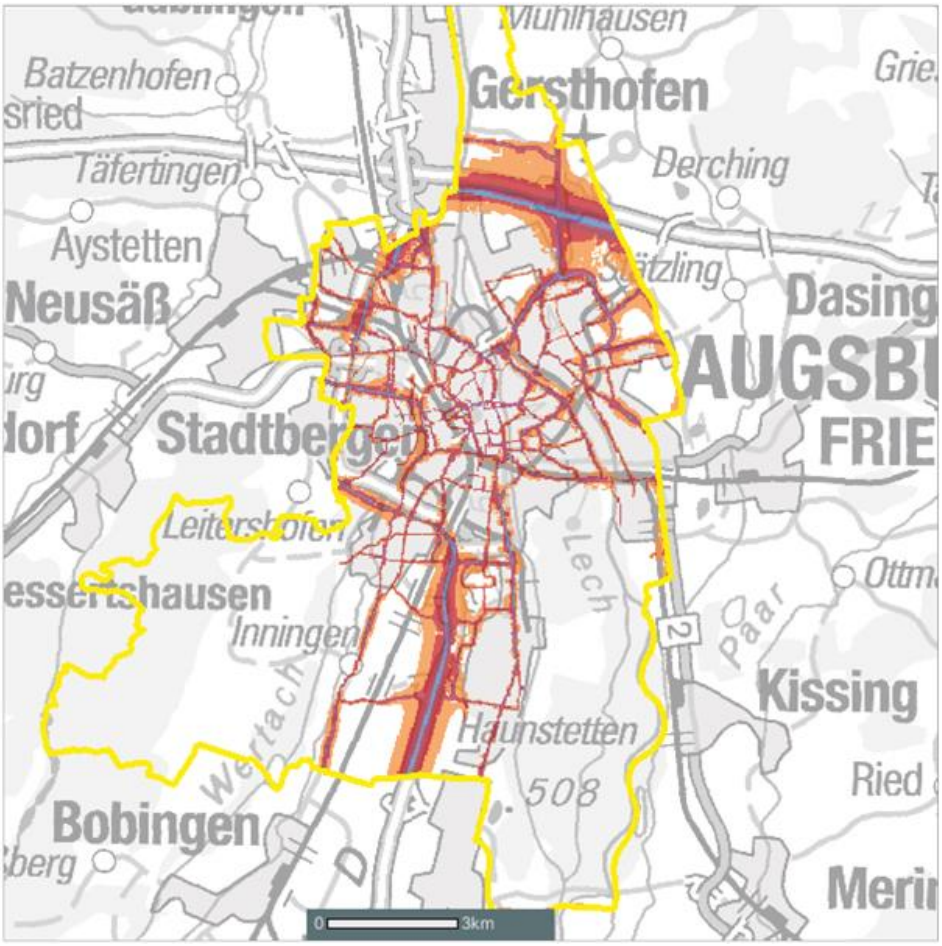
[101] The numbers in this row show the change in the proportion of cases of hypertensive heart disease due to noise exposure

[102] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

F.1.3 Case study – Augsburg, Germany agglomeration

The city of Augsburg, Germany is a vibrant industrial city with about 270,000 inhabitants and an area of 150 km². Therefore it counts as a smaller agglomeration why it was chosen as a case study. Nevertheless especially inner-city noise as well as noise from two major motorways that cross the city is an issue. The mapped road network of the city has a length of about 450 km. Augsburg is connected to five train lines and has a tram network with a length of about 76 km. Due to the very low utilization of Augsburg airport, noise from aviation is not relevant to the city.

Responsible for the preparation of the NAP is the city Augsburg in consultation with the local county government. The 2008 NAP is in an ongoing implementation phase where the Round 2 NAP is currently under review and will be updated and approved on the basis of the Round 2 noise maps.



L_{den} for roads in Augsburg agglomeration

1. Costs

The total cost of END implementation incurred from 2008 onwards is presented in the table below. The total costs over a 25-year-assessment period are expected to amount to just over € 5.3 M.

Table 75 – Costs

Total costs of END Implementation (€, discounted)[103]	
Additional staff time	15,867
Consultants	1,824
(Mapping) software - noise calculation	2,128
Reporting	-
Costs of measures (€, discounted)[104] ***over 25 years***	
Total discounted capital costs of measures[105]	4,710,245
Total discounted maintenance costs of measures[106]	**-**
GRAND TOTAL COSTS (€, discounted)	**5,361,362**

The following table presents the measures taken on the basis of the NAP. In addition to the general development of the transport system, in particular short term measures such as speed limits and speed enforcement as well as long term measures such as noise optimized asphalt were planned. In addition to the measures for road transport, especially rail noise abatement was of importance to the city of Augsburg.

Table 76 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise optimised asphalt	since 2008	Complete	2,913,871
Speed limits (roads)	since 2008	Complete	-
Speed enforcement with speed control (roads)	since 2008	Ongoing	-
Window sound insulation programme	2009 - 2010	Complete	1,796,374
Installation of rubber mats in the substructure (rail)	since 2008	Underway	-
Wheel-rail maintenance programme, elimination of irregularities	n.s.	-	-
On-board measures such as fitting of sound absorbers (rail)	n.s.	-	-
Lubrication systems for curves (rail)	2008	Complete	-

[103] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[104] These are the total costs of measures to reduce or minimise noise levels

[105] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[106] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

For speed limit reduction measures and speed enforcement the costs are rather low and not quantifiable. Likewise, the costs of the measures on the tram line are not known.

Most of the measures listed above have been completed or are underway. Some measures are not yet finalised which means that the impact of some measures will only materialise in the future. The benefits presented further below need to be interpreted in that context.

2. Benefits

Using information from the Noise Action Plan 2008, it is possible to determine the change in the number of people exposed to noise levels above 55 dB L_{den} and 50 dB L_{night}, as presented in table 3.

Table 77 – Benefits – exposed population[107]

Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures under the END:	L_{den}		
	Road	Rail	Total
45-49.9 dB(A)	0	0	0
50-54.9 dB(A)	0	0	0
55-59.9 dB(A)	2,600	7,830	10,430
60-64.9 dB(A)	800	1,820	2,620
65-69.9 dB(A)	700	40	740
70-74.9 dB(A)	-400	530	130
Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures under the END:	**L_{night}**		
	Road	**Rail**	**Total**
45-49.9 dB(A)	0	0	0
50-54.9 dB(A)	1,700	6,270	7,970
55-59.9 dB(A)	800	450	1,250
60-64.9 dB(A)	-300	550	250
65-69.9 dB(A)	0	120	120
70-74.9 dB(A)	0	130	130

As the table above shows, the impact of noise reduction measures did reduce the number of people exposed above 55 dB (L_{den}) by more than 14,000 overall against a total population of about 280,000 in the agglomeration.

The main benefits were incurred due to noise reduction measures focussing on roads and railways, although road measures also increased the number of people exposed to certain noise levels, probably due to a reallocation of residents exposed to noise at higher intervals.

[107] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 4 and 5).

Table 78 – Benefits – annoyance

Change in size of the annoyed population[108]	Road	Rail	Total	DALYs per year
Annoyed[109]	872	1,606	2,478	
Highly Annoyed[110]	335	528	863	17

As the table above illustrates, the number of people annoyed was reduced by about 2,500 due to noise reduction measures, and the number of people highly annoyed was reduced by nearly 900 people, resulting in a decrease in disease-adjusted life years of 17.

Table 79 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	Rail	Total	DALYs per year	Present Value (€)
Sleep Disturbed	342	737	1,079		
Highly Sleep Disturbed	150	293	442	31	30,533,023

Another benefit of the noise reduction measures in the Augsburg agglomeration is that the number of people whose sleep is disturbed could be reduced by more than 1,000, and the number of people whose sleep is highly disturbed could be reduced by another 442. This corresponds to a decrease in disease-adjusted life years of 31 and is valued at € 30.5 M.

The following tables 6 and 7 summarize the effects of the noise abatement measures on cardiovascular disease and hypertension. The data available shows that a reduction in road noise has resulted in a reduction of DALYs of about 4, valued at just under € 0.5 M., and a total benefit of more than € 54 M. as a result of avoided DALYs.

[108] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[109] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[110] Data below 45dB and above 75dB (Lden) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

Table 80 – Benefits - Cardiovascular disease

	Road	Rail	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[111]	0.006	n/a		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[112]	0.139	n/a	0.139	153,731
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI				1,870,240

Table 81 – Benefits – Hypertension

	Road	Rail	DALYs per year	Present Value (€)
Change in the % of the population suffering from hypertensive heart disease that is attributable to environmental noise[113]	0.946	n/a	1	
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[114]	38.77	n/a	4	4,302,715
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease				52,345,409

The benefit of the END implementation for the population of Augsburg agglomeration amounts to:

Net Present Value (€): 97,048,234.

[111] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

[112] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

[113] The numbers in this row show the change in the proportion of cases of hypertensive heart disease due to noise exposure

[114] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

3. Cost Benefit Analysis of Individual Measures

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Appendix D)

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Appendix D.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Appendix E.

3.2 CBA of individual measures

The following tables present the results of the CBA performed for individual measures in Augsburg agglomeration.

Noise proof window campaign

Eligibility for the campaign was derived from a priority rating based on the noise level. A total of 300 applications for funding were received and approximately 1,200 windows were covered by the campaign. In a rough approach that each window protects one inhabitant, approximately 1,200 inhabitants profited from an improved noise level.

The benefits of measure exceed the costs many times over. The noise proof window campaign of Augsburg agglomeration shows one of the best CB-Ratio of all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
1,200	0.85 million	9.4 million	712	7,865	1:11

Rehabilitation of roads/ Low noise road surfaces

Residents along five road sections in Augsburg profited from a noise optimized surface. A total of approximately 1,150 residents benefited from the measure which is assumed to lower the noise level by 4 dB(A).

The benefits of measure are smaller than for other measures but with a CB-ratio of 1:3 clearly positive. The use of noise-optimized asphalt in the Augsburg agglomeration shows one of the best CB-Ratio of all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
1,150	2.12 million	8.4 million	1,850	7,310	1:4

Speed reduction (in selected road sections)

Since 2008 residents along ten road sections in Augsburg profited from a speed limit reduction by 20 km/h (e.g. 50/30 or 70/50). A total of approximately 780 residents benefited from the measure which is assumed to lower the noise level by 3 dB(A).

Due to the low costs associated with the measure, the benefits exceed the costs many times over. Speed reduction therefore presents one of the most effective measure available in noise action planning.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
780	0.33 million	4 million	43	5,107	1:119

Speed control

In areas of high noise exposure, the frequency of traffic surveillance was increased. The city of Augsburg mainly monitored street sections with a speed limit of 30 km/h near schools and kindergardens as well as accident black spots.

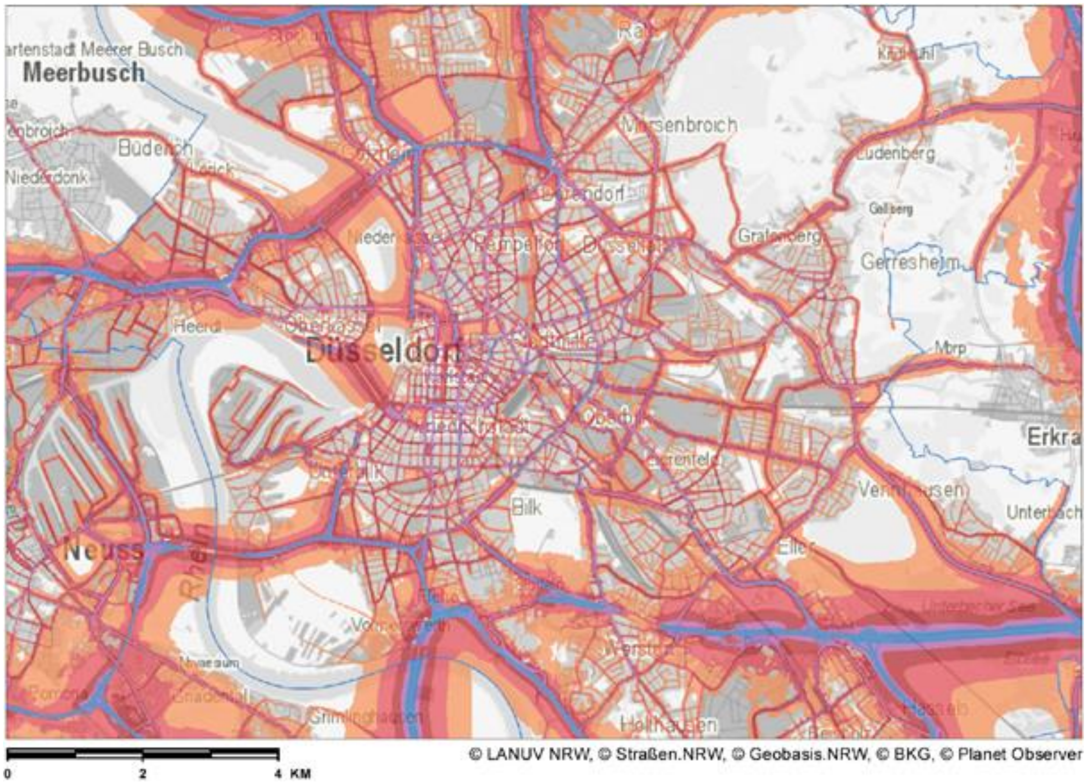
Since speed control is already performed in the city of Augsburg noise relevant road sections can be monitored as a priority. Therefore no measurable costs in addition to the proportion of costs for END implementation were incurred. This leads to a high CB-ratio that is not stated below, since the comparison with other cases is not practical.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
370	34	0.4 million	0.1	1,300	-

F.1.4 Case Study – Duesseldorf, Germany Agglomeration

The city of Düsseldorf, Germany is the center of the Rhine-Ruhr metropolitan area and counts among the 10 largest cities in Germany. It covers an area of 217 km² with a population of about 600,000. The city is an economic hub with nearly as many workplaces as residents. Düsseldorf was chosen as a case study due to its dense traffic flow and extensive road network. The concentration of living and work space in the city leads to extensive noise conflicts at over 350 road sections. Düsseldorf has a well-established public transport system including busses, tramways and railways. Due to the vicinity to the Düsseldorf airport the population is also affected by air traffic noise. The city of Düsseldorf therefore presents a case study agglomeration heavily exposed to traffic noise of all types in a densely populated area.



L_{den} for noise from roads in Düsseldorf agglomeration and major roads

1. Costs

The total cost of END implementation incurred from 2008 onwards is presented in the table below. It has not been possible to obtain information on costs of implementation of the END in the city of Düsseldorf. Not included are noise abatement measures implemented by Düsseldorf Airport as well as the national railway authority that accounts for high expenditures and significant effects. However, those measures were partly realized outside the scope of the noise reduction plan.

Table 82 – Costs

Total costs of END Implementation (€, discounted)[115]	
Additional staff time	n.s.
Consultants	n.s.
(Mapping) software - noise calculation	n.s.
Reporting	n.s.
Total discounted capital costs of measures[116]	13,125,969
Total discounted maintenance costs of measures[117]	n.s.
GRAND TOTAL COSTS (€, discounted)	**13,125,969**

Over the past several years the city of Düsseldorf has conducted noise abatement programs and measures to reduce noise at the most affected streets in the city, including:

- Noise protection in urban and transport planning,
- Master plan to reduce road traffic noise,
- Soundproof windows program Düsseldorf,
- Built-in noise-reducing road surfaces.

Most of the individual measures are part of the Master plan "Reduction of road traffic noise in Düsseldorf". The following table presents those measures as well as the measures the federal railway authority, federal government (state roads) and the competent authority (airport) are responsible for. Costs are only available for measures that are in the responsibility of the city of Düsseldorf and the federal government (state roads).

[115] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[116] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[117] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Table 83 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Master plan to reduce road traffic noise on city roads including: • Noise optimized window programme • Noise optimized surfaces • vegetated tram tracks • barriers/walls • improvement of tram tracks	Since 2006	underway	9,844,476
Master plan to reduce road traffic noise on federal roads including: • Speed reduction • Speed control • Noise optimized surfaces • barriers/walls	since 2006	underway	3,281,492
Federal Railway noise remediation program (length of 15 km in Duesseldorf): • rail dampers • gabion noise barrier • padded sleepers • composite brake blocks in freight car (whispering)	-	n.s.	n.s.
Proposed reduction measures for air traffic noise by the city of Dusseldorf to the competent airport licensing authority: • soundproofed aerators for bedrooms • structural noise abatement measures for living rooms • financial compensation of 2% of the market value for real estate • optimizing departure routes	-	n.s.	n.s.

2. Benefits

Using information from the Strategic Noise Maps, it is possible to determine the change in the number of people exposed to noise levels above 50 dB, as presented in table 3.

Since air traffic related noise abatement is the responsibility of DüsseldorfAirport and railway noise from the federal railway network is covered by the Federal Railway Authority, those noise types are not included in the table. Data on the number of people profiting from tram track improvements are not specified.

Table 84 – Benefits – exposed population[118]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[119]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	-49,413	-49,413
55-59.9 dB(A)	15,261	15,261
60-64.9 dB(A)	-1,095	-1,095
65-69.9 dB(A)	25,899	25,899
70-74.9 dB(A)	21,472	21,472

As the table above shows, noise reduction measures did reduce the number of people exposed above 49.9 dB by about 12,000 overall against a total population of about 600,000 in the agglomeration. The benefits were achieved due to noise reduction measures for roads, although the measures also increased the number of people exposed to certain noise levels, probably due to a reallocation of the population exposed to noise at higher intervals.

Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 4 and 5).

Table 85 – Benefits – annoyance

Change in size of the annoyed population[120]	Road	DALYs per year
Annoyed[121]	18,739	
Highly Annoyed[122]	10,747	215

[118] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[119] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[120] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[121] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[122] Data below 45dB and above 75dB (Lden) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

As the table above illustrates, the number of people annoyed was reduced by nearly 19,000 due to noise reduction measures, and the number of people highly annoyed was reduced by nearly 11,000 people, resulting in a decrease in disease-adjusted life years per year of 215.

Table 86 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	DALYs per year	Present Value (€)
Sleep Disturbed	2,756		
Highly Sleep Disturbed	1,340	94	85,233,960

Another benefit of the noise reduction measures in the Dusseldorf agglomeration is that the number of people whose sleep is disturbed could be reduced by 2,756, and the number of people whose sleep is highly disturbed has been reduced by another 1,340 This corresponds to a decrease in disease-adjusted life years of 94 per year and is valued at just over € 85 M over the 25-year assessment period.

The following tables 6 and 7 summarize the effects of the noise abatement measures on cardiovascular disease and hypertension. The data available shows that a reduction in road noise has resulted in a reduction of DALYs of about 452 per year, valued at just over € 50 M per year and a total benefit of more than € 584 M. as a result of avoided DALYs.

Table 87 – Benefits - Cardiovascular disease

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[123]	1.028		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[124]	230.780	23.078	25,613,633
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI			298,457,627

[123] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

[124] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

Table 88 – Benefits – Hypertension

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from hypertensive heart disease that is attributable to environmental noise[125]	5.408	5.408	
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[126]	221.519	22.152	24,585,763
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease			286,480,576

The benefit of the END implementation for the population of Düsseldorfagglomeration amounts to:

Net Present Value (€): 852,354,778.

[125] The numbers in this row show the change in the proportion of cases of hypertensive heart disease due to noise exposure

[126] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

3. Cost Benefit Analysis of Individual Measures

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Appendix D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Appendix D.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Appendix E.

3.2 CBA of individual measures

The following tables present the results of the CBA performed for individual measures in Düsseldorf agglomeration.

Noise proof window campaign

The program for soundproof windows Dusseldorf was launched in 2004 and extends to residential buildings at selected road sections with a noise level of L_{den} > 70 dB (A) and L_{night} > 60 dB (A). After installation an inside daytime level of 40 dB (A) and 30 dB (A) at night can be achieved.

The program is particularly employed where active noise protection measures are not feasible or appropriate. Until April 2010, subsidies for soundproof windows with a total volume of 2 million € was paid for 270 households. The overall positive response from the affected households has led to an increase in the funding allocated.

The benefits of the measure exceed the costs by a factor of 21. The noise proof window campaign of Düsseldorf agglomeration therefore rates as one of the best CB-ratios of all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
1,900	1 million	20 million	578	10,479	1:18

Rehabilitation of roads / Low noise road surfaces

The aim of the measure is the continuous exchange of conventional standard road surface by new noise-reducing asphalt in the context of necessary road renewals.

On basis of investigations of the city Düsseldorfthe effectiveness of low-noise road surfaces was verified for two road sections. Due to the promising results with a noticeable reduction in noise emission in car tires by 4 dB and in truck tires by 1 to 2 dB, it is planned to extend the measure on other sections.

However the CB-ratio rates lower than in other agglomerations, possibly due to less dense building structures along the relevant road sections.

Rehabilitation of roads / Low noise road surfaces

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
4,350	2.7 million	22 million	628	5,073	1:8

Barriers / Walls

Noise protection using barriers and walls was defined in the Master Plan "Reduction of road traffic noise in Dusseldorf". It includes 9 road sections with a total length of 4 km set to be protected by the measure. The majority of these projects have already been implemented.

The CB-ratio of Barriers/Walls is not as good as for other measures but the benefit still outweighs the cost.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
3,900	2.8 million	15.4 million	741	3,965	1:5

Embedded tracks for trams

The city of Dusseldorf has conducted over the past years in particular, a noise abatement program for rail sections of the tram lines. Embedded tracks for trams are currently in a trial phase. The trial is performed to determine the vibration behaviour and assessing the installation and maintenance properties as well as wheel and rail wear, so that in the long term the regular tracks can be exchanged.

Therefore the CB-Analysis was carried out for an exemplary track section of 450 m length.

The CB-ratio for this measure lies within the range of other agglomerations. In comparison other measures have a much higher CB-ration, however the benefit still outweighs the cost four times.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
400	0.16 million	0.57 million	412	1,434	1:3

Vegetated tram tracks

Lawn tracks are unsealed tram routes sown with grass in the streets that do not act simultaneously as a road for vehicle traffic. A reduction in the noise level of at least 2 dB is assumed. So far 12 km tram tracks have already been fitted with lawn. In this context it should be noted that by far the largest share of the city tram tracks is shared with motor vehicle traffic and is therefore unavailable for this measure. As also shown in other case studies, the measure is cost neutral with a balanced CB-ratio.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
6,350	8.2 million	7 million	1,297	1,107	1:1

F.1.5 Case Study – Helsinki, Finland Agglomeration

The city of Helsinki consists of a densely populated downtown area near the former port and surrounding suburbs that extend along the main roads and railway lines of the city. Large green spaces are located in between the suburbs.

The city covers an area of approximately 214 km² with an increasing population of about 560,000 in 2011. The average population density is slightly less than 2,800 inhabitants per square kilometer.

The city is affected by most of the typical noise types found in agglomerations such as road traffic, railway and tram lines as well as a metro system. **The** main land use changes were the relocation of the commercial port in 2008 and the redevelopment of the old harbor areas for residential purposes. This resulted in less rail and heavy road traffic in the inner city reducing traffic induced noise in densely build areas.

The current objectives of land-use planning - making community structures denser, preserving recreational areas and planning residential areas within the reach of good public transportation connections - are challenging from the perspective of noise prevention. The main objectives of the 2013 revision of the noise abatement action plan for improving the noise situation in Helsinki are as follows:

Noise will be considered in procurements and planning:

- The city will lead by example by, for instance, considering noise in the procurement criteria of new vehicles.
- Noise will be considered in land-use and traffic system planning.
- Noise effects will be assessed in traffic planning.
- The attractiveness of public transportation will be increased.
- Walking and cycling will be promoted.

Noise emissions and exposure will be reduced:

- Low noise pavement will be implemented within the target network.
- Noise barriers will be built on roads and near sensitive sites.
- Traffic speed control will be heightened.
- The use of hybrid and electric buses will be promoted.
- Technical conditions of rail traffic will be improved.

Property-specific noise reduction possibilities will be communicated to the public:

- More information will be provided on how to improve the sound insulation of the windows.
- More information will be provided on property barriers that residents can build to protect their lots from noise.

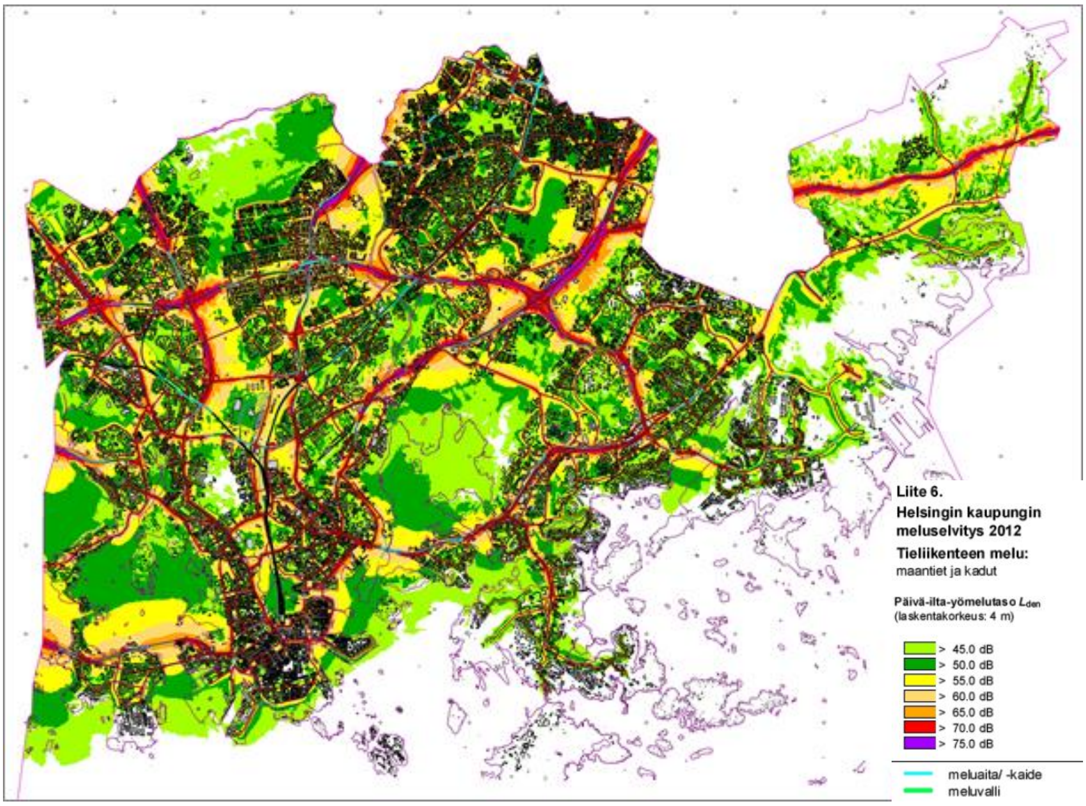
Quiet areas will be preserved and developed:

- The possibility of taking quiet areas into consideration in the new master plan will be studied.
- New, so called urban quiet areas will be developed.

People will be trained in quieter driving e.g. by offering training in eco-driving that reduces both noise and traffic emissions.

The effects of noise will be researched e.g. the annoyance of noise will be studied.

The action plan includes a total of 23 measures, with a responsible party defined for each. Most of the measures are continuous. The Regional Government authority, Centre for Economic Development, Transport and the Environment, is in charge of the noise control measures on the highways. Cities are in charge of the noise control measures on the roads and streets.



Helsinki Noise Level Map – Day – Road Traffic Noise, dB(A)

1. Costs

The costs of END implementation incurred from 2008 onwards are presented in the table below. Since costs can only be specified for certain measures a selection of the noise control measures is listed. These mainly relate to measures like noise barriers and noise optimized surfaces.

Furthermore, the Helsinki agglomeration implemented noise reduction projects to procure more silent public transport vehicles but costs for this measure are difficult to determine. The action program of the current NAP includes 23 actions, and these are expected to be continued in R2.

Table 89 - Costs (round 1 and 2)

Total costs of END Implementation (€, discounted)[127]	
Staff costs (City of Helsinki office work)	79,815
Consultation and (mapping) software - noise calculation	106,005
Consultation - noise action plan	70,906
Creation and print of info-brochures	3,094
Costs of measures (€, discounted)[128] over 25 years	
Total discounted capital costs of measures[129]	6,508,854
Total discounted maintenance costs of measures[130]	n.s.
GRAND TOTAL COSTS (€, discounted) [131]	6,768,674

Table 90 – List of measures supported in R1 NAP, Helsinki

Name of measure	Year of implementation	Status Complete/Underway/ Planned	Present value (€, 2014 prices)
Silent road surfaces (4 different destinations)	2009	Complete	210,600
A noise barrier in a new residential area	2009	Complete	853,851
Two noise barriers in collaboration with Regional Government authority* in existing residential areas	2009	Complete	1,753,656 (share of City of Helsinki: 600,000)
Silent road surfaces (4 different destinations)	2010	Complete	223,000
A noise barrier in a new residential area	2008-2010	Complete	156,677

[127] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[128] These are the total costs of measures to reduce or minimise noise levels

[129] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[130] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[131] Included are quantifiable costs only.

Name of measure	Year of implementation	Status Complete/Underway/ Planned	Present value (€, 2014 prices)
A noise barrier in collaboration with the Regional Government authority in existing residential area	2009-2010	Complete	1,684,100 (share of City of Helsinki : 600,000)
Electronic speed signs to monitor drivers (in 20 different destinations)	2010	Complete	14,052
Quiet areas (analysing the material of quiet areas questionnaire for residents and producing mapping and descriptions of quiet areas)	2010	Complete	7,433 (+ office work)
Silent road surfaces (5 different destinations)	2014	Complete	177,272
A noise barrier in collaboration with the Regional Government authority in existing residential area (Secondary non-polluted soil placed to the noise embankment).	2012-2014	Complete	562,426
A noise barrier in a new residential area	2014-2015	Underway	796,361
A guide how to improve noise protection on real estates (Brochure made in collaboration with 3 other cities)	2015	Complete	n.s.

The NAP also proposes that the sites defined in the low noise pavement target network be paved with low noise pavement when the condition of the current pavement deteriorates to the point that repaving becomes necessary. As a result, 2–3 road sections are paved with noise optimized asphalt each year. The additional cost of repaving with low noise asphalt amounts to 100,000 € annually.

2. Benefits

Since the number of residents benefiting from the implementation of the measures outlined above is not calculated in the NAP the total benefit achieved cannot be calculated.

In Helsinki in particular noise barriers and noise optimized asphalt was implemented as a measure within the scope of END. Due to the construction of noise barriers from 2008 till 2012 the number of residents that fell below 55 dB(A) amounted to 7,200 people. In between 2013 and 2017 this number is calculated to be 2,000 people. This measure is analysed in the section below.

3. COST BENEFIT ANALYSIS OF INDIVIDUAL MEASURES

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Appendix D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Appendix D.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Appendix E.

3.2 CBA of individual measures

The following tables present the results of the CBA performed for individual measures in Helsinki agglomeration.

Box 4 Barriers / walls – measure description

Barriers / Walls

Noise barriers have already been implemented during 2008 and 2012 at several road sections in Helsinki. For the actual planning period 2013 to 2017 this measure is planned for 11 new areas throughout the city. Due to the measure 2,000 residents fall below the threshold value of L_{den} 55 db (A). Based on this figure it can be assumed that the total number of residents profiting from the measure sums up to about 8,300 people. The measure achieves a noise level reduction of 3 dB (A).

Due to the relatively low number of people profiting from the measure in comparison to the high expense, the CB-ratio for this measure only has a slightly positive effect.

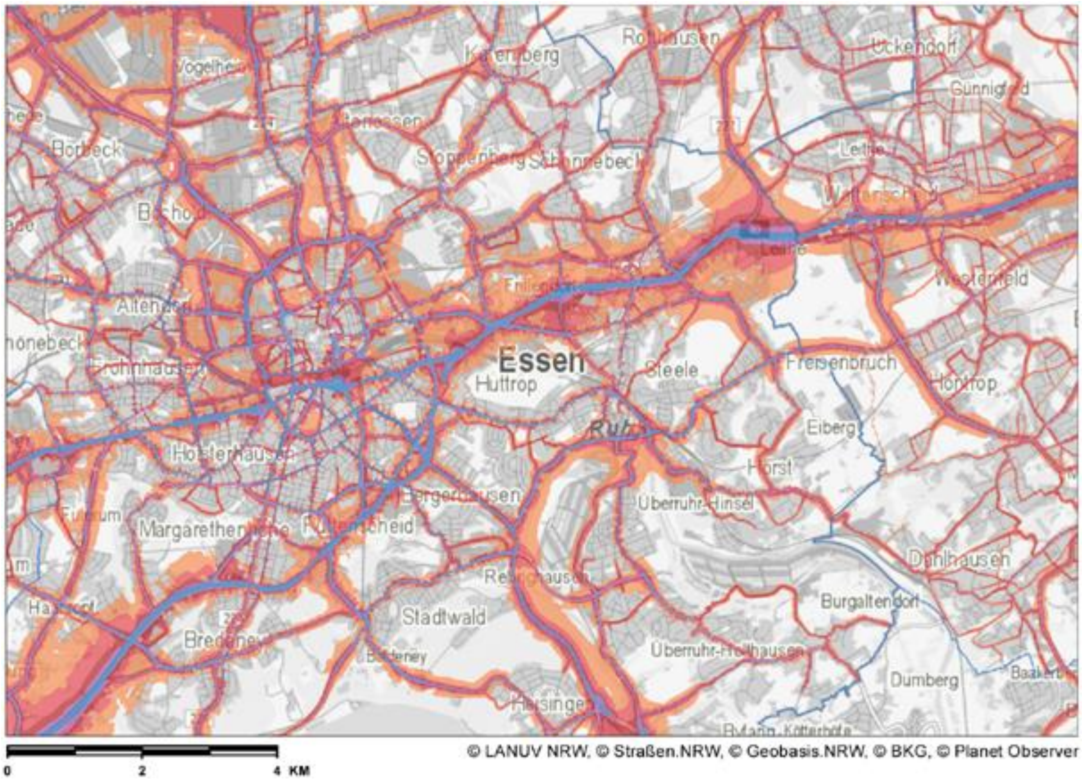
The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
8,300	13.7 million	16.6 million	1,646	1,994	1:1.2

F.1.6 Case Study – Essen, Germany Agglomeration

The city of Essen, Germany is part of the Rhine-Ruhr metropolitan area and counts among the 10 largest cities in Germany. It covers an area of 210 km² extending 20 km from north to south und 17 km from east to west. Essen was chosen as a case study due to its dense road network of roughly 1,600 km and the highly congested Ruhr expressway cutting across the city. Another two motorways touch the city in the north and south. Essen has a well-established public transport system including busses, tramways and railways. Due to the vicinity to the airport Essen/Mülheim the population is also affected by air traffic noise. The city of Essen therefore presents a case study agglomeration heavily exposed to traffic noise of all types in a densely populated area.

Figure 10 - L_{den} for noise from roads in Essen agglomeration and major roads



1. Costs

The total cost of END implementation incurred from 2008 onwards is presented in the table below. The bulk of expenditure in the Essen agglomeration relates to human resources, although consultation and noise mapping also created considerable costs. The total costs over a 25-year-assessment period are expected to amount to over € 10 M.

Not included are noise abatement measures implemented by the federal roads authority as well as the national railway authority that account for high expenditures and significant effects. However, those measures were partly realized outside the scope of the noise reduction plan.

Table 91 – Costs

Total costs of END Implementation (€, discounted)[132]	
Staff costs (2 full time jobs)	463,457.89
Workplace costs and staff training	20,428.81
Consultation and (mapping) software - noise calculation	162,490.70
Consultation - noise action plan	70,208.69
Online consultation	69,880.67
Creation and print of info-brochures	3,694.37
Costs of measures (€, discounted)[133] over 25 years	
Total discounted capital costs of measures[134]	9,127,535.35
Total discounted maintenance costs of measures[135]	144,228.57
GRAND TOTAL COSTS (€, discounted)	10,061,925.04

The following table presents the measures taken or planned on the basis of the noise reduction plan.

[132] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[133] These are the total costs of measures to reduce or minimise noise levels

[134] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[135] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Table 92 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise optimised asphalt LOA 5 D	2007	Complete	2,312,220
Noise optimised asphalt LOA 5 D	2012	Complete	2,229,811
Speed limit on urban roads at night	2010	Underway	-
Noise monitoring / surveillance	2010	Planned	-
Speed display	2010	Planned	-
Passive noise protection (noise protective windows programme)	2009	Underway	215,726
Noise optimised asphalt LOA 5 D	2007	Underway	-
Further noise limits on urban roads at night	-	Planned	-
Continued passive noise protection programme	2012	Planned	-
Promote public transportation	2008	Planned	-
Promote cycling and walking			-
Truck guidance concept	2010	Planned	-
Other guidance concepts	2009	Complete	-
Mobility management	-	-	-
Activities promoting e-mobility in Essen (long-term impact)	2010	Planned	-
Support to homeowners to reduce noise	2007	Underway	7,200
Rail head treatment	2009	Complete	344,546
North Rhine Westphalia roads measures	2009	Underway	
DB Netz AG (German railways) measures	2013	Planned	4,162,260

Out of the 17 measures listed above, only four have indeed been completed, while five are underway but eight are only planned thus far. This means that the impact of many of these measures will only materialise in the future, and the benefits presented further below need to be interpreted in that context.

2. Benefits

Using information from the Strategic Noise Maps produced, it is possible to determine the change in the number of people exposed to noise levels above 55 dB, as presented in table 3. Since air traffic related noise abatement is responsibility of Essen Airport, this noise type is not included in the table.

Table 93 – Benefits – exposed population[136]

Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures under the END:	L_{den}		
	Road	Rail	Total
45-49.9 dB(A)	0	0	0
50-54.9 dB(A)	0	0	0
55-59.9 dB(A)	19 400	0	19 400
60-64.9 dB(A)	19 400	-11 860	7 540
65-69.9 dB(A)	19 400	9 080	28 480
70-74.9 dB(A)	13 500	2 250	15 750
Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures under the END:	**L_{night}**		
	Road	**Rail**	**Total**
45-49.9 dB(A)	0	0	0
50-54.9 dB(A)	20 100	0	20 100
55-59.9 dB(A)	20 100	-6 070	14 030
60-64.9 dB(A)	15 000	4 420	19 420
65-69.9 dB(A)	4 900	1 290	6 190
70-74.9 dB(A)	200	360	560

As the table above shows, noise reduction measures did reduce the number of people exposed above 50 dB by 77,600 (L_{den}) overall against a total population of about 570,000 in the agglomeration. The main benefits were incurred due to noise reduction measures focussing on roads and railways, although railways measures also increased the number of people exposed to certain noise levels, probably due to a reallocation of the population exposed to noise at higher intervals.

Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 4 and 5).

[136] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

Table 94 – Benefits – annoyance

Change in size of the annoyed population[137]	Road	Rail	Total	DALYs per year
Annoyed[138]	29,264	1,476	30,739	
Highly Annoyed[139]	14,684	824	15,508	310

As the table above illustrates, the number of people annoyed was reduced by nearly 31,000 due to noise reduction measures, and the number of people highly annoyed was reduced by around 15,500 people, resulting in a decrease in disease-adjusted life years of 310.

Table 95 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	Rail	Total	DALYs per year	Present Value (€)
Sleep Disturbed	12,664	290	12,954		
Highly Sleep Disturbed	6,147	155	6,301	441	435,192,999

Another benefit of the noise reduction measures in Essen, is that the number of people whose sleep is disturbed could be reduced by nearly 13,000 and the number of people whose sleep is highly disturbed could be reduced by another 6,300. This corresponds to a decrease in disease-adjusted life years of 441 and is valued at € 435 M.

The following tables 96 and 97 summarize the effects of the noise abatement measures on cardiovascular disease and hypertension. The data available shows that a reduction in road noise has resulted in a reduction of DALYs of nearly 669 per year, valued at over € 74 M per year, and a total benefit of more than € 900 M. as a result of avoided DALYs.

Table 96 – Benefits - Cardiovascular disease

	Road	Rail	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[140]	1.057	n/a		
Change in the number of DALYs per year resulting from ischaemic heart	237.127	n/a	237.127	26,318,154

[137] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[138] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[139] Data below 45dB and above 75dB (Lden) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

[140] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

	Road	Rail	DALYs per year	Present Value (€)
disease and attributable to transport noise[141]				
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI				320,177,946

Table 97 – Benefits – Hypertension

	Road	Rail	DALYs per year	Present Value (€)
Change in the % of the population suffering from hypertensive heart disease that is attributable to environmental noise[142]	10.549	n/a		
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[143]	432.139	n/a	432.139	47,961,947
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease				583,489,159

The benefit of the END implementation for the population of Essen agglomeration amounts to:

Net Present Value (€): 1,634,793,564

[141] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

[142] The numbers in this row show the change in the proportion of cases of hypertensive heart disease due to noise exposure

[143] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

3. Cost Benefit Analysis of Individual Measures

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Annex D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Annex E.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Chapter G.

3.2 CBA of individual measures

The following tables present the results of the CBA performed for individual measures in Essen agglomeration.

Passive noise protection programme (sound insulation windows, low noise fans)

The passive noise protection program is subsidized by the city of Essen and is open to all residential buildings along municipal main roads, whose facade level are L_{den} > 70 dB (A) and L_{night} > 60 dB (A). In a first phase 350,000 € were budgeted. Depending on the acceptance and availability of additional funds, the program is planned to be continued.

The benefits of the measure exceed the costs by a factor of 25. The noise proof window campaign of Essen agglomeration therefore rates as one of the best CB-ratios of all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
443	0.3 million €	7.9 million €	700	17,800	1 : 25

Rehabilitation of roads / Low noise road surfaces

The aim is to equip road sections with particular noise problems with noise optimized asphalt, if this can contribute to a substantial reduction in noise emissions. In 2009 the measure started with the surface renewal in 7 road sections. Another 22 sections are to follow in the future. Depending on the vehicle speed and percentage of trucks reductions by 3 to 5 dB (A) were measured.

The CB-ratio of this measure is significantly positive and rates in the mid-range of all studied agglomerations.

The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
3,800	2.8 million €	19.8 million €	740 €	5,200 €	1 : 7

Speed reduction

In three road sections a speed limit of 30 km/h is planned during night time. Traffic counts, noise monitoring and speed measurements are to examine the effectiveness of the measure. The measure can reduce the noise level at night by about 2.5 dB (A). There are only marginal costs for signage, municipal traffic control and possibly for the purchase and installation of a speed display panel.

Due to the low costs associated with the measure, the benefits exceed the costs many times over. Speed reduction therefore presents one of the most effective measure available in noise action planning.

The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
1,540	0.03 million €	3.9 million €	25 €	2,500 €	1 : 100

Re-distribution / Reduction of heavy trucks

A considerable proportion of heavy through traffic burdens urban roads. Restrictions in conjunction with truck steering systems can help the inner-city to reduce heavy truck traffic without the need to limit source / destination traffic. Halving the proportion of heavy traffic on urban roads can lead to noise level reductions of 4-6 dB (A).

Currently, two feasibility studies for the deflection of truck traffic in Essen are carried out, in which the feasibility of the measure is examined.

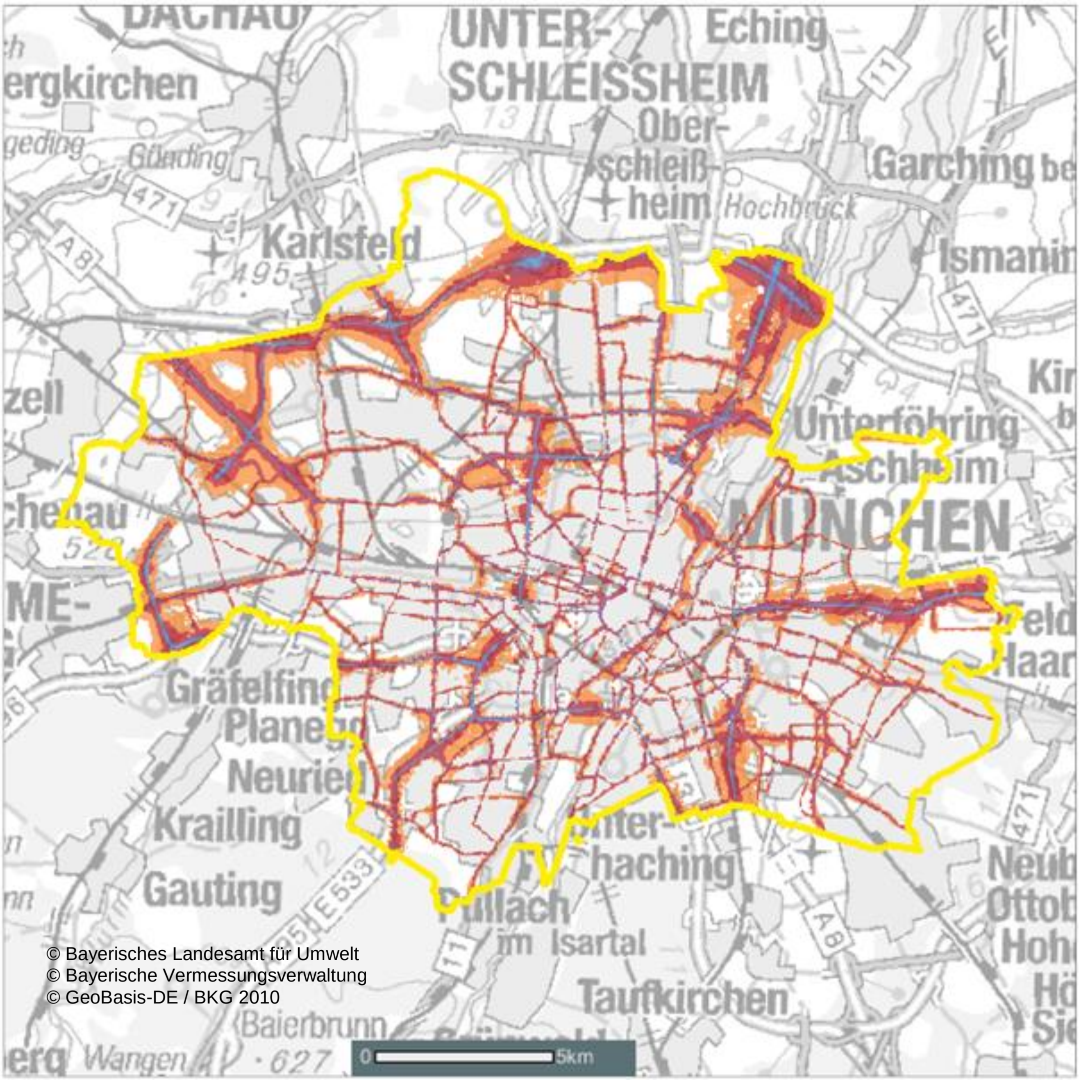
Due to the high number of improved residents the benefit of the measure outweighs the cost by a multiple.

The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
570,000	1.2 million €	429.8 million €	2 €	750 €	1 : 375

F.1.7 Case Study – Munich, Germany Agglomeration

The city of Munich is the third largest agglomeration in Germany with a population of 1.3 million residents. It covers an area of 310 km² extending 21 km from north to south und 27 km from east to west. Munich was chosen as a case study due to its dense inner-city road network of roughly 2,800 km and its function as hub for long-distance traffic both on road and rail. The public transport network is extensive with 93 km subway, 66 km tramway, 442 km railway and various bus lines. The city road network connects to an outer and an inner circular road as well as to seven motorways in the vicinity of the city. Due to the distance of Munich to its airport, noise from aviation is not relevant for the agglomeration. The city of Munich therefore presents a case study agglomeration heavily exposed to traffic noise in a densely populated area.



L_{den} for noise from roads in Munich agglomeration

1. Costs

The total cost of END implementation incurred from 2008 onwards is presented in the table below. The bulk expenditure in the Munich agglomeration relates to human resources including consultants. A detailed allocation of costs is available and applied in the study but not presented in the table below.

The total costs of END implementation cannot be calculated to date, since not all measures have been approved. However, the soundproof windows program as well as the action program "Mittlerer Ring" incur high costs and are underway. Therefore, only the cost of those two measures are listed in the table below. Also not included are noise abatement measures implemented by the federal state government for federal roads and rail that account for high expenditures and significant effects.

Table 98 – Costs

Total costs of END Implementation (€, discounted)[144]	
Additional staff time	< 600,000
Consultants	
(Mapping) software - noise calculation	
Reporting	
Costs of measures (€, discounted)[145] over 25 years	
Total discounted capital costs of measures[146, 147]	12,242,764
Total discounted maintenance costs of measures[148]	-
GRAND TOTAL COSTS (€, discounted)	12,754,160

The following table presents the measures taken on the basis of the NAP. A total of 24 affected areas were defined in which the selected measures shown in the above table were implemented. Based on an evaluation matrix the appropriate measures were identified for each area. In most road sections passive measures such as noise optimized windows were proposed. In addition an overall strategic plan to reduce noise at city level was included. These general measures include optimized traffic flow, environmentally conscious traffic management, diversion of truck transit traffic, mobility management and improving public transport, parking facility management and others.

[144] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[145] These are the total costs of measures to reduce or minimise noise levels.

[146] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[147] Only costs from soundproof windows program as well as the action program "Mittlerer Ring"

[148] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Table 99 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise optimized surface (8 road sections)	-	evaluation phase	-
Noise protective windows (24 road sections) within the framework of a city-wide program	2013	underway	592,163
Enclosure for road (one road section)	-	-	-
Reduction of rolling noise and screeching in curves at tram line (one section)	2013	complete	n. s.
Overall strategic plan to reduce noise at city level	-	ongoing	n. s.
Support program „Wohnen am Ring" (Living along the city road circle)	2010	underway	11,659,601

2. Benefits

Since the number of residents benefiting from the implementation of the measures with known costs cannot be determined, the total benefit achieved cannot be calculated. However, the cost benefit for the individual measures are presented in the following section.

3. Cost Benefit Analysis of Individual Measures

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Annex D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Annex E.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Chapter G.

3.2 CBA of individual measures

The following tables present the results of the CBA performed for individual measures in Munich agglomeration.

Noise proof window campaign

The city-wide program for noise optimized windows is preferably used in the affected areas of the noise action plan, in which active noise protection measures are not possible. The program was extended to residents with a noise exposure exceeding L_{den} 70 dB(A) / L_{night} 60 dB(A).

Assuming the maximum grant of 3,000 € is made available to each applying household, about 270 flats can be fitted with noise optimized windows. On the basis of 1.6 residents per flat, about 430 people profit from the campaign.

The benefits of the measure exceed the costs of the measure by a factor of 10. The noise proof window campaign of Munich agglomeration has one of the lowest CB-ratio compared to all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
432	0.5 million	4.4 million	1,252	10,349	1:8

Rehabilitation of roads / Low noise road surfaces

Residents along eight road sections in Munich will profit from a noise optimized surface. A total of approximately 11,000 residents will benefit from the measure which is assumed to lower the noise level by 4 dB(A) in all noise level classes.

Due to the dense building structure in the relevant road sections, the CB-rate of the measure rates as one of the highest compared to all assessed agglomerations.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
11,000	2.8 million	45.8 million €	259	4,164	1:16

Speed reduction
The introduction of speed limits is evaluated in the Noise Action Plan for some road sections, but is not selected as a measure for any road. However, in order to show the effect of the measure, the effect of speed reduction in Munich was evaluated as part of the CB-analysis. Speed reduction was evaluated for two sections of about 1.500 metre in a dense city structure with 3,600 affected residents. A noise reduction of 2,4 dB(A) is expected from lowering the speed level from 50 to 30 km/h for all noise classes. Due to the low costs associated with the measure, the benefits exceed the costs many times over. Speed reduction therefore presents one of the most effective measure available in noise action planning but is not the preferred option on main roads in Munich agglomeration. The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
3600	0.026 million	9 million	7	2,497	1:335

Barriers / Walls
Since 2002 noise protection walls with a length of about 500 m were constructed to protect existing residential buildings. Due to the relatively low number of people effected by the measure in comparison to the high expense, the CB-ratio for the investigated barrier is negative. The actual NAP does only consider one similar concept of road enclosure since no other measures are suitable to reach the noise level target. The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
190	1.5 million	0.5 million	7,654	2,355	3:1

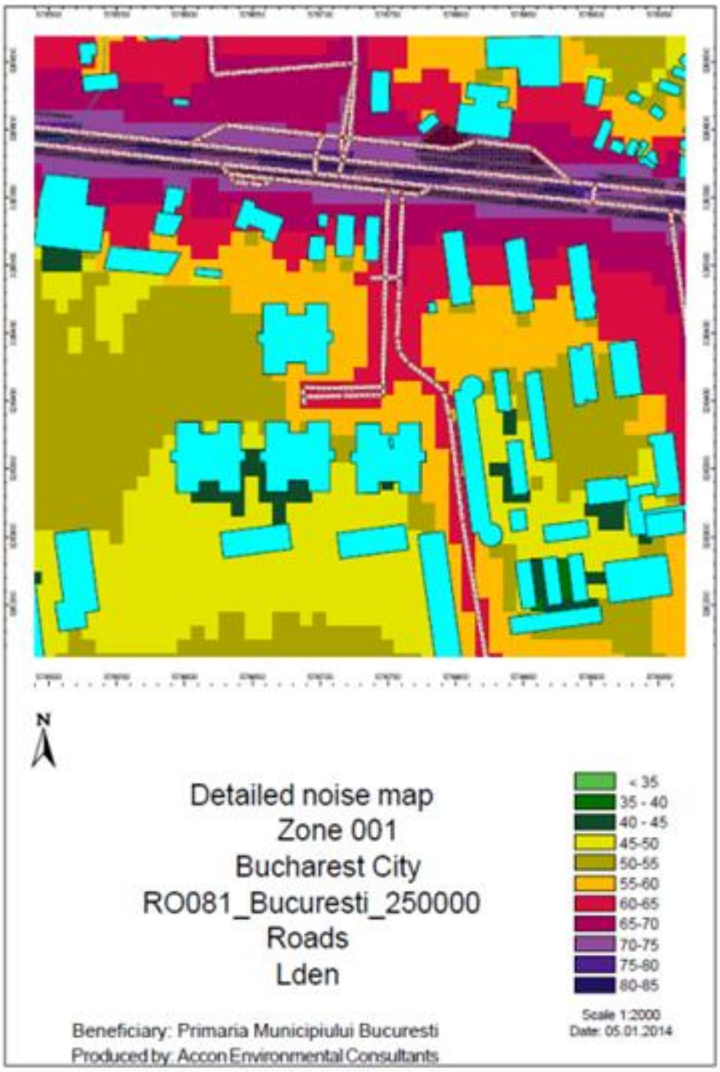
Vegetated tram tracks
A noise reduction can be achieved through the replacement of gravel with turf tracks. Although vegetated tram tracks are not included in the actual NAP, the effect was evaluated in the actual NAP. Conversion to a vegetated track is usually only feasible during the next revision (medium to long term measure). Since tram and vehicle traffic both have an impact on the noise level in the investigated road section, improvement of the noise level is reduced to L_{den} 1 dB(A) and L_{night} 2 db(A). The measure is associated with high costs compared to the noise level reduction reflected by a low CB-ratio. The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
1,200	0.65 million	0.86 million	541	721	1:1.3

F.1.8 Case Study – Bucharest, Romania Agglomeration

The city of Bucharest is the capital city Romania with about 1.88 M inhabitants and an area of 228 km². It counts as a large agglomeration, especially taking into account the neighbouring localities with around 430,000 inhabitants and the fact, that Bucharest daily hosts three million people. The mapped road network of the city has a length of about 800 km. Bucharest is connected to five train lines and has an underground network with a length of about 71 km. The public transport network will be complemented by 70 bus lines, 16 trolley buses and 23 tram lines. Two international operating airports (Henri Coanda Airport and Aurel Vlaicu Airport) are situated within the agglomeration.

Most annoying in Bucharest is the road traffic noise. More than 3800 buildings exceeding the 65 dB limit, around 200 buildings that exceeds the limit of 70 dB and there are also a number of buildings exceeding 75 dB L_{den}. Responsible for the preparation of the NAP is the city Bucharest. In 2008 a "Local Environmental Action Plan" was developed, which also contains some specific actions to improve environmental quality in the municipality of Bucharest (including noise related issues). The new 2014 NAP according END is in public debate and describes proposed measures accompanied by cost-efficiency and cost-benefit assessments.



1. Costs

The total cost of END implementation incurred from 2008 onwards is not published. The Local Environmental Action Plan aiming at "Developing a specific action plan to improve environmental quality in the municipality of Bucharest" includes noise related issues, but no cost estimations. Also costs for implemented measures are not known.

The following presents selective measures taken from the "Environmental Action Plan" from 2008 and from the published NAP 2014. In addition to the general development of the transport system, in particular short term measures such as speed limits and speed enforcement as well as long term measures such as noise optimized asphalt were planned and implemented. In addition to the measures for road transport, especially rail noise abatement was of importance to the city of Bucharest.

Table 100 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise optimised asphalt	since 2008	unknown	
Speed limits (roads)	in public discussion	-	-
Window thermal/sound insulation programme	since 2008	unknown	
Heavy traffic redistribution	since 2008	complete	-
Creation of cycle paths	since 2008	in progress	-
Creation of special lanes for public transport	since 2008	in progress	-
Traffic flow optimization	since 2008	in progress	-

2. Benefits

The "Environmental Action Plan" 2008 identifies a significant decrease of number of affected persons by noise levels exceeding administrative (L_{den}) limits from 112,137 persons to 50,510 persons arising from noise reduction measures at the main road network. Though, the available data are not suitable for a sound consideration of costs and benefits (in relation to noise action planning activities according END).

In the following section the planned specific measure to optimize the road surface along 50 km major roads will be considered.

3. Cost Benefit Analysis of Individual Measures

Below selected generally effective measure is evaluated in terms of cost and effectiveness in the case study area. The planned measure was chosen to show the cost benefit relation of an individual measure.

The calculation of costs is based on typical approved specific costs, in this case 50 € / m² road surface improvement.

The benefit of the measure was determined on the basis of the calculated reduction of affected inhabitant (within 5 dB bands). As there are only L_{den}-noise level data available, the reduction of noise damage costs can only be calculated on annoyance effects. This will lead to a strong underestimation of the monetized benefit, as the reduced number of sleep disturbed inhabitants will not be considered.

The following table present the results of the CBA of the surface optimization at Bucharest road network:

Surface optimization at main roads

The improvement of the road surface along 50 km length leads to a reduction of 2,413 highly annoyed persons. This matches 4 % of the total number of highly annoyed persons (55,000) along the investigated network.

The benefits of measure exceed the costs, although the benefit at night time was not considered.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
55,492	22.4 million	66 million	405	1,185	1:3

F.1.9 Case study – Malmo, Sweden agglomeration

The city of Malmö, Sweden has about 320,000 inhabitants the third largest city in Sweden. Malmö covers an area of 158 km² and constitutes the transnational Øresund Region, the most densely populated area in Scandinavia. Responsible for the preparation of the NAP is the city of Malmö.

Figure 11 - Malmö agglomeration noise map - roads, daytime

1. Costs

The total cost of END implementation incurred from 2008 onwards is presented in the table below. The bulk of expenditure in the Malmö agglomeration relates to human resources including consultants. The total costs of the planned measures over a 25-year-assessment period are expected to amount to about € 18.2 M.

Table 101 – Costs

Total costs of END Implementation (€, discounted)[149]	
Additional staff time	65,863.32
Consultants	73,181.47
(Mapping) Software	7,318.15
Reporting	3,659.07
Costs of measures (€, discounted)[150] ***over 25 years***	
Total discounted capital costs of measures[151]	18,084,436.03
Total discounted maintenance costs of measures[152]	-
GRAND TOTAL COSTS (€, discounted)	**18,234,458.04**

The following table presents the measures planned and taken on the basis of the NAP.

Table 102 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Continued development with coating	2014	On-going	-
Clearer link between traffic regulation related activities and noise impacts	2014	On-going	-
Monitor and follow up on noise from public transport (buses)	2014	On-going	-
Investigation into the use of electric buses	2015	On-going	-
Road related noise to be incorporated into public traffic campaigns	2015	On-going	-
Noise proof window campaign	2014	On-going	6,561,331
Guidelines aimed at property owners describing window campaign (see ID 6)	2014	On-going	
Raise noise barriers in identified locations	2014	On-going	305,865
Noise reducing activities at the most exposed pre-schools and schools	2014	On-going	3,288,221
Noise reducing activities in selected locations within parks, recreation areas and in squares	2014	On-going	7,929,019

[149] These are the total discounted costs incurred by the relevant implementing authorities in implementing the END

[150] These are the total costs of measures to reduce or minimise noise levels

[151] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[152] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
(and other public places)			
Investigation into/identification of additional areas which would benefit from screens.	2014	On-going	-
Development of routines to secure guidelines for noise pollution when establishing new pre-schools and schools	2014	On-going	-
Continue work with identifying designated Quiet Areas	2014	On-going	-
Noise level requirements in public procurement	2014	On-going	-
Collaboration with other cities and actors	2014	On-going	-

Out of the 15 measures listed above, all are currently on-going. This means that the impact of many of these measures will only materialise in the future, and the benefits presented further below need to be interpreted in that context.

2. Benefits

Using information from the Noise Action Plan, it is possible to determine the change in the number of people exposed to noise. Data on effected residents was only presented in the NAP for selected noise level classes as presented in the table below.

Table 103 – Benefits – exposed population

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[153]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	22,000	0
55-59.9 dB(A)	0	64,410
60-64.9 dB(A)	16,500	0
65-69.9 dB(A)	0	0
70-74.9 dB(A)	0	0

As the table above shows, noise reduction measures did not have an impact on the number of people exposed to noise (L_{den}) up to 49.9 dB but did reduce the number of people exposed above 49.9 dB by 7,301 overall against a total population of 318,107 in the agglomeration. The main benefits were incurred due to noise reduction measures on roads.

Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 4 and 5).

[153] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

Table 104 – Benefits – annoyance

Change in size of the annoyed population[154]	Road	DALYs per year
Annoyed[155]	8,095	
Highly Annoyed[156]	3,223	64

As the table above illustrates, the number of people annoyed was reduced by 8,095 due to noise reduction measures, and the number of people highly annoyed was reduced by 3,223 people, resulting in a decrease per year in disease-adjusted life years of 64.

Table 105 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	DALYs per year	Present Value (€)
Sleep Disturbed	12,972		
Highly Sleep Disturbed	6,155	431	425,074,207

Another benefit of the noise reduction measures in the Malmö agglomeration is that the number of people whose sleep is disturbed could be reduced by about 13,000, and the number of people whose sleep is highly disturbed could be reduced by another 6,155, corresponding to a decrease in disease-adjusted life years of 431 per year valued at € 425 M over the 25-year assessment period.

The following tables 6 and 7 summarize the effects of the noise abatement measures on cardiovascular disease and hypertension. The data available shows that a reduction in road noise has resulted in a reduction of DALYs of about 31, valued at over €3 M, and a total benefit of more than € 41 M as a result of avoided DALYs.

Table 106 – Benefits - Cardiovascular disease

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[157]	0.078		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[158]	1.795	1.795	199,174
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI			2,423,090

[154] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[155] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[156] Data below 45dB and above 75dB (Lden) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of “survivors” is high at very high levels.

[157] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

[158] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

Table 107 – Benefits – Hypertension

The benefit of the END implementation for the population of Malmö agglomeration amounts to:

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from hypertensive heart disease that is attributable to environmental noise[159]	10.867		
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[160]	28.773	28.773	3,193,462
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease			38,850,606

Net Present Value (€): 511,718,377.

[159] The numbers in this row show the change in the proportion of cases of hypertensive heart disease due to noise exposure

[160] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

3. Cost Benefit Analysis of Individual Measures

3.1 Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Annex D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Annex E.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Chapter G and in the efficiency section.

3.2 CBA of individual measures

The following table presents the results of the CBA performed for one individual measure of Malmö agglomeration.

Noise proof window campaign

The noise levels to participate in the programme have been further reduced, so that funding is already available at a noise level of 61 dB(A) on the facade and 31 dB(A) indoors.

The benefits of the measure exceed the costs of the measure by a factor of 18.

The costs and benefits shown below present value prices based on 2014.

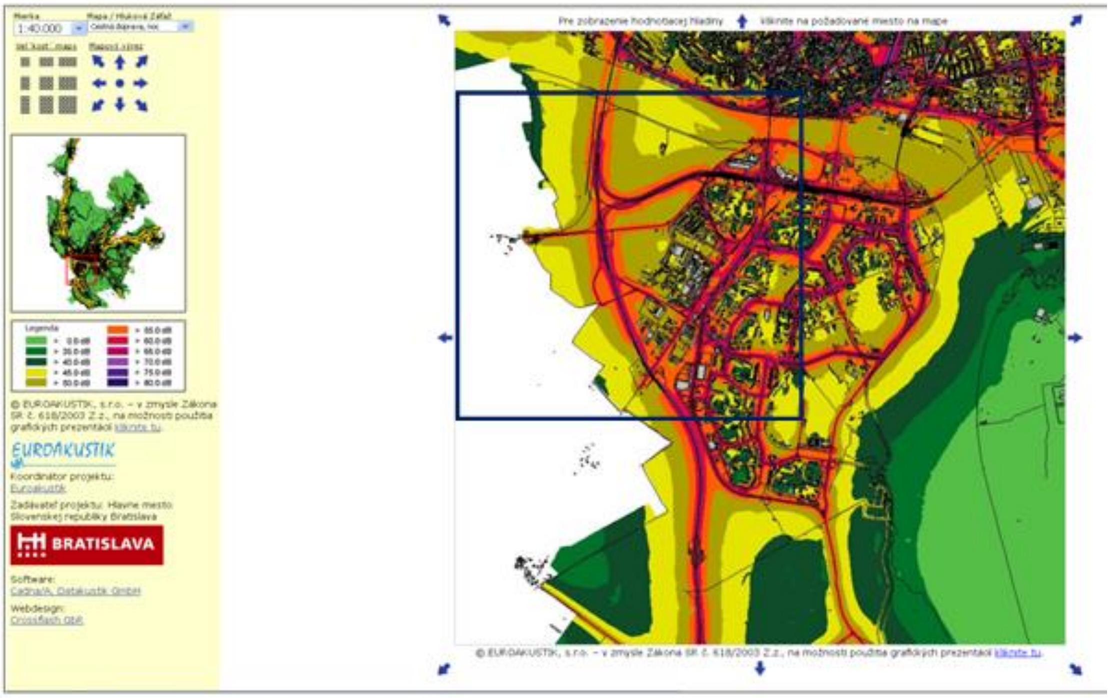
Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
1,920	0.6 million	9.7 million	329	5,064	1:15

F.1.10 Case Study – Bratislava, Slovakia Agglomeration

Bratislava is the capital of Slovakia with a population of 460,000. The agglomeration is defined within the bounds of the municipality (draft NAP 2015), whereas the greater metropolitan area includes another 100,000 people. The city of Bratislava covers an area of 368 km^2 with a population density of 1,250 inhabitants/km^2.

The mapped road network of the city has a length of about 840 km. The total length of roads with a traffic flow of more than 3 million vehicles per year is 290 km. Bratislava is connected to seven train lines. Noise mapping in Bratislava covered a total of about 3,300 km of roads, 311 km of railway and 79 km tram lines. In addition the international airport (M. R. Stefanik) situated 9 km outside the city as well as 31 industrial businesses were included in the noise mapping.

Responsible for the preparation of the NAP is the city of Bratislava. In 2007 and 2013 strategic noise maps were prepared. National action planning in accordance to END on the basis of year 2006 was prepared in 2009, but was not published. Between the first and the second round of noise mapping there were various activities and actions to reduce noise at identified hotspots within the city. The first "official" NAP according to END for the Bratislava agglomeration will be published towards the end of 2015. Although this NAP is not published yet, it entails actual hot-spots and describes proposed measures accompanied by cost-benefit assessments.



Strategic Noise Map of Bratislava for road traffic noise (L_{den}) in the district of Petržalka (http://www.laermkarten.de/bratislava/)

In the following section selected road and railway noise measures are analysed in regard to the cost-benefit relation.

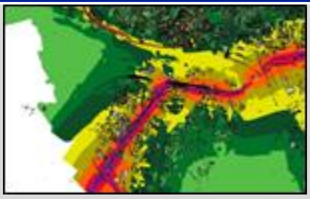
Two selected measures in the hotspot district Bratislava-Petržalka, which were considered within the NAP, were evaluated in terms of cost and effectiveness. The measures were chosen to show the cost benefit relation of specific measures chosen to reduce the number of residents effected by noise under the given circumstances in the case study area.

The costs of the measures are estimations by the author of the NAP.

The benefit of the measures was determined on the basis of the calculated reduction of effected residents (within 5 dB noise level classes).

The following tables present the results of the CBA for the analysed measures:

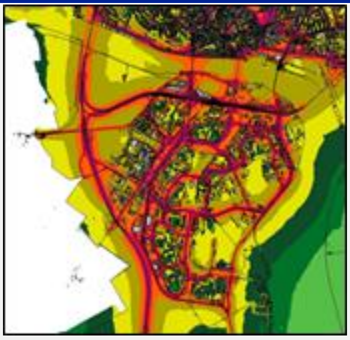
Noise barrier along the railway tracks at district Petržalka



The implementation of a noise barrier with an average high of 4 m and a total length of 5,300 m at both sides of the rail way track achieves to the following cost and benefits:

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
17,306	5.4 million	36 million	380	2,985	1:7

Low Noise Surface on motorway D4 within the district of Petržalka



The improvement of the road surface along 50 km length leads to a reduction of 2413 highly annoyed persons. This matches 4 % of the total number of highly annoyed persons (55,000) along the investigated network.

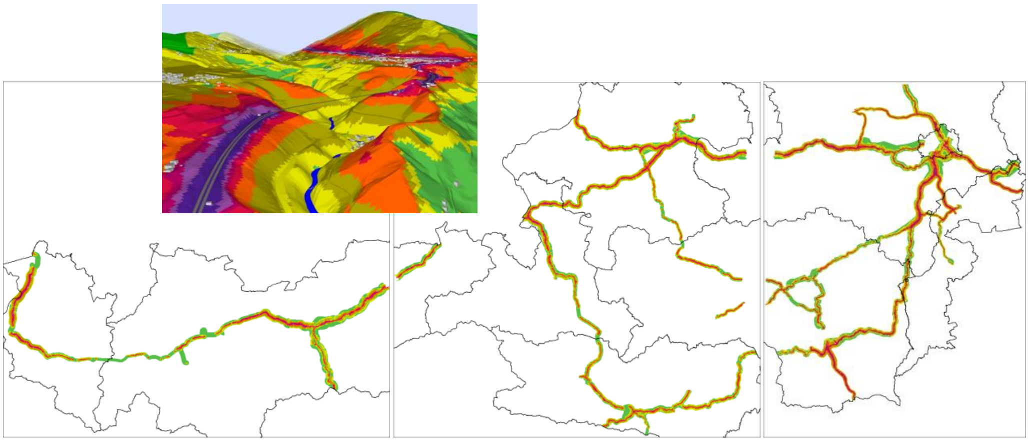
The benefits of measure exceed the costs, although the benefit at night time was not considered.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
38,675	1.4 million	14.2 million	45	405	1:10

F.2: ROADS

F.2.1 Case study – Austria Major Roads

Austria Major Roads were chosen as a case study, because the strategic noise maps were produced for all motorways and major highways under the responsibility of one authority (ASFINAG) and the strategic noise maps of the 1st and 2nd round were prepared by ACCON. Hence detailed mapping results were available. Considering a 2500 km road net and a mapped area of 8500 km² let expect hard knowledge of costs and benefits of measures. Also NAPS were published in time in 2008 and 2013.



The published NAP (2008) summarizes the implemented measures at the major road network since 1999 (according national programs) and shows planned measures and long-term strategies. Also a rough estimation of expenditure in the past and future costs is mentioned. The published NAP (2013) for the 2nd round also mentions an estimation of the benefit of the implemented measures within the period 2007-2012.

1. Costs

From the NAPs (2008 and 2013) it was possible to interpolate costs for existing noise abatement programs. It may be assumed, that the mentioned costs contain planning and realization of measures. There are no cost estimates for END implementation available, but taken into account the very simple design of the NAP and very simple public participation and discussion of measures, we may expect no relevant costs for END implementation.

Table 108 – Costs

Total costs of END Implementation (€, discounted)[161]	
Administrative costs (€, discounted)	
Additional staff time, consultants, reporting	1,004,838
Costs of measures (€, discounted)[162] over 25 years	
Total discounted capital costs of measures[163]	146,579,115.8
Total discounted maintenance costs of measures[164]	-
GRAND TOTAL COSTS (€, discounted)	147,583,953.67

The total costs of measures over a 25-year-assessment period are expected to amount to € 146.5 M. Together with the administrative costs associated with noise mapping and preparation of action plans, the total present value costs are € 147,583,953.67.

Table 109 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise abatement measures along existing motorways and expressways (A1, A2, A4, A7,A8, A9, A10, A12, A14, A21, A22, S5, S36)	2008-2015	implemented	146,579,115.8
Noise abatement measures along existing motorways and expressways (A1, A2A8, A9, A10, A12, A13, A14, A23, S6, S16)	2015	ongoing	

[161] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[162] These are the total costs of measures to reduce or minimise noise levels

[163] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[164] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

2. Benefits

General notes on benefits:

1. Disability-Adjusted Life Years (DALYs) are the sum of the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

2. The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

The benefit of implemented measures until 2013 was estimated by ACCON based on statistics derived from the comparison of the 2007/2012 noise mapping results, as presented in table 3.

Table 110 – Benefits – exposed population[165]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[166]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	46,377
50-54.9 dB(A)	0	43,171
55-59.9 dB(A)	52,122	29,041
60-64.9 dB(A)	42,042	14,078
65-69.9 dB(A)	24,377	662
70-74.9 dB(A)	10,216	6
>75.0 dB(A)	312	0
Total	129,069	133,335

As the table above shows, noise reduction measures have an impact on about 129,000 residents (L_{den}) and 133,000 residents (L_{night}) against total affected number of people of around 714,000.

Table 111 – Benefits – annoyance

Change in size of the annoyed population[167]	Road	DALYs per year	Present Value (€)
Annoyed[168]	39,603		
Highly Annoyed[169]	17,822	356	508,233,832

[165] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[166] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[167] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[168] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[169] Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

As the table above illustrates, the number of people annoyed was reduced by about 40,000 due to noise reduction measures, and the number of people highly annoyed was reduced by about 18,000 people, resulting in a decrease in disease-adjusted life years of 356.

Table 112 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	DALYs per year	Present Value (€)
Sleep Disturbed	21,428		
Highly Sleep Disturbed	9,683	678	966,474,887

Another benefit of the noise reduction measures for major Roads in Austria is that the number of people whose sleep is disturbed has been reduced by about 21,000, and the number of people whose sleep is highly disturbed has been reduced by another about 10,000, corresponding to a decrease in disease-adjusted life years of 678. This decrease is valued at € 966 M.

Table 113 – Benefits - Cardiovascular disease

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[170]	0.661		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[171]	15.99	15.99	
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI			4,056,100

The data available shows that a reduction in road noise has resulted in a reduction of DALYs of 15.99, valued at about € 1.78M per year and a total benefit of €4M as a result of avoided DALYs.

The net benefit of the END measure at Austria Major Road network for the population, and assuming 100% attribution, amounts to:

Net Present Value (€): 1,119,545,523.

[170] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

[171] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

F.2.2 Case study 2 – Greece Major Roads (Attica Tollway)

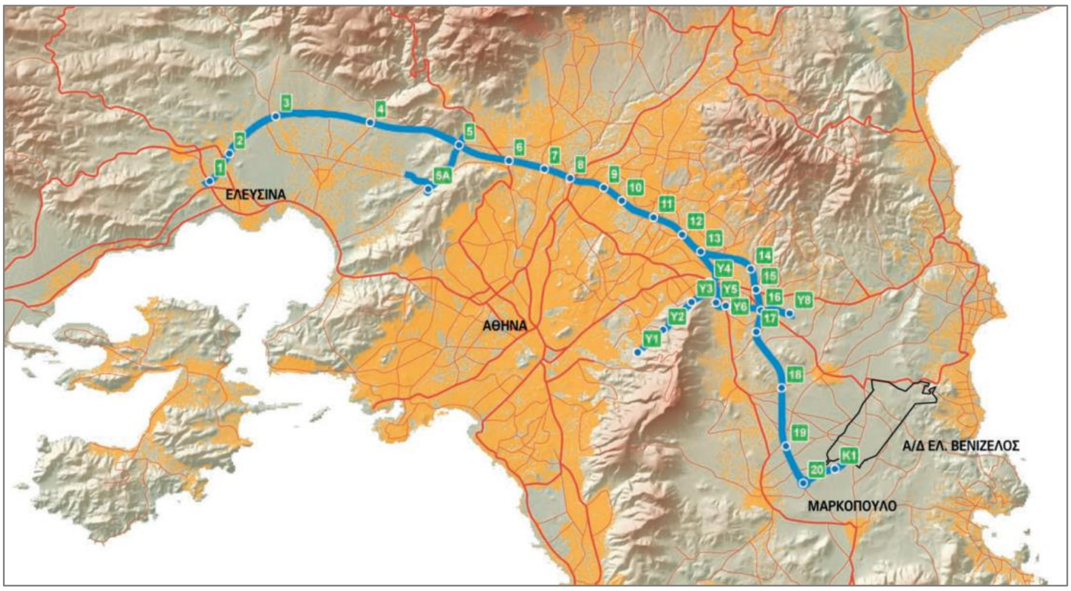
Attica Tollway serves as a ring road for the greater metropolitan area of Athens with a length of 70 km per direction. Due to the close location to the metropolitan area of Athens it functions as bypass road concentrating and routing traffic flows. It connects 30 municipalities of the Attica basin and meets the transportation needs of millions of people.

The average traffic has declined in 2008 to 2011 by about 7 % from 300,000 to 280,000 vehicles. In the subsequent years a further decline by 10 % is expected due to the financial situation of the country.

The motorway affects an area of about 19 million sqm in 16 municipalities. Due to different land uses a total of about 8,500 buildings are in the vicinity of the road thereof 70 % residential buildings. This accounts for about 28,000 residents living in the study area.

In the NAP 2010 noise barriers with a total surface area of 87,000 sqm were proposed for 138 different sections of the motorway with acoustically effective heights varying from 3.5 to 4.5 m. The implementation of the measure has already been completed. The results of this measure is outlined in the cost benefit analysis below.

In addition to the construction of noise barriers the implementation of partial covering of the motorway are planned to improve the situation further in some road sections. This will create a further benefit that is not considered in the case study analysis.



Attika Tollway, Source: Attiki Odos, Annual Report 2011

1. Costs

Detailed data on costs occurred from this measure are not available. A general assumption for costs usually associated with the construction of noise barriers is 1,000 € per sqm wall. The total surface area constructed totals to 87,000 sqm which amounts to costs of 87 million € (undiscounted) for this measure. In the table below the discounted costs, including the administrative costs of END implementation are presented.

Table 114 – Costs

Total costs of END Implementation (€, discounted)[172]	
Administrative costs (€, discounted)	
Costs associated with additional staff time, consultants, reporting, etc	40,938.17
Costs of measures (€, discounted)[173] over 25 years	
Total discounted capital costs of measures[174]	77,382,346
Total discounted maintenance costs of measures[175]	n.s.
GRAND TOTAL COSTS (€, discounted)	63,643,586.03

2. Benefits

Using information from the Strategic Noise Maps produced in 2009 and 2011, it is possible to determine the change in the number of people exposed to noise levels above 50 dB (A), as presented in table 3.

Table 115 – Benefits – exposed population[176]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[177]	
	L_{den}	L_{night}
45-49.9 dB(A)	-56	-1,204
50-54.9 dB(A)	-784	-1,064
55-59.9 dB(A)	-1,232	224
60-64.9 dB(A)	-1,092	868
65-69.9 dB(A)	532	1,428
70-74.9 dB(A)	896	392
>75.0 dB(A)	1,736	28
Total	840	672

[172] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[173] These are the total costs of measures to reduce or minimise noise levels

[174] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[175] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[176] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[177] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

As the table above shows, noise reduction measures had an impact on 840 residents (L_{den}) and 672 residents (L_{night}) against total affected number of people of around 28,000.

Table 116 – Benefits – annoyance

Change in size of the annoyed population[178]	Road	DALYs per year	Present Value (€)
Annoyed[179]	1,174		
Highly Annoyed[180]	863	17	24,621,373

As the table above illustrates, the number of people annoyed was reduced by 1,174 due to the installation of noise barriers, and the number of people highly annoyed was reduced by 863 people, resulting in a decrease in disease-adjusted life years of 17.

Table 117 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Road	DALYs per year	Present Value (€)
Sleep Disturbed	609		
Highly Sleep Disturbed	361	25	36,040,530

Another benefit of the noise reduction measures at Attica Tollway is that the number of people whose sleep is disturbed has been reduced by 609, and the number of people whose sleep is highly disturbed has been reduced by another 361, corresponding to a decrease in disease-adjusted life years of 25. This decrease is valued at € 36M.

[178] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[179] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[180] Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

Table 118 – Benefits - Cardiovascular disease

	Road	DALYs per year	Present Value (€)
Change in the % of the population suffering from ischaemic heart disease that is attributable to environmental noise[181]	2.287		
Change in the number of DALYs per year resulting from ischaemic heart disease and attributable to transport noise[182]	95.68	95.68	10,619,313
Total value of avoided DALYs from a reduction in the incidence of noise-induced AMI			129,191,040

The data available shows that a reduction in road noise has resulted in a reduction of DALYs of 95.68, valued at € 10 M per year and a total present value benefit of € 129M as a result of avoided DALYs.

Combing the cost and benefit estimates, the net benefit of the measure, assuming 100% of the benefits attributed to END implementation is:

Net Present Value (€): 112,833,233.

3. Cost Benefit Analysis

Below the measure is valuated regarding the monetary ratio of costs and benefits. The calculation is based on the data provided in the previous chapters.

Barriers / Walls
For the measure described in the previous chapters a near balance of cost and benefits was reached. However, the cost still exceed the benefit. Due to the large amounts, the rounded CB-Ratio is even. The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
28,000	77.4 million €	75.5 million €	2,750 €	2,700 €	1:1

[181] The numbers in this row show the change in the proportion of cases of myocardial infarction due to noise exposure

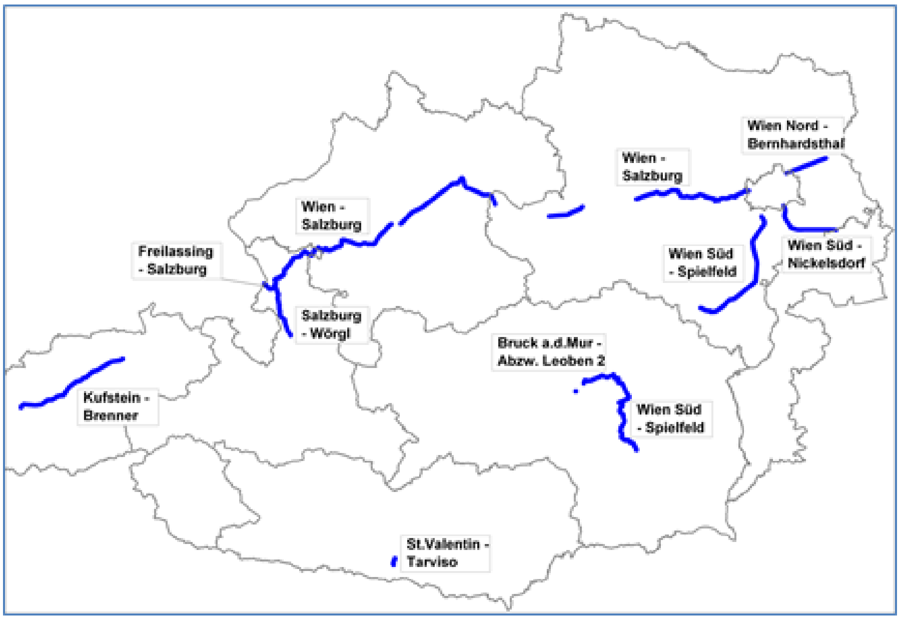
[182] The change in DALYs is calculated as the % of all DALYs from ischaemic heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY.

F.3 RAIL

F.3.1 Case study – Austria Major Railways

Austria Major Rails were chosen as a case study, because the strategic noise maps were produced for all major railways under the responsibility of one authority (OEBB) and the strategic noise maps of the 1^{st} and 2^{nd} round were prepared by ACCON. Hence detailed mapping results were available. ACCON considered a 550 km rail net within the 1^{st} round and a 2100 km rail net in the 2^{nd} round. NAPS were published in time in 2008 and 2013. From the published "Umgebungslaerm-Aktionsplan Oesterreich 2008, Teil B11 – Schienenstrecken (bmvit)" the number of affected persons from planned measures within the years 2008-2013 could be estimated. From cost-statistics of the 2^{nd} round noise mapping costs were estimated with € 0.6 M.

550 km rail within the round noise mapping Austria



net 1^{st}

The published NAP (2008) summarizes the activities in relation to noise abatement at the major rail network since 1999 (according national programs) and shows planned measures and long-term strategies. Also a rough estimation of expenditure in the past and future costs is mentioned.

1. Costs

From the NAPs (2008 and 2013) it was possible to interpolate costs for existing noise abatement programs. It may be assumed, that the mentioned costs contain planning and realization of measures. There is also a rough cost estimates for END implementation available, that is mainly determined by known costs for data acquisition (GIS implementation) and contains also the very simple design of the NAP and very simple public participation and discussion of measures.

Table 119 – Costs

Total costs of END Implementation (€, discounted)[183]	
Additional staff time, Consultants, Reporting, land-survey/GIS	487,155
Costs of measures (€, discounted)[184] over 25 years	
Total discounted capital costs of measures[185]	19,350,869
Total discounted maintenance costs of measures[186]	-
GRAND TOTAL COSTS (€, discounted)	19,838,024

A breakdown of the costs of implementation of the END for the Major Railways in Austria has not been obtained.

The total costs of measures over a 25-year-assessment period are expected to amount to just over €19 M.

Table 120 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise abatement measures targeting persons affected over highest four dB classes	Starting 2009	ongoing	19,350,869

[183] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[184] These are the total costs of measures to reduce or minimise noise levels

[185] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[186] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

2. Benefits

General notes on benefits:

1. Disability-Adjusted Life Years (DALYs) are the sum of the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

2. The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

The yearly benefit of implemented measures until 2009 was estimated by the responsible authority with 12,500 persons less affected by rail noise. This fact will lead to a total reduction of affected people by 62,500 until 2013. Assuming a weighted reduction of affected persons over all 5 dB bands (based on person distribution in 2008) the following benefit can be expected.

Table 121 – Benefits – exposed population[187]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[188]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	(-32,411)
50-54.9 dB(A)	(-62,500)	19,398
55-59.9 dB(A)	35,729	8,606
60-64.9 dB(A)	17,937	2,851
65-69.9 dB(A)	5,943	1,085
70-74.9 dB(A)	1,991	472
>75.0 dB(A)	900	0
Total	**62,500**	**32,411**

As the table above shows, noise reduction measures did not have an impact on the number of people exposed to noise L_{den} up to 55 dB and 50 dB L_{night}. The increase of in these 5 dB bands are caused by a shifting of household to lower dB bands due to measures.

Table 122 – Benefits – annoyance

Change in size of the annoyed population[189]	Rail	DALYs per year
Annoyed[190]	6,224	
Highly Annoyed[191]	2,573	51

[187] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[188] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[189] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[190] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[191] Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

As the table above illustrates, the number of people annoyed was reduced by 6,224 due to noise reduction measures, and the number of people highly annoyed was reduced by 2,573 people, resulting in a decrease in disease-adjusted life years of 51.

Table 123 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Rail	DALYs per year	Present Value (€)
Sleep Disturbed	1,355		
Highly Sleep Disturbed	650	45	54,588,346

Another benefit of the noise reduction measures for Major Railways in Austria is that the number of people whose sleep is disturbed has been reduced by 1,355, and the number of people whose sleep is highly disturbed has been reduced by another 650, corresponding to a decrease in disease-adjusted life years of 45. This decrease is valued at around € 55 M.

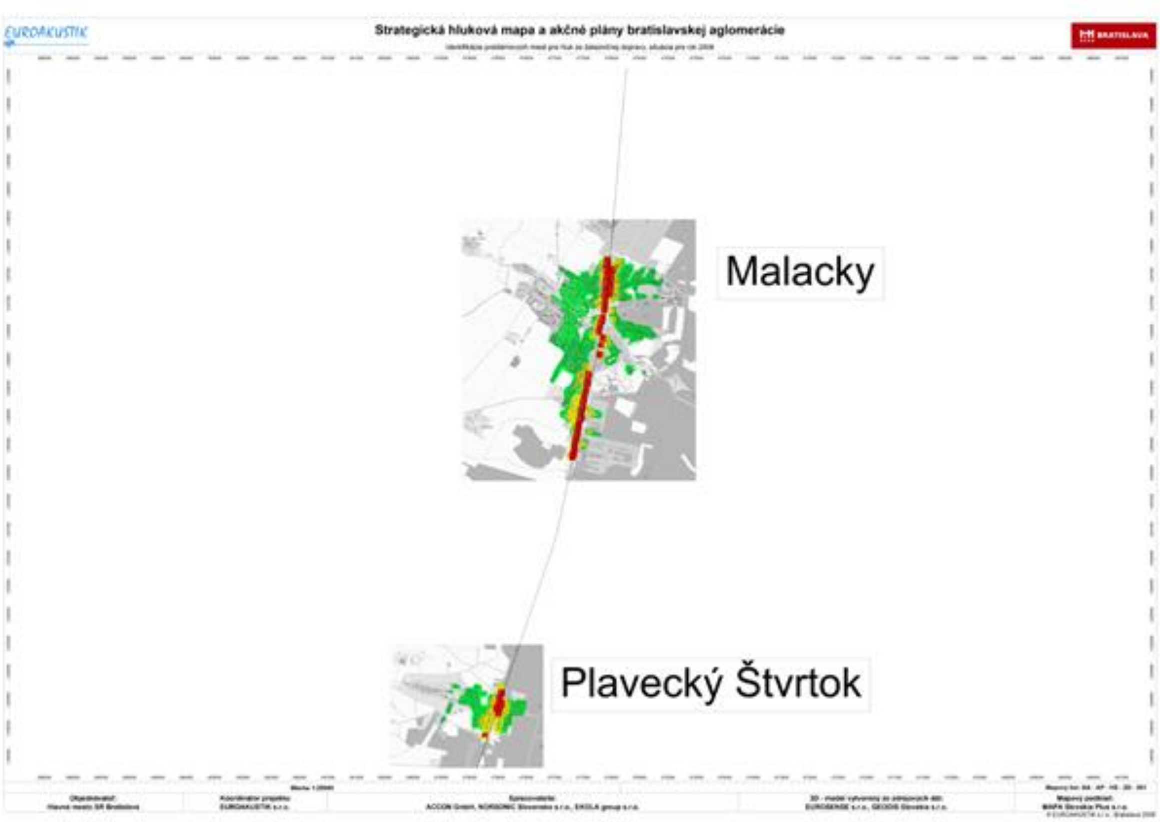
The benefit of the END implementation for major rails in Austria (assuming 100% of the benefits can be attributed to END implementation) amounts to:

Net Present Value (€): 96,515,675

F.3.2 Case study – Slovakia Major Railways

Malacky is an important regional transport hub connected to a highway and a national road that service the agglomeration Bratislava. The main train line connecting Bratislava and the Czech Republic traverses the city in north-south direction. The Malacky railway station is part of the Bratislava Integrated Public Transport System. The route is highly frequented and was therefore chosen as a case study.

For noise improvement along the Malacky rail route, various measures were analysed to improve the noise situation in the surrounding residential areas. As a result, the installation of a noise barrier was selected as the most effective measure. The publication of the results in the context of a noise action plan is still pending.



Noise map "hot spots" rail sections Malacky and Plavecky Stvrtok, 2006

1. Costs

The costs for the measure are based on estimates prepared for the authorities by a consultant and is not publicly available. It may be assumed, that the cost stated below contain planning and realization of the measure.

Table 124 – Costs

Total costs of END Implementation (€, discounted)[192]	
Additional staff time, Consultants, Reporting	22,688.68
Costs of measure (€, discounted)[193] over 25 years	
Total discounted capital costs of measures[194]	3,331,587
Total discounted maintenance costs of measures[195]	n.s.
GRAND TOTAL COSTS (€, discounted)	3,354,276

Table 125 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Noise barrier, railway section Malacky	2016	planned	3,331,587

2. Benefits

General notes on benefits:

1. Disability-Adjusted Life Years (DALYs) are the sum of the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

2. The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

The total benefit of the implemented measure is estimated with 6,800 persons less affected by rail noise. Assuming a weighted reduction of affected persons over all 5 dB bands (based on distribution of effected residents from noise mapping in 2008) the following benefit can be expected.

[192] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[193] These are the total costs of measures to reduce or minimise noise levels

[194] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[195] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Table 126 – Benefits – exposed population[196]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[197]	
	L_{den}	L_{night}
45-49.9 dB(A)	-	- 300
50-54.9 dB(A)	- 1,000	2,000
55-59.9 dB(A)	1,300	2,500
60-64.9 dB(A)	2,600	1,900
65-69.9 dB(A)	2,200	500
70-74.9 dB(A)	700	200
>75.0 dB(A)	400	-
Total	6,200	6,800

As the table above shows, noise reduction measures increased the number of people exposed to noise L_{den} up to 55 dB and 50 dB L_{night}. This is caused by a shift of effected residents to lower dB bands implicated by the measure.

Table 127 – Benefits – annoyance

Change in size of the annoyed population[198]	Rail	DALYs per year
Annoyed[199]	1,700	
Highly Annoyed[200]	684	14

As the table above illustrates, the number of people annoyed can be reduced by 1,700 due to the noise barrier, and the number of people highly annoyed was reduced by 684 people, resulting in a decrease in disease-adjusted life years of 14.

Table 128 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Rail	DALYs per year	Present Value (€)
Sleep Disturbed	874		
Highly Sleep Disturbed	371	26	31,135,803

[196] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[197] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[198] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[199] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[200] Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

Another benefit of the noise barrier at Malacky railway section is that the number of people whose sleep is disturbed has been reduced by 874, and the number of people whose sleep is highly disturbed has been reduced by another 371, corresponding to a decrease in disease-adjusted life years of 26. This decrease is valued at around € 31 M.

The net benefit of the measure for the population along Malacky railway line, assuming that 100% of the benefits can be attributed to END implementation, amounts to:

Net Present Value (€): 44,192,494.

3. Cost Benefit Analysis

Below the measure is valuated regarding the monetary ratio of costs and benefits. The calculation is based on the data provided in the previous chapters.

Barriers / Walls

The Malacky rail noise barrier is planned to be implemented in 2016 or later. The expected cost of the measure in 2006 is calculated with € 6 M. The total number of residents profiting from the measure sums up to about 6,800 out of 16,400 people in the case study area.

Due to the high noise pollution from rail tracks the benefits of the planned noise barrier exceed the costs by a factor of 14. Noise barriers for railway tracks therefore offer a much better cost benefit ratio than barriers along roads.

The costs and benefits shown below present value prices based on 2014.

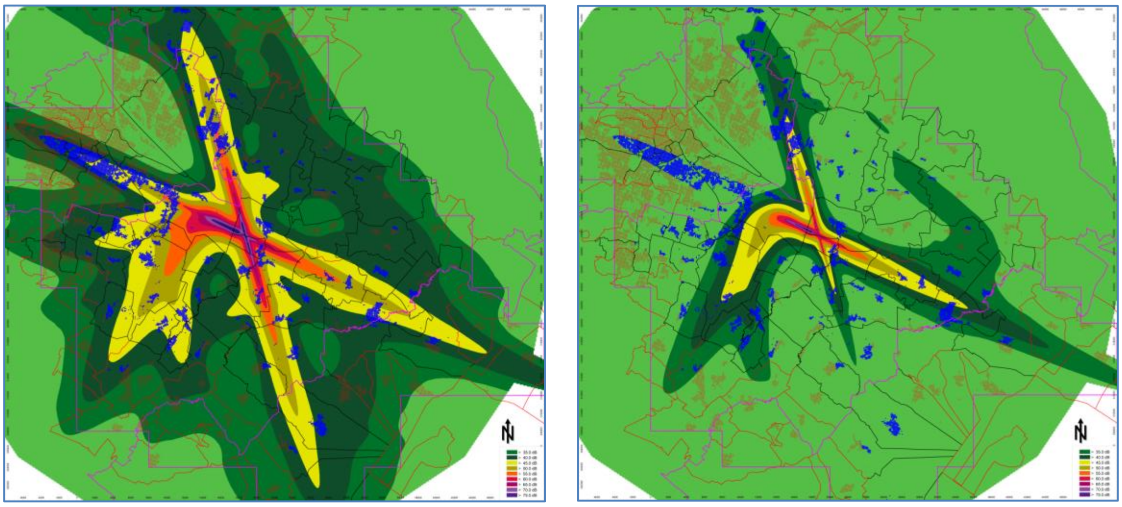
Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
16,400	4.0 million €	56.5 million €	250 €	3,400 €	1 : 14

F.4 AIRPORTS

F.4.1 Case study – Vienna Airport, Austria

Figure 12: Noise maps L_{den} and L_{night} for Vienna Airport

Vienna Airport was chosen as a case study, because the responsible authority has published NAPs for each of the reporting periods (2008 and 2013). Furthermore Vienna Airport is a typical hub airport but with comparatively small noise annoyance in the surrounding area due to its situation in a rural area with mean population density and compared to other hubs Vienna airport is less busy (in terms of aircraft movements). The results of this case study may be transferred to **other airports exhibiting similar characteristics**.



1. Measures

The NAP published in 2008 analyses the present noise situation and shows in connection with technical and legal framework in the past implemented noise reduction measures. The NAP does not name any long-term measures for the future. In the short term it is planned to define common regulations for limitations of the operation time together with all MS of the EU (based on 2002/30/EG from March 26th 2002). These restrictions will apply to all European airports (and as such would not result in displacement of movements to other airports).

2. Costs

From the published NAPs which also contain expenditures for actions undertaken prior to the introduction of the END, it was possible to estimate the full costs of existing ongoing noise abatement programs where the full costs of these ongoing measures had not been published. It may be assumed that the published costs cover both the planning and implementation of measures. There are no cost estimates for END implementation available (not published and not provided on request), but taking into account the very simple design of the NAP which didn't include any public participation or wider discussion of measures, we may expect that the costs of END implementation are less than €100,000 which are negligible in comparison to the €27 million to be spent on measures.

Table 129 – Costs

Total costs of END Implementation (€, discounted over a 25 year assessment period)[201]	
Additional staff time, consultants, software, reporting	70,367
Costs of measures (€, discounted)[202] over 25 years	
Total discounted capital costs of measures[203]	21,965,699
Total discounted maintenance costs of measures[204]	-
Costs of measures (€, discounted)[205] over 25 years	
Total discounted capital costs of measures[206]	21,965,699
Total discounted maintenance costs of measures[207]	-
GRAND TOTAL COSTS (€, discounted)	22,036,065.91

From the given information the total costs over a 25-year-assessment period are expected to amount to approximately € 28 million.

Table 130 – List of measures

Name of measure	Year of implementation	Status	Present Value Costs (€, 2014 prices)
Noise related compensation for take-off and landing	2009	implemented	**21,965,699**
Noise optimized departure and arrival procedures	2008	ongoing	
Checking of flight restrictions according *Balanced approach*, described in ICAO resolution A33-7 "Consolidated statement of continuing ICAO policies and practices related to environmental protection"	2008	ongoing	
Passive noise protection (e.g. soundproof windows)	Since 2005	ongoing	

No more details of completion status or costs have been obtained for Vienna Airport.

[201] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END
[202] These are the total costs of measures to reduce or minimize noise levels
[203] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)
[204] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)
[205] These are the total costs of measures to reduce or minimize noise levels
[206] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)
[207] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

3. Benefits

The benefit of the measures is documented by the results of the Strategic Noise Mapping in 2012.

Table 131: Estimates of the change in the number of people exposed to harmful noise levels[208]

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[209]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	0	405
55-59.9 dB(A)	732	-105
60-64.9 dB(A)	53	0
65-69.9 dB(A)	-5	0
70-74.9 dB(A)	0	0
Total	**779**	**300**

As the table above shows, noise reduction measures had a significant positive impact on the number of households exposed to noise (L_{den}) exceeding 54.9 dB. However, the number of households exposed above 65 dB L_{den} also increased by 5 (negative number corresponds to an increase in the number of people exposed). The number of households with L_{night} levels above 55 dB also increased by 105 against a total number of affected households of around 15,000 in close proximity to Vienna Airport.

Table 132: Benefits associated with a reduction in the size of the annoyed and highly annoyed population

Change in size of the annoyed population[210]	Aircraft	Total	DALYs per year	Present Value Benefits (€, millions)
Annoyed[211]	490	490	Not applicable*	Not applicable
Highly Annoyed	208	208	4	5

** Note that there are no established disability weights for the annoyed population and therefore it is not possible to calculate DALYs.*

[208] Note that negative numbers indicate an increase in the size of the population exposed to noise at that interval. This is most likely to be due to a reallocation of the population exposed to noise at higher intervals

[209] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[210] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[211] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

As the table above illustrates, the number of people annoyed was reduced by 490 due to noise reduction measures, and the number of people highly annoyed was reduced by 208 people, resulting in a decrease in disease-adjusted life years of 4. The stated reduction of annoyed and highly annoyed persons is the net result of both a reduction in the 55-65 and an increase in the 65-70 band.

Table 133: Benefits associated with a reduction in the size of the sleep disturbed and highly sleep disturbed population

Change in size of the sleep disturbed population	Aircraft	Total	DALYs per year	Present Value Benefits (€, millions)
Sleep Disturbed	72	72	Not applicable*	Not applicable
Highly Sleep Disturbed	43	43	3	3.65

** Note that there are no established disability weights for the annoyed population and therefore it is not possible to calculate DALYs.*

Another benefit of the noise reduction measures in Vienna is that the number of people whose sleep is disturbed has been reduced by 72, and the number of people whose sleep is highly disturbed has been reduced by another 43, corresponding to a decrease in disease-adjusted life years of 3 per year. This decrease is valued at around € 3.65M over the 25 year assessment period.

The size of the benefits is, however, understated as the most effective noise reduction measure (soundproofing of windows) only has an effect on indoor noise levels which will not be picked up by the strategic noise mapping which is based on external noise measured at the most exposed façade. If we presume, that according to Austrian legislation all residential buildings, which are affected by aircraft noise (exceeding 55 dB by night) will be improved in a way, that no more sleep disturbance may be expected, the benefit will increase by around €45 million over the 25 year assessment period.

Combining information on the total costs and benefits of implementation of measures related to the END at Vienna airport generates a NPV of negative €13.2 million. This is because the measures implemented (at a discounted present value of €21.9 million) result in relatively small improvements. The average cost per person (based on L_{den} only) is in the order of €1,791 and only 12% of the population exposed to L_{den} levels above 55 dB(A) benefits.

4. Cost Benefit Analysis of individual measures

Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Appendix E).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Appendix E.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Appendix D.

CBA of individual measures

The following table present the results of the CBA performed for an individual measure at Vienna Airport.

Improvement of Windows/ façades

Eligibility for the campaign was based on limiting noise levels according Austrian law. A total of around 122 applications for renewal were carried out and approximately 244 persons were covered by the campaign.

The benefits of measure exceed the costs many times over. The noise proof window/façade campaign at Vienna Airport shows a positive CB-Ratio.

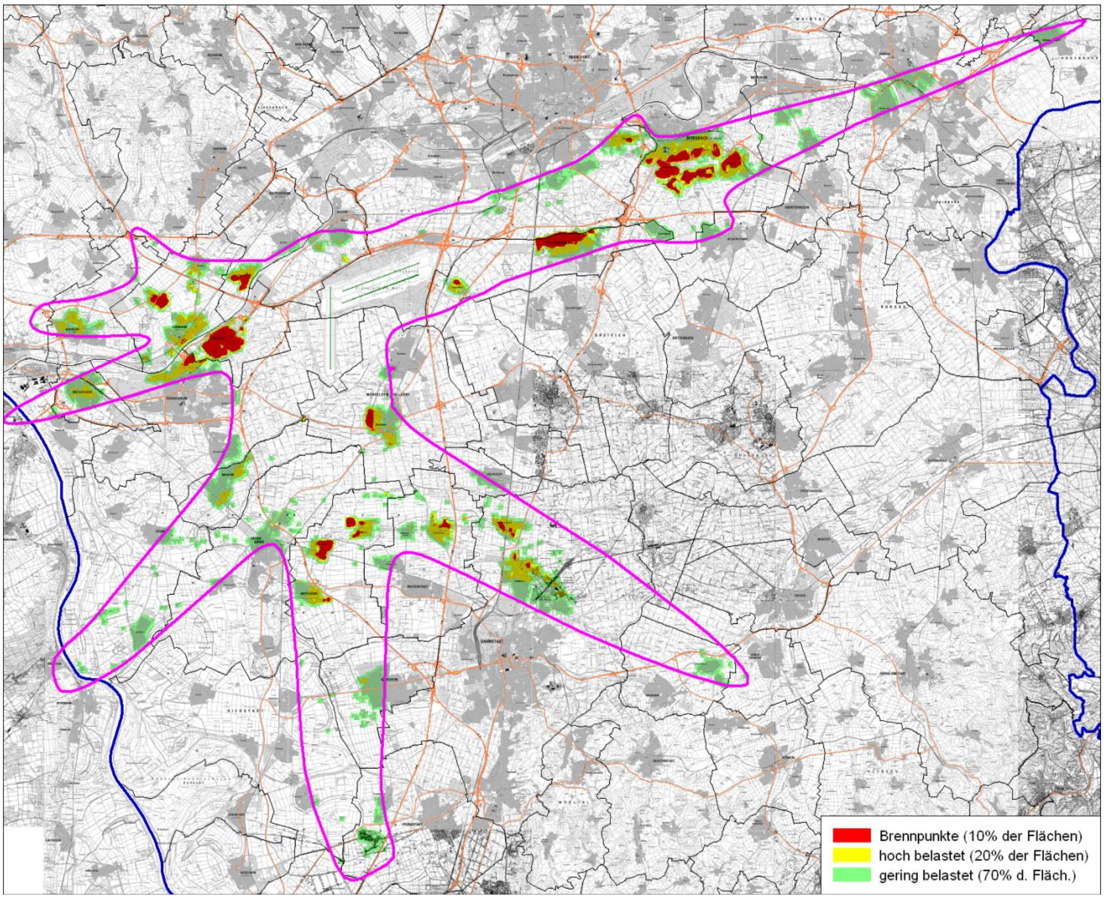
The costs and benefits shown below present value prices based on 2014.

Affected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
244	610.000	2.965.201,13	2.500,00	12.152,46	1 : 4,9

F.4.2 Case study – Frankfurt Airport, Germany

Frankfurt Airport was chosen as a case study because Frankfurt Airport is one of the busiest airports in Europe w2. ith comparatively high noise annoyance given its location in an urban area with high population density. The findings from the case study may be transferred to other major hub airports in Europe.

Figure 13: Detected hotspots of annoyance in the vicinity of Airport Frankfurt / Main



Note: The published NAP analyses the present and the future noise situation and shows in connection with technical and legal framework noise reduction measures, which were already implemented, are planned or are under discussion).

1. Planned and implemented measures

For the purposes of the CBA, it was only possible to include measures associated with the mandatory improvement of the sound insulation in residential buildings (e.g. soundproof windows) in accordance with the German aviation noise regulations (the "Fluglärmgesetz") as for this measure cost estimates were known. There were, however, a large number of measures, including flight or airport management optimizations, implemented over the last ten years, which have, according to the regularly updated noise maps, resulted in improvements. The costs of these measures have not, however, been included in the NAP and are therefore excluded from the analysis.

The improvement of sound insulation of residential buildings is one of the most effective measures in the short term, as noise reduction at source (aircraft) has to be agreed at the international level (ICAO) and require a change in the way in which aircraft fleets are operated.

These changes take much longer to implement and therefore the benefits (in the form of reduced noise levels) are less immediate.

Nevertheless, airports can incentivise the use of quieter aircraft and ban particular types as shown in the table below.

The table below shows the measures and status of implementation together with the total discounted capital costs of measures:

Table 134: List of measures

Name of measure	Year of implementation	Status	Present Value Costs (€, 2014 prices)
Restrictions for flights at night time	2004/2012	implemented	7,031,378
Restrictions for flight routes at night time	2007	implemented	
Noise related compensation for take-off and landing	2013/2014	implemented	
Noise optimized departure and arrival procedures	2007/2012	implemented	
Noise monitoring and tracking of distinctive noise events	2012	implemented	
Passive noise protection (e.g. soundproof windows)	ongoing since 2012	underway	5,417,685

Note – in Germany, it is common that cost estimates for groups of measures are provided rather than for individual measures.

The following chapters shows the costs and benefits of passive and active noise measures planned or implemented at Frankfurt airport.

2. Passive noise reduction measures

Costs

From interviews and additional written details from the responsible authority it was possible to interpolate costs for staff, consultants, public participation and the noise reduction measure itself. The costs are for the most part related to passive noise reduction and/or ventilation measures according to the 'Fluglärmgesetz' such as noise optimized windows.

The table below shows the accruing costs for END implementation and implemented passive noise measures.

Table 135: Costs

Total costs of END Implementation (€, discounted over a 25-year assessment period)[212]	
Staff Costs	2,244,442[213]
Consultants	37,617
Creation of the NAP draft, inventory	140,267
Creation of the NAP (Evaluation of questionnaires, publications, reporting)	178,522
Costs of measures (€, discounted)[214] over 25 years	
Total discounted capital costs of measures[215]	5,417,685
Total discounted maintenance costs of measures	-
GRAND TOTAL COSTS (€, discounted)	**8,018,533**

The total discounted costs over a 25-year-assessment period for passive noise measures are expected to amount to over € 10M.

Benefits

Table 136: Estimates of the change in the number of people exposed to harmful noise levels

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[216]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	0	34 652
55-59.9 dB(A)	0	1 514
60-64.9 dB(A)	0	0
65-69.9 dB(A)	0	0
70-74.9 dB(A)	0	0
Total	**0**	**36,166**

[212] These are the total costs incurred by the relevant implementing authorities in implementing the requirements of the END, discounted over a 25-year assessment period

[213] The responsible authority provided an estimate of 119, 000 hours and total personal costs between 2011 and 2015 of €3.1 million. The staff costs include the management of the measure "Passive noise protection at residential buildings" and the processing of 11,000 challenges from public participation.

[214] These are the total costs of measures to reduce or minimise noise levels

[215] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[216] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

Based on this information, and using established dose-response relationships for each of annoyance and sleep disturbance, the change in the size of the population that is sleep disturbed or highly sleep disturbed is estimated and the change in the *highly* sleep disturbed population valued in terms of DALYs (see Table 4).

Table 4 – Benefits associated with a reduction in the size of the sleep disturbed and highly sleep disturbed population

Change in size of the sleep disturbed population	Total	DALYs per year from a reduction in noise	Present Value Benefits (€, millions)
Sleep Disturbed	5,206	Not applicable*	Not applicable
Highly Sleep Disturbed	3,235	226	223

** Note that there are no established disability weights for the sleep disturbed population and therefore it is not possible to calculate DALYs.*

The present value represents the discounted value of DALYs over a 25-year assessment period. Note that this is a reflection of the value with the current range of measures in place. It does not take account of additional measures that could potentially be identified in future NAPs (and then implemented).

Another benefit of the noise reduction measures in Frankfurt Germany is that the number of people whose sleep is disturbed has been reduced by 5,206, and the number of people whose sleep is highly disturbed has been reduced by another 3,235, corresponding to a decrease in disability-adjusted life years of 226 per year. This decrease is valued at € 223 million over a 25 year assessment period.

The benefit of the passive noise reduction measures at Frankfurt airport amounts to:

Net Present Value (€): 208,388,541.

3. Active noise reduction measures

Costs

The airport estimates the costs for active noise reduction measures implemented between Round 1 and 2 are €1.5 M per year (2008-2011). In 2012 the costs amount to about € 4.2 M. This adds up to a total discounted cost (based on 2014) of € 8.5 M over a period of 5 years.

Benefits

Using information from the Strategic Noise Maps produced under each of the first and second rounds of reporting (2007 and 2012 respectively), it is possible to determine the change in the number of people exposed to noise levels above 55 dB L_{den} and 50 dB L_{night} at Frankfurt Airport (see Table 3).

Table 137: Estimates of the change in the number of people exposed to harmful noise levels

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction measures[217]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	0	33,158
55-59.9 dB(A)	3,211	2,053
60-64.9 dB(A)	13,211	0
65-69.9 dB(A)	0	0
70-74.9 dB(A)	0	0
Total	**16,421**	**35,211**

Based on this information, and using established dose-response relationships for each of annoyance and sleep disturbance, the change in the size of the population that is highly annoyed or highly sleep disturbed is estimated and the change in the *highly* annoyed and *highly* sleep disturbed population valued in terms of DALYs (see Tables 5 and 6).

Table 138: Benefits associated with a reduction in the size of the annoyed and highly annoyed population

Change in size of the annoyed population	Total	DALYs per year as a result of noise reduction	Present Value Benefits (€, millions)
Annoyed	12,738	Not applicable*	Not applicable
Highly Annoyed	6,294	126	124

** Note that there are no established disability weights for the annoyed population and therefore it is not possible to calculate DALYs.*

As the table above illustrates, the number of people annoyed was reduced by 12,738 due to noise reduction measures, and the number of people highly annoyed was reduced by 6,294 people, resulting in a decrease in disability-adjusted life years (for the highly annoyed population) of 126 per year.

The present value represents the discounted value of DALYs over a 25-year assessment period. Note that this is a reflection of the value with the current range of measures in place. It does not take account of additional measures that could potentially be identified in future NAPs (and then implemented).

[217] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

Table 139 – Benefits associated with a reduction in the size of the sleep disturbed and highly sleep disturbed population

Change in size of the sleep disturbed population	Total	DALYs per year from a reduction in noise	Present Value Benefits (€, millions)
Sleep Disturbed	9,680	Not applicable*	Not applicable
Highly Sleep Disturbed	6,022	422	416

** Note that there are no established disability weights for the sleep disturbed population and therefore it is not possible to calculate DALYs.*

Another benefit of the noise reduction measures in Frankfurt Germany is that the number of people whose sleep is disturbed has been reduced by 9,680, and the number of people whose sleep is highly disturbed has been reduced by another 6,022, corresponding to a decrease in disability-adjusted life years of 422 per year. This decrease is valued at € 416 million over the 25 year assessment period.

The estimate of the total value of the beneficiary population that lives within the vicinity of Frankfurt is however considered to be understated for the following reasons:

- The tables above show changes in number of households and population affected above 55 dB (L_{den}) and 50 dB (L_{night}). These are the limits set to fulfil the minimum requirement for Strategic Noise Mapping and do not allow the conclusion of no effects at lower noise levels. More simply, the benefit estimates do not take account of those who may previously (prior to the END) have experienced noise levels at or below 55 dB L_{den} or 50 dB L_{night} and who have since experienced a further reduction in noise levels as a result of the END.

- The stated benefits do not take account of the effects of one of the most widespread and effective noise reduction measures (soundproofing of buildings). This is because strategic noise mapping measures noise at the most exposed façade of the building and therefore cannot take account of measures that improve indoor noise levels. If we assume that (in accordance with German legislation) all residential buildings that are affected by aircraft noise (exceeding 55 dB by night at the external façade) are sound-proofed such that no more sleep disturbance may be expected, the benefit will increase by approximately €10 million per year.

This benefit can easily calculated by reducing the number of affected persons in the 5 dB-band to 0, as after implementation of ventilation and improved windows and façades the indoor level will be reduced by at least 15 dB(A). This will lead to indoor levels, which will not cause sleep disturbance due to aircraft noise anymore.

The benefit of the active noise reduction measures at Frankfurt airport amounts to:

Net Present Value (€): 814,868,622.

4. Cost Benefit Analysis of individual measures

Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Appendix D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Appendix D.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Appendix E.

CBA of individual measures

The following tables present the results of the CBA performed for individual measures at Frankfurt Airport.

Improvement of Windows/Facades

Eligibility for the campaign was based on limiting noise levels according German law (Fluglärmgesetz). A total of around 1600 applications for funding were received and approximately 3176 persons were covered by the campaign.

The benefits of measure exceed the costs many times over. The noise proof window/fassade campaign at Frankfurt Airport shows one of the best CB-Ratio of all assessed measures.

The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
3,176	10.3 M €	322.9 M €	3,240 €	101,000 €	1: 31

Combination of all planned and implemented measures (low noise routing, flight restriction by night, land use planning, quietest practicable aircraft operations) including strategic Noise mapping and noise action planning

The NAP for Frankfurt Airport describes many activities and efforts of the airport operator, the communities in the surrounding of the airport and the responsible authorities. Besides research on optimized aircraft operations and health effects also an ongoing process of a dialog with affected inhabitants and representatives of communities were started many years ago.

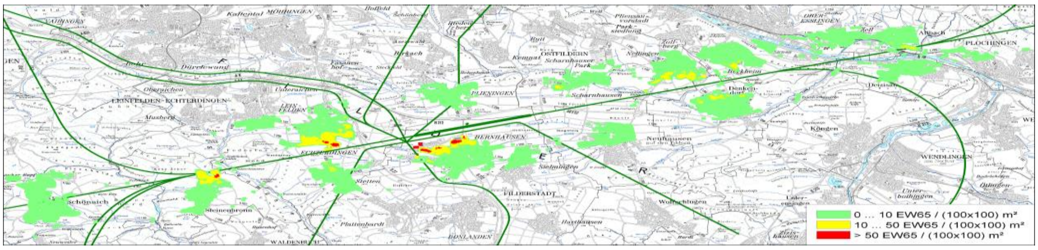
The costs and benefits shown below present value prices based on 2014.

Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio
240,000	21 M €	910 M €	88 €	3791	1: 43

F.4.3 Case study – Stuttgart Airport, Germany

Stuttgart Airport is a typical single runway airport, with comparatively small noise annoyance in the surrounding due to its situation in a rural area with mean population density. From the results of the case study we may expect transferable knowledge for other **European single runway airports**.

Figure 14: Detected hotspots in the vicinity of Stuttgart Airport



The published NAP analyses the present and the future noise situation and shows in connection with technical and legal framework noise reduction measures, which were already implemented, or are planned or are in discussion.

1. Planned and implemented measures

For the purposes of the CBA, it was only possible to include measures associated with the mandatory improvement of the sound insulation in residential buildings (e.g. soundproof windows) for the same reasons as for the Frankfurt airport.

The table below shows the measures and status of implementation together with the total discounted capital costs of measures:

Table 140: List of measures

Name of measure	Year of implementation	Status	Present Value Costs (€, 2014 prices)
Restrictions for flights at night time	2004/2012	implemented	120,362
Restrictions for flight routes at night time	2007	implemented	
Noise related compensation for take-off and landing	2013/2014	implemented	
Noise optimized departure and arrival procedures	2007/2012	implemented	
Noise monitoring and tracking of distinctive noise events	2012	implemented	
Improvement of windows and installation of ventilation	2013 ongoing	underway	54,366

2. Costs

From interviews and additional written details from the responsible authority it was possible to interpolate costs for staff, consultants, public participation and the noise reduction measure itself.

The table below shows the accruing costs for END implementation and implemented measures:

Table 141: Costs

Total costs of END Implementation (€, discounted over a 25 year assessment period)[218]	
Additional staff time	91,888
Noise mapping	9,484
Technical consultant	15,315
Public consultation	3,676
Costs of measures (€, discounted)[219] over 25 years	
Total discounted capital costs of measures[220]	54,366
Total discounted maintenance costs of measures[221]	-
GRAND TOTAL COSTS (€, discounted)	**174,727.96**

The bulk of expenditure at Stuttgart Airport to additional staff time and consultant costs. The total costs of measures over a 25-year-assessment period are expected to amount to just under €175,000.

3. Benefits

Based on the Strategic Noise Maps of the 1st round (2007) the change of affected people until 2012 was estimated. This was necessary, as the airport was not mapped in the second round of strategic noise mapping. The reason was that there were nearly the same number of movements and mix of aircrafts operating at the airport, so that the estimated small improvement of the noise situation did not justify a repeated calculation of the strategic noise indices.

Based on these estimated small "number of people affected in 5 dB noise bands" the "Change in number of households" affected by aircraft noise and the monetized change in "annoyance" and "sleep disturbance" can be calculated.

Based on this information, and using established dose-response relationships for each of annoyance and sleep disturbance, the change in the size of the population that is highly annoyed or highly sleep disturbed is estimated and the change in the *highly* annoyed and *highly* sleep disturbed population valued in terms of DALYs (see Tables 4 and 5).

[218] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[219] These are the total costs of measures to reduce or minimise noise levels

[220] Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

[221] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

The following tables show the benefit in detail:

Table 142: Estimates of the change in the number of people exposed to harmful noise levels

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction[222]	
	L_{den}	L_{night}
45-49.9 dB(A)	0	0
50-54.9 dB(A)	0	0
55-59.9 dB(A)	0	50
60-64.9 dB(A)	0	0
65-69.9 dB(A)	100	0
70-74.9 dB(A)	0	0
Total	**100**	**50**

As the table above shows, noise reduction due to measures had an impact on the number of people exposed to noise (L_{den}) exceeding 65 dB and on the number of people exposed to noise (L_{night}) exceeding 55 dB. This is in fact a small reduction against the total population affected by aircraft noise around Stuttgart Airport of 44,200 people.

Table 143: Benefits associated with a reduction in the size of the annoyed and highly annoyed population

Change in size of the annoyed population	Total	DALYs per year	Present Value Benefits (€)
Annoyed	54	Not applicable*	Not applicable
Highly Annoyed	32	1	622,290

** Note that there are no established disability weights for the annoyed population and therefore it is not possible to calculate DALYs.*

As the table above illustrates, the number of people annoyed was reduced by 54 due to noise reduction measures, and the number of people highly annoyed was reduced by 32 people, resulting in a decrease in disability-adjusted life years of 1 per year.

Table 144: Benefits associated with a reduction in the size of the sleep disturbed and highly sleep disturbed population

Change in size of the sleep disturbed population	Total	DALYs per year	Present Value Benefits (€)
Sleep Disturbed	9	Not applicable*	Not applicable
Highly Sleep Disturbed	6	0.426	420,438

** Note that there are no established disability weights for the sleep disturbed population and therefore it is not possible to calculate DALYs.*

---

[222] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures. These numbers do not, however, include the effects of sound-proofing and improved ventilation systems.

Another benefit of noise reduction measures for Stuttgart Airport is that the number of people whose sleep is disturbed has been reduced by 9, and the number of people whose sleep is highly disturbed has been reduced by another 6, corresponding to a decrease in disability-adjusted life years of 153. This decrease is valued at around € 420,000.

On the basis of the available information, the total Net Present Value is estimated to be around €2.4 million over the 25 year assessment period. This is, however, believed to understate the level of benefits as the most effective reduction measure "improvement of the sound insulation" only improves the indoor noise level and will not affect the (outdoor based) strategic noise indicators (at the most exposed facade). Therefore the real benefit in particular on reduction of sleep disturbance (which correlates with noise levels at the ear of the sleeper) is underestimated.

If we presume that according to German legislation all residential buildings, which are affected by aircraft noise (exceeding 55 dB by night) will be improved in a way, that no more sleep disturbance may be expected, the benefit will increase by around €1.4 million per year.

4. Cost Benefit Analysis of individual measures

Employed method

Below selected generally effective measures or measure combinations are evaluated in terms of cost and effectiveness in the case study area. Both planned and implemented measures were chosen to show the cost benefit relation of individual measures.

The calculation of costs is based on published noise action plans and interviews with the competent authorities. If no specific costs are available, cost estimates in accordance with recognized procedures and methods were employed (see Appendix D).

The effectiveness of the measures was determined on the basis of measures outlined in the noise action plan in conjunction with recognized procedures set out in Appendix D.

Initially an assessment of the reduction of noise affected people on the basis of 5 dB level classes was carried out. This forms the basis of a monetary evaluation of the reduction of noise damage based on the method described in Appendix E.

CBA of individual measures

The following table present the results of the CBA performed for an individual measure at Stuttgart Airport.

Improvement of Windows/ façades

Eligibility for the campaign was based on limiting noise levels according German law. A total of around 25 applications for renewal were carried out and approximately 50 persons were covered by the campaign.

The benefits of measure exceed the costs many times over. The noise proof window/façade campaign at Vienna Airport shows a positive CB-Ratio.

The costs and benefits shown below present value prices based on 2014.

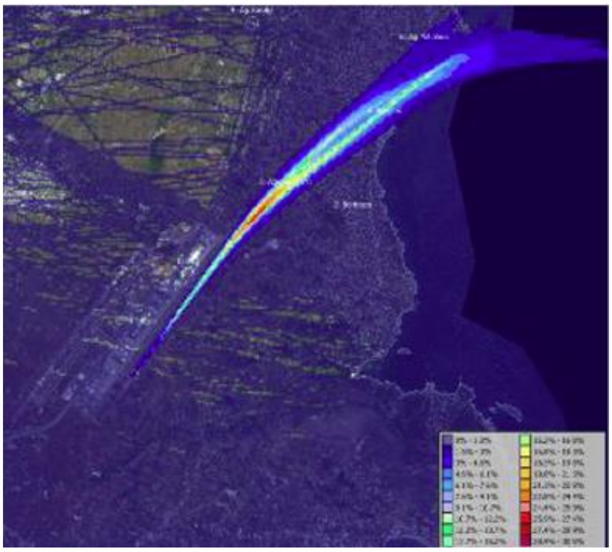
Effected Residents	Total Present Value Costs	Total Present Value Benefits	Average present value cost per person	Average present value benefit per person	CB-Ratio

50	66.144,79	607.623,18	1.322,90	12.152,46	1: 9.2

F.4.4 Case study 4 – Athens Airport, Greece

Athens International Airport is a typical south European major 2-runways airport, with comparatively small noise annoyance in the surrounding due to its situation in a rural area with mean population density and close to the sea. From the results of the case study we may expect transferable knowledge for other **European 2- runway airports**.

Figure 1: Detected take-off movements in the vicinity of Athens



The published NAPs from 2007 and 2012 analyses the present noise situation and shows implemented noise reduction measures at the airport. Most of the measures are operational noise abatement procedures, which have been established prior to the operation of the airport in cooperation with the Helenic Civil Aviation Authority. The procedures have been published in the AIP Greece and include measures concerning runway use including restrictions during night, the aircraft engine testing and Auxiliary Power Unit (APU) usage.

Planned and implemented measures

For the purposes of the CBA, only measures planned or implemented within the first and second round strategic noise mapping according END will be considered.

The table below shows the measures and status of implementation together with the total discounted capital costs of measures:

Table 145: List of measures

Name of measure	Year of implementation	Status	Present Value Costs (€, 2014 prices)
Flight restrictions for quiet noise marginally accepted Chapter 3 aircrafts on runway 03R for take-off and runway 21 L for landing	2010	implemented	Not published
Flight restrictions for military aircrafts on runway 03R for take-off and runway 21 L for landing	2011	implemented	Not published
Implementation of noise reducing take-off and landing procedures (unless necessary for safety reasons)	2011	implemented	Not published

1. Costs

Based on an interview with the responsible consultant for the preparation of the NAPs and knowledge about the comparable costs at other airports the total costs for staff, consultants, public participation and the noise reduction measure itself were estimated.

The table below shows the accruing costs for END implementation and implemented measures:

Table 146: Costs

Total costs of END Implementation (€, discounted over a 25 year assessment period)[223]	
Additional staff time	51,776
Consultants	
(Mapping) Software	
Reporting	
Costs of measures (€, discounted)[224] over 25 years	
Total discounted capital costs of measures[225]	523,979 (assumed to be 10% of Frankfurt airport costs)
Total discounted maintenance costs of measures[226]	-
GRAND TOTAL COSTS (€, discounted)	575,755.17

2. Benefits

Based on the Strategic Noise Maps of the 1st round (2007) and the 2nd round (2012) it is not possible to quantify exactly the effects of the implemented measures within this period, as there was also a general decrease of flight movements due to economic crisis.

The table below show the change of aircraft group specific movements which ends in an overall reduction of about 15.000 movements per year.

Table 147: aircraft group specific movements in 2006 and 2011

SNM	P1	P 2.1	P 2.2	S 5.1	S 5.2	S 5.3	S 6.1	S 6.2	S 6.3	S 7	TOTAL YEAR
2006	4.805	39.134	399	25.662	97.100	3.953	10.667	176	2.395	303	**184.594**
	2.6%	21.2%	0.2%	13.9%	52.6%	2.1%	5.8%	0.1%	1.3%	0.2%	**100.0%**
2011	1.807	38.284	347	12.963	108.323	496	6.242	366	376	269	**169.473**
	1.1%	22.6%	0.2%	7.6%	63.9%	0.3%	3.7%	0.2%	0.2%	0.2%	**100.0%**

NB * military and other special flights as well as helicopters are not included

Nevertheless compared to the noise situation in 2006 a significant decrease of affected persons in the surrounding of the airport can be recognized.

---

223 These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

224 These are the total costs of measures to reduce or minimise noise levels

225 Note that these are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

226 These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

Table 148: Distribution of affected residents at Athens Airport 2011

NOISE ZONE		DISTRIBUTION OF REAL POPULATION IN NOISE ZONES FOR L_{den}	
from	To	No of residents	No of residents in hundreds
55	60	9.605	96
60	65	1.320	13
65	70	0	0
70	75	0	0
	>75	0	0

NOISE ZONE		DISTRIBUTION OF REAL POPULATION IN NOISE ZONES FOR L_{night}	
from	to	No of residents	No of residents in hundreds
50	55	1435	14
55	60	0	0
60	65	0	0
	>65	0	0

Table 149: Distribution of affected residents at Athens Airport 2006

NOISE BUFFER ZONE		DISTRIBUTION OF REAL POPULATION PER NOISE INDEX (%)	
from	to	Lden	
	<55	49.394	76,7%
55	60	12.676	19,7%
60	65	2.294	3,6%
65	70	0	0,0%
70	75	0	0,0%
	>75	0	0,0%
TOTAL OF REAL POPULATION for the urban land uses of the study area		64.364	100,0%
NOISE BUFFER ZONE		DISTRIBUTION OF REAL POPULATION PER NOISE INDEX (%)	
from	to	Lnight	
	<50	59.654	92,7%
50	55	4.518	7,0%
55	60	192	0,3%
60	65	0	0,0%
	>65	0	0,0%
TOTAL OF REAL POPULATION for the urban land uses of the study area		64.364	100,0%

Using this noise data, and using established dose-response relationships for each of annoyance and sleep disturbance, the change in the size of the population that is highly annoyed or highly sleep disturbed is estimated and the change in the *highly* annoyed and *highly* sleep disturbed population valued in terms of DALYs. The following tables show the benefit in detail:

Table 6: Estimates of the change in the number of people exposed to harmful noise levels

Noise interval	Change in the number of people exposed to noise at the following intervals as a result of noise reduction[227]	
	L_{den}	L_{night}
45-49.9 dB(A)	-	-
50-54.9 dB(A)	0	3083
55-59.9 dB(A)	3071	192
60-64.9 dB(A)	974	0
65-69.9 dB(A)	-	-
70-74.9 dB(A)	-	-
Total	**4045**	**3275**

As the table above shows, noise reduction due to measures and general reduction of number of flight movements had an impact on the number of people exposed to noise (L_{den}) exceeding 55 dB and on the number of people exposed to noise (L_{night}) exceeding 50 dB. This is in fact a significant reduction against the total population affected by aircraft noise around Athens Airport of 14,970 people.

Table 7: Benefits associated with a reduction in the size of the annoyed and highly annoyed population

Change in size of the annoyed population	Total	DALYs per year	Present Value Benefits (€)
Annoyed	1.417	Not applicable*	Not applicable
Highly Annoyed	631	13	18.005.509

** Note that there are no established disability weights for the annoyed population and therefore it is not possible to calculate DALYs.*

As the table above illustrates, the number of people annoyed was reduced by 1,417 due to noise reduction measures and general decrease of flight movements, and the number of people highly annoyed was reduced by 631 people, resulting in a decrease in disability-adjusted life years of 13 per year.

Table 150: Benefits associated with a reduction in the size of the sleep disturbed and highly sleep disturbed population

Change in size of the sleep disturbed population	Total	DALYs per year	Present Value Benefits (€)
Sleep Disturbed	474	Not applicable*	Not applicable
Highly Sleep Disturbed	295	21	20,361,207

** Note that there are no established disability weights for the sleep disturbed population and therefore it is not possible to calculate DALYs.*

[227] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures. These numbers do not, however, include the effects of sound-proofing and improved ventilation systems.

Another benefit of noise reduction measures for Athens Airport is that the number of people whose sleep is disturbed has been reduced by 474, and the number of people whose sleep is highly disturbed has been reduced by another 295, corresponding to a decrease in disability-adjusted life years of 21 per year. This decrease is valued at just over € 20 m over the 25 year assessment period.

On the basis of the available information, the total Net Present Value is estimated to be around €98 million over the 25 year assessment period. This is, however, significantly influenced by a decrease of flight movements in the past. This effect is not caused by the implemented noise reduction measures itself.

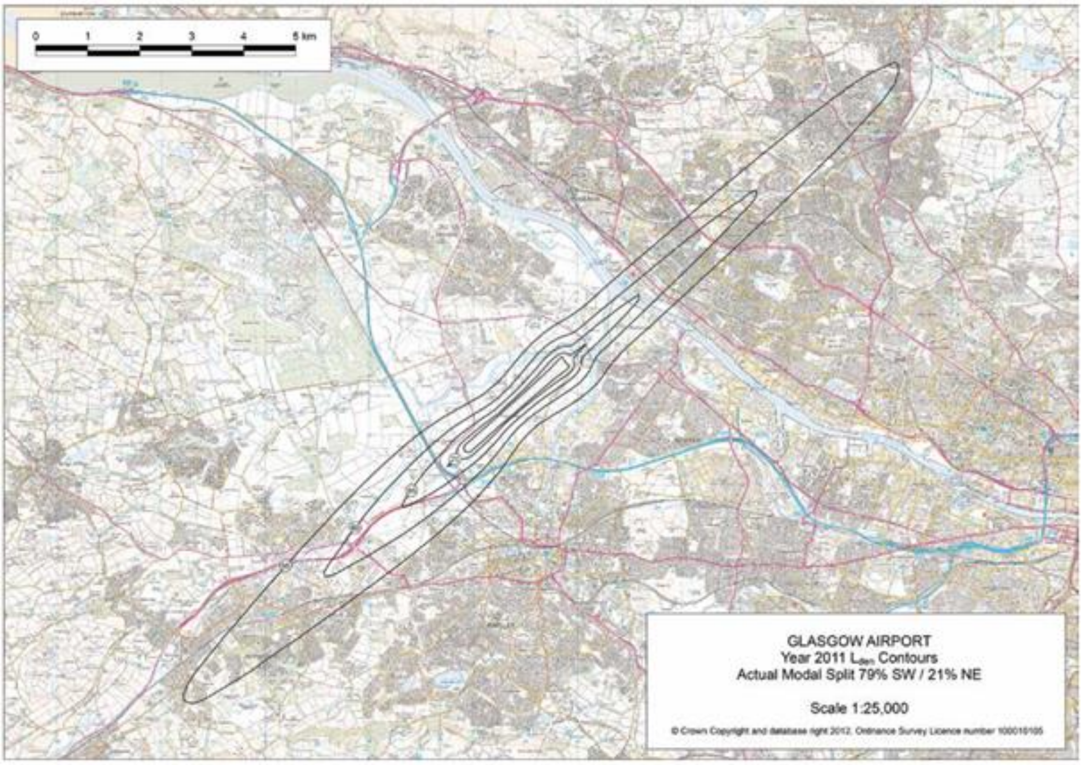
3. Cost Benefit Analysis of individual measures

A reliable statement of a CB-ratio of single measures or combinations of measures is not possible due to data deficiencies in the database at Athens Airport and the fact that the noise reductions after implementation of measures are significantly influenced by a reduction of flight movements due to economic reasons (i.e. the economic crisis in Greece).

F.4.5 Case study 5 – Glasgow Airport, UK

Glasgow Airport was chosen as a case study because it is a good example for a remote but at the same time very frequented airport. Glasgow airport handles 7 to 8 million passengers per year serving the Glasgow area but also providing transatlantic connections. Located 11 km west of Glasgow city centre it still affects some urban areas of the city. The findings from the case study may be transferred to other regional airports in Europe.

The airport has published NAPs for Round 1 and 2 of the END. All noise abatements measures of NAP 2008-2012 were implemented by the year 2012. Further measures and ongoing efforts are outlined in the NAP 2013-2018.



Lden Noise Map Glasgow Airport 2011, Source: Draft Noise Action Plan 2013-2018, Aug. 2013

1. Costs

The total cost of END implementation incurred from 2008 onwards is presented in Table 1 below. The bulk of expenditure of implementation of the END for Glasgow Airport relates to staff, computer and equipment costs. The costs of measures were not provided as separate costs although a general statement on the investment in improvements was obtained.

The following information on investment in improvements was obtained:

> '*Since 2006, more than £60 million has been invested in developing and improving Glasgow Airport to create an airport of which Glasgow and Scotland can be proud. This is an on-going process which is being undertaken at no cost to the taxpayer. It is anticipated that over £200 million will be invested over the next 1O years to build on these improvements'* (Glasgow Airport Draft Master Plan 2011"; "draft-master-plan-web-small-4.pdf", page 28).

The total costs over a 25-year-assessment period are expected to amount to approximately € 128,000.

Table 151 – Costs

Total costs of END Implementation (€, discounted)[228]	
Staff Costs	49,091
Computer Costs	26,509
Equipment Costs	19,636
Publications	4,909
Fines	982
Costs of measures (€, discounted)[229] over 25 years	
Total discounted capital costs of measures[230]	5,755,179
Total discounted maintenance costs of measures[231]	-
GRAND TOTAL COSTS (€, discounted)	5,856,305.65

[228] These are the total discounted costs incurred by the relevant implementing authorities in implementing the requirements of the END

[229] These are the total costs of measures to reduce or minimise noise levels

[230] Note that these are total estimated costs taken from published NAP

[231] These are total discounted costs (i.e. total projected costs discounted over a 25-year assessment period)

The following table presents the measures taken on the basis of the noise action plans 2008 and 2012.

Table 152 – List of measures

Name of measure	Year of implementation	Status	Present value (€, 2014 prices)
Quietest Fleet Practicable	2009	completed	-
Quietest practicable aircraft operations, balanced against NOX and CO2 emissions	2008	partly completed /underway	-
Effective and credible noise mitigation schemes	2008	ongoing	-
Engage with communities affected by noise impacts to better understand their concerns and priorities, reflecting them as far as possible in airport noise strategies and communication plans	2008	On-going	-
Influencing planning policy to minimise the number of noise sensitive properties around our airports	2008	On-going	-
Organising ourselves to manage noise efficiently and effectively	2008	On-going	-
Achieving a full understanding of aircraft noise to inform our priorities, strategies and targets	2008	On-going	-
Aircraft technology	2012	On-going	-
Quieter operation procedure	2012	On-going	-
Noise insulation and land use planning	2012	On-going	-
Operating restrictions	2012	On-going	-

All measures listed above are underway; however the degree of completion is unknown as most of the actions are on-going management efforts and organisational changes. This means that the impact of many of these measures will only materialise in the future, and the benefits presented further below need to be interpreted in that context.

2. Benefits

Using information from the Strategic Noise Maps produced under each of the first and second rounds of reporting, it is possible to determine the change in the number of people exposed to noise levels above 55 dB L_{den} and 50 dB L_{night}, as presented in table 3.

Table 153 – Benefits – exposed population

Noise interval	Change in the number of households exposed to noise at the following intervals as a result of noise reduction measures[232]	
	L_{den}	L_{night}
45-49.9 dB(A)	-	-
50-54.9 dB(A)	-	-
55-59.9 dB(A)	26,950	21,100
60-64.9 dB(A)	8,550	1,550
65-69.9 dB(A)	400	-
70-74.9 dB(A)	-	-
>75.0 dB(A)	-	-
Total	35,900	22,650

As the table above shows, the impact of noise reduction measures on the number of people exposed to noise (L_{den} and L_{night}) up to 54.9 dB was not estimated, but did reduce the number of people exposed above 54.9 dB by about 35,900 overall against a total affected population of about 68,000 in the study area.

Based on this information, and using established dose-response relationships for annoyance and sleep disturbance, the changed numbers of people highly annoyed or highly sleep disturbed is estimated and valued in terms of DALYs (see tables 152 and 153).

Table 154 – Benefits – annoyance

Change in size of the annoyed population[233]	Aircraft	Total	DALYs per year	Present Value (€)
Annoyed[234]	12,657	12,657	n/a	n/a
Highly Annoyed[235]	5,668	5,668	113	111,833,249

[232] Note that these include noise reductions that may have been achieved independently of the END. It is not possible to distinguish between noise reductions that may be attributed to END versus noise reductions that may be attributed to other measures.

[233] This is an estimate of the burden of disease from noise-induced annoyance. It reflects the variety of negative responses (e.g. anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion) that people may experience. Noise exposure and annoyance has also been shown to be associated with stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress.

[234] The Present Value represents the discounted stream of annual benefits over a 25-year assessment period

[235] Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels.

As the table above illustrates, the number of people annoyed was reduced by 12,657 due to noise reduction measures, and the number of people highly annoyed was reduced by 5,668 people, resulting in a decrease in disease-adjusted life years of 113 per year and is valued at € 112m over 25 years..

Table 155 – Benefits – sleep disturbance

Change in size of the sleep disturbed population	Aircraft	Total	DALYs per year	Present Value (€)
Sleep Disturbed	4,323	4,323	n/a	n/a
Highly Sleep Disturbed	2,822	2,822	198	194,860,300

Another benefit of the noise reduction measures for Glasgow Airport is that the number of people whose sleep is disturbed could be reduced by 4,323, and the number of people whose sleep is highly disturbed has been reduced by another 2,822. This corresponds to a decrease in disease-adjusted life years of 198 and is valued at € 282 M.

Another benefit of the noise reduction measures for Glasgow Airport is that the number of people whose sleep is disturbed could be reduced by 4,323, and the number of people whose sleep is highly disturbed has been reduced by another 2,822. This corresponds to a decrease in disease-adjusted life years of 198 per year and is valued at € 282m over 25 years.

Table 6 – Benefits – Hypertension

	DALYs per year	Present Value (€)
Change in the number of DALYs per year resulting from hypertensive heart disease and attributable to transport noise[236]	34	3,733,107
Total value of avoided DALYs from a reduction in the incidence of noise-induced hypertensive heart disease		33,184,835

The benefit of the END implementation for the population around Glasgow Airport amounts to:

Net Present Value (€): 334,022,079.

3. Cost Benefit Analysis of individual measures

The database at Glasgow Airport does not allow a reliable statement of a CB-ratio of single measures or combinations of measures is not possible.

[236] The change in DALYs is calculated as the % of all DALYs from hypertensive heart disease in the relevant Member State that can be attributed to environmental noise. The Present Value is the number of DALYs multiplied by the value of a DALY

APPENDIX G - CHALLENGES IN IMPLEMENTING THE REVISED ANNEX II (DIRECTIVE 2015/996) AND THE EXTENT OF TECHNICAL AND SCIENTIFIC PROGRESS

The terms of reference for this study set out a number of questions relating to assessing progress towards the objective of a common approach. One of the main elements of a common approach, although by no means the only one, was the development of common noise assessment methods through CNOSSOS. In this annex, we review the following:

- The development of the CNOSSOS methodology - and examination of the extent to which the common noise assessment method was adapted to technical and scientific progress.
- Outstanding challenges in implementing the revised Annex II, Directive 2015/996 based on the CNOSSOS methodology.
- Implementation challenges – strategic noise mapping.

The development of CNOSSOS – and extent to which the common noise assessment method was adapted to technical and scientific progress

In addressing EQ7(a), the following question has been considered: **EQ7e - Has the Directive been adapted to technical and scientific progress?** There is a requirement in the END to take into account state of the art and technical and scientific developments in the development of common noise assessment methods[237]. This is relevant in particular to the revision of Annex II (common noise assessment methods) and Annex III (assessment methods for harmful effects).

The assessment of the extent to which the development of a common approach has taken into account technical and scientific progress drew on stakeholder feedback from the interviews and desk research to review the process of developing CNOSSOS (how it was organised, the extent to which relevant expertise was drawn upon etc.).

The development of the CNOSSOS-EU methodology was the result of **in-depth technical consultation between relevant stakeholders,** notably the EC services, the EEA, the European Aviation Safety Agency (EASA), the World Health Organization (WHO-Europe) and nearly 150 noise experts. By 2015, work to develop CNOSSOS provided the technical basis for preparing a Directive to revise Annex II of the END.

[237] In accordance with Art. 6.2 of the END, the EC developed the common noise assessment framework (CNOSSOS-EU) for road, railway, aircraft and industrial noise for the purpose of strategic noise mapping (Art. 7).

Many elements of the development of CNOSSOS were of a technical nature. An overview of the roadmap for the development of CNOSSOS is reproduced below to help facilitate an understanding of the complexity of the development of the CNOSSOS-EU methodological framework and the scientific, technical and technological challenges:

Table 156 - Roadmap for the development of the CNOSSOS-EU methodological framework

1	The assessment of the equivalence of existing noise assessment methods in the EU;
2	The definition of the target quality and input value requirements for strategic noise mapping;
3	The establishment of requirements and criteria for the screening, rating and pre-selection amongst existing assessment methods in the EU, the USA and Japan that best cover the needs and requirements of the END;
4	The conceptualisation of a 'fitness for purpose' framework allowing for the application of CNOSSOS-EU methodology at two levels of detail and conformity, depending on the objectives of the assessment (i.e. strategic noise mapping on a mandatory basis — first level of application, and action planning on a voluntary basis — second level of application);
5	The selection of components for common noise assessment methods through a series of dedicated workshops, benchmarking/testing exercises and meetings with European noise experts;
6	The drafting of the CNOSSOS-EU methodological framework including guidelines for its use for strategic noise mapping and associated requirements for input data collection and modelling;
7	The preparation of the operational part of CNOSSOS-EU and long-term planning to assist EU MS to implement CNOSSOS in the context of the future rounds of strategic noise mapping in Europe.
8	The legal act to revise Annex II of the END and for subsequent enforcement of CNOSSOS-EU in EU Member States.

Source: JRC and DG ENV - http://www.sciencedirect.com/science/article/pii/S0048969714001934

The steps above required an ongoing assessment of technical and scientific state of the art, and regular liaison with the 150 noise experts that assisted in the CNOSSOS process which involved technical input to develop a common assessment method for each source. The noise experts contributed to the development of the technical part of CNOSSOS relating to the modelling of noise emissions.

The results of EU-funded research projects to identify state of the art were also incorporated into CNOSSOS' development, namely through the **Harmonoise project**[238] and the **IMAGINE project**[239], which aimed to harmonise the assessment of environmental noise for improved noise mapping through a holistic approach to mapping and modelling noise pollution. Both projects were funded through FP6's Support to Policies Programme (SPP).

[238] FP6 - HARMONOISE (Harmanised Accurate and Reliable Methods for the EU Directive on the Assessment and Management of Environmental Noise).

[239] https://ec.europa.eu/research/fp6/ssp/imagine_en.htm

The **HARMONOISE model** requires impedance values to be assigned to all surfaces in the propagation path, including vertical walls and facades. A comparative assessment was undertaken of the advantages of the HARMONOISE method in comparison with alternative methods and was considered by the Commission's ENV and the JRC to be superior to the NMPB 2008 and ISO 9613-2 methods. The results from the **IMAGINE project** (IMAGINE WP 1, 2007) were used relating to the classification of noise barriers according to the EN 1793-1 standard. These were then converted these back into DLɑ values into equivalent impedance values. The integration of the results of 'state of the art' research projects into CNOSSOS' development demonstrates that **due account has been taken of scientific and technological state of the art.**

A research paper[240] was produced relating to the challenges encountered in the development of CNOSSOS which emphasised that a number of specific challenges of a scientific and technical nature were taken into consideration in its development. Overall, the Directive has been adapted to technical and scientific progress in noise assessment and has drawn on existing best practice in this area from the Member States.

Outstanding challenges in implementing the revised Annex II, Directive 2015/996

Whilst recognising the considerable achievements of CNOSSOS, it is important to examine the outstanding challenges to its full and effective implementation and also to consider any less positive feedback from END stakeholders.

A number of areas of weakness were identified that still need to be addressed before a common approach can be regarded as having been fully realised. It was observed by a number of END stakeholders interviewed that although the development of a common approach is an important step, this will only lead to comparable data across the EU in R4 (2022) at the earliest, since the implementation of CNOSSOS at national level will only be voluntary in R3.

The stakeholders interviewed pointed out that this means that it will be more difficult to **achieve comparable data**:

- ***Between EU countries*** – the EEA needs comparable population exposure data across EU28 in order to fulfil its reporting obligations under the END and for the preparation of the Noise in Europe report. Data produced on a comparable basis will not however be available until R4.
- ***Between END implementation rounds –*** until CNOSSOS is fully implemented in R4 (2022), it will not be possible to make comparisons of changes in population exposure on a consistent basis across each five year cycle. A dataset comparable between rounds will only be possible in R5 (2027), when there will then be two successive rounds of noise mapping using CNOSSOS (i.e. R4 and R5).

Interviewees in smaller countries also raised the issue about the need for **greater caution in making cross-country comparisons without suitable contextualisation** even once data comparability between countries has been improved.

Several stakeholders also noted that perceptions of environmental noise at receptor may vary depending on local-specific factors. This was mentioned for instance by a European aviation association and a number of acoustics consultants interviewed.

[240] Advances in the development of common noise assessment methods in Europe: The CNOSSOS-EU framework for strategic environmental noise mapping, Stylianos Kephalopoulos, Marco Paviotti1, Fabienne Anfosso-Lédée, Dirk Van Maercke, Simon Shilton, Nigel Jones. www.sciencedirect.com/science/article/pii/S0048969714001934

A technical issue raised relating to how the effectiveness of CNOSSOS might be further strengthening was the **lack of standardised input data**. A small number of stakeholders observed that although input databases have been developed by source (e.g. road, rail) in the CNOSSOS-EU database of input data, there is limited standardised input data available, which means that post-CNOSSOS implementation, output data may not always be comparable. Some stakeholders thought that over the longer term, input data should be harmonised. However, other stakeholders pointed out that it is difficult to harmonise input parameters, for instance because standardised input data may not be appropriate for some sources. The difficulty in standardising input data was confirmed in research papers[241] and in the CNOSSOS methodology itself.

A few stakeholders stated that CNOSSOS fell short of their expectations and would not be able to fully substitute some interim methods currently used. Specifically, the Nord2000 method, which is used in some Scandinavian countries, was mentioned. Although some countries such as **Denmark** and **Sweden** will continue to use their own national mapping methods alongside CNOSSOS for their own purposes, other than strategic noise mapping and reporting, this is not expected to exacerbate the problem of comparable data provided they also implement CNOSSOS in parallel. In such cases, however, the administrative costs of providing data under CNOSSOS for EU reporting purposes and under an interim method to meet national reporting requirements may be high.

A small number of END stakeholders, including two competent authorities, expressed concern that CNOSSOS goes **beyond the concept implied by '<u>strategic</u> noise mapping'** because it requires mapping that some Member States regard as being more detailed than the minimum that would be necessary to provide the data needed to develop action plans for the management of environmental noise. There were concerns that increasingly detailed mapping could be required by the EC in future, with limited benefits for noise action planning. One stakeholder suggested that whilst CNOSSOS was a positive step forward, they would have preferred it to be less detailed and complicated.

More generally, there were concerns among some national competent authorities about the **additional one-off administrative costs of the transition to implementing CNOSSOS-EU**, given that R1 and R2 have been implemented using a combination of national and interim methods (e.g. mentioned in France, Denmark and Sweden).

Implementation challenges – strategic noise mapping

There are a number of **implementation challenges** identified in relation to Strategic Noise Mapping through the research, which are now examined.

Firstly, perhaps the most crucial limitation to full implementation relates to **data quality.** Ensuring **access to reliable input data** is vital for the measurement of noise, since producing reliable output data is pre-conditioned on the availability of quality input data. In R1, there was a general problem with regard to the lack of availability of input data and / or the poor quality of inputs data. In R2, although some interviewees made clear that the quality of input data had improved, the lack of adequate input data remained an important issue (11 MS – **BG, CZ, EE, FR, HR, HU, LV, LT, NL, RO** and **SE**).

---

241 Advances in the development of common noise assessment methods in Europe: the CNOSSOS-EU framework for strategic environmental noise mapping, Stylianos Kephalopoulos, Marco Paviotti, Fabienne Anfosso-Lédée, Dirk Van Maercke, Simon Shilton and Nigel Jones http://www.sciencedirect.com/science/article/pii/S0048969714001934

Examples of the specific problems that were identified are: assigning accurate population data to estimate the average number of people per dwelling, inaccuracies in input data and in some cases outstanding data gaps. Such challenges have made it difficult to calculate noise exposure accurately, even when the number of buildings is known.

There remains a **challenge in measuring the actual population exposure,** rather than the **number of people potentially exposed.** Examples of the types of challenges that need to be considered that influence the accuracy of population exposure data are now outlined.

Table 157 - Noise measurement issues – producing accurate exposure data (selected examples).

Noise measurement issue	Description
The average number of people per dwelling	Since actual demographic data on the number of inhabitants per dwelling is often unavailable, estimates are commonly produced by consultants to measure the exposed population. Whilst this is a practical solution given the lack of data, there are risks that when actual data is obtained, the number of persons exposed may be distorted, such that the data is not fully comparable between Rounds. Similar problems can arise when public authorities produce estimates of the number of persons per dwelling at national level, but there are many region and city-specific variations.
dB(A) levels outside and inside dwellings	Data collected through noise mapping is based on the number of exposed persons *outside* dwellings. It was pointed out that there can be a significant difference in the level of noise outside and inside dwellings, especially given that current mapping methods cannot be distinguish whether noise insulation measures have been implemented.

Feedback on the problems identified above was received through the interview programme and written responses to the working papers presented at the validation workshop. For instance, in relation to the problem of the average number of people per dwelling, a stakeholder in the **Netherlands** mentioned that there is a legal requirement to use an average figure of 2.3 inhabitants per dwelling in reporting procedures to the Ministry of the Environment (and for EU reporting purposes). However, in Rotterdam, for instance, data has been obtained that there are only 2.1 inhabitants per dwelling. If actual data were to be used, however, this would have resulted in non-comparable data between R1 and R2 of noise mapping, so the data estimates were instead used in both rounds.

In relation to the issue that the END measures noise outside dwellings, whereas the health effects linked to dose responses inside dwellings which are not presently captured through noise mapping, a European industry association in the aviation field which commented in a written response that there is a significant difference between inside and outside levels of noise. "The WHO selected an average insulation value of 21 dB to differentiate between inside and outside noise, which takes into account slightly open windows".

A similar point was raised by an acoustic consultant in the UK active in supporting the implementation of the END commented that *"given population growth, and the expansion of housing stock, there is a need to collect more sophisticated data and information on numbers of exposed properties that have good acoustic design or special insulation against noise, otherwise reported data will give a misleading impression".*

With regard to the **level of detail of SNM**, differences in approach between Member States were identified, with **Luxembourg** going beyond the minimum requirements in the END and providing noise maps that report on dB thresholds below 50dB L_{night} and 55dB L_{den}.

A participant from **Romania** in the validation workshop held in September 2015 pointed out that local authorities may have more detailed mapping data on noise but noted that this is not used in SNMs at national level. A Slovenian stakeholder pointed out that input data can be unreliable when it builds on the number of permanent residents in any given area when in fact many are temporary residents.

Consequently, using only permanent residents for population metrics can result in implausible data. Participants from Germany maintained that data protection is an issue that limits the accuracy, and consequently the utility, of population exposure data.

Several stakeholders attested to the problem that updating data on population exposure between Rounds using different thresholds (i.e. transitional and definitive) in R1 and R2 can lead to misunderstandings among citizens and politicians, who perceive from the data that the problem of high levels of noise is getting significantly worse. Since the applicable thresholds changed between R1 and R2 for major rail, major roads and agglomerations, it may appear from at first sight of population exposure that there has been a significant increase in population exposure. However, this may simply be due to greater volume of noise mapping due to changes to the scope of the END now that the definitive reporting thresholds are applicable. Equally, other changes between Rounds may also complicate the use and interpretation of the data, such as a change in the population or in traffic volumes.

Issues relating to the utility of the data produced through strategic noise mapping in further detail in the evaluation part of this report (see Section 3.2.3 on effectiveness).

Utility of data collected on population exposure through noise mapping

The utility of the data from the perspective of different stakeholders is now considered.

At **EU level**, although the END has already had a positive impact on source legislation revised since 2014, as shown in detail later in Section 3.2.3.6 (Progress in achieving the END's second objective), the END's role has primarily been in providing a strategic reference point for source legislation to highlight the problem of environmental noise.

In the views of EU policy makers from DG GROW and DG MOVE responsible for EU source legislation, population exposure data by dB band produced through the END has strong potential utility, but is not yet sufficient to be used to inform source legislation, since there remain gaps in data completeness in some EU countries (see Section 2 – implementation review) and outstanding comparability issues until CNOSSOS is fully implemented.

However, it was acknowledged by EU policy makers that once comparability challenges have been addressed, END data will have significant utility to inform the review and possible legislative revision of different pieces of source legislation, for instance by citing END source-specific population exposure data in impact assessments and in technical studies relating to source legislation.

However, some END stakeholders were adamant that the data should already be used. For example, a national competent authority commented that in their opinion, "the data collected through noise mapping is already good enough to be used to inform source legislation and should not be used as an excuse by EU policy makers responsible for different transport sources to delay reviewing existing source legislation".

The argument was made that existing END data collection on noise at receptor by source already provides a strong enough evidence base to assess the scale of the problem. Similar concerns were expressed during the workshop, reflecting the considerable level of effort made to date in END data collection that EU policy makers responsible for source legislation should make full use of existing population exposure data and not wait until 2022, since data collection started in R1 in 2007.

Data collected through the END will also be **highly useful in assessing the health effects of environmental noise at EU level**. However, the data's utility will only be fully realised once comparable data is available and once Annex III has been developed based on revised WHO guidance on dose-response relationships.

The EEA commented that END data is already useful for EU **monitoring and reporting purposes**. Under Art. 11 of the END, the Commission has to report on population exposure data collected through strategic noise mapping across the EU. The data collected was seen as highly useful by the EEA in helping the Commission to fulfil their monitoring and reporting responsibilities not only in respect of the END and also in meeting their wider role in reporting on the state of the environmental situation in the EU. END data already feeds into reporting by the EEA on progress towards the EU strategic policy goals set out the 6^{th} and 7^{th} Environment Policy Action Programmes.

Population exposure data was already seen as very **useful for a wide variety of decision makers at national, regional and local levels.** According to many interviewees and workshop participants, the data is significantly better than what existed before. A number of participants in the workshop expressed the view that although CNOSSOS's full implementation would strengthen the quality and utility of the data by improving confidence intervals compared with the current population exposure dataset collected in R2, until CNOSSOS is fully implemented in all 28 EU MS, it will not be possible to determine what the error margins will be.

In respect of **local authorities**, there was a difference in perception as to the utility of the data depending on the size of urban area concerned. A general trend observed in the interview feedback was that local authorities In cities and in larger towns within agglomerations tended to view the collection of population exposure data by dB threshold through the END as being very useful, since it fed into strategic planning across a number of different policy areas (e.g. urban development, local transport planning, prioritisation of noise mitigation measures at local level).

Conversely, in the discussions with national competent authorities (e.g. in **FR, DK and NL**), it was observed that local authorities in smaller municipalities did not view noise maps as being that useful, since it was clear to them what the main sources of noise were, and they did not understand the value added of mapping relative to the cost. This was especially the case when mapping in France, where mapping for agglomerations was required in smaller communes, which may have as few as 2000 inhabitants.

With regard to the utility of the data for the **private sector**, although a few specific examples were identified of such actors downloading maps and looking at the data, the level of interest in terms of the number of downloads was seen as disappointing by stakeholders interviewed, compared with initial expectations when the END was adopted.

From a citizen perspective, several stakeholders mentioned that the **lack of aggregated data on *cumulative* environmental noise exposure** in a particular area may **undermine the practical utility of noise maps** from a citizen engagement point of view**.** According to a small number of stakeholders, (e.g. in **DK, IE** and NL), it is unlikely that anyone but a technical specialist audience would utilise noise maps relating to a single source. Efforts to engage the public in noise mapping results had not succeeded because SNM were not regarded as being sufficiently user-friendly or of practical use to citizens. However, acoustic consultants pointed out that it remains the case that because of **differences in dose response relationships for different sources of noise**, there are practical reasons for not showing cumulative noise maps. Moreover, there would be higher costs in producing such maps, in addition to the source-specific maps needed to inform source legislation.

A general concern among END stakeholders, expressed in several EU countries, was that the two key noise indicators used in the END (L_{den} and L_{night}) are conceptually difficult for a non-technical audience to understand. This may limit the audience among EU citizens for accessing such data and information. Given the high costs involved in producing such data, the small number of downloads of SNMs was mentioned as a concern (e.g. **DK, NL**).

Overall, END data is already useful for different policy making and reporting purposes. However, it is not yet being utilised by policy makers responsible for source legislation. Its utility will be strengthened over time as the data becomes more comparable.

Whilst the main purposes of the END is to collect population exposure data through noise mapping to inform the identification of measures for NAPs and secondly to information legislation, the evaluation feedback identified END population exposure data was useful for wider purposes for different types of stakeholders, namely:

- **EU policy makers** – informing source legislation (once comparability issues overcome), informing EU noise policy more generally, and EU-level environmental monitoring and reporting by the EEA for the Noise in Europe Report and 7th Environmental Action Programme.
- **National and regional policy makers** –prioritising noise mitigation measures in areas with high levels of population exposure. It can also be used across different areas such as urban development, land use planning, long-term infrastructure development planning etc. The data can also potentially be combined with other datasets, such as air quality, spatial data for land use planning, public health datasets for epidemiological studies etc.
- **Local authorities –** prioritising environmental noise mitigation, strategic planning, etc.
- **Local community groups and NGOs** interested in information and data about environmental noise at receptor by source. Maps disaggregated by source are seen as highly useful to inform policy debates.
- **Private sector stakeholders,** such as investors, developers, planners and architects.

APPENDIX H – LIST OF EVALUATION AND EVALUATION SUB-QUESTIONS

Table 158 - List of evaluation questions and sub-questions

Evaluation questions	Evaluation sub-questions
Relevance	
EQ 1- Are the objectives of the Directive still relevant?	EQ1a - How far does the Directive meet identified policy needs? (e.g. high levels of environmental protection, human health)?
Coherence	
EQ2 – How far is the END coherent and consistent with other EU legislation on noise (e.g. noise at source legislation (including by transport type i.e. automotive, railways, aviation)?	
EQ3 - Are there any specific legal gaps, overlaps and inconsistencies identified between the END and other EU legislation?	
EQ4 - How does the Directive relate to national noise policies and legislation? Is it consistent and to what extent – if at all - does it duplicate existing requirements?	
EQ5 - Are there any elements of the Directive (e.g. specific Articles, definitions of key terms, requirements for public authorities) that are unclear?	Are there any provisions that are obsolete and if yes, why?
EQ6 - To what extent is the Directive sufficiently clear in setting out the obligations of Member States at the level of (i) the Competent Authority and (ii) other stakeholders involved in national implementation?	
Effectiveness (and impacts)	
EQ7 - What progress have Member States made towards achieving the objectives set out in the Directive?	EQ 7a – What progress has been made in respect of Article 1(1) – strategic noise mapping EQ 7b - What progress has been made in respect of Article 1(1)b) - making information on environmental noise and its effects is made available to the public? EQ 7c - How much progress has been made towards Article 1(1)c - the Adoption of Noise Action Plans by the Member States, based upon noise mapping results? EQ7d - How effective have public consultations been in informing noise action planning processes and in the finalisation of NAPs? EQ7e - Has the speed of progress been in line with expectations? EQ7f - Has the Directive been adapted to technical and scientific progress?

Evaluation questions	Evaluation sub-questions
EQ8 – What progress has been made towards the second objective of the END - “to provide a basis for developing Community measures to reduce noise at source” (Article 1(2))?	E8a - What is the extent of the END’s influence on noise at source legislation? EQ8b - Has the speed of progress been in line with expectations?
EQ9 - What are the main impacts of the Directive?	EQ9a How far has the Directive achieved any significant changes (positive or negative)? EQ9b Has the Directive contributed to ensuring that by 2020 noise pollution has significantly decreased? EQ9c Can any unexpected or unintended consequences be identified? EQ9d. To what extent can these be quantified?
EQ10 - How have the provisions of the Directive been accepted by the stakeholders? In particular, how have each of the following END provisions been accepted?	EQ10a - Noise measurement through a system of common indicators and a common methodology (CNOSSOS); EQ10b - Noise mapping; EQ10c - The preparation of action plans; EQ10d - Information and consultation of the public; and EQ10e - Reporting to the Commission / EEA and reporting by them under Art. 11.
Efficiency	
EQ11 - How far are the administrative costs of END implementation proportionate?	EQ11a – How far do administrative costs differ between Member States and what are the reasons for this? EQ11b - What factors cause the greatest administrative burdens?
EQ12 - To what extent is the END reporting mechanism efficient?	
EQ13 - To what extent does the Directive demonstrate cost-effectiveness based on an assessment of the costs and benefits to date?	This EQ addresses the findings from the CBA.
EU added value	
EQ14 - What has been the overall EU added value of the Environmental Noise Directive?	EQ14a - To what extent did Member States have environmental noise legislation in place to address noise at receptor prior to the END?” EQ14b - If particular MS already had mitigation measures at receptor in place, how far, if at all, has there been a change in the level of attention among policy makers and politicians, the budget allocated and types of measures being supported?
EQ15 - Do the issues addressed by the Directive continue to require action at EU level?	
EQ16 - Are there are any ways in which the European added value of the END could be further enhanced?	
EQ17 - What would happen if the END were to be repealed?	

Evaluation questions	Evaluation sub-questions
Prospective questions	
EQ18 - Is the scope of the Directive (as laid down in Art. 2) appropriate or does it need to be modified?	
EQ19 - Are there gaps where further EU noise legislation is required in order to achieve the objectives of the Directive?	

APPENDIX I - ASSESSMENT OF UTILITY EU FUNDED RESEARCH PROJECTS ON ENVIRONMENTAL NOISE

The study team identified a number of examples of END-relevant EU research projects in the environmental noise field, often funded through the EU RTD Framework Programme (FP6 and FP7, but also through other funding programmes such as LIFE+. An illustration of the types of projects supported – and where there is potential to strengthen the effectiveness of END implementation. In reviewing EU research projects, the main question considered was:

To what extent could previous EU funded research projects on environmental noise be useful in strengthening the effectiveness and Union added value of END implementation?

Where appropriate, comments are made by the consultancy team's evaluators and acousticians to highlight the potential utility of particular EU funded projects to strengthening END implementation:

Table 159 - Examples of END-relevant EU funded research projects

Funding programme	Project name	Description and commentary - why relevant to strengthening END implementation? Website links
FP5	NOPHER	The Noise pollution health effects reduction project covered research on noise pollutions and its impact on health through intra-disciplinary cooperation amongst European researchers. Its results include a consensus on the strength of causal relationships between environmental noise and health effects, a new international journal Noise and Health, and wider range of publications.
FP6	The HEATCO project "Developing Harmonised European Approaches for Transport Costing and Project Assessment" http://heatco.ier.uni-stuttgart.de/	Description: Development of improved methodologies for noise impact assessment, monetary valuation of health impacts, the treatment of values over time and the calculation procedures for measuring environmental noise. Comment: HEATCO is highly END-relevant, especially in terms of how health impacts are monetised, how values are treated over time e.g. discounting to reach a NPV when assessing the costs and benefits of noise mitigation and abatement measures.
FP6	The IMAGINE & HARMONOISE projects	Description: The HARMONOISE and IMAGINE project built a database for road, rail, aircraft and industrial noise at source. They also developed propagation models. The objective was to support the development of a common assessment method used for strategic mapping as defined by the END. The European Harmonoise algorithm has been developed over more than 10 years, and offers a consistent method for prediction of noise levels under arbitrary meteorological conditions. It is implemented in open-source code, and has been validated to some extent in Europe. The outputs extended to technical and practical guidelines, a database of different sources of noise, and a harmonised and reliable method for estimating noise levels of these sources. Comment: The issue of harmonised data remains an important one for the effective implementation of the END. The development of guidelines was also important, especially in the early period of END implementation, in the period before

Funding programme	Project name	Description and commentary - why relevant to strengthening END implementation? Website links
		national guidelines had been developed.
FP6	QCITY project - http://www.qcity.org/	Description: the QCITY project was a FP6 research project, under the 6th FP has developed an integrated technology infrastructure for the efficient control of road and rail ambient noise by considering the attenuation of noise generation at source at both vehicle/infrastructure levels. The activities support European noise policy to eliminate harmful effects of noise exposure and decrease levels of transport noise creation, especially in urban areas. Comment: – the project was END-relevant and explored what could actually be done about the problem of environmental noise particularly in an urban environment.
FP6	CANTOR	CANTOR brought together a number of the major European academic/research institutes in acoustic research, and engaged a series of experts from government agencies and the vehicle manufacturing industry chain to focus on a way of improving vehicle noise performance. The co-operation among the laboratories in CANTOR enforced common best-practice protocols and experimental techniques in their work. The outputs may evolve into noise standards and reference materials, which may be later proposed to European institutions for further unified use in industry normalisation activities and environmental noise control.
FP6	CALM II	The focus of the CALM II project was directed towards cross-sectoral coordination of the European transport noise research facilitating the networking of organisations, the coordination of activities and the exchange and dissemination of knowledge. A further focus was the updating of the noise research strategy plan. One of the outcomes was the Strategy Paper 'Research for a Quieter Europe in 2020' describing future research in covering road, rail and air as well as outdoor equipment as the major sources of environmental noise.
FP6	SILENCE	The SILENCE project (Quieter surface transport in urban areas) addressed urban noise issues from first principles, taking a longer-term scientific perspective. The participants aimed to develop integrated methodologies and technologies for improving the control and coordination of surface transport, to reduce human-generated noise in urban areas. The project provided relevant technologies, innovative strategies and concrete action plans for urban transport noise abatement along with practical tools for their implementation.
FP7	The Cityhush project - www.cityhush.eu/. CityHush Acoustically Green Road Vehicles and CityAreas.	Description: The 3 year Cityhush research project - was designed to support European noise policy to eliminate harmful effects of noise exposure and to decrease levels of transport noise creation, especially in urban areas, deriving solutions that would ensure compliance with the constraints of legislative limits. A major objective was to provide municipalities with the tools to establish noise maps and action plans in accordance with Directive 2002/49/EC and to provide them with a broad range of validated technical solutions for the specific hot-spot problems they encounter in their specific city. Comment: this project appears to be well known among stakeholders in the environmental noise field. The focus on tackling noise in hotspots is in accordance with the approach in the END to using noise maps and population exposure data for

Funding programme	Project name	Description and commentary - why relevant to strengthening END implementation? Website links
		prioritising measures in Noise Action Plans.
FP7	ENNAH – European Network on Noise and Health (www.ennah.eu/network-structure)	Description: the ENNAH project - was a co-ordinating network of the health effects of research. Among the recommendations made through the project are to: • Strengthen the evidence on existing exposure effect relationships and to use more robust methods such as longitudinal rather than cross sectional studies. It is particularly relevant to the research on environmental noise and hypertension and coronary heart disease and on studies of noise and children's learning. • Encourage new research increasingly relevant for policy that will test whether interventions to reduce noise are effective and cost optimized and also whether they have a measurable impact on health. • Assess where new investment is needed in noise research, whether this relates to previously non- or poorly studied health outcomes or improvements in the noise and health methodological framework. Comment - END-relevant. Strengthening understanding of the health effects will help to underpin the achievement of the aims relating to Article 1(2) – EU Noise at Source.
The LIFE + Programme	The QUADMAP project (QUiet Areas Definition and Management in Action Plan). http://www.quadmap.eu/	Description: The QUADMAP project www.quadmap.eu/ - aims to deliver a method and guidelines regarding identification, delineation, characterisation, improvement and managing Quiet Areas in urban areas as meant in the END. The focus on strengthening knowledge / understanding about quiet urban areas through the QUADMAP project has helped to develop insights into the importance of designating quiet urban areas. Comment - since quiet areas have been one of the more problematic areas of END implementation, QUADMAP has helped to advance state of the art in this area. Only 5 MS have designated more than a few quiet areas (see Task 1 – EU level synthesis assessment of END implementation). This is partly because they are not obligatory, but also because of difficulties in the definition and delimitation of quiet areas Quiet areas have been a problematic area of END implementation.
5th PRCR R&D Framework Program.	SILENCE(R)[242]	The SILENCE(R) project focused on tackling noise at source through research in the field of aircraft noise reduction technologies. The project brought together representatives from the European aviation industry such as Airbus, Rolls-Royce, MTU Aero Engines and Snecma, along with the research community and universities. The objective was to validate individual technologies and to produce a cost/benefit analysis of technological applications across the product range. Large-scale noise reduction solutions regarding various noise-generating aircraft elements were validated including: • Engine– research on engine noise spanned fan, compressor, turbine and jet noise.

[242] http://www.xnoise.eu/fileadmin/user_upload/Projects/SILENCER_FinalExecutivePublishableSummary-1.pdf

<table>
<tr><th>Funding programme</th><th>Project name</th><th>Description and commentary - why relevant to strengthening END implementation?

Website links</th></tr>
<tr><td></td><td></td><td>Nacelle (engine housing) – research focused on both nacelle geometry and acoustic liners.
Airframe– extensive airframe noise tests focused on technologies to reduce landing gear noise and noise generated by high-lift devices (flaps, etc.).
Combined with innovative low-noise operational procedures studied in parallel with SILENCE(R), the project achieved a 5 dB noise reduction. This meets the medium-term objective of the European Commission's PCRD R&D Framework Programs, and was a significant advance towards ACARE1's research goal of a 10 dB reduction in aircraft noise by 2020. More than 35 prototypes were tested as part of the SILENCE(R) program, along with studies of improved operational procedures to reduce aircraft noise.</td></tr>
<tr><td>FP7</td><td>QUIESST</td><td>The Quietening the Environment for a Sustainable Surface Transport project addressed surface transport noise abatement (road and rail), considered cost benefit analysis and addressed the END objectives, covering true holistic noise abatement solutions through wave propagation and systems for passive compensation.</td></tr>
</table>

A number of interviewees commented that there are **valuable methodologies that have been developed and interesting research outcomes** through previous EU research projects.

The national competent authorities in the UK and in NL for instance raised the possibility of the EU having a role to play in ensuring the further dissemination of research results. Given the number of implemented and existed projects, there is already a lot of information available. The European Commission / EEA could play a useful role in synthesising some of the research results and in drawing out especially relevant aspects for competent authorities involved in END implementation. These activities would also have the benefit of promoting the uptake of EU-funded research results more generally (which is a key issue).

Prospective issues

Greater consideration could therefore be given in future as to how the results from EU funded research projects relevant to environmental noise could be centrally co-ordinated and then more widely disseminated in order to support the Member States in improving the effectiveness of END implementation. Each project will have disseminated its findings.

One suggestion is for the EU to increase the exchange of best practices between sectors and Member States and provide further guidance on designing NAPs – this has already been regarded as helpful but could be enhanced (as confirmed by interview with Italian authority). Another relates to tightening timelines and obliging Member States to make available budget to implement corrective measures. Another idea would be to embed the END in a wider EU noise policy strategy. The period of devising a NAP could perhaps be extended in future to 1-2 years to allow sufficient time for public consultation.

APPENDIX J – QUALITATIVE CASE STUDIES

The purpose of the case studies, which were undertaken in addition to the formal requirements for this assignment, is to provide interesting examples of good practices that can be used to support and illustrate particular points in addressing the evaluation issues. The case studies could be integrated into the main report, and/ or could be included in a standalone compendium of good practices.

A further possibility is that the validation workshop in September 2015 could be used as an opportunity to generate further ideas on good practices. Participants could be asked to semi-complete the case study template with the study team then undertaking follow-up to complete the case studies.

Case study no. 1 & title	**Publication of online FAQs relating to the interpretation of Strategic Noise Maps**
Member State	Ireland (IE)
Public authority / economic operator	Irish Rail (Iarnród Éireann)
Purpose of case study	The purpose is to demonstrate that public authorities need to provide appropriate context when making Strategic Noise Maps (SNMs) accessible online. The case study is concerned with an examination of effective practice in disseminating the results of Strategic Noise Mapping
Description (including rationale / objectives of measure)	Irish rail produced a set of FAQs to help citizens and other end users in the interpretation of the rail noise maps http://www.irishrail.ie/media/strategicnoicemapfaq1.pdf?v=gr5ucqy . Among the specific FAQs posed include "What is the baseline year of the maps?", "What do the contour levels mean?", "What is L_{den} and L_{night}?", "What are the noise maps for?", "How were the maps made?", "How accurate are the maps?" and "Do noise maps show how noisy it is where I live?" Irish Rail's rationale for producing a set of FAQs was that outside of environmental noise specialists, citizens and public authorities often have difficulty in interpreting (or misinterpret) SNMs. Secondly, a key aim was to minimise the risk that the maps are taken out of context. There are reputational risks for mapping bodies if SNMs are not well understood or are misrepresented. Among the possible unintended consequences of publishing SNMs without contextualising these is the increased risk of generating additional noise-related complaints from citizens. Complaints about environmental noise already require expending considerable human resource for many transport organisations in Ireland, including Irish rail. Appropriate disclaimers are needed to avoid noise maps being presented as evidence in legal cases about noise. A disclaimer has therefore been added in the website FAQs that "the noise maps have been produced for use at a strategic level and give an acceptable level of accuracy. They will not however necessarily properly represent the situation at a local level and the results of the noise mapping should not be used alone for any land use planning or location-specific assessments". The disclaimer included in the website FAQs makes clear that: "The maps are only intended to be used for strategic assessment of noise levels in any given area. They should not be used to attempt to determine, represent or imply precisely the noise levels at individual locations (e.g. individual houses, windows)". It is also emphasised that noise maps are calculated using a modelling approach to arrive at an average value over a year. They do not represent actual noise levels at a particular point in time using modelling data.

Effectiveness and added value	Providing an explanation to users of SNMs as to how noise maps should be interpreted and their advantages and limitations was viewed as an effective means of strengthening understanding of strategic noise mapping and enhancing the utility of the maps for Irish citizens, policy makers and local level decision-makers (e.g. planning and transport authorities). It is important to convey to citizens and stakeholders that noise maps are only an approximation, rather than an actual reading.
Transferability/ replicability potential	**High.** A number of stakeholders in other countries also confirmed that it is a common problem that stakeholders (especially citizens) misunderstand and misinterpret noise maps. There is a lack of familiarity with what the L_{den} and L_{night} indicators measure.
Impacts	• Strengthened accessibility for citizens to information about SNM. • Reduced risk of noise maps being interpreted erroneously and/ or misrepresented.

Case study 2 & type	**Environmental noise reduction measure - railways (noise at source)**
Case study title	Methodological enhancements to more accurately measure rail roughness so as to better assess the contribution of enhanced railway grinding to reduced environmental noise emissions.
Member State	UK
Public authority / economic operator	Network Rail and the Rail Safety and Standards Board (RSSB)
Purpose of case study	The purpose of this case study is twofold, namely to: • Analyse an example of a measure where environmental noise is a secondary consideration, but where there are major indirect benefits in terms of reducing rolling noise emissions. • Examine progress made in improving the accuracy of the measurement of noise due to rail roughness to complement the CRN method. This could in future be used as part of a "common approach" to measuring railway noise under the technical guidelines for CNOSSOS.
Description (including rationale / objectives of measure)	There are three main contributors to operational railway noise at source – rolling noise, traction noise and aerodynamic noise. Of these, railhead roughness has a significant influence on the level of rolling noise. Network Rail (NR) operates the UK's rail infrastructure network. It has made significant changes to its rail grinding strategy in the UK, mainly for safety reasons. However, there was a recognition that more frequent rail grinding also has benefits in reducing rolling noise emissions by tackling railhead roughness. A strengthened rail grinding system was put in place by Network Rail (NR) between 2002 and 2004 as part of a new preventative maintenance grinding strategy to address rolling contact fatigue. This involved the purchase of three new grinding machines. The frequency of rail grinding was then reviewed in 2007 and changes were made to better reflect measured rail wear rates on straight track. From 2009, grinding of straight track was revised so that it was planned to be carried out every 45 Equivalent Million Gross Tonnes (EMGT) with curves continuing to be ground every 15 EMGT. Although environmental noise reduction was a secondary driver, there were expected to be major benefits in reducing noise at source due to the measure being implemented. Due to the existence of the END, NR was very interested in measuring the level of benefit i.e. the magnitude of noise reductions. This required further methodological improvements to strengthen the quality of input data relating to railway noise.

	In 2004, a study was completed on behalf of Defra (by AEA Technology) to consider the implications on noise predictions of a level of rail roughness different from that assumed in the UK "Calculation of Railway Noise 1995" (CRN) interim method, through the development of a new indicator to measure the "Acoustic Track Quality" (ATQ). Rail roughness was measured using sound level measured on board a train, close to a smooth wheel, as a proxy. The system was calibrated with measurements at the trackside to establish the under-floor level that occurred when the trackside vehicle noise emission was the same as that predicted by CRN. A large amount of data was gathered over a significant proportion of the UK rail network. By establishing a network-wide average level, correction factors could then be applied to calculate the actual level of acoustic track roughness rather than that assumed using CRN, the UK chosen method. The study found that, on average, CRN under-estimated the level of rail roughness, as measured in terms of ATQ, by 4dB. The estimations for Round 1 noise mapping were then corrected using an algorithm to reflect the improved accuracy of measured railway noise roughness. A follow-up study was then carried out for Network Rail in 2012. In the second study, the ATQ roughness indicator had gone down by more than 4dB on average across the rail network. This fed into 2nd round of noise mapping. Improvements to the methodology for measuring railway noise stimulated by the END were presented at a workshop.243 The second study found that the impact of rail grinding had been very positive and that this had eradicated the additional 4dB of noise roughness identified in the earlier study using an improved methodology for capturing railway noise. It should be noted that the reductions in ATQ reflect rail roughness reduction, not necessarily the resultant noise. For smooth wheels, ATQ reduction = rolling noise reduction. For rough wheels, the reduction will be smaller, or non-existent.
Effectiveness and added value	Although rail grinding was undertaken for safety reasons, the END has clearly played an important role in encouraging NR to take a closer interest in the benefits of rail grinding than would otherwise have been the case.
Transferability/ replicability potential	The new methodology for measuring rail roughness has been presented at a workshop to peers in 2012 and has been accepted as adding to the accuracy of noise measurement. It could therefore be used to assist in deciding appropriate CNOSSOS rail roughness values in future.
Impacts	• The change in UK-wide policy at NR on rail grinding has led to a significant and measurable reduction in environmental noise attributable to a reduced rail roughness of at least 4dB compared with 2004. • Strengthening the accuracy of the measurement of noise from rail roughness. • It should be noted that the use of better quality attribute data for railways in R2 mapping showed that the R1 maps had rather underestimated noise exposure. A consequence is that despite the acoustic benefit from railhead grinding, the noise levels indicated in noise maps and in the reported exposure data appeared to increase between R1 and R2.

[243] Responding to the Environmental Noise Directive by demonstrating the benefits of rail grinding on the GB railway network, Nick Craven, Network Rail, Oliver Bewes, Arup, Benjamin Fenech, Arup, and Rick Jones, Independent Consultant. Web - pif.sagepub.com/content/early/2013/07/11/0954409713494948 Paper presented at RRUKA Annual Conference, 7 November 2012

Good practice guidance

Case study type	Good practice guidance
Case study title	Role of good practice guidance in promoting the mitigation of environmental noise by tackling noise at source.
Member State	IE
Public authority / economic operator	National Road Authority (IE)
Purpose of case study, rationale / objectives of measure	The purpose of the case study is to: • Demonstrate the role of the development and dissemination of good practice guidelines and guidance documents in ensuring that environmental noise issues are taken into account in the design of transport infrastructure (in this case roads). • Illustrate the importance of incorporating European and international best practice and lessons learned into the implementation of the END as part of a process of continuous improvement.
Description	In 2008, the NRA commissioned Atkins Ireland to undertake a study to review Environmental Impact Statements of national road schemes after the 2004 publication of the *Guidelines for the Treatment of Noise and Vibration in National Road Schemes*[244]. The study led to the publication of update guidelines in 2014. The research study also focused on Constraints Studies, Route Selection Studies, present practice in other countries both in Europe and beyond, and published revisions to the UK DMRB which contains advice on noise prediction. The purpose of the review was to evaluate the effectiveness of the Guidelines, (including the effectiveness of noise mitigation measures) in achieving the NRA's noise design goal set out in the Guidelines "to ensure that the current roads programme proceeds on a path of sustainable development". The guidelines cover the Constraints, Route Corridor Selection and Environmental Impact Assessment stages. A further aim of the review was to identify good practice and potential deficiencies in current practice, and to provide advice on the practice to be adopted in the planning of national road development proposals. The NRA also commissioned a noise research study with Trinity College Dublin to "*Examine the design of noise barriers and the development of a method for assessing the effectiveness of noise barriers in-situ".* The 2004 guidelines have been supplemented in 2014 through the publication of new *Good Practice Guidance for the Treatment of Noise during the Planning of National Road Schemes*[245]. The guide is meant to be in used conjunction with the 2004 guidelines. It is based on the lessons learned from the two studies mentioned above. The new guidance "provides advice for the information and use by acousticians, which also has some relevance for traffic, motorway and pavement engineers. The advice amplifies and supplements the Guidelines, and should be read in conjunction with them". The guidance incorporates a number of headings such as a phased approach to acoustic design, monitoring activities and noise monitoring requirements, making noise predictions and computer-based modelling, and crucially, *acoustic design, amelioration and mitigation*. The guidance aims to encourage and facilitate the positive acoustic design of road schemes from the earliest planning stages through to construction so as to minimise the need for local mitigation at a later stage in the design process.

244 http://www.nra.ie/environment/environmental-planning-guidelines/Guidelines-or-the-Treatment-of-Noise-and-Vibration.PDF
245 http://www.nra.ie/environment/new-noise-good-practice-g/GPG_SB_20122013.pdf - March 2014

	The rationale is that wherever noise amelioration takes place at an early stage in the design process, a wider range of options remain open. For instance, at the design stage, a noise-sensitive horizontal and vertical alignment may be adopted. During the construction stage, a low noise road surface may be utilised. Low-noise road surfacing may be used as a mitigation measure to deal with localised noise problems. The guidance stresses that if an early decision is made to adopt a low noise road surface throughout the length of a scheme, then this should have widespread benefits. Local noise mitigation measures may still be required at a later stage, but on a smaller scale. A key premise is that amelioration is *part of the scheme design*, whilst *mitigation is an add-on* to address any residual problems that the scheme creates.
Effectiveness and added value	The guidance has been effective in enhancing understanding of environmental noise considerations and increasing their visibility among acousticians, engineers, road authorities, local authorities, etc. One of the elements highlighted that adds value is the fact that the guidance is technical but non-prescriptive, since it will need to be applied differently depending on the type of individual road scheme in question. Each section of the guidance ends with a checklist, whose objective is not to tick particular boxes, but rather to help make a positive contribution to the development of noise-sensitive road schemes. Since noisy road surfaces can be a major contributing source of noise, incorporating due consideration at the design stage of new road infrastructure has helped to raise awareness about the issue. This is in keeping with the concept of a sharing of the burdens between public authorities responsible for roads (and noise from road surfaces) and tyre and automotive manufacturers who are responsible for noise at source legislation. The fact that the 2014 guide is based on lessons learned through the implementation of the guidelines over a 10 year period is an effective approach because it demonstrates an ongoing commitment to continuous improvement. The development of practical guidance has added value by providing concrete examples of European and international good practices to decision makers within road authorities.
Transferability/ replicability potential	<u>High.</u> Whilst the EEA has produced a good practice guidance document on noise and the potential health effects for action planning authorities[246] and a separate good practice guide on quiet areas[247], there is as yet no guidance on ensuring that noise is taken into account in the design of different types of transport infrastructure. The guidance from Ireland could be adapted and replicated elsewhere.
Impacts	• The 2004 guidelines have been taken into account by the NRA and other stakeholders in road planning. • The availability of and updating of the guidance has facilitated the exchange of good practices with other EU countries. • Greater consideration of environmental noise as an issue in road design from the outset.

[246] EEA, Good practice guide on noise exposure and potential health effects, http://www.eea.europa.eu/publications/good-practice-guide-on-noise

[247] Guide on quiet areas (EEA), Tech 04 2014, http://www.eea.europa.eu/publications/good-practice-guide-on-quiet-areas/download

Role of good practice guidance in promoting the mitigation of environmental noise by tackling noise at source.

The National Road Authority (NRA) in Ireland developed *Guidelines for the Treatment of Noise and Vibration in National Road Schemes*[248] in order to provide technical support for acousticians and road planning authorities as to how to incorporate environmental noise as an issue in road design from the outset of the design process. The guidance is technical but is purposely non-prescriptive, since it will need to be applied differently depending on the type of individual road scheme in question.

With regard to the practical application of the guidelines, a stakeholder in IE provided an example of how the END has played an indirect role in tackling environmental noise problems in respect of major roads. The M50 scheme was a planned road upgrade – road widening, extra lanes, free flow junctions etc. where incorporating noise into design requirements was important. The noise control measures weren't implemented due to 2002/49/EC *per se*. However, since noise was a contentious issue, there was a desire to work to the highest relevant (and practicable) standards.

The biggest problem in assessing the benefits was the lack of post-construction data for the purposes of evaluating the efficacy and residual impacts. Furthermore, some alignments have been changed and speed limits modified since the scheme was completed. Therefore, any actual "before and after" measurements to assess the change in noise levels would not be comparable.

Reference should be made to the full length case study in Appendix F.

Although the development of technical guidelines at Member State and EU level to facilitate the implementation of the END has clearly played a positive role in strengthening the effectiveness of implementation, the importance of ensuring that guidelines developed are **practical and user-friendly** was emphasised. For instance, in France, a number of different sets of guidelines have been developed, but in the views of stakeholders, one particular guidance document on quiet areas was viewed as being too theoretical and not fit for purpose.

Case study type	**Good practice example from Member State & EU projects**
Case study title	Quiet Urban Areas
Member State	Netherlands & EU level
Public authority / economic operator	European Commission; Dutch Ministry of Infrastructure and Environment and other Member State institutions
Purpose of case study, rationale / objectives of measure	To showcase good practices in an area in which progress in many Member States has been limited to date
Description	The CityHush project financed by the European Commission identified a number of significant shortcomings in National Action Plans in relation to quiet areas, such as: a) A poor correlation between hot spots with annoyance and complaints; b) Most measures lead to increased emissions; c) Only indoor noise comfort is addressed. d) Hot spots, which show high correlation with annoyance and complaints CityHush also identified optimum sizes of quiet zones within cities. Moreover, it developed a methodology for cost benefit analysis before setting up quiet zones.[249]

[248] http://www.nra.ie/environment/environmental-planning-guidelines/Guidelines-or-the-Treatment-of-Noise-and-Vibration.PDF

[249] Parry, Graham and Markus Petz. 2012. Cost/benefit analysis of mitigation measures against potential benefits for local residents and park visitors

	Some of the aforementioned weaknesses could have been addressed by another project financed by the EU (under the programme LIFE+): The QUADMAP project (QUiet Areas Definition and Management in Action Plans). The aim here is to develop a harmonised methodology for the selection, assessment and management of quiet urban areas (QUAs). Best practices, lessons learned and empirical study data are assessed in order to define – acoustic and other – parameters relevant for the perception and evaluation of quiet urban areas by the citizens. Tools are made available for local stakeholders, such as (noise policy) decision makers, urban planners, and citizens, in order to assess and manage QUAs. A number of different assessment tools are developed through the project, including a. questionnaire for visitors about the soundscape and other qualities of the quiet (urban) area. As one output of QUADMAP, the city of Rotterdam, along with project participants in Belgium, Norway, and the UK, came up with a good practice guide. According to the report[250], the UK is best in class when it comes to precise identification of quiet urban areas. It emerges that "The relative quietness of the area" and "Visual attributes" are the two most important criteria when it comes to identifying quiet urban areas. In the Netherlands, surveys are carried out and factors such as functionality and safety taken into account. A resulting finding was that higher noise levels in a particular area would not be of much concern to the public. Legislation is followed up by government commitments and policies in the Netherlands and the UK. In the Netherlands, the impact of noise reduction on city attractiveness and businesses such as restaurants is also considered. In Rotterdam in particular, a surveys was carried out (250 interviewees) in the context of QUADMAP on the soundscape of selected areas (urban parks) to add human perception data to acoustic data already collected. As a result, motorised 2-wheelers were identified as particularly annoying sources of noise.[251] Dutch stakeholders consulted for this study conceded that the accessibility and visibility of quiet areas could be improved, and enforcement and monitoring are virtually non-existent to date. Generally, designating quiet zones in urban areas is still more challenging than in rural ones.
Effectiveness and added value	The surveys and clear methodology in identifying quiet urban areas has achieved several things: 1. Awareness of such areas was raised where before the focus lay on quiet areas in rural regions 2. The involvement of citizens ensured acceptance of the results and increased pressure on politicians to follow up 3. In many cases, survey findings differed from previous assumptions about noise and the relative annoyance of various sources of it 4. The importance of addressing noise outdoors in general was highlighted 5. The CBA methodology developed under the CityHush project should facilitate planning and maximise efficiency of any measures adopted
Transferability/ replicability potential	Given the involvement of several European countries in the projects discussed the findings are by default transferable to other countries.
Impacts	TBC

[250] Gezer, Sevgi. Noise Department DCMR EPA. Silence & the City. WPA2: Data collection and analysis in The Netherlands, Belgium, Norway and United Kingdom.

[251] Weber, Miriam. 2012. Quiet Urban Areas: repositioning local noise policy approaches – questioning visitors on soundscape and environmental quality

Good practice guidance

Case study type	**Noise mapping method**
Case study title	Nord2000
Member State	Denmark, Sweden, (Norway)
Public authority / economic operator	Environmental Protection Agency (Denmark), Environmental Protection Agency (Sweden)
Purpose of case study, rationale / objectives of measure	Details some sophisticated noise modelling methods that have already been applied in several Member States
Description	Initially developed from 1996-2001 by DELTA (Denmark, project leader), SINTEF (Norway), and SP (Sweden), Nord2000 is a calculation method for prediction of noise propagating outdoors. The method may be applied to a wide variety of noise sources, and covers most major mechanisms of attenuation. The Nord2000 method can be used for predicting short term noise levels in one-third octave bands from 25 Hz to 10 kHz when sound is propagating over ground from a source to a receiver. The method can be used for any terrain shapes including screens and can be applied to a variety of weather conditions, allowing a precise annual average to be determined. Complicated terrain is handled by a concise procedure, so the interpretation of terrain shapes by skilled personnel that earlier used to be necessary is now abandoned, and the method can be applied to automated noise mapping without loss of accuracy. The propagation part of the Nord2000 method has been validated by more than 500 propagation cases based on measurements as well as reference results obtained by accurate numerical prediction methods. In Denmark, the guidelines no. 4/2006 prescribe Nord2000 as the noise calculation method for mapping of road and rail noise.
Effectiveness and added value	In some cases, the Nord2000 method led to re-evaluation of noise abatement measures. For example, under Nord2000, road surface conditions are taken into account by correcting default values for the pavement lifetime average condition. Noise barriers now seem to come out slightly less effective than before, when noise levels were predicted for conditions of a slight downwind perpendicular to the road.
Transferability/ replicability potential	**High**: The team responsible for Nord2000 took part in the EU funded Harmonoise project, where the Nord2000 model formed a basis for the development of the Harmonoise Engineering model. Several of the findings from this project have been subsequently introduced in an update of Nord2000 and the data from both projects are assumed to be comparable.
Impacts	The Nord2000 model may be more widely introduced across Europe under the Harmonoise project in subsequent rounds of the END implementation. In this case, the impact on noise maps and resulting action plans can be large. An important issue will be data comparability.

APPENDIX K - IMPLEMENTATION REPORT - 28 COUNTRY REPORTS

The full set of 28 country reports is bound as a standalone document.

APPENDIX L - INPUT DATA SHEETS

The full set of supporting Input Data Sheets for roads, railways and airports are provided as input data sheets in Excel as separate attachments.