Rail Diesel Study
Work Package 3

The contribution of rail diesel exhaust emissions to local air quality

By Melanie Hobson, Anne Wagner and Paul Cumine (AEA Technology)

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AEA Technology Environment
The Gemini Building
Harwell International Business Centre
Didcot
Oxfordshire
OX11 0QR
Telephone +44(0)870 190 6513
Facsimile +44(0)870 190 6327

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	Name	Signature	Date
Author	Melanie Hobson Anne Wagner Paul Cumine		18th October 2005
Reviewed by	Sujith Kollamthodi		18th October 2005
Approved by	Sujith Kollamthodi		18th October 2005

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1 Background

The environmental benefit demonstrated by the railways over other modes of transport is a vital precondition to ensuring social and political support for this mode of transport. The railways have shown that on specific consumption of resources and specific emissions of carbon dioxide their values are lower than those obtained by their main competitors on the road (in particular due to lower running resistance of the wheel-rail system). A transport shift from road to rail can therefore contribute substantially to meeting the CO_2 reduction targets required by the Kyoto Protocol. Apart from the depletion of resources and global warming effects, the impact of traffic on the environment in the form of local air pollution must be given due attention. Despite the general improvement in ambient air quality in European urban conurbations over the last decades, there is still evidence of air pollution in these areas that is critical to health. A large proportion (although declining) is attributable to transport activities. Road transport is considered to be the main polluter, but emissions from diesel-powered locomotives and railcars are increasingly attracting more attention. Directive 2004/26/EC has been extended to cover all new diesel engines for railway vehicles and sets emissions limit values for new engines for railway use. In addition, the European Commission (DG Energy and Transport), in direct contact with the CER, called for initiatives from the railways in the field of diesel exhaust emissions, with particular emphasis on the existing railway fleet.

2 Work package 3 purpose and objectives

Work package 1 collated information on the existing rail diesel fleet in Europe and provided an insight into future development of the fleet. Work package 2 has assessed the technical and operational possibilities for diesel exhaust emissions reductions. This Work Package, Work package 3, builds on WP1 and WP2 and assesses whether rail diesel exhaust emissions are significant contributors to local air quality problems and if so where the hotspots are.

As with the other Work Packages, Work package 3 has focused on rail diesel operations in the “EU Railway 27” (EU 15 + 8 new “railway” member states + Norway, Switzerland, Bulgaria and Romania).

3 Introduction

A series of European Directives have been introduced to control levels of certain pollutants and to monitor their concentrations in the air. In 1996, the Environment Council adopted Framework Directive 96/62/EC on ambient air quality assessment and management. This Directive covers the revision of previously existing legislation and the introduction of new air quality standards for previously unregulated air pollutants, setting the timetable for the development of daughter directives on a range of pollutants. The list of atmospheric pollutants to be considered includes sulphur dioxide, nitrogen dioxide, particulate matter, lead and ozone – pollutants governed by already existing ambient air quality objectives- and benzene, carbon monoxide, poly-aromatic hydrocarbons, cadmium, arsenic, nickel and mercury.

The Framework Directive was followed by daughter directives which set the numerical limit values, or in the case of ozone, target values for each of the identified pollutants.

3.1 POLLUTANTS OF CONCERN

This work package concentrates on the contribution of rail diesel emissions to nitrogen dioxide and particulate matter emission hotspots as these are the pollutants of most concern from the railway sector. In the past the contribution of rail to sulphur dioxide concentrations may have been an issue. However, this is only now thought to be the case in a few specific countries where low sulphur fuel or sulphur free fuel is currently not in use. Even in these specific countries, this issue will no longer arise following the necessary introduction of sulphur free fuels in the railway industry required under Directive 97/68/EC in 2011.

The corresponding daughter directive that covers these pollutants is the First Daughter Directive (99/30/EC). This came into force in July 1999. Member States had two years to transpose the Directive and set up their monitoring strategies. The health limit values for particulate matter must be met by 2005. Health limit values for nitrogen dioxide must be met by 2010. (See section 3.1.6 for further information). Each of these pollutants and in addition ozone is now discussed in turn.

3.1.1 Nitrogen dioxide

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides –(which consist of nitric oxide (NO) and nitrogen dioxide (NO_2), and are collectively known as NO_x) is transport, which is responsible for approximately half the emissions in Europe. NO and NO_2 concentrations are therefore greatest in urban areas where traffic is heaviest. Other important sources are power stations, heating plants and industrial processes.

Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. Continued or frequent exposure to concentrations that are typically much higher than those normally found in the ambient air may cause increased incidence of acute respiratory illness in children. In addition, nitrogen oxide is an acidifying gas and is a major contributor to acidification and is an indirect greenhouse gas and ozone pre-cursor (see section 3.1.2).

3.1.2 Ozone

Ground-level ozone (O_3), unlike other pollutants, is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2), hydrocarbons and sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground level and can be ‘good’ or ‘bad’ depending on its location in the atmosphere. ‘Good’ ozone occurs naturally in the stratosphere 10 to 30 miles above the earth’s surface and forms a layer that protects life on earth from the sun’s harmful rays. In the earth’s lower atmosphere ozone is considered ‘bad’.

Vehicle exhausts as well as industrial emissions and chemical solvents emit NOx and hydrocarbons that help to form ozone. The highest ozone concentrations tend to occur in and around large urban areas that generate the precursors necessary for ozone formation. However, rural areas can also experience high concentrations due to transport of the pollutant. Low ozone concentrations often occur in the centre of urban areas near large sources of NOx such as roads. This is due to the scavenging of ozone by NO molecules creating O_2 and NO_2. Sunlight provides the energy to initiate ozone formation; consequently, high levels of ozone are generally observed during hot, still sunny, summertime weather.

Ozone irritates the airways of the lungs, increasing the symptoms of those suffering from asthma and lung diseases. In addition it damages crops and other vegetation.

3.1.3 Sulphur Dioxide

Sulphur dioxide (SO_2) is an acidic gas which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry deposition have been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials and watercourses. SO_2 in ambient air can also affect human health, particularly in those suffering from asthma and chronic lung diseases. Even moderate concentrations may result in a fall in lung function in asthmatics. Tightness in the chest and coughing occur at high levels, and lung function of asthmatics may be impaired to the extent that medical help is required. Sulphur dioxide pollution is considered more harmful when particulate and other pollution concentrations are high.

The principal source of this gas is power stations burning fossil fuels which contain sulphur. Major SO_2 problems now only tend to occur in cities in which coal is still widely used for domestic heating, in industry and in power stations. As many power stations are now located away from urban areas, SO_2 emissions may affect air quality in both rural and urban areas. In addition, high concentrations may exist near to railway lines where trains are running on high sulphur fuel. This problem is limited to only a few EU countries where high sulphur fuel is still in use (see the individual country sections for further information and Section 3.3).

3.1.4 Particulate Matter

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of very small size (<10 µm)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. Larger particles meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation. Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases. In addition, they may carry surface-absorbed carcinogenic compounds into the lungs.

The principal source of airborne PM_{10} matter in European cities is traffic emissions, particularly from diesel vehicles. In the transport sector, emissions arise not only from the exhaust but also from brake and tyre wear. This report however only focuses on exhaust emissions. It has however been suggested however that emissions from the latter sources may be significant (see Section 5.1 for further details).

3.1.5 Implications of the Air Quality Framework Directive and the Daughter Directives

The Air Quality Framework Directive and the various Daughter Directives have had far-reaching consequences for the ways in which Member States assess and manage air quality problems. Firstly, Member States have been required to designate "competent authorities" at the appropriate levels (national, regional and local) who are responsible for carrying out the activities required by the Directive. Secondly, Member States have been required to divide their territories into a number of zones and agglomerations in order that ambient air quality can be assessed in each zone or agglomeration. "Zones" are part of a Member State's territory, and each zone is defined by the Member State in question. "Agglomerations" are zones where the population exceeds 250,000 inhabitants.

Member States (or their competent authorities) are then required to make an initial assessment of the air quality in all zones and agglomerations. This initial assessment is based on direct measurement of pollutant concentrations in zones and agglomerations. Depending on the outcomes of this initial assessment, specific ambient air quality assessment regimes will be set for each zone and agglomeration. In zones where the ambient air quality is good, the Directive allows that methods other than direct measurement can be used to assess ambient air quality after the initial assessment. Typically, these other methods are based on using modelling techniques. However, regular monitoring is mandatory for all agglomerations.

Based on the results of the assessment programme, zones and agglomerations are then divided into three categories:

- **Category A:** Where concentrations of one or more pollutants exceed the limit values and the margins of tolerance
- **Category B:** Where concentrations are above the limit values but within the margins of tolerance
- **Category C:** Where all levels are below the limit values

Depending on which category the zone or agglomerations falls into, the competent authorities are required to take the following steps:

- **Category A:** Prepare action plans or programmes to achieve compliance with the limit values within the time limit given within the relevant Daughter Directive for that pollutant
- **Category B:** Take actions to achieve compliance with the limit values with the time limit given within the relevant Daughter Directive for that pollutant
- **Category C:** Maintain status quo

In the case of Category A zones and agglomerations, the action plans or programmes are the main instruments used for linking air quality management activities to regional development policies in the particular zone or agglomeration.

3.1.6 Limit values in ambient air.

The objective of the Directive is to establish limit values in ambient air to avoid, prevent or reduce harmful effects on human health and the environment as a whole. According to the Directive 'ambient air' shall mean outdoor air excluding work places.

The table below gives full details of the concentration limit values that have been set by the European Commission with respect to each pollutant. It should be noted that in all cases, limit values have been set for both short-term and long-term exposure, with higher limit values for short-term exposure. Air quality should therefore be assessed where members of the public are likely to be regularly present and are likely to be exposed over the averaging period of the objective.

Table 3.1.6A. Limit values for nitrogen dioxide, sulphur dioxide and PM_{10} as set out in Council Directive 99/30/EC.

Pollutant	Averaging period	Limit value	Date by which limit value has to be met
SO_2	1 hour	350µg/m^3 not to be exceeded more than 24 times a year	1st January 2005
SO_2	24 hours	125µg/m^3 not to be exceeded more than 3 times a year	1st January 2005
NO_2	1 hour	200µg/m^3 not to be exceeded more than 18 times a year	1st January 2010
NO_2	1 year	40µg/m^3	1st January 2010
PM_{10} (Stage 1)	24 hours	50µg/m^3 not to be exceeded more than 35 times a year	1st January 2005
PM_{10} (Stage 1)	1 year	40µg/m^3	1st January 2005
PM_{10} (Stage 2)	24 hours	50µg/m^3 not to be exceeded more than 7 times a year	1st January 2010
PM_{10} (Stage 2)	1 year	20µg/m^3	1st January 2010

3.1.7 Occupational exposure limits

European Directive 98/24/EC covers the health and safety of workers from the risks of chemical substances at work. For any substance for which an occupational exposure limit (OEL) has been set at the European level, Member States must establish a national occupational exposure limit taking into account the community level. Where an OEL is exceeded, the employer must immediately take steps to remedy the situation.

Occupational exposure limits are divided into two time categories - short and long-term exposure. The short-term exposure limits (STEL's) are set to help prevent effects such as eye irritation, which may occur following exposure for a few minutes. The reference period used for STEL's is 15 minutes. The long-term exposure limits (LTEL's) are intended to control exposure by restricting the intake by inhalation over one or more workshifts, with a reference period of 8 hours. The LTEL's are provided here as they reflect the working patterns in a railway station.

Table 3.1.7A: Occupational Exposure Standards: Long-Term (8 hour averaging period)

Compound	Current Standard	Equivalent in µg/m^3	Averaging Period
NO_2 (Inside)	3ppm	5730	8 hour
SO_2 (Inside)	2ppm	5320	8 hour

Source: Values taken from 98/24/EC

There are no occupational exposure standards set specifically for PM_{10}, however there are limits set for various forms of respirable dust. Several examples of these different forms of dust, and the corresponding occupational exposure standard are given below in Table 3.1.7B.

Table 3.1.7B: Occupational Exposure Standard for Respirable Dusts: 8 Hour Standards

Compound/ Substance	Current Standard (mg/m^3)	Compound/ Substance	Current Standard (mg/m^3)
Barium sulphate	2	Marble	4
Calcium carbonate	4	Mica	0.8
Calcium silicate	4	PVC	4
Cellulose	4	Silica (amorphous)	2.4
Limestone	4	Silicon	4
Magnesite	4	Welding Fumes	5

The main objective of this study has been to identify the contribution of diesel rail emissions to ambient pollutant concentrations, and for this reason, occupational exposure is dealt with in less detail in the remainder of this report.

3.2 AIR QUALITY IMPROVEMENTS

The transport sector is a major source of air pollution. It is now the dominant source in urban areas, having overtaken the contribution from the combustion of high sulphur coal and industrial processes. Emissions from these latter sources have been reduced due to technologies being applied before, during and after combustion.

Although air quality in Europe (and particularly in the large urban areas) has improved in recent years (EEA, 2001), meeting the air quality standards specified in 96/62/EC still presents a considerable problem in some urban areas. The European Environment Agency has estimated that in 1995 nearly all EU urban citizens were exposed to air pollution levels exceeding the (at the time, proposed) EU air quality standards set for the protection of human health.

The outlook for 2010 shows that some 70% of the EU urban population will still be exposed to PM_{10} levels exceeding the limit values and some 20% to NO_2 exceedances (EEA, 2001).

3.3 CONTRIBUTION OF TRANSPORT TO URBAN EMISSIONS.

Due to air quality standards potentially not being met in some urban areas, pressure has been put on reducing emissions from the transport sector as it is emissions from this source which often contribute the most in urban areas. See for example, Table 3.3A below.

Table 3.3A Contribution of transport (road transport, rail, shipping & airports) to total emissions in London, UK in 2001.

Pollutant	Emission in tonnes from transport	Total emissions in London	% contribution from transport
NOx	61,652	87,077	71%
SO_2	1,135	5,016	23%
PM_{10}	2,583	4,516	51%

Source: LAEI, 2001

However, the contribution from rail traffic is relatively small as shown in Table 3.3B.

Table 3.3B. Contribution of rail emissions to transport emissions in London.

Pollutant	Road	Rail	Shipping	Airports
NOx	90%	3%	1%	6%
SO_2	32%	14%	26%	28%
PM_{10}	92%	4%	0%	4%

Source: LAEI, 2001

The contribution of sulphur dioxide from the railway sector is relatively high in London due to high sulphur fuel (with up to 2000ppm Sulphur content) still being used by the railway industry in the UK. A questionnaire survey asked UIC members about the quality of the fuel that they used. 28% reported that they now use low sulphur fuel with a maximum sulphur content of 10ppm and a further 32% reported that they use diesel with a sulphur content of between 10 – 50ppm (see WP1 Report). Therefore the high contribution from the rail sector to SO_2 emissions in London is not representative of the EU railway 27 countries as a whole.

Figure 3.3A: NOx emissions in London, 2001

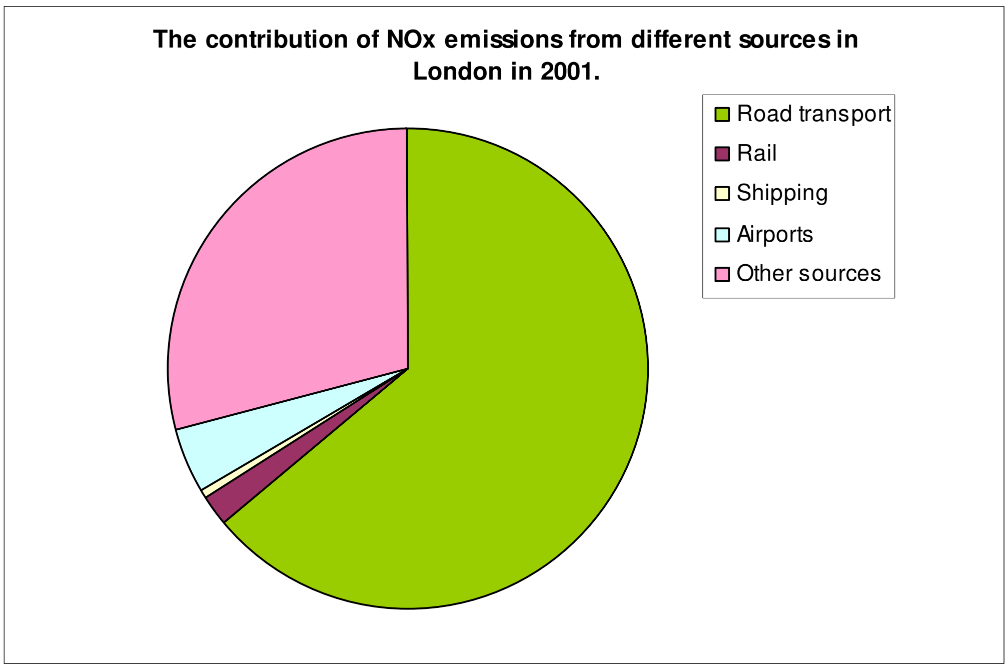


Figure 3.3B: SO_2 emissions in London, 2001

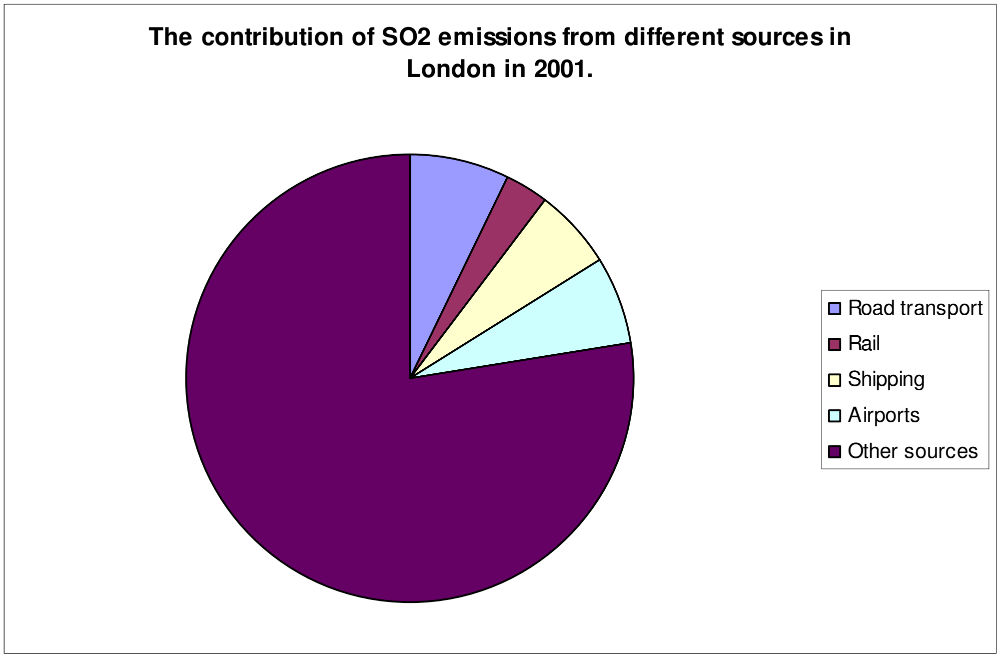
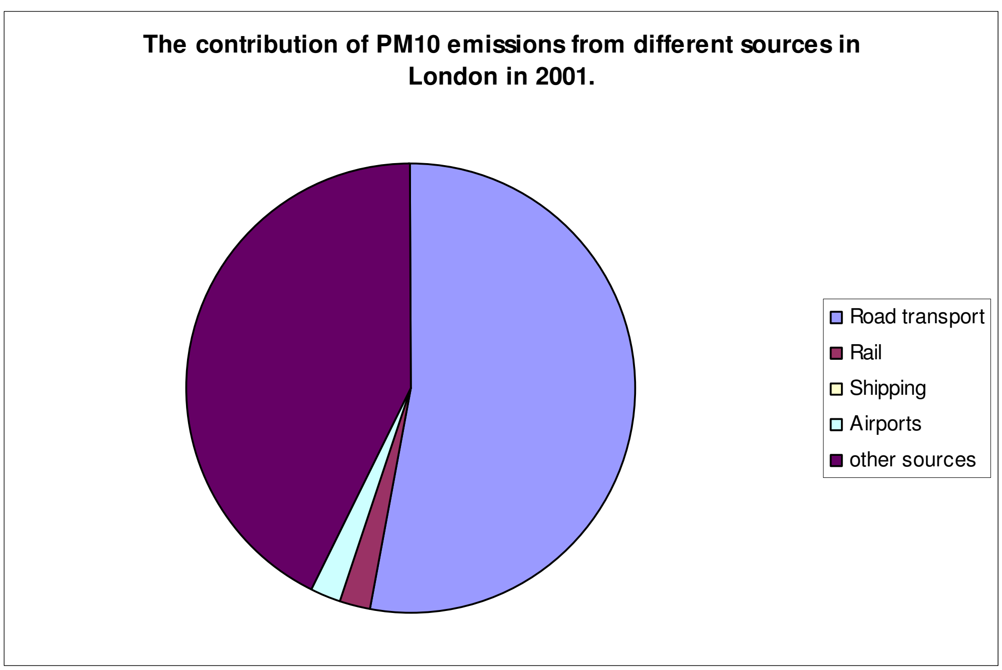


Figure 3.3C: PM_{10} emissions in London, 2001



Unfortunately no other city inventories were available to compare the contribution of rail diesel emissions to total emissions. However, it is thought that London is a typical city apart from the SO_2 issue discussed previously.

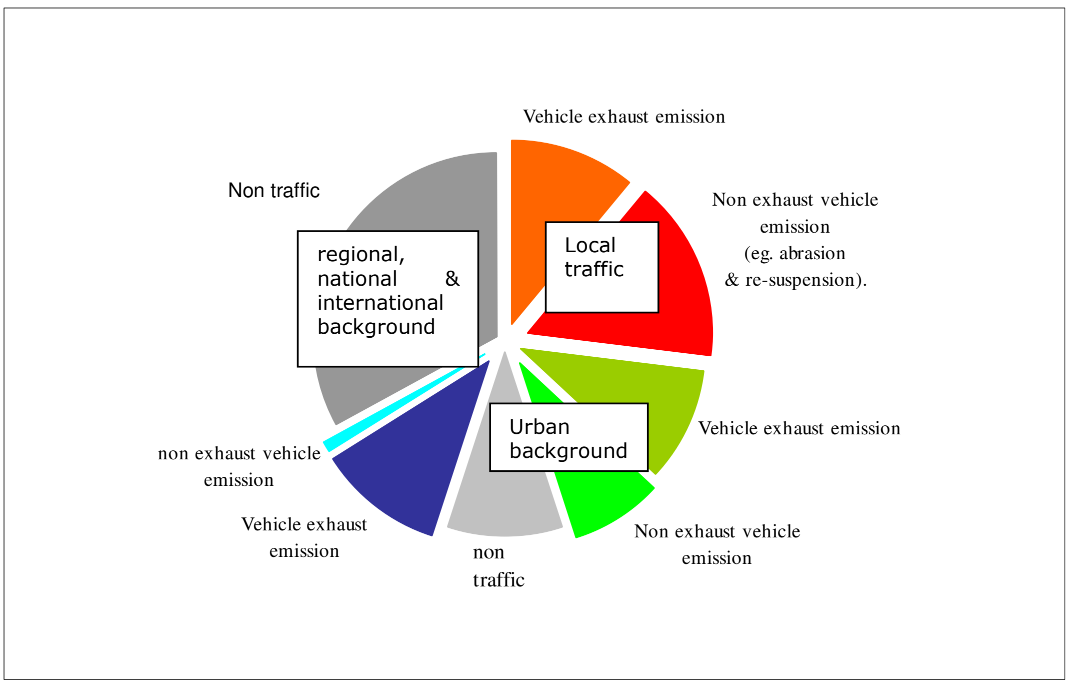
Although the contribution of rail emissions to total emissions in urban areas is likely to be small (as suggested by the London Inventory study), there is the possibility of rail emission hotspots occurring in certain localised areas. This will be further investigated in this study using emissions data and a dispersion model.

Before having the results of a more detailed analysis within this work package, it is assumed that the following parameters may lead to the railway sector contributing to ambient pollutant concentrations:

- Emissions due to railway activities have to be high as can be the case at shunting yards, terminal stations, highly used lines, stops at signals etc.
- The railway emission must be high compared to emissions from other sources such as road traffic, industry or heating from houses.
- If dilution and dispersion of pollutants is restricted, a build up of pollutants may occur.

In addition to rail emission hotspots, it should also be noted that diesel rail emissions will contribute to background pollutant concentrations. Figure 3.3D below, highlights the fact that if transport emissions of PM_{10} for example were reduced by 50%, total emissions would not be reduced by 50% as there are many sources that contribute to total PM_{10} concentrations.

Figure 3.3D Source apportionment of PM_{10} concentrations in a typical inner city area close to a major road in Germany.
Source: Hőpfner, 2004.



3.4 DATA COLLATED

During this study, a questionnaire was sent out to UIC members asking them for information on known air quality problems related to their operations. Responses to this questionnaire have been received from 21 countries, and these responses have provided useful information for WP3.

Environment ministries in the “EU railway 27” countries and the organisations responsible for reporting data for the Convention on long range trans-boundary air pollution (CLRTAP) to the EU have been contacted for information regarding complaints about air quality linked to rail operations. Where possible, the name of the station(s) / line section(s) concerned was obtained. Further inquiries were made about the activity occurring at these possible emissions hot spots, and whether there was relevant exposure (see Pollutants of concern, Section 3.1.5). Rail Atlases have been used to help identify locations of shunting yards and busy diesel rail junctions. In addition web research has been carried out to ascertain further information.

This report builds on the German and UK research and identifies the likely causes and locations of rail emission hotpots in the “EU Railway 27” (EU 15 + 8 new “railway” member states + Norway, Switzerland, Bulgaria and Romania).

Chapter 4 summarises the information obtained from each of the EU railway 27 countries and identifies the likely rail emission hotpots. More detail for each country is provided in Appendix B. Chapter 5 presents the results of the dispersion modelling carried out at (a) a busy line section, (b) a busy shunting yard and (c) a busy terminal station with a high proportion of diesel traction. Chapter 6 presents the conclusions of this study and makes recommendations for further research.

4 Summary of data obtained

This section summarises the data obtained from the responses to the questionnaire and from Environment Ministries in each of the EU27 countries. In addition an assessment has been made of locations which may have high emissions. Further detail is provided in Appendix B.

Table 4.1 Summary of rail emission hotspots identified.

Country	% of gross tkm by diesel	AQ problems identified by country? (either rail operator or other authority)	Reported or suggested locations with high emissions	Comments
Austria	5%	Yes (complaints received)	Shunting yards & idling trains	Between 1 – 10 complaints received per year.
Belgium	11%	Yes (complaints received)	<5 locations near diesel filling stations and <10 locations near shunting yards	Between 1 – 10 complaints received per year.
Bulgaria	10%	No	Uncertain	No complaints received
Czech Republic	15%	Yes (complaints received)	Shunting yards & busy line sections	Between 1 – 10 complaints received per year.
Denmark	19%	Yes (complaints received)	Restricted air exchange, idling & shunting yards	<10 complaints received/year from restricted air exchange & idling trains. 10 – 20 relating to shunting yards.
Estonia	98%	No	Marshalling depot, 2 major junction depots & main railway junctions	No response received from rail operator.
Finland	26%	Yes (complaints received)	Shunting yards?	Complaints received from shunting yards.
France	11%	Yes (complaints received)	Shunting yards, restricted air exchange & idling trains	10 – 20 complaints received per year.
Germany	19%	Yes (complaints received)	10 Shunting yards & 10 busy line sections.	Between 1 – 10 complaints received per year.
Greece	99%	No	Shunting yards?	No information received from either rail operators or Gov depts.
Hungary	18%	No	Shunting yards?	No complaints received
Ireland	95%	No	Shunting yards, line sections?	No complaints received
Italy	6%	Yes (complaints received)	Idling & shunting yards	10 – 20 complaints received per year
Latvia	97%	No	6 major junction depots & marshalling yard at	

Country	% of gross tkm by diesel	AQ problems identified by country? (either rail operator or other authority)	Reported or suggested locations with high emissions	Comments
			Dangavpils.	
Lithuania	99%	No	In & around the 7 shunting yards and possibly at four junctions	
Luxembourg	27%	No	Uncertain, however due to high % of electrification likely to be few.	No information received from either rail operators or Gov depts.
Netherlands	34%	No	2 Shunting yards.	No complaints received. The Netherlands have stated that railways and air pollution is not an issue.
Norway	45%	No	Uncertain	No information received from either rail operators or Gov depts.
Poland	9%	No	Uncertain	No information received from either rail operators or Gov depts.
Portugal	35%	No	Depots & busy line sections	
Romania	27%	No complaints received but at Lasi depot PM limit exceeded. However likely to be due to proximity of road.	Shunting yards & depots?	Concentrations below limit vales at depots apart from at Lasi.
Slovakia	14%	No	Shunting yards & busy line junctions ?	No complaints received
Slovenia	17%	No	3 busy line sections	No complaints received
Spain	13%	Yes (complaints received)	Shunting yards & restricted air exchange	1 – 10 complaints received per year.
Sweden	5%	No	Uncertain	No information received from either rail operators or Gov depts.
Switzerland	0%	Yes (complaints received)	Stations with restricted air exchange	All commercially used lines are electrified. 1 – 10 complaints received per year.
United Kingdom	43%	Yes (complaints received)	Restricted air exchange?	

In all, feedback for this study was obtained from 22 countries. No information was made available from railway operators in Greece, Luxembourg, Norway, Poland and Sweden. In addition it was not possible to obtain any information from Environment Ministries in these countries. For the remaining countries good information has been obtained on the numbers of complaints about air quality and where these complaints arise from.

Of the 22 countries from which responses were received, 10 reported receiving complaints from members of the public about poor air quality arising from rail activity. Of the 17 countries remaining, 12 reported that they never receive complaints relating to poor air quality and five did not respond. Therefore from the results of this study it appears that more rail operators do not receive complaints than do. However, it is possible that the results may be misleading as the reason that complaints are not received may be because air quality is not perceived as a problem rather than there being no locations with high pollutant concentrations. The awareness of air quality problems will differ from location to location.

On average those rail operators that did receive complaints received between one and ten complaints per year. There were no countries which reported receiving more than 20 complaints in a year. Therefore, this study shows that few air quality complaints are made by members of the public to railway operators or Environment ministries.

In most cases it has been suggested that shunting yards, locations with restricted air exchange and idling trains may cause emission hotspots. Few countries reported busy line junctions or busy line sections as being a problem.

5 Dispersion modelling results

Chapter 4 has highlighted the potential emission hotspots in each of the EU railway 27 countries. This chapter presents the results of some dispersion modelling carried out along a busy line section, a shunting yard and from an idling train to assess the impact of railway emissions on pollutant concentrations. The results are then used to assess whether other examples presented in Chapter 4 and Appendix B may contribute to an exceedance of the air quality objectives and Occupational Exposure limits.

According to Directive 99/30/EC (this Directive sets out the concentration limit values for SO_2, NO_2, PM_{10}, and lead in ambient air) the following guidelines should be met as far as possible: the sampling point should be within 1.5 metres (breathing zone) to 4 metres above the ground. Therefore in all cases the pollutant concentrations have been predicted at 1.5 metres above ground level. Further detail regarding the dispersion model that has been used and the input parameters is provided later in this section and in Appendix C.

The emissions from railway movements are provided in terms of NOx and PM_{10}. The dispersion model predicts the dilution and dispersion, translating emissions on a mass basis to concentrations in micrograms per cubic metre ($\mu g/m^3$). Complications arise in the case of pollutants that undergo chemical transformations in the atmosphere. This occurs in the case of nitrogen oxides (NOx) (the sum of nitric oxide (NO) plus nitrogen dioxide (NO_2)). The emissions occur primarily as NO but some of this is later transformed in the atmosphere to NO_2, principally by reaction with ozone. The air quality limit values and occupational exposure values provide an objective for NO_2 rather than NOx. This is because it is NO_2 that is associated with adverse health effects not NOx. It is thus necessary to predict the transformation of NO to NO_2. Various studies have suggested differing complex formulae for deriving annual mean NO_2 concentrations from annual mean NOx concentrations. However, in order to use the formulae, information must be available on the background NOx concentrations, and in some cases also the background oxidant concentration (NOx + O_3). This information was not available on a site by site basis for this study. However, to give some idea of resulting NO_2 concentrations, predicted background NOx concentrations in 2005 have been taken from a large urban area in the UK to enable NO_2 concentrations to be estimated. These results will be indicative only but will allow a comparison with the NO_2 air quality limit values to be made. Whilst if a different background NOx concentration was used to estimate NO_2 concentrations, the resulting NO_2 concentrations would vary, the difference would not be significant and the conclusion as to where and when rail movements may contribute to emission hotspots would remain the same. This can be seen in the sensitivity sections in which predicted background NOx concentrations have been taken from three areas in the UK and applied to the model outputs.

The following equation to convert from NOx to NO_2 concentrations has been used as provided in UK LAQM. TG(03):

$$NO_{2\,(road)} = ((-0.068 * \ln(NOx_{(total)}) + 0.53 * NOx_{(road)}$$

Where $NOx_{(total)} = NOx_{(background)} + NOx_{(road)}$ and ln is log to the base e.

Whilst the above equations relate to NO_2 from road transport, for this study, the same equations linking NOx to NO_2 have been assumed to hold true for rail transport as well.

As discussed above, it should be noted that the background NOx concentration will vary from location to location so the results should be taken as indicative values only.

A summary of the parameters used in the modelling are described in Table 5 below. Further detail is provided in Appendix C.

For a line section, both a maximum emission per kilometre and an average emission per kilometre have been modelled. This data has been taken from a German DB internal investigation (DB, 2005) covering the whole of the DB network. It has not been possible to check whether the values also represent the maximum and average for the EU27. However due to the size of the network it has been assumed that they are a good indication.

For the shunting yards, three scenarios have been modelled with information being obtained from the DB internal investigation. Shunting yard (1) is the maximum (in tonnes per year) emitting shunting yard; Shunting yard (2) is the maximum emission per kilometres squared out of all the shunting yards in the DB internal investigation and shunting yard (3) is an average shunting yard in terms of emissions and size (km^2).

For idling trains a maximum emission case has been modelled with information obtained from a UK study. As no information was available as to what constituted an average case a model run has been carried out with fewer idling trains than in the maximum case and this has been assumed to be representative of an 'average' case in the EU27.

Table 5. Model runs

Emission hotspot	Max/ Average	Modelled as..	Pollutant	Emission per year	Emission factor	Operating information
Busy line section	Max	Line source	NOx		9500 kg/km/year	181 trains/day
			PM_{10}		130 kg/km/year	
	Average		NOx		542 kg/km/year	19 trains/day
			PM_{10}		10.4 kg/km/year	
Shunting yard (1)	Max	Area source	NOx	40279 kg	77g/m^2/year	0.52km^2, 60975 operating hours
			PM_{10}	1785 kg	3g/m^2/year	
Shunting yard (2)	Max		NOx	12303 kg	123g/m^2/year	0.1km^2, 17546 operating hours
			PM_{10}	545 kg	5g/m^2/year	
Shunting yard (3)	Average		NOx	14811 kg	32g/m^2/year	0.47km^2, 31639 operating hours
			PM_{10}	656 kg	1g/m^2/year	
Idling train	Max	Point source	NOx	33696Kg	729g/hour/train	12 trains idling for 44% of the day
			PM_{10}	1307Kg	28g/hour/train	
	Average		NOx	5616Kg	729g/hour/train	2 trains idling for 44% of the day
			PM_{10}	218Kg	28g/hour/train	

Note: for hours of operation at shunting yards, please see Section 5.2.
Note: for further detail on the input parameters used in the dispersion model please see Appendix C.

The results from the modelling are provided in Sections 5.1 to 5.3. In all cases only the resulting contribution from the railway exhaust activities is shown. The contour plots do not take into account background concentrations or those arising from nearby industry or road traffic.

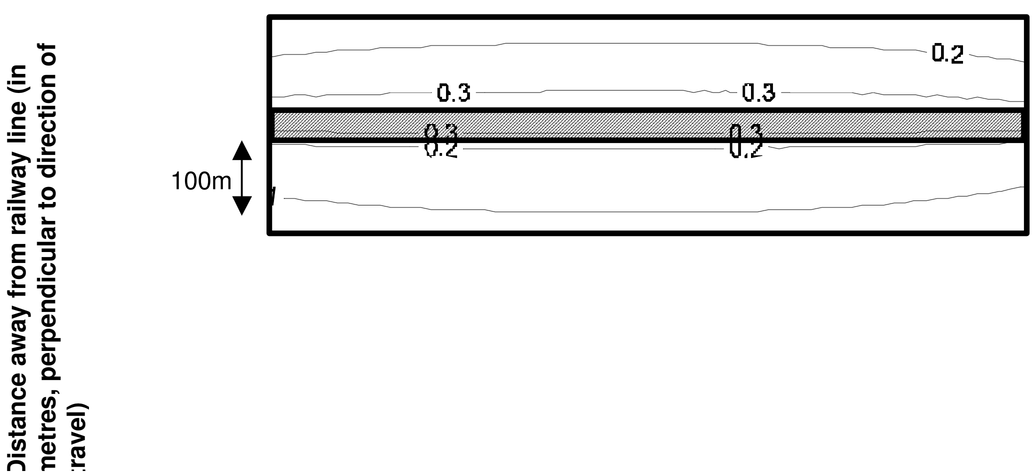
The contour plots show annual average NO_2 concentrations. This is because this is the most stringent of the NO_2 objectives and it is likely that if this objective is achieved, then the hourly objective will also be achieved. For PM_{10}, the annual objective is also shown rather than the 24 hour objective. With PM_{10}, the 24 hour objective is the most stringent of the objectives. However the 24 hour objective is potentially a difficult standard against which to carry out an assessment due to the day to day variations in PM_{10} concentrations and composition. It is therefore often recommended that the annual mean is assessed and that the 90^{th} percentile of the 24 hour mean is then calculated from this. The 90^{th} percentile of daily means in a calendar year is approximately equivalent to 35 exceedence days. An empirical relationship between the annual mean and the 90^{th} percentile of daily means has been derived from an analysis of monitoring data at UK automatic monitoring sites. That analysis showed that the PM_{10} 24 hour objective is highly unlikely to be exceeded if the annual mean concentration is below 28µg/m^3.

5.1 BUSY LINE SECTIONS

The results of the modelling show that the contribution from the busy diesel line sections to NO_2 concentrations is small (see Figure 5.1A and 1B). The maximum concentration is of the order of 0.3µg/m^3. The air quality limit value in ambient air is 40 µg/m^3 as an annual average. Therefore it can be seen that railway movements along a busy line section would not, on their own, generate a NO_2 hot spot (i.e. a location where annual average NO_2 concentrations exceed the limit value of 40 µg/m^3). Even in situations where a NO_2 hot-spot has been generated by a combination of sources (e.g. due to a combination of emissions from road transport, railways, and industry), it is clear from the concentration plots shown that the contribution from railway sources would be minimal.

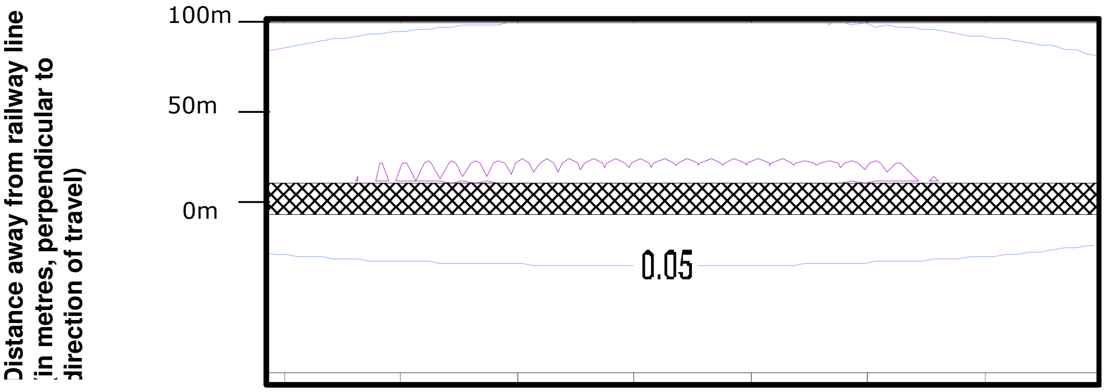
The occupational exposure limit for NO_2 is 3 parts per million (ppm) over an 8-hour time weighted average period. To convert between µg/m^3 and ppb the results need to be multiplied by 1.91. The maximum NO_2 concentration value of 0.3 µg/m^3 predicted for a worst-case line section therefore equates to 0.6 parts per billion. This is several orders of magnitude less than 3ppm, and hence it is clear that busy railway line sections would not lead to exceedances of occupational exposure limits.

Figure 5.1A: The contribution of a maximum emission line section to annual average NO_2 concentrations in µg/m^3.



Note: The railway line is the shaded area.

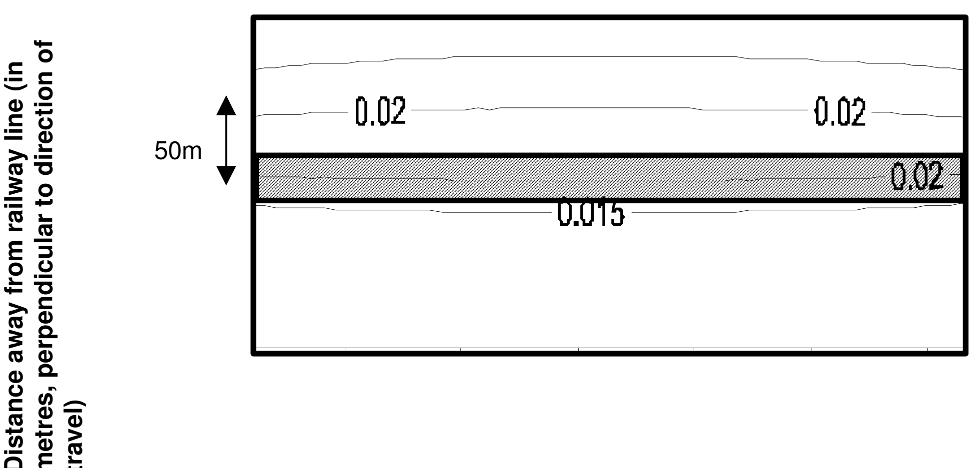
Figure 5.1B: The contribution of an average line section to annual average NO_2 concentrations in µg/m^3.



Note: The railway line is the shaded area.

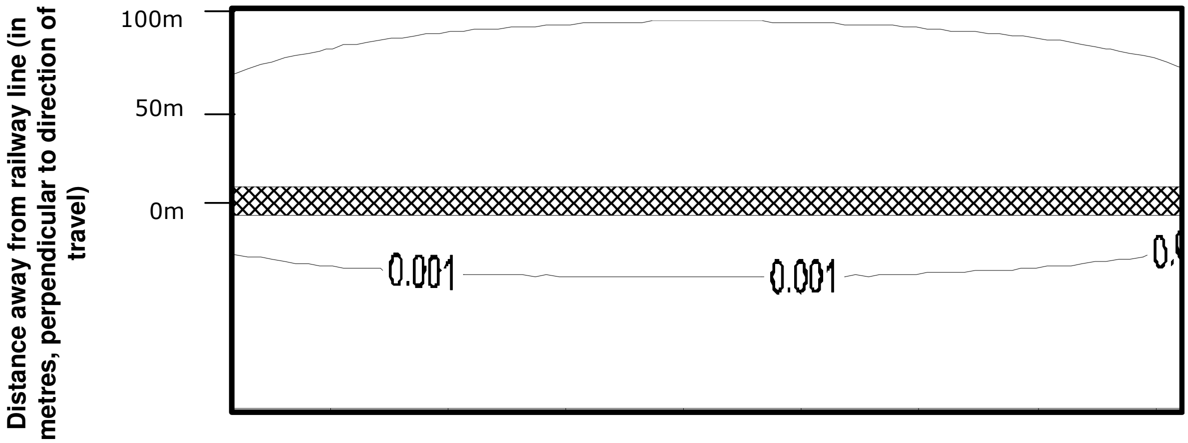
The following modelling results show that the contribution from railway movements along a busy line section to PM_{10} concentrations is small and well below either the ambient air quality limit values and occupational exposure limits. In fact, it is clear from the results that rail's percentage contribution to any PM_{10} hot spots would be even smaller than the contribution to NO_2 hot spots.

Figure 5.1C: The contribution of a maximum emission line section to annual average PM_{10} concentrations in µg/m^3



Note: The railway line is the shaded area.

Figure 5.1D: The contribution of an average line section to annual average PM_{10} concentrations in µg/m^3



Note: The railway line is the shaded area.

When carrying out the dispersion modelling for PM_{10}, only exhaust emissions have been taken into account. Emissions from brake and tyre wear and abrasion for example have been excluded. It has been suggested however, that emissions from the latter category may be more significant than those from the exhaust. For example along a heavily used line section near Zurich, Switzerland, field measurements suggest a contribution of 1 – 2 µg/m^3 (Chretien, 2005). However, this is still not significant enough to lead to an emission hotspot.

5.1.1 Line section - sensitivity analysis

The emissions used in the above examples were provided from a DB internal investigation of line sections in Germany. As a sensitivity analysis, the model runs were repeated assuming the same amount of high activity (181 train movements per day) in the maximum emission example but with the highest emission factor obtained in the WP1 report for a mainline locomotive. It is extremely unlikely that this situation would exist anywhere within any of the EU27 countries, but the results show the upper limit of NO_2 and PM concentrations along a busy railway line.

For comparison, predicted background NOx concentrations in 2005 have been taken from three areas in the UK and applied to the model outputs.
These are:

- Metropolitan (population up to 1 million) - 47µg/m^3 background NOx concentration
- Urban large (population > 100,000) - 41µg/m^3 background NOx concentration
- Rural- 12µg/m^3 background NOx concentration

Table 5.1.1 The predicted NO_2 and PM_{10} concentrations arising from a line section using the highest emission factors obtained in the WP1 Report for a locomotive.

Pollutant	Background NOx concentration used (if applicable)	Max predicted NO_2 and PM_{10} concentrations
NO_2	Metropolitan - 47µg/m^3	0.53µg/m^3
NO_2	Large urban - 41µg/m^3	0.55µg/m^3
NO_2	Rural - 12µg/m^3	0.70µg/m^3
PM_{10}	N/A	0.04µg/m^3

The results re-iterate the earlier conclusion that busy diesel line sections will not on their own lead to NO_2 and PM_{10} emission hotspots. Even in combination with emissions from industry and road traffic and other sources the contribution from diesel line sections will be small. The results also show that differing the background NOx concentration does not change the results significantly.

5.1.2 Comparison with road

The NOx and PM_{10} emissions arising from a typical average motorway and a typical average minor road compared to that from a busy diesel rail line section are provided in Table 5.1.2A below.

Table 5.1.2A: Estimated emissions per kilometre arising from 2 types of road and a busy railway line section.

Type of activity	NOx (kg/km/annum)	PM_{10} (kg/km/annum)
Motorway	73,840	2,197
Minor Road	2,059	125
Busy diesel line rail section	9,480	130
Average diesel line rail section	542	10

Note: emissions for the motorway and minor road have been calculated using UK road transport emission factors.
For detail of the fleet composition assumed, please see Table 5.1.2B below.

The table shows that typically NOx emissions from a busy railway section are more than that from an average minor road but substantially less than that from an average motorway. NOx emissions from an average line section are however substantially less than that from a minor road. PM_{10} emissions from a busy line section are similar to that from a minor road with those from an average railway line being less than one tenth as that from a minor road.

The relationship between emissions and concentrations is complex and will depend on a number of factors including the physical characteristics of the emitting sources and the meteorological conditions. Therefore dispersion models are needed to predict resulting concentrations and no direct comparison can be made between emissions and concentrations from different sources.

To give some idea of the significance of the NO_2 concentrations predicted in the 'busy line section' modelling, emission concentrations arising from the average major and minor road (discussed above) have been calculated using the UK's Design Manual for Roads and Bridges (DMRB) model. The DMRB model is the UK government's recommended model for Local Authorities to use in the first stage of the Air Quality Review and Assessment process (See Section 8.27 on the UK for further information). The background NOx concentration used is that from a large urban area in the UK.

Table 5.1.2B: Predicted pollutant concentrations 20 metres from a typical major and minor road and busy railway line in 2005.

Type of road/rail line section	Predicted NO_2 conc arising from road/rail traffic (μg/m^3)	Predicted PM conc arising from road/rail traffic (μg/m^3)
Motorway (average speed 112 km/hr, 100,000 vehicles per day, 7% HGVs)	12.8	8.7
Minor (average speed 48 km/hour, 10,000 vehicles per day, 2% HGV)	2.1	1.3
Very busy rail line section	0.3	0.02
Average rail line section	0.05	0.001

Notes: HGV = heavy goods vehicles; Conc = concentration; PM = particulates

The concentrations arising from road traffic give some idea of the relative contribution of road versus rail. It can be seen that even a minor road contributes a lot more to NO_2 and PM_{10} concentrations than a busy diesel line rail section.

5.2 SHUNTING YARDS

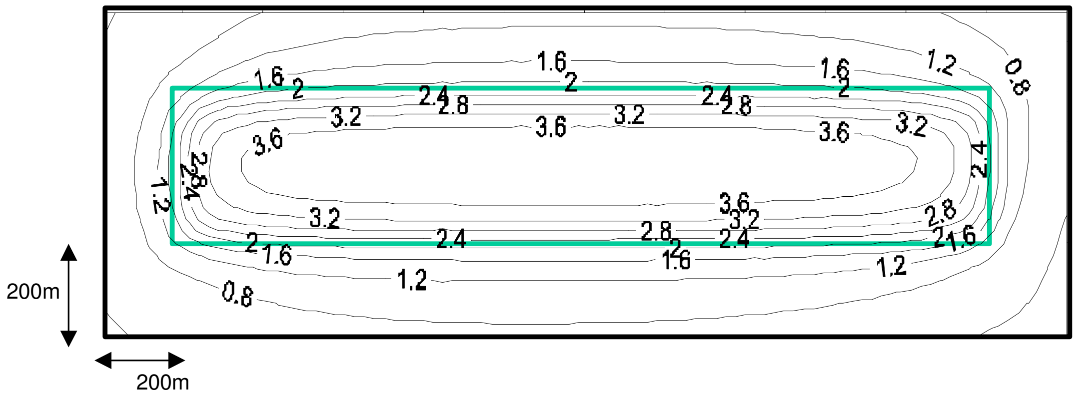
Dispersion modelling has been carried out for three shunting yards. Shunting yard (1) has been chosen because of the high emissions generated at this site. Shunting yard (2) has been chosen because it has the highest emissions per metre squared but covers a small area and shunting yard (3) has been chosen as it represents an average shunting yard.

The emissions generated by the shunting yards have been calculated from the hours of operation of shunting locomotives at certain shunting yards. It also includes the emissions arising from train movements such as access to the yard but assumes that all emissions occur within the yard boundaries. Therefore the concentrations of pollutants in the surroundings are likely to be over-estimated.

The resulting NO_2 concentrations are shown in Figures 5.2A –C below and PM_{10} concentrations in Figures 5.2D – F.

It is worth noting that shunting yards mainly operate at night when there is little road transport activity and therefore the two peaks of these activities when emissions are highest do not coincide.

Figure 5.2A: The predicted contribution of shunting yard (1) to annual average NO_2 concentrations in µg/m^3.



Note: The shunting yard is the area within the green box.
The modelling output extends 200 metres in each direction from the shunting yard.

Figure 5.2B: The predicted contribution of shunting yard (2) to annual average NO_2 concentrations in µg/m^3.

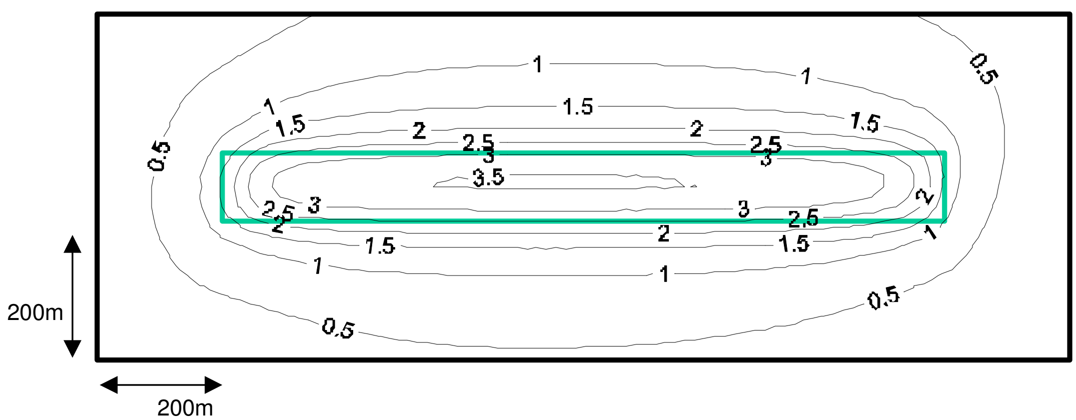


Figure 5.2C: The predicted contribution of shunting yard (3) to annual average NO_2 concentrations in $\mu g/m^3$.

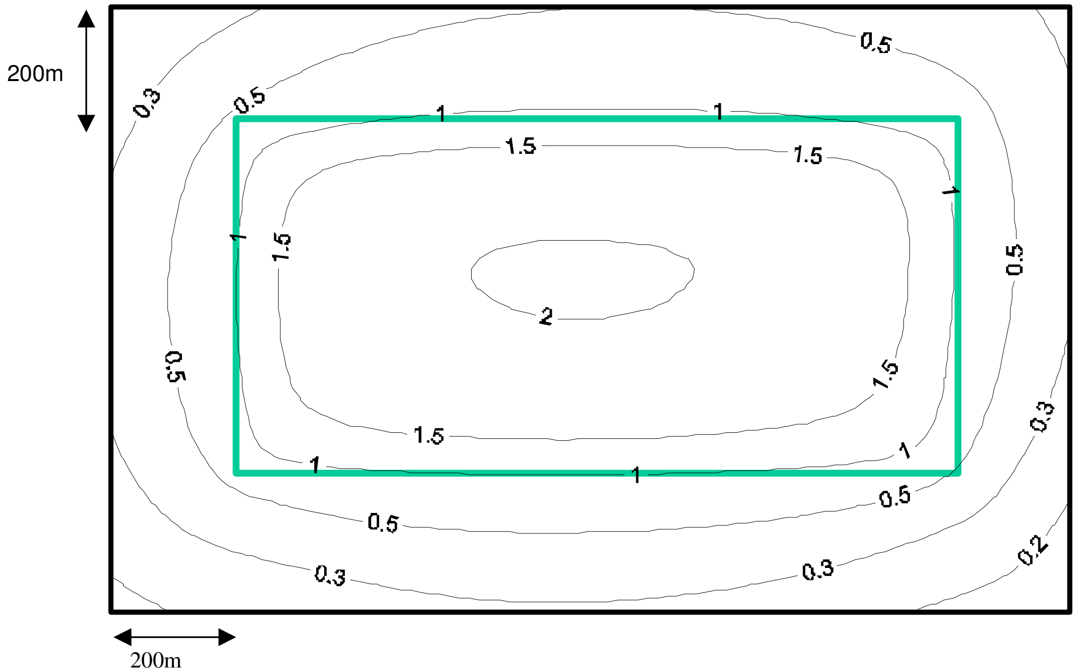


Table 5.2 provides the maximum annual mean NO_2 concentrations at the boundary of each of the shunting yards modelled.

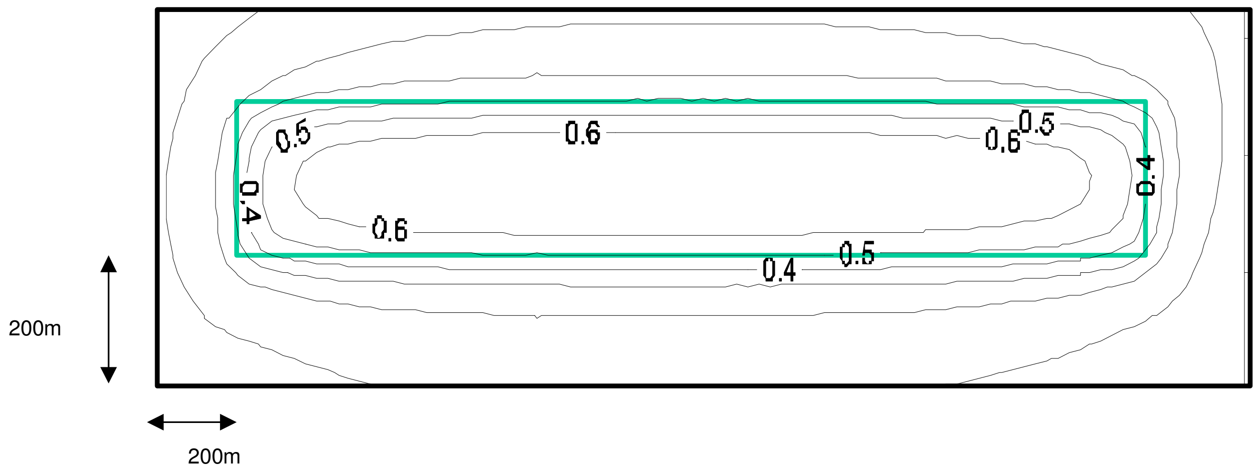
Table 5.2 Maximum annual mean NO_2 concentrations predicted at the shunting yard boundaries and corresponding sizes and hours of operation of shunting locomotives.

Location	Max. predicted concentration at boundary (NO_2)	Size (km^2)	Hours of operation per year.
Shunting yard (1)	$2\mu g/m^3$	0.52	60,975
Shunting yard (2)	$2.5\mu g/m^3$	0.1	17,546
Shunting yard (3)	$1\mu g/m^3$	0.47	31,639

Table 5.2 has shown that both the size and hours of operation of a shunting yard are important. Shunting yard (2) for example, has fewer hours of operation than either shunting yard (1) or (3) but significant concentrations are obtained due to the dense network of activity.

The modelling has shown that NO_2 concentrations surrounding a shunting yard could be significant where activity levels are high although they would not lead to an emission hotspot (where limit values are exceeded) on their own. This is further investigated in the sensitivity analysis section.

Figure 5.2D: The predicted contribution of shunting yard (1) to annual average PM_{10} concentrations in μg/m^3.



Note: The shunting yard is the area within the green box.
The modelling output extends 200 metres in each direction from the shunting yard.

Figure 5.2E: The predicted contribution of shunting yard (2) to annual average PM_{10} concentrations in μg/m^3.

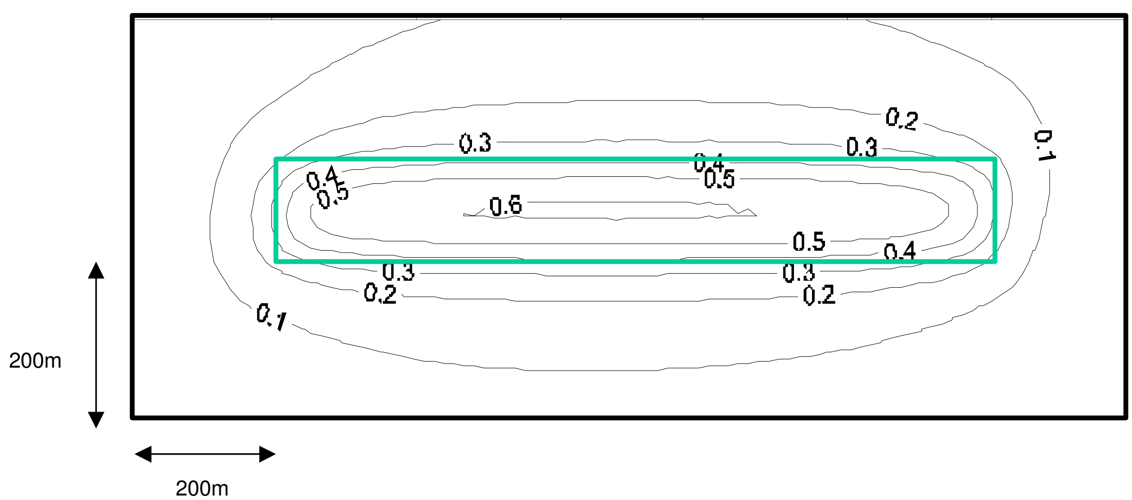
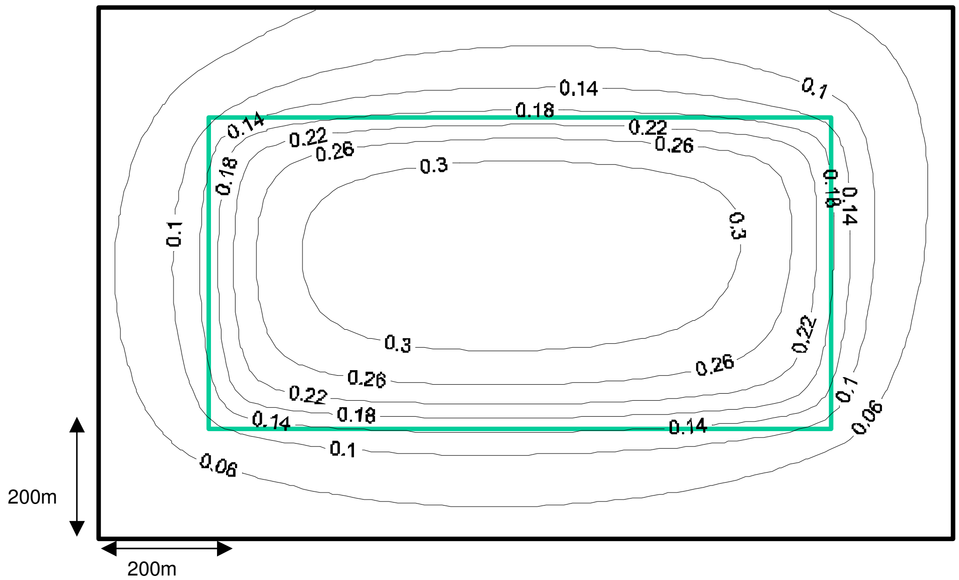


Figure 5.2F: The predicted contribution of shunting yard (3) to annual average PM_{10} concentrations in µg/m^3.



The modelling results show that shunting yard operations impact little on PM_{10} concentrations in their vicinity. Even in the worst case, PM_{10} concentrations arising from shunting operations are a maximum of 0.5µg/m^3. This compares to an annual average limit value of 40µg/m^3. As discussed in Section 5.1, if the annual mean PM_{10} concentration is predicted to be less than 28µg/m^3 then the 24 hour objective is likely to be met.

5.2.1 Shunting yard – sensitivity analysis.

The emissions utilised in the dispersion modelling for the shunting yard examples were taken from the DB internal investigation. To assess the highest possible concentrations that could arise from shunting operations, the activity (train movements) associated with the busiest shunting yard in Germany has been combined with the highest shunting locomotive emission factor (g/kwh) provided in the WP1 report. This scenario is very unlikely to occur (as the highest activity levels have been combined with the highest emission factors) in any of the EU27 countries, but it provides an idea of the highest NO_2 (given the background NOx concentration) and PM_{10} concentrations that could ever occur.

For comparison a predicted background NOx concentration in 2005 has been taken from three areas in the UK and applied to the model outputs.
These are:

- Metropolitan (population up to 1 million) - 47µg/m^3 background NOx concentration
- Urban large (population > 100,000) - 41µg/m^3 background NOx concentration
- Rural- 12µg/m^3 background NOx concentration

Table 5.2.1 The predicted NO_2 and PM_{10} concentrations arising from a shunting yard using the highest emission factors obtained in the WP1 Report for a shunting locomotive.

Pollutant	Background NOx concentration used (if applicable)	Max predicted NO_2 and PM_{10} concentrations
NO_2	Metropolitan - 47µg/m^3	4.9µg/m^3
NO_2	Large urban – 41µg/m^3	5.0µg/m^3
NO_2	Rural - 12µg/m^3	5.9µg/m^3
PM_{10}	N/A	1µg/m^3

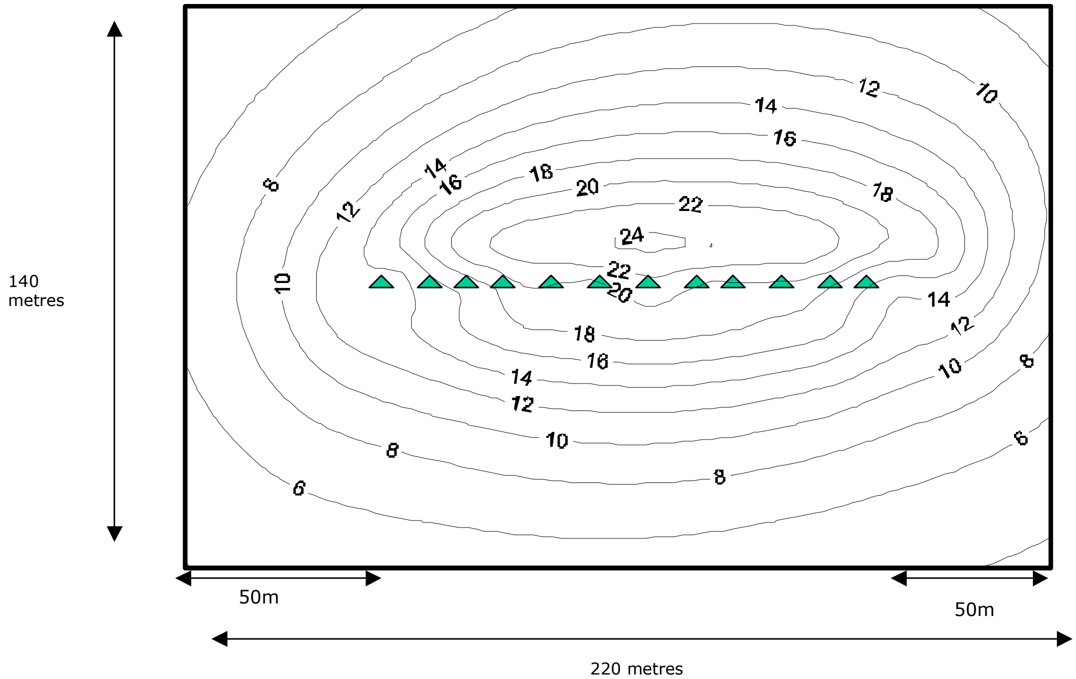
The modelling shows that in this theoretical worst case shunting yard example, NO_2 concentrations are predicted to be a maximum of 5.9µg/m^3 at the shunting yard boundary. NO_2 concentrations arising from shunting yards on their own will not lead to an exceedence of the air quality limit values. PM_{10} concentrations are predicted to be a maximum of 1µg/m^3 at the shunting yard boundary. It is clear from the modelling results that PM_{10} is not an issue from shunting yard operations and that they do not contribute significantly to ambient PM_{10} concentrations.

5.3 IDLING TRAINS

Very complex dispersion modelling would be needed to assess air quality within a covered station environment and this is beyond the scope of the report. In addition, it is uncertain how accurate the modelling would be due to complex air flow in partially covered stations and other uncertainties. Instead of attempting to model pollutant dispersion in the complex station environment described above, a simpler approach has had to be used. In place of a covered station environment, it has been assumed for the purposes of the modelling, that terminal stations are open environments, with no restricted air-flow. This obviously limits the accuracy of the modelling outputs, but does provide an indication of the theoretical maximum pollutant concentrations in the area surrounding the station. The input data used for this modelling exercise is based on actual train movements and idling patterns at a large city-centre terminal stations where diesel trains are utilised on a regular basis. The results of this modelling have allowed the ambient NO_2 and PM_{10} concentrations that result from a busy terminal station with 12 platforms where inter-city trains are left in idle operation for approximately 40% of the day to be estimated (although it must be stressed that ambient concentration levels modelled using this simplified, open-environment, approach are likely to be higher than would be the case in reality for a semi-enclosed station. NOx concentrations have been converted into NO_2 concentrations using a background NOx concentration of 91µg/m^3 which is typical for London in 2005.

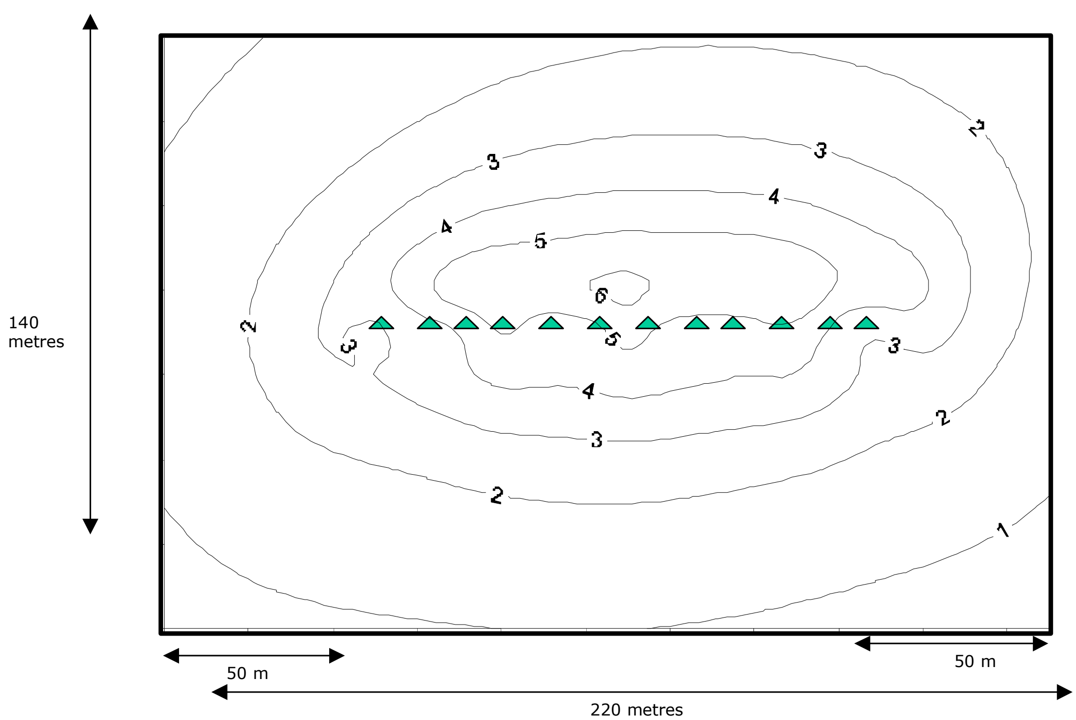
The results of the dispersion modelling are presented in figure 5.3A and 5.3B below.

Figure 5.3A: The predicted contribution of a busy rail station to annual average NO_2 concentrations (μg/m^3)



Note: the triangles represent the trains.

Figure 5.3B: The predicted contribution of a busy railway station to annual mean PM_{10} concentrations (μg/m^3)



Note: the triangles represent the trains

The results of the dispersion modelling of a busy railway station with 12 platforms with idling trains show that potentially idling trains could lead to NO_2 and PM_{10} emission hotspots. Concentrations of NO_2 outside of the station were found to reach a maximum of 12 μg/m^3, whilst concentrations of PM_{10} outside the station reached a maximum of 3 μg/m^3. This means that in theory emissions from diesel trains idling at terminal stations could be a significant contributor to NO_2 and PM_{10} hotspots. It must, however, be reiterated that due to the limitations of the modelling techniques used for assessing the impacts of idling at stations, the values for the contributions of rail engine idling emissions are likely to be overestimates, as a large proportion of the emissions generated in a semi-enclosed environment would not contribute to ambient pollutant concentrations due to air flow restrictions. It is suggested that monitoring should be undertaken at a range of stations which have restricted air flow to clarify the results. ***It is likely however, due to the high amount of diesel activity in this particular example, that this situation is very limited and would only occur in very few station environments in the EU Railway 27. In the majority of European countries, large terminal stations will occur in large conurbations where a high proportion of trains are electrified as diesel activity tends to be concentrated in rural areas. This issue needs to be investigated in greater detail.***

The occupational exposure limit for NO_2 is 3 parts per million (ppm) over an 8-hour time weighted average period. To convert between μg/m^3 and ppb the results need to be multiplied by 1.91. The maximum NO_2 concentration value of 24 μg/m^3 predicted for a worst-case terminal station therefore equates to 46 parts per billion. This is several orders of magnitude less than 3ppm, and hence it is clear that busy railway line sections would not lead to exceedances of occupational exposure limits for NO_2. The same is true with particulate matter with occupational exposure limits being a maximum of 4 mg/m^3 and the maximum concentration predicted within the station environment being 6 μg/m^3.

To give some idea of pollutant concentrations arising from an 'average' location with idling trains, the modelling has been repeated but assuming there are only two trains idling rather than the 12 in the example above due to no further information being available. The same emission factors (grams/hour/train) have been used in the maximum and average example. The WP2 Report provided a range of idling emission factors from the EU27. These were: 75 to 800 grams per hour for NOx and 10 to 70 grams per hour for PM. The emission factors used in the modelling were 729 grams per hour and 28 grams per hour for NOx and PM respectively. Therefore the NOx factors fall within the range provided in WP2 but are towards the higher end. For PM, the factors again fall within the range provided but are towards the lower end. Therefore, the NO_2 concentrations shown are towards the upper bound of the likely contribution with two trains idling whereas the PM values are towards the lower. As a rough guide, if an assessment of the resulting concentration of PM with an emission factor of 10 grams per hour was required the current concentrations should be divided by a third as the emission factor is approximately a third of that used. The results are presented in Figures 5.3C and 5.3D below.

Figure 5.3C: The predicted contribution of an 'average' rail station to annual average NO_2 concentrations (μg/m³).

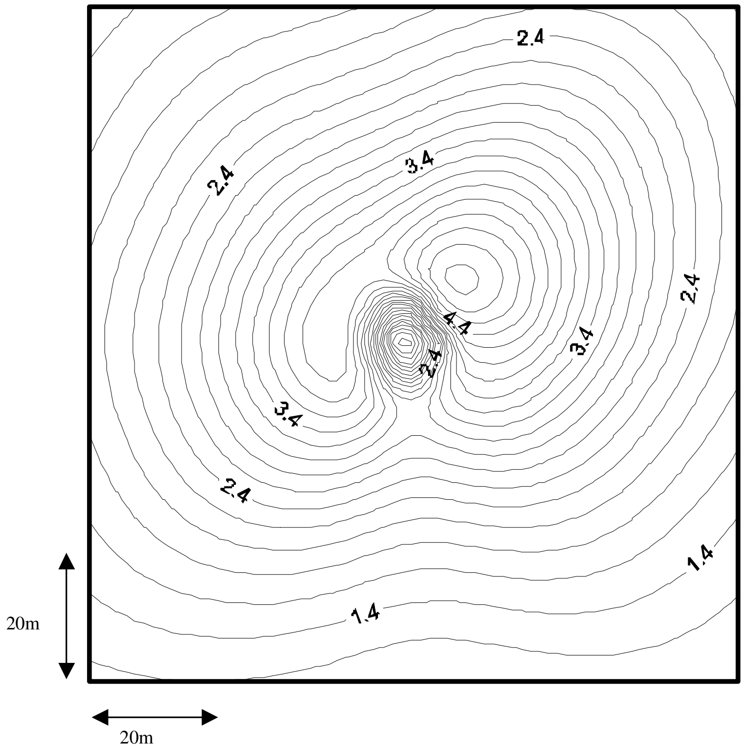
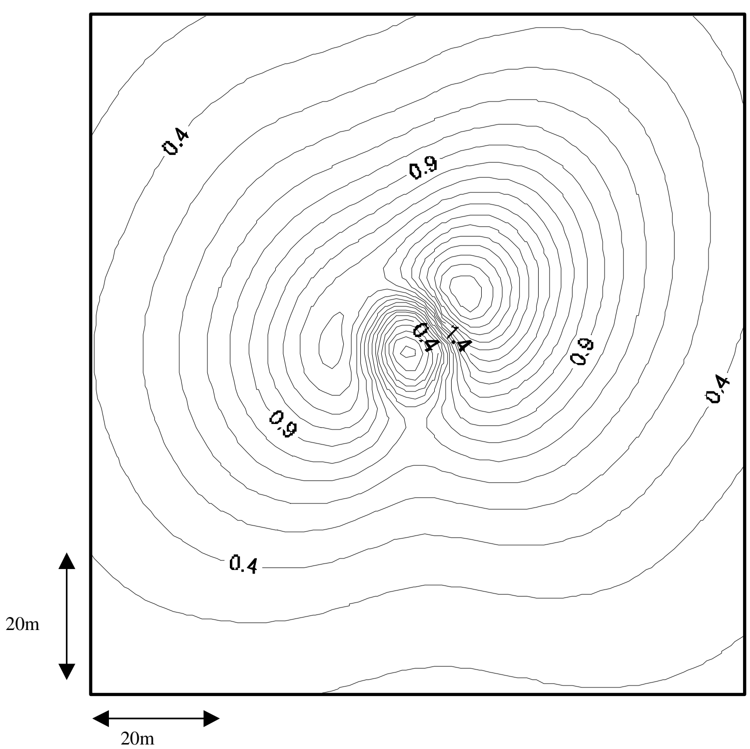


Figure 5.3D: The predicted contribution of an 'average' rail station to annual average PM_{10} concentrations (μg/m³).



The modelling shows that with two diesel trains idling for approximately 40% of the day that the contribution to NO_2 and PM_{10} concentrations is significant (approximately 4.2µg/m^3 of NOx and 1 µg/m^3 of PM, 20 metres from the idling trains) but again it will not lead to air quality limit values being breached on their own.

5.3.1 Idling trains – sensitivity analysis

The modelling carried out in Section 5.3 for idling trains in a busy station environment are based on approximately average emission factors (g/kwh) from the WP1 report. However, idling times are long and so it is unlikely that there are many (if any other) stations in the EU27 where NO_2 and PM_{10} concentrations would exceed that predicted in Figures 5.3A & B. In order to carry out a sensitivity analysis the very highest emission factors for locomotives have been taken from the WP1 report and combined with the idling times from that modelled previously. This is a very artificial assumption and is highly unlikely to happen in the real world. Concentrations of NO_2 outside of the station were found to reach a maximum of 22 µg/m^3 (using the large urban background NOx concentration), whilst concentrations of PM_{10} outside the station reached a maximum of 3 µg/m^3. The modelling therefore shows that emissions from diesel trains idling at terminal stations could be a significant contributor to NO_2 and PM_{10} hotspots where there is intense activity but that on their own will not contribute to an exceedance of the air quality limit values.

6 Conclusions.

This study has provided a background to air quality in general and then assessed the contribution of rail emissions to pollutant concentrations.

Questionnaire feedback from rail operators and information provided by Environment Ministries showed that:

- shunting yards and idling at locations with restricted air exchange were thought to be the largest emission sources. However, in the majority of cases, there was no quantitative data available to determine whether such locations caused emission hotspots in reality.
- There were either no complaints or few complaints (less than 20 per year) received from the public regarding air quality arising from rail operations.

Due to the lack of detailed measured pollutant concentration data for potential rail emission hot spots, pollutant dispersion modelling was carried out to quantify the likely contribution of typical shunting yards, busy line sections and terminal stations to ambient NO_2 and PM_{10} concentrations. The results of the dispersion modelling showed the following:

- Even very busy line sections gave rise to insignificant NO_2 and PM concentrations.
- Very busy shunting yards gave rise to low level NO_2 and PM concentrations
- More relevant contributions (but still below the limit values) are possible at large terminal stations where there is a high amount of diesel activity.

Contributions from rail	**Status**	**NO_2(µg/m^3)**	**PM (µg/m^3)**
Rail line section	Average	0.05	0.001
Rail line section	Very busy	0.3	0.02
Shunting yard	Average	1	0.18
Shunting yard	Very busy	2.5	0.5
Terminal station	Average	4.2*	1*
Terminal station	Very busy	12*	3*

* see section 5.3 on modelling limitations

Limit values (according to Directive 99/30/EC)	**NO_2(µg/m^3)**	**PM (µg/m^3)**
Long term exposure	40 (in 2010)	40 (in 2005) 20 (in 2010)

It is recommended that further work should be carried out to attempt to quantify more accurately the contribution of idling stations and shunting yards to pollutant concentrations. In particular, it is recommended that monitoring at a small number of busy terminal stations could be carried out to assess more accurately the contribution of idling trains to pollutant concentrations both inside and outside of stations. When monitoring data is received, this should be used in preference to the modelling results. This is because dispersion models are only a tool to estimate dispersion and are by no means 100% accurate. However in the absence of monitoring data they provide indicative results and also provide good spatial coverage whereas monitoring results are only spot results. The results from this will then enable a conclusion to be drawn as to whether high pollutant concentrations are found in a few locations or whether this is more widespread.

Further information would be needed to estimate in more detail the number of locations within the EU27 that have shunting yards and idling diesel trains at terminal stations that contribute significantly to ambient pollutant concentrations.

7 Appendix A

7.1 ORGANISATIONS CONTACTED:

The following organisations were contacted to obtain information on air quality complaints arising from train movements and the locations of emission hotspots.

Austria:

- - OBB

Belgium:

- Belgium railway operator (SNCB holding)
- Ministry of the Environment
- Person responsible for reporting CLRTAP emission data to EU
- IRCEL, Emission Expert for Waloon Region

Bulgaria:

- Bulgarian Railways (BDZ)
- Ministry of Environment and Water
- Executive Environmental Agency
- Statistics Office, Railway Administration
- Institute of Transport Science.

Czech Republic:

- Ceske Drahy (CD)
- Environmental Ministry, Emission Inventory Department
- Czech Hydrometeorological Institute (CHMI) &
- Transport Research Centre (CDV Brno)

Denmark:

- DSB
- The National Environmental Research Institute

Estonia:

- Estonian Railways Ltd
- Ministry of Environment
- Statistics Office
- Ministry of Economic Affairs and Communications/ Road and Railways Department
- Ministry of Transport & Communication
- Ministry of Social Affairs
- Person responsible for reporting CLRTAP emission data to EU

Finland:

- VR Ltd
- Air Quality Research Group
- Environmental Protection Agency
- Environment Information Unit, Finland Government

France:

- Connex
- SNCF

Germany:

- Deutsche Bahn (DB) AG

Greece:

- Greece railway operator (CH Railways)
- Hellenic Railways Organization
- Ministry of Transport

Hungary:

- - MAV Hungarian State Railway Company
- - Environmental Ministry
- - Institute for Transport & Science
- - Ministry of Economy and Transport
- - Research Institute for Transportation

Ireland:

- Irish Rail
- The Department for Transport
- Department of the Environment, Heritage and Local Government.
- The Environmental Protection Agency

Italy

- Trenitalia
- Litrail

Latvia:

- Latvia rail operator (State JSC Latvian Railway – LDZ)
- Ministry of Transport
- Ministry of Transport and Communications
- Ministry of Environment
- Ministry of Transport and Communications
- Statistics Office, Ministry of Health
- State Joint Stock Company “Latvijas Dzelzcelsh” Latvian Railway
- Person responsible for reporting CLRTAP emissions data to EU

Lithuania:

- Rail operator (Lithuanian railways)
- Environmental Protection Agency
- Ministry of Transport, Statistics Office
- Health Ministry
- Person responsible for reporting CLRTAP emission data to EU.

Luxembourg:

- CFL
- Luxembourg Environment Department

Netherlands:
- ProRail
- NS
- Nedtrain Consulting
- Dutch air quality monitoring system

Norway:
- NSB
- JBV
- Jernbaneverket
- Norwegian Institute for Air Research
- Ministry of the Environment
- Ministry of the Environment, Department for Pollution Control.

Poland:
- PKP Polish Railway lines
- National Emission Centre,
- Ministry of Infrastructure,
- Environmental Monitoring Laboratory,
- Railway Scientific and Technical Centre

Portugal:
- CP Railways
- Portuguese Environment Department

Romania:
- The Romanian Company for Passengers Transportation (S.N.T.F.C)
- Ministry of Environment,
- Environmental Protection Agency,
- ICIM (National Air Quality Network Romania), and
- Transport Research Institute

Slovakia:
- Slovakian railways - Zeleznicna spolocnost CARGO Slovakia a.s
- Slovak Environmental Agency
- Slovakia Hydrology Institute
- Person responsible for reporting CLRTAP emission data to EU.

Slovenia:
- Environmental Agency of the Republic of Slovenia
- SL

Spain
- EVR
- RENFE
- ADIF, Environment Manager

Sweden:

- Swedish Environmental Protection Agency (air pollution & monitoring)
- Green Cargo
- SJ (FTR representative)

Switzerland

- SBB AG
- BLS Lotschbergbahn

UK

- The Association of Train Operating Companies (ATOC)
- EWS (freight operator)
- Network Rail
- Charnwood Borough Council
- Plymouth City Council

8 Appendix B – The "EU railway 27"

This chapter summarises the information obtained from questionnaire feedback (where available) for each of the 27 European countries assessed in this study. Information on the percentage of gross tonne kilometres hauled by diesel trains, the fuel consumption, number of vehicles and the age profile of the fleet has been taken from the 'Third party assessment of the WP1 Report' (Kollamthodi, 2005). In some cases data provided by individual countries is also presented.

8.1 AUSTRIA

The railway network in Austria covers 6,021km[1] with diesel operations accounting for approximately 5% of gross tonne kilometres hauled (WP1 report, 2005).

The Austrian diesel rail fleet is used mainly for freight transport and maintenance purposes. Just under 30% of all freight in Austria is transported by rail, whilst road freight accounts for 52% of all freight transported. The diesel rail fleet consists of 198 DMU train-sets and 620 locomotives (European Railway stock list, 2005). The average age of railcars and DMU train-sets is 18.7 years and the average age of a locomotive is 28.9 years (European Railway Stock list, 2005). This compares to average ages of 22.9 years and 35.8 years for railcars and locomotives respectively across all countries. Therefore Austria has a railcar fleet that is slightly newer than the majority of the EU railway 27 countries, whilst the locomotive fleet is, seven years newer than the European average.

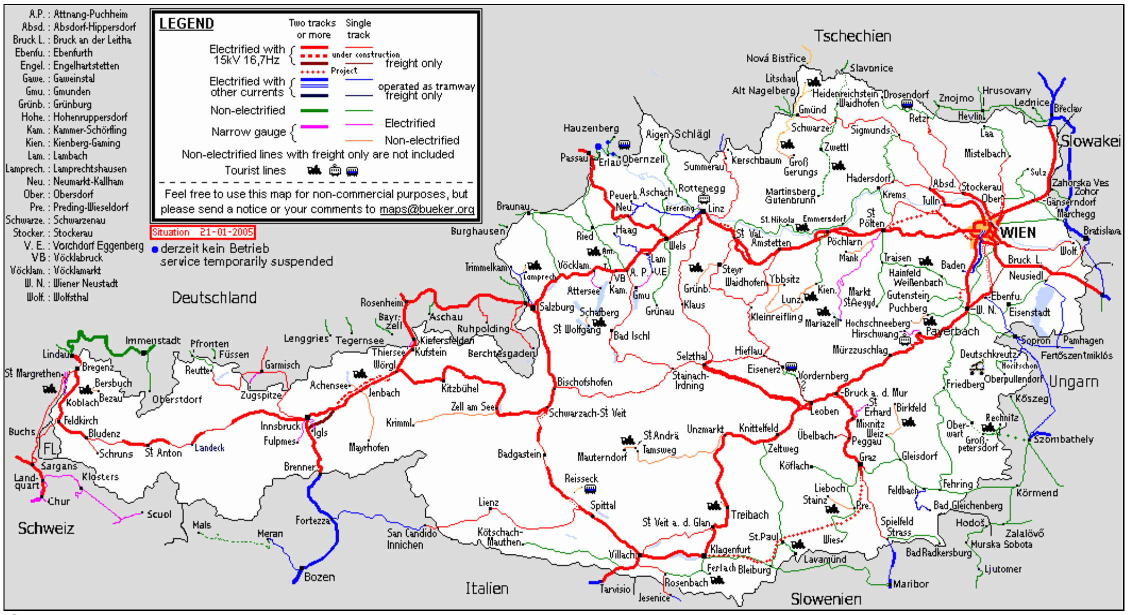
The annual fuel consumption in 2003 was approximately 2,241 Tera Joules (UNFCCC, 2004) of diesel with a sulphur content of 10ppm (Response to Questionnaire A). This is classed as sulphur free fuel. Therefore sulphur dioxide (SO_2) emissions from the railway sector will be minimal. The use of low sulphur fuel will also helps to enable retrofit abatement equipment to be fitted.

The Austrian railway company, ÖBB has received fewer than ten complaints about poor air quality surrounding shunting yards, and idling trains outside/at stations. The complaints were focused on the areas Ebensee, Mistelbach, Wieselburg, and Grein Bad Kreuzen, where there are shunting yards. It was, however, felt that the information was not complete and that the public could be complaining to other authorities about other problems that ÖBB were unaware of.

Shunting yards were predicted to be the highest source of emissions. However, no information was provided on the total number of shunting yards in Austria.

[1] http://www.cia.gov/cia/publications/factbook/geos/au.html#Trans

Figure 8.1 Austrian rail map



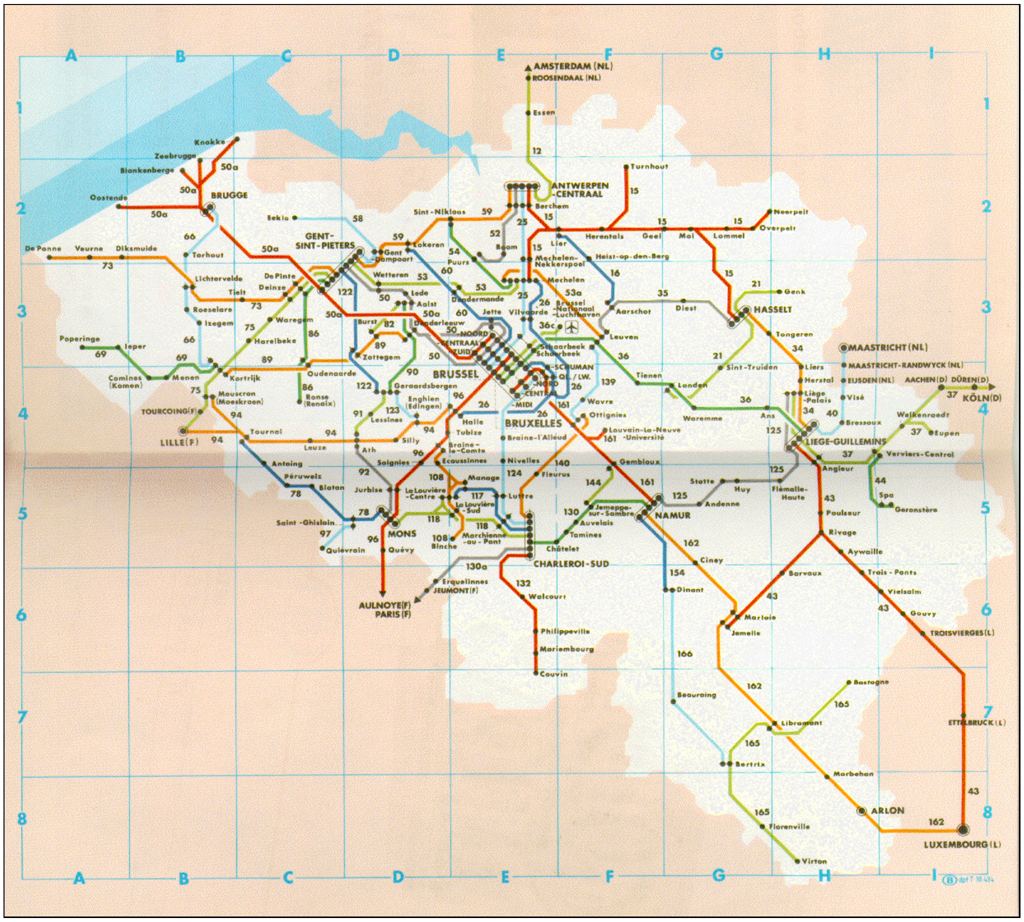
Source: http://members.telering.at/hans.goebl/hg-austrian-network-05-01-21.gif

It is suggested that the most likely hotspots are at the four mentioned locations where there are shunting yards and idling trains.

8.2 BELGIUM

Figure 8.2 provides a map of the Belgium rail network.

Figure 8.2 Belgium rail map



Source: http://ccl.kuleuven.be/~corn/railinfo/nmbs.gif

The Belgian railway network is very dense and covers approximately 3,518 km[2]. Diesel operations account for approximately 11% of gross tonne kilometres hauled (WP1 report, 2005). Diesel traction is mainly used in shunting areas and on railway lines in rural areas. This could change, however, in the next 5-10 years if new freight operators obtain substantial market share and operate mainly by diesel traction.

The fleet consists of 649 diesel locomotives according to the European Railway stock list, 2005 (or 441 as provided by Belgium's NMBS – Holdings) and 96 diesel railcars and DMU train-sets. The average age of a railcar is 5 years and a locomotive 32.2 years (European Railway stock list, 2005). This compares to average ages of 22.9 and 35.8 years respectively across the EU railway 27. The Belgian railcar fleet is very new and is one of the youngest of all the countries in this study. In addition, approximately 54% of the large locomotives have been manufactured since 1999.

In 2003 total diesel fuel consumption by the rail sector was 1,935 Tera Joules (UNFCCC, 2004) (or 1,778 TJ as provided by NMBS Holdings) with a sulphur content of 50ppm. This is classed as low sulphur fuel.

[2] http://www.cia.gov/cia/publications/factbook/geos/be.html#Trans

SNCB (the Belgian rail operator) receives on average between one and ten complaints per year relating to air quality as a result of rail operations. Those complaints mostly concern the smell of diesel fumes from a particular locomotive type used for infrastructure work. In addition to complaints about smell and noise they also receive complaints about emissions from idling trains at a diesel filling station situated in a densely populated area.

SNCB indicated that shunting yards were the most important emission source followed by diesel filling stations. More detail and the number of locations relevant to each emission source in Belgium is provided in Table 4.2 below.

Table 8.2: Source of emissions from the rail network as identified by SNCB.

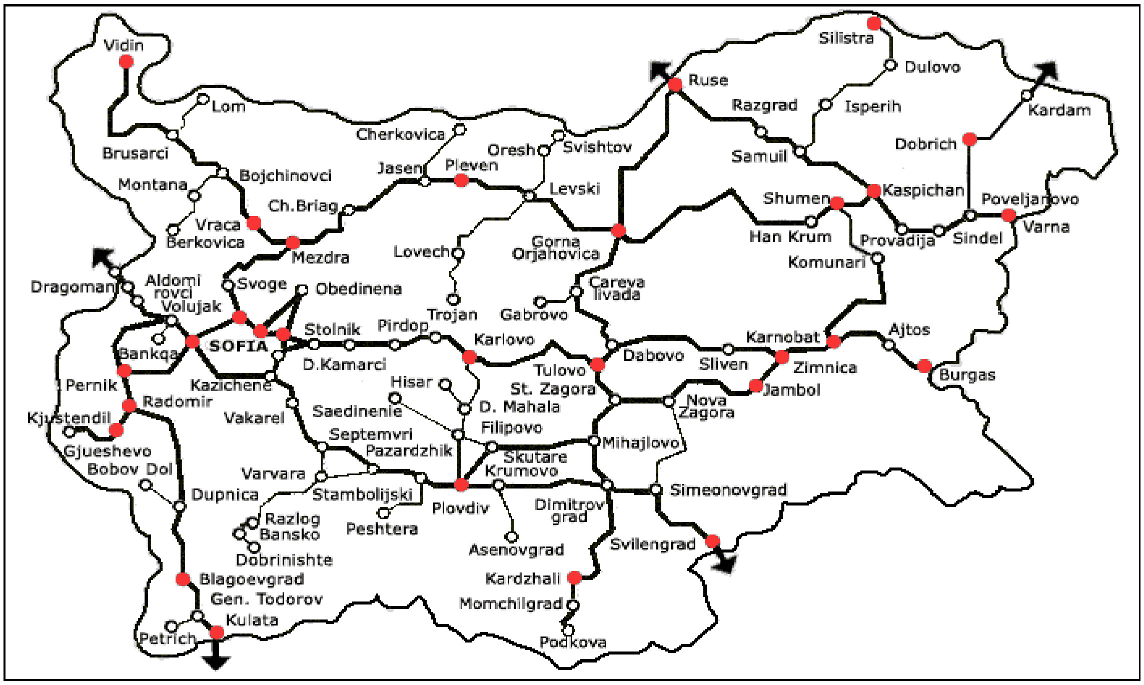
Type of location or operation	Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)	Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from housing.
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	3	None with diesel traction
Shunting operations	1	<10
Locations with high emissions from line sections with diesel traction	4	No sensible areas known
Diesel filling stations	2	<5

The information provided confirms that there are no emission hotspots in Belgium at locations with restricted air exchange or from line sections, as electric traction is used at these locations. It is suggested that both the ten shunting operations and five diesel filling stations may be potential emission hotspots in Belgium.

8.3 BULGARIA

Figure 8.3 below shows the main railway lines in Bulgaria.

Figure 8.3 Bulgaria rail map



Source: http://razpisanie.bdz.bg/cgi-bin/ph_lat.pl

The rail network in Bulgaria extends over 4,294 km[3] of which diesel operations account for approximately 10% of gross-tonne kilometres hauled (WP1 report, 2005). The Bulgarian railways (BDZ) operate 629 diesel locomotives and 25 railcars (European Railway Stock list, 2005). The railcars are very new Siemens units that were only put into service during 2005, and hence Bulgaria has one of the newest DMU railcar fleets in Europe. However, with an average age of 37.6 years, Bulgaria's locomotive fleet is older than the European average (European Railway Stock list, 2005). In 2003 the annual consumption of diesel fuel by the rail sector was approx 1,279 Tera Joules (UNFCCC, 2004) and the sulphur content was 350ppm. This is classed as fuel with a high sulphur content.

The Bulgarian railways (BDZ EAD) stated in their response to the questionnaire that they never receive any complaints regarding air quality from railway operations. Although the rail fleet is old in Bulgaria, BDZ EAD is subject to emission requirement at a local and national level.

In their questionnaire response, BDZ EAD did not rank the emission sources in terms of importance as they felt that none were significant. Their response is provided in Table 8.3 below.

[3] http://www.cia.gov/cia/publications/factbook/geos/bu.html#Trans

Table 8.3: Source of emissions from the rail network as identified by BDZ EAD.

Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from housing.**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic		No locations that are less than 50 meters away from housing
Shunting operations		No locations that are less than 50 meters away from housing
Locations with high emissions from line sections with diesel traction		No locations that are less than 50 meters away from housing
Other		

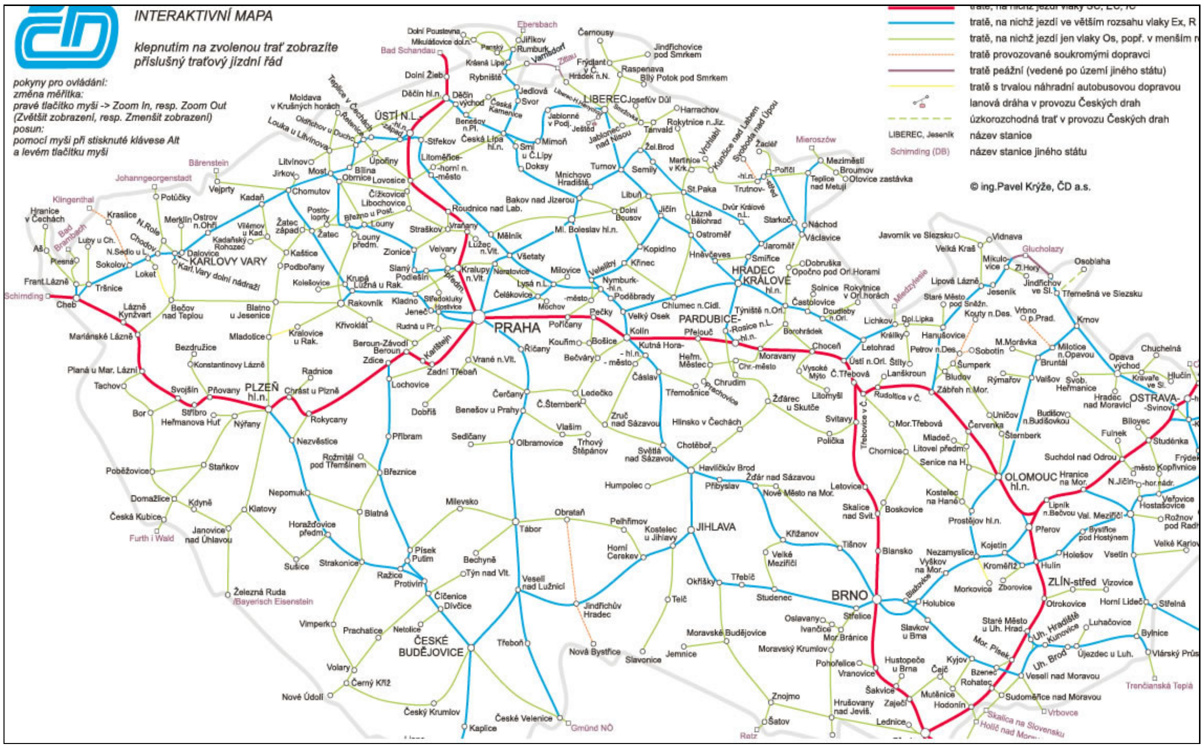
The railway map shows that the main railway junctions are at Sofia, Varna, Burgas, Plovdiv, Ruse and Vidin.

BDZ has indicated that there are no locations with restricted air exchange, shunting operations or lines with large amounts of diesel trains running on them that have housing within 50 metres. As discussed in Section 3.1.6, these locations therefore do not represent relevant exposure and can be ignored when assessing whether ambient air quality objectives have been met. It is likely therefore that Bulgaria does not have any rail emission hotspots.

8.4 CZECH REPUBLIC

Figure 8.4 shows the main railway lines in the Czech Republic.

Figure 8.4 Czech railway map



Source: http://www.cdrail.cz/CP1250/sluzby/online/mapa.svgz

The average railway length of 0.12 km per km^2 makes the Czech railway network, together with Germany and Belgium, one of the densest in the world. The Czech railway network stretches for a total distance of 9,543 km[4] of which diesel operations account for approximately 15% of gross-tonne kilometres hauled (WP1 report, 2005).

The Czech fleet consists of 1045 diesel locomotives and 898 diesel railcars (European Railway Stock List). The average age of the railcar fleet in the Czech Republic is 33.4 years and the average age of a locomotive is 26.6 years (European Railway Stock List, 2005). This compares to average ages of 22.9 years and 35.8 years respectively across the EU27. Therefore the Czech railcar fleet is significantly older than the average across Europe, whilst the locomotive fleet is significantly younger than the average.

In 2003 the Czech railways consumed 3,485 Tera Joules of diesel (UNFCCC, 2004) with a sulphur content of 50ppm. This is classed as low sulphur fuel.

Based on the response received to the questionnaire, the Czech railway operator (České Dráhy) receives fewer than ten complaints from the public per year as a result of poor air quality arising from shunting operations and high diesel line use. They do not receive complaints as a result of restricted air exchange or idling trains outside or at stations. They feel that the information that they have on air quality complaints is complete and that the public do not complain to any other authorities. In accordance with this, they perceive shunting yards followed by highly used line sections as the highest source of emissions.

[4] http://www.cia.gov/cia/publications/factbook/geos/ez.html#Trans

However, no details are provided as to the number of these types of locations. It is likely that this is where the highest pollutant concentrations will occur.

8.5 DENMARK

Figure 8.5 shows the main railway lines in Denmark.

Figure 8.5 Denmark rail map.

Source: http://www.bane.dk/1024/visArtikel.asp?artikelID=1017

The total rail network in Denmark is 2,628 km[5] of which diesel operations account for approximately 19% of gross-tonne kilometres hauled (WP1 report, 2005). According to the European Railway Stock list - 2005, Denmark has 373 railcars and DMU train-sets and 151 locomotives. The average age of the Railcar fleet is 18.1 years old and the locomotive fleet 31.2 years. The rail vehicle fleet is therefore approximately three to five years younger than the European average.

[5] http://www.cia.gov/cia/publications/factbook/geos/da.html#Trans

In 2003, the rail fleet in Denmark consumed 2,845 Tera Joules of liquid fuel (UNFCCC, 2004) with a sulphur content of 10ppm. This is classed as sulphur free fuel.

The only major shunting/marshalling yard identified is the Kobenhavn Yard in Copenhagen (http://www.odci.gov/cia/publications/factbook/geos/da.html#Trans and European Rail Atlas, 1998).

DSB (the Danish rail operator) receive between one and ten complaints each year relating to problems in areas with restricted air exchange (covered train stations/stations in tunnels etc) and idling trains outside or at stations, and between 10 and 20 relating to shunting yards. The complaints relate to the following locations specifically:

- Noerreport – Electric line (must have diesel activity too).
- Nykoebing F – Diesel line passenger station in built up area.
- Skoerping - Diesel line passenger station in built up area.
- Copenhagen Central - Electric line (must have diesel activity too).
- Aarhus
- Haslev – Diesel secondary line passenger station.
- Copenhagen West - Electric line (must have diesel activity too).
- Roskilde - Busy junction where diesel and electric lines meet in built up area.
- Copenhagen East - Electric line (must have diesel activity too).

DSB get most complaints from the smaller sidings and places where trains are having breaks or turn-arounds lasting approximately 30 minutes. However, they feel that the information that they have on air quality complaints is not complete and that members of the public complain to other authorities. In most cases however the complaints are then passed onto DSB.

DSB believes that the highest source of pollutant emissions on their rail network are locations with high emissions from line sections with diesel traction, followed by locations with restricted air exchange, and then other locations. These "other locations" were not specified. More detail and the number of locations relevant to each emission source in Denmark is provided in Table 8.5 below.

Table 8.5: Source of emissions from the rail network as identified by SNCB.

Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from housing.**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	2	4
Shunting operations		
Locations with high emissions from line sections with diesel traction	1	14
Other	3	3

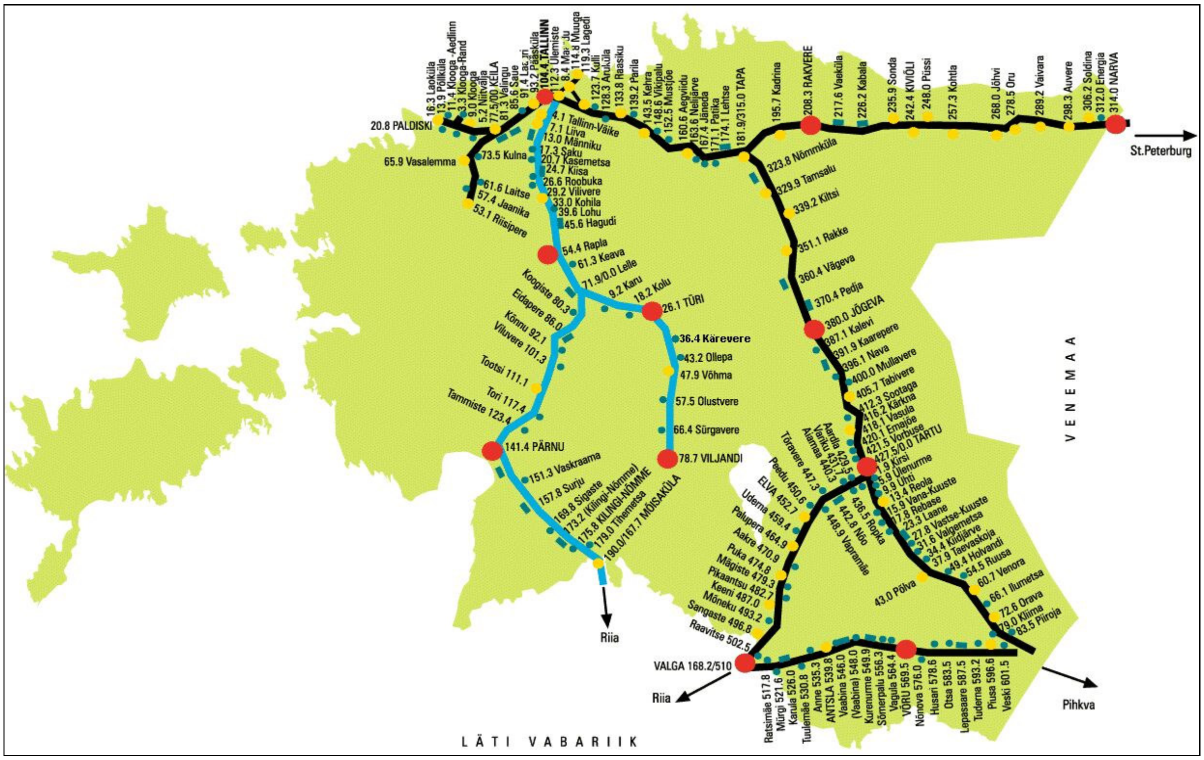
No further information was provided on the whereabouts of the locations provided in the third column of the table above. In addition, shunting yards were excluded and yet DSB report receiving between 10 to 20 complaints per year as a result of these operations.

It is likely that the nine locations identified as receiving the most complaints and the shunting yard in Copenhagen could be potential emission hotspots.

8.6 ESTONIA

Figure 8.6 shows the main railway lines in Estonia.

Figure 8.6. Estonia Rail map



Source: http://www.railfaneurope.net/links.html

The rail network in Estonia stretches for 958 km[6] of which diesel operations account for approximately 98% of gross-tonne kilometres hauled (WP1 report, 2005). The railway network is operated by 4 companies:

- EVR - Eesti Raudtee,
- EVR Ekspress,
- Elektriraudtee, and
- Edelaraudtee.

The 2003 liquid fuel consumption by the railways sector in Estonia was 2,202 tera joules (UNFCCC, 2004) with a sulphur content of 2,000ppm. This is a high sulphur content and so therefore may lead to high sulphur dioxide and particulate matter emissions. At present there are no restrictions on the sulphur content of fuel consumed by the railway sector. Reducing the level of sulphur in railway diesel would not only results in an immediate reduction in sulphur dioxide emissions but would also pave the way for the introduction of retrofit abatement equipment unable to tolerate high sulphur levels.

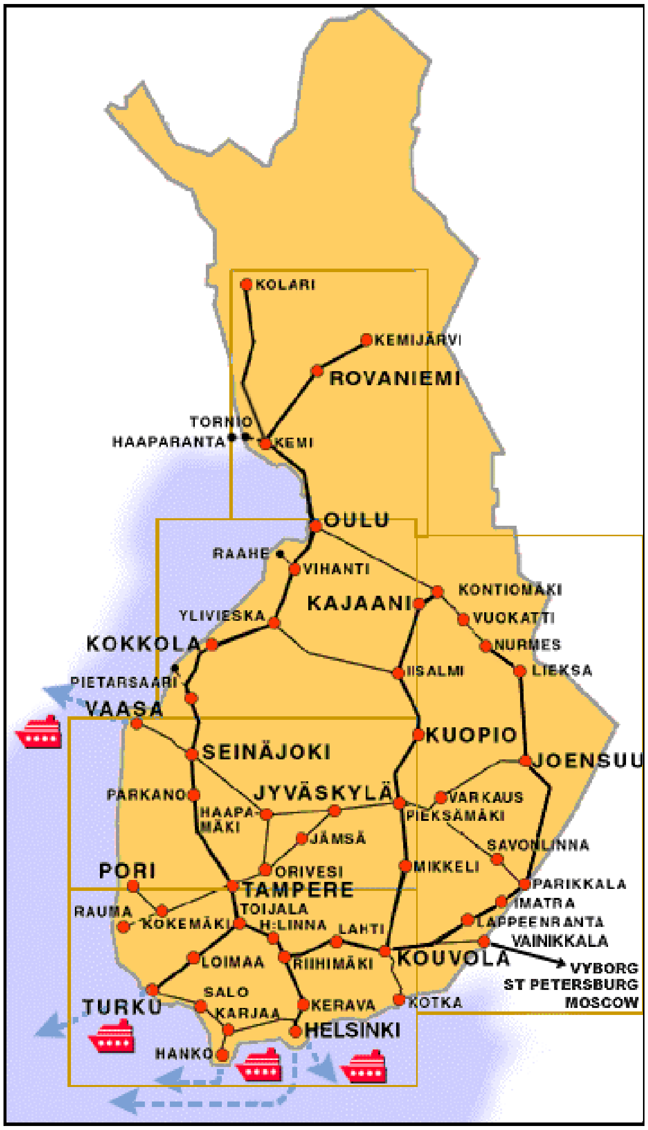
[6] http://www.cia.gov/cia/publications/factbook/geos/da.html#Trans

In total, the four Estonian Railway operators operate 111 diesel locomotives and 27 diesel railcars. The average age of the locomotive fleet is, at 13.5 years, much lower than the European average, whilst the average age of the railcar fleet, at 35.6 years is much higher than the European average (European Railway Stock List, 2005). The major railway junctions are at Tallinn, Rakvere, Rapla, Turi, Parnu, Viljandi, Jogeva, Tartu, Narva, Valga and Voru. Estonian Railways Ltd (EVR) operates one marshalling yard, located at Ülemiste, which handles approximately 30 trains per day and two major junction depots (Muuga depot – which consumes 2,400 tons of fuel a month and Tapa depot – which consumes 300 tons of fuel a month).

8.7 FINLAND

The Finnish rail network stretches over 5,851 kilometres[7] and diesel operations account for approximately 26% of gross-tonne kilometres hauled (WP1 report, 2005). A map of the rail network in Finland is provided in Figure 8.7.

Figure 8.7 Rail map of Finland



Source: http://service.vr.fi/ticket/application?browse=null

Finnish Railways operate 331 diesel locomotives and 16 railcars and the railcar fleet is very new with all of these vehicles entered into service in 2005 (European Railway stock list, 2005). However, the locomotive fleet is older than the European average, with an average age of 39.2 years (European Railway Stock list, 2005). The fleet consumed 1,797 Tera Joules of liquid fuels in 2003 (UNFCCC, 2004) with a sulphur content of less then 10ppm. This is classed as sulphur free fuel. In their questionnaire response, Finnish Railways (VR Ltd) stated that they receive between one and ten complaints annually from the vicinity of shunting yards, but no information was supplied on the location of these yards. No complaints are received from areas with restricted air exchange or from idling trains. VR Ltd

[7] http://www.cia.gov/cia/publications/factbook/geos/fi.html#Trans

believes that the highest source of pollutant emissions on their rail network are locations with high emissions from line sections, followed by shunting yards and then locations with restricted air exchange. More detail and the number of locations relevant to each emission source in Finland is provided in Table 8.7 below.

Table 8.7: Source of emissions from the rail network as identified by VR Ltd.

Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from housing.**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	3	0
Shunting operations	2	0
Locations with high emissions from line sections with diesel traction	1	0
Other		

VR Ltd state that there are no locations with restricted air exchange, shunting yards or locations with high emissions from busy line sections where the public are exposed on a regular basis. It is likely that the highest pollutant concentrations arising from railway movements occur in areas surrounding the shunting yards as this is where the complaints are received. More information is needed on the locations of the shunting yards.

8.8 FRANCE

The main train operator in France is the state owned SNCF who run most of the 29,519 km[8] of track in the country. A map showing the main railway lines in France is shown in Figure 8.8 below.

Figure 8.8 Rail map of France

SNCF's diesel rail fleet consists of 2,374 locomotives and 1,122 railcars (European Railway Stock list, 2005). The average age of their locomotives is 40.6 years, whilst the railcar fleet has an average age of 19.2 years (European Railway stock list, 2005).

Due to the sheer size of the railway network in France, overall diesel tonne kilometres is large even though diesel operations account for only 11% of gross-tonne kilometres hauled (WP1 report, 2005). In 2003, the French railways consumed 9,902 Tera Joules of liquid fuel (UNFCCC, 2004).

SNCF stated that they received between ten and twenty complaints a year regarding air pollution from shunting yards and areas of restricted air exchange, and between one and ten complaints each year regarding trains idling in stations. However, no details of specific locations were given. SNCF felt that the information they had on complaints relating to air quality was complete and that the public did not complain to other authorities.

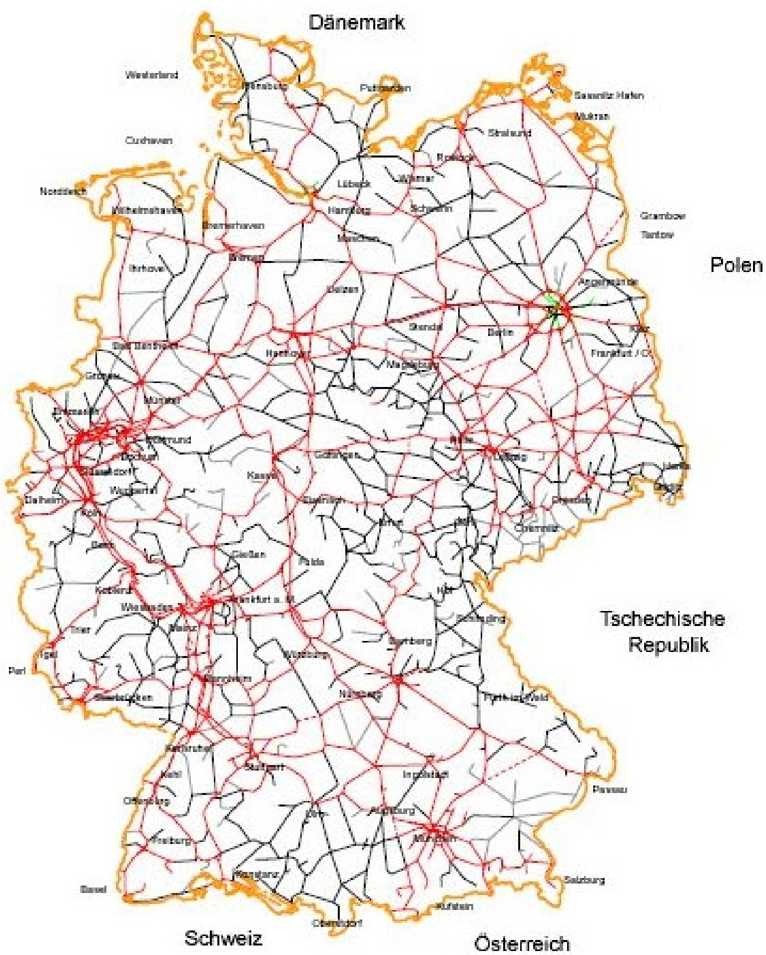
8 http://www.cia.gov/cia/publications/factbook/geos/fr.html#Trans

SNCF ranked locations with restricted air exchange and shunting yards jointly as the highest source of emissions. Line sections were thought of as being of a lesser concern. No information was provided as to the numbers of such locations where the public may be exposed. Further information is required in order to be able to predict where the likely emission hotspots may occur.

8.9 GERMANY

Figure 8.9 shows the main railway lines and junctions in Germany.

Figure 8.9 The German railway network.



Note: the red lines are electrified lines.

DB (Deutsche Bahn AG) is the main railway operator in Germany, and the rail network stretches for 46,142 km[9]. Due to the sheer size of the railway network in Germany overall diesel tonne kilometres is large even though diesel operations account for only 19% of gross tonne kilometres hauled (WPI report, 2005). The annual liquid fuel consumption by the railway sector in 2003 was 21,910 tera Joules (UNFCCC, 2004) with a sulphur content of 10ppm.

[9] http://www.cia.gov/cia/publications/factbook/geos/gm.html#Trans

The fleet contains 3,930 diesel locomotives and 2,353 diesel railcars (European Railway Stock list, 2005). The average age of the railcar and locomotive fleet is 13.7 years and 22.2 years respectively (European Railway stock list, 2005). The fleet is significantly younger than the European average.

The German railway operator (DB) receives between one and ten complaints annually relating to air quality. These are a result of shunting yard operations, areas of restricted air exchange and idling trains outside/at stations. This information is not complete, however, as the public complains to other organisations as well, such as local authorities. Further detail on the number of such locations is provided in Table 8.9A below.

Table 8.9: Source of emissions from the rail network as identified by DB.

Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from housing.**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	3	?
Shunting operations	1	10
Locations with high emissions from line sections with diesel traction	2	10
Other		

DB are unsure of the number of locations with restricted air exchange with nearby housing.

Based on a DB internal investigation, the following areas have been identified as possible rail emission hotspots:

- Hamburg-Lübeck, Hamburg-Westerland
- Herne/ Bochum & Oberhausen, Duisburg (6 shunting yards)
- Hosena-Horka border
- Nürnberg (east, shunting yard)

Table 8.9B provides an overview of shunting yards in Germany with a description of their surroundings.

In modelling studies carried out by DB they have identified 73 km of the railway network system (approx. 0.2% of the total) that have PM_{10} emission levels higher than that of a typical road highway (approximately 175 kg/km per annum). For NOx, 283 kilometres of track (less than 1% of total rail network) have emissions greater than typical road highways (approximately 4.5 tonnes/km per annum).

Table 8.9B: Overview of shunting yards

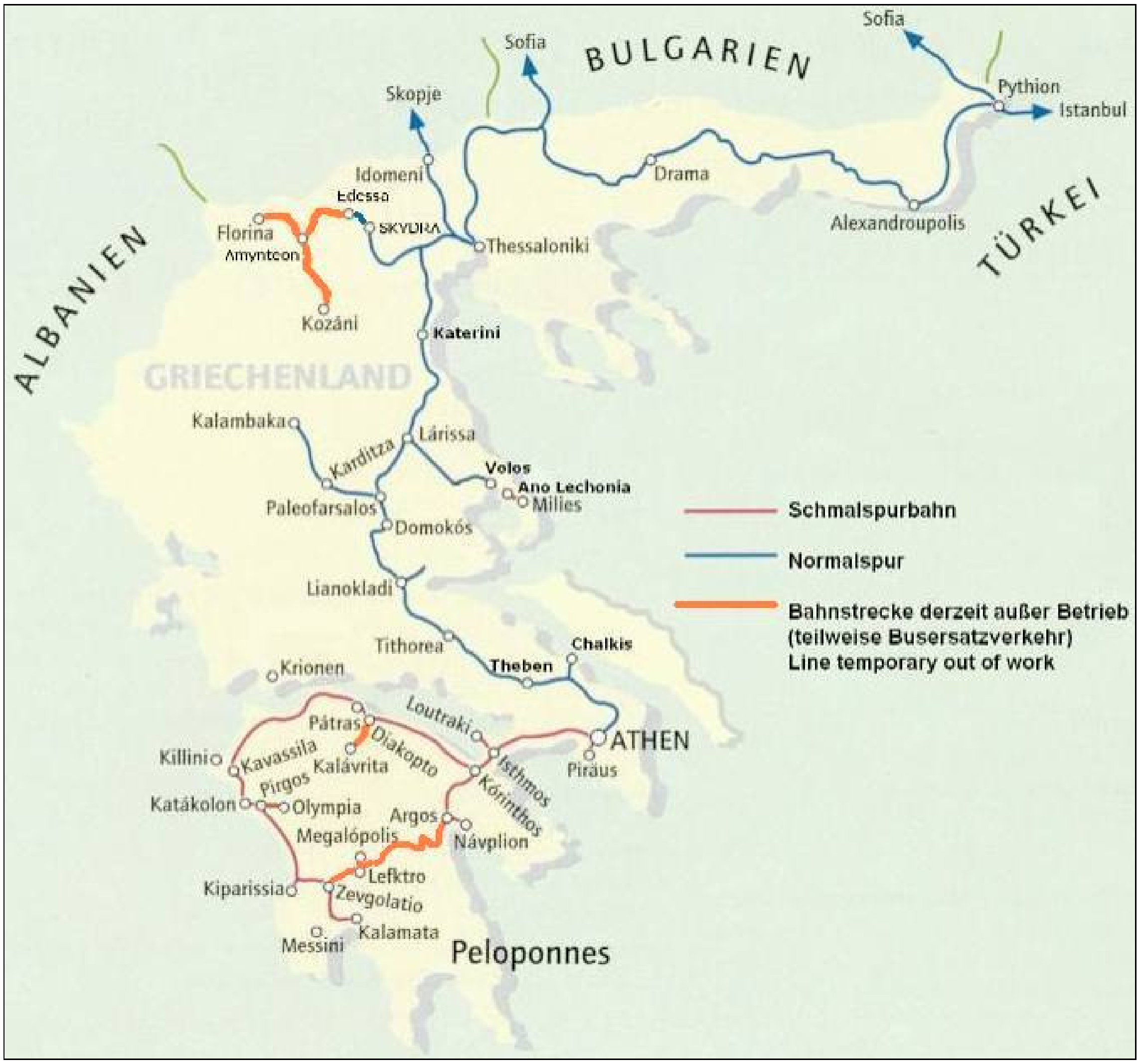
Shunting yard	Surrounding
Nürnberg	Park, highway, residential areas, industry
Hamburg Süd	Harbour, industry
Saarbrücken	Residential area, forest, highway
Kornweststein	Residential area, farmland, industry
Mannheim Rbf	Farmland, highway, residential area
Offenburg	Farmland, industry, residential area
Wanna-Eickel	City centre, industry
Dresden	City centre, residential areas, industry
Gremberg	NPA, highway, industry, residential areas
Köln-Kalk Nord	Residential area
Maschen (HH)	NPA, farmland, residential area
Zwickau	City centre, residential area, industry
Engelsdorf	Residential area, industry
Hagen-Vorhalle	Residential areas, forest, NPA
Seelze	Residential area, forest, NPA
Mainz-Bischofsheim	Farmland, residential area
Oberhausen- Osterfeld Süd	Park, highway, residential area
Oberhausen	Industry, highway, residential area
Koblenz-Lützel	Residential area, industry, park, highway
Rostock Seehafen	Open space, industry

Detailed information on yearly train movements for the whole of the DB network and vehicle specific emission factors has been provided by DB for this study. This data has been utilised as the basis of a dispersion modelling study to quantify the contribution of rail vehicle movements and operations to NO_2 and PM_{10} concentrations (see Section 5). It is important to note that the reason that data from the German investigation has been used in the dispersion modelling section is because DB have carried out more work to quantify rail emissions from their network than operators in other countries. It is not because Germany has any more rail emission hotspots than other countries in the study.

8.10 GREECE

Figure 8.10 below shows the main railway lines and junctions in Greece.

Figure 8.10 Greece rail map



The Greek railway system covers approximately 2,571 km[10] and diesel operations account for nearly 100% of gross-tonne kilometres hauled (WPI report, 2005). Together with Ireland, Greece has the least proportion of electrified track in any of the EU27 countries.

The fleet includes 165 diesel locomotives and 116 DMUs (European Railway stock list, 2005). Therefore the fleet is small by the standards of many other European countries. The average age of a DMU is 13 years and the average age of a locomotive is 30.2 years (European Railway stock list, 2005). In 2002 the annual liquid fuel consumption by the railways was 1,773 TJ; again one of the smaller consumers.

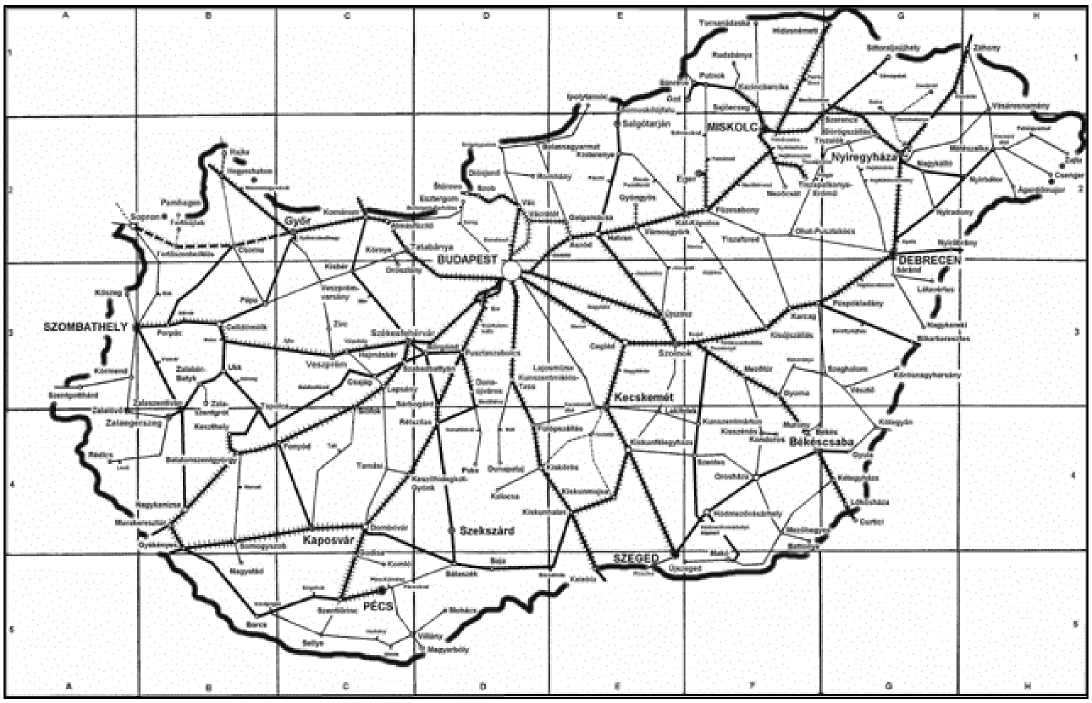
[10] http://www.cia.gov/cia/publications/factbook/geos/gr.html#Trans

There is little information available to make an assessment regarding likely rail emission hotspots in Greece. It is possible that high pollutant concentrations may occur around shunting yards due to the age of the shunting fleet.

8.11 HUNGARY

Figure 8.11 shows the main railway lines in Hungary.

Figure 8.11 Hungary rail map



Source: http://www.interrailnet.com/images/companies/l_carte12_1.gif

According to the Institute for Transport and Science, the majority of railway lines in Hungary are electrified. This is in contrast with the EU Energy and Transport Statistical Pocketbook 2004 (DG TREN) which states that 64% of the network in Hungary is not electrified. MAV (the Hungarian State Railway operator) reported in their questionnaire response that 70% of rail traffic was by electric traction. Therefore, there are conflicting views and perhaps the percentage of electrified track does not give a good idea of the amount of diesel traffic. Diesel operations account for approximately 18% of gross-tonne kilometres hauled by MAV operated trains (WP1 report, 2005).

The railway fleet is comprised of 1153 diesel locomotives and 357 DMUs (European Railway Stock List, 2005). The average age of a DMU is 25.1 years and the average age for a locomotive is 39.8 years (European Railway stock list, 2005). For both of these vehicle types the fleet is above the average age of the EU27 fleet.

The 2003 annual liquid fuel consumption by the railways in Hungary was 2,955 Tera Joules with a sulphur content less than 10ppm. This is the ninth highest fuel consumption in the EU27 countries.

MAV has reported that they receive between one and ten environmental complaints annually. Each of the complaints is related to very different situations, and in the majority of cases the complaints actually concern noise rather than air quality. It was suggested that the public also complain to other authorities. No further information was provided.

No information was available on the number of shunting yards operating in Hungary. However, MAV has confirmed that some shunting is carried out by electric locomotives.

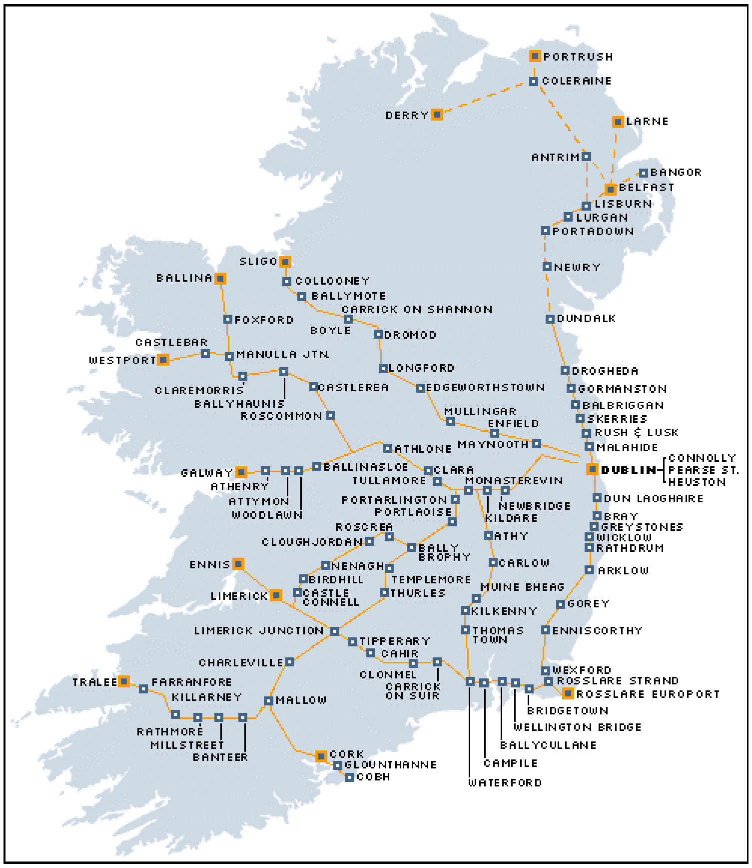
The Hungarian Ministry of Environment and Water, when contacted, suggested that emissions from railway diesel engines are of minor importance and that they are not aware of any emission hotspots. Their view was that noise is the major environmental impact of the railways. The Research Institute for Transportation reported that they receive complaints about railways related to noise emissions but not air quality.

Information needs to be obtained on the numbers and activities (including whether diesel or electric operated) of the shunting yards in operation in Hungary so that an assessment can be made of the likelihood of rail emission hotspots occurring.

8.12 IRELAND

Figure 8.12 shows the main railway lines and junctions in Ireland.

Figure 8.12 Ireland rail map



Source: http://www.irishrail.ie/your_journey/intercity_map.asp

The total rail network is 3,312 km, of which 3,266km is non-electrified track[11]. 1,947 km is broad gauge and 1,365 km is narrow gauge operated by the Irish Peat Board to transport peat to power stations and briquetting plants. Diesel operations account for approximately 95% of gross-tonne kilometres hauled (WP1 report, 2005).

In 2003, Irish Rail was running a total of 115 DMUs and 122 locomotives (European Railway Stock list, 2005). Together these consumed a total of 1,698 Tera Joules of liquid fuel (UNFCCC, 2004) with a sulphur content of 50ppm. This is classed as low sulphur fuel.

The locomotives in Ireland are of fairly old stock (average age of 31.1 years, European Railway Stock List, 2005), and the number of shunting/marshalling yards in Ireland is unknown. However it has been possible to ascertain that the potentially busy junctions include Limerick Junction, Dublin, Mallow and Rosslare Europort.

The Irish Environmental Protection Agency has confirmed that they do not receive complaints or enquiries about air quality problems associated with railway operations.

[11] http://www.cia.gov/cia/publications/factbook/geos/ei.html#Trans

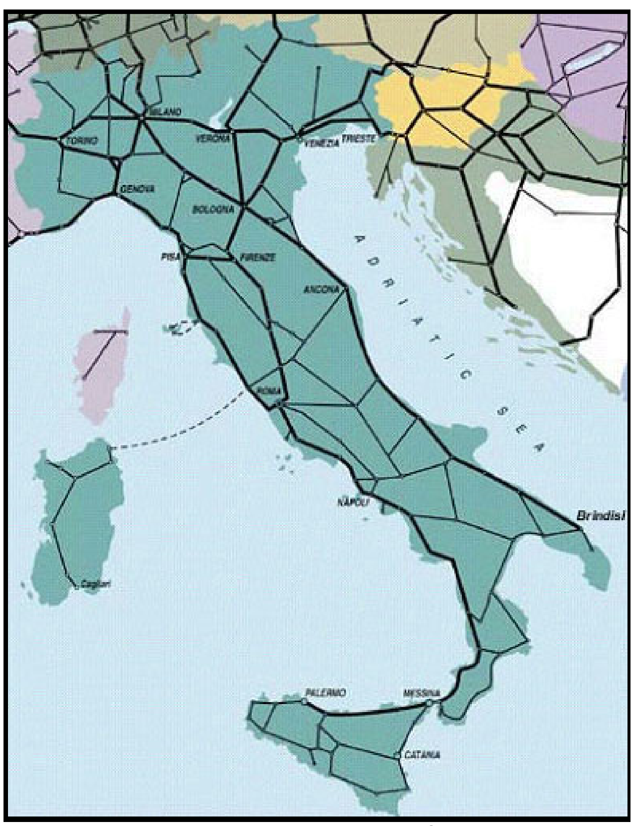
8.13 ITALY

The national Italian network and operations are all owned by FS (State Railway) Holdings, a fully government owned company. It has three key operating subsidiaries: Trenitalia operates all freight and passenger trains, including the high-speed trains, RFI (Rete Ferroviaria Italiana) manages the infrastructure, and TAV (Treno Alta Velocita) is responsible for the planning and construction of new high speed infrastructure. Some separate local rail services also exist, provided by regional governments.

The Italian rail network stretches for 19,319km[12] and diesel operations account for approximately 6% of gross-tonne kilometres hauled (WP1 report, 2005). The fleet consists of 1,291 DMUs and 1,960 diesel locomotives (European Railway stock list, 2005). Italy's DMU fleet is older than average with an average age of 27.8 years. The locomotive fleet is younger than average, with an average age of 32.6 years (European Railway Stock list, 2005). In 2003, the Italian railways consumed 5,231 Tera Joules of fuel (UNFCCC, 2004) with a sulphur content of 50ppm.

The Italian rail operators stated that they received between ten and twenty complaints a year regarding air pollution from shunting yards and the same number regarding trains idling outside/at stations. The complaints are spread over a large area rather than at a few locations. They also stated that highest source of pollutant emissions come from shunting yards, but provide no details of specific locations. In order for an assessment to be made of potential emission hotspots in Italy further information is required on the activities at shunting yards.

Figure 8.13: Rail map of Italy



http://www.interrailnet.com/member.dhtml?country_id=14

[12] DG TREN, 2004

8.14 LATVIA

The main role of the railway in Latvia is to move large volumes of freight and passengers from east to west along the main transit corridors (Zilupe–Ventspils and Indra–Rīga) (See Figure 8.14 below). On average, 38 million tonnes of goods and 20 million passengers are transported by railway each year. Diesel operations account for approximately 97% of gross-tonne kilometres hauled (WP1 report, 2005).

Figure 8.14. Latvia Rail map

Source: http://www.railfaneurope.net/links.html

The Latvian railway (LDZ) network covers 2,269.8km[13] of which approximately 89% is non-electrified (DG TREN, 2004). In 2003 the railways in Latvia consumed 2,974 tera joules of liquid fuel with a sulphur content less than 50ppm.

In total there are 171 railway stations including two marshalling yards, 34 freight stations, four central section stations, 128 line stations, 76 railway stations with freight activities and six major junction depots[14].

The railway company "Latvijas Dzelzcels" operates approximately 251 diesel locomotives and 51 diesel railcars (European Railway Stock list, 2005).

The DMU fleet in Latvia is fairly old; the average age of a DMU is 32.2 years. However, the locomotive fleet is younger than the European average, at 29.9 years (European Railway Stock list, 2005). In 2005, Latvia will announce an international tender for the modernisation of their locomotives. The proposals will include emissions requirements for diesel engines in line with the terms of the Directive 2004/26/EC.

Marshalling yards are located in Riga and Dangavpils with a daily activity of 105 and 1,008 trains respectively, which are all run on diesel.

[13] http://www.ldz.lv/en/statistika/statistika_4.htm
[14] http://www.ldz.lv/en/statistika/statistika_3.htm

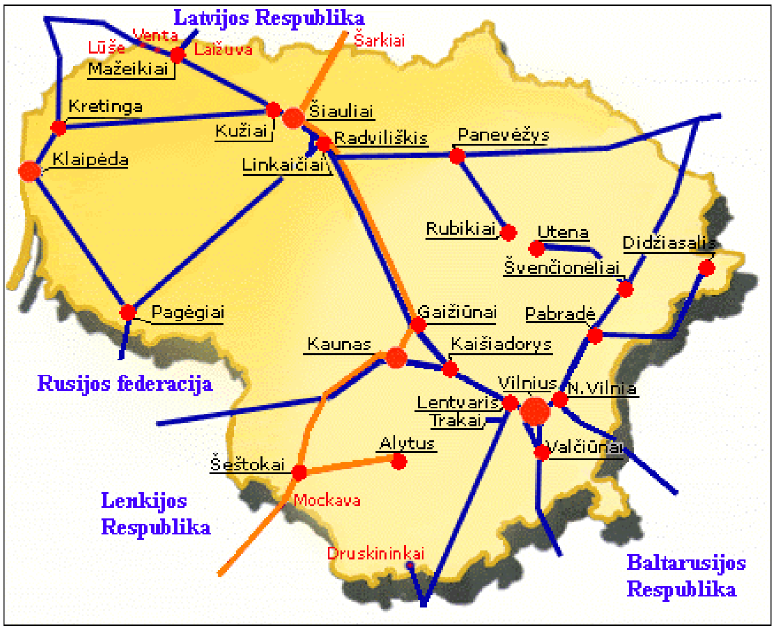
Latvijas Dzelzcels reported in their response to the questionnaire that they do not receive any complaints relating to air quality. They identified shunting yards as being the highest source of emissions on the rail network followed by highly used line sections.

The main emission hotspots are likely to be located at the six major junction depots and at the marshalling yard at Daugavpils.

8.15 LITHUANIA

Figure 8.15 shows the main railway lines in Lithuania.

Figure 8.15 Lithuania Rail map



Source: http://www.railfaneurope.net/links.html
The blue lines show diesel railway lines and the red lines represent electrified lines.

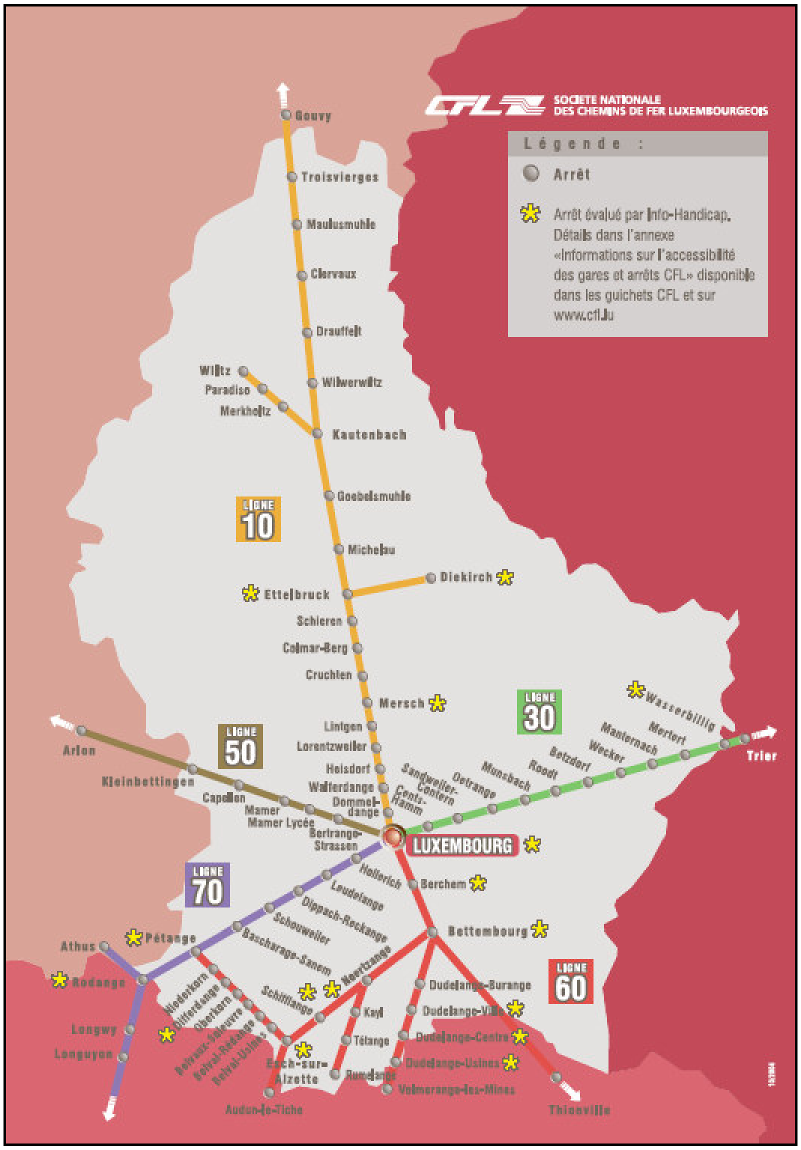
As shown in Figure 8.15, the vast majority of rail operations in Lithuania are undertaken by diesel traction units. The total rail network is 1,998 km in length, and diesel operations account for nearly 100% of gross-tonne kilometres hauled (WP1 report, 2005).

Lithuania has an old railcar and rail locomotive fleet. There are currently 24 DMUs in operation and 256 locomotives. The average age of the DMUs is 42 years, whilst the average age of the locomotives is 36.5 years (European Railway stock list, 2005). In 2003, the annual diesel consumption by the railway sector in Lithuania was 2,836 Tera Joules (UNFCCC, 2004) with a sulphur content of between 10ppm and 50ppm.

The map of Lithuanian's railway system indicates several major junctions such as at Klaipeda, Siauliai, Kaunas and the capital Vilnius. The fact that a high percentage of trains are diesel and that the fleet is old, leads to the conclusion that emissions resulting from the rail network are likely to be fairly high. The highest pollutant concentrations are likely to occur in and around the shunting yards and at the four named junctions.

8.16 LUXEMBOURG

Figure 8.16 Rail map of Luxembourg



Source: http://www.cfl.lu/

As one of the smallest countries in Europe, Luxembourg has a relatively small rail network stretching only 275km[15] with diesel operations accounting for 27% of gross-tonne kilometres hauled (WP1 report, 2005).

There are 14 DMUs and 69 locomotives operating in Luxembourg. The average age of the DMU fleet is 13.7 years old whereas the average age of the locomotive fleet is 38.6 years (European Railway stock list, 2005). Luxembourg consumes the least liquid fuel of all the EU27 countries, 294 tera joules.

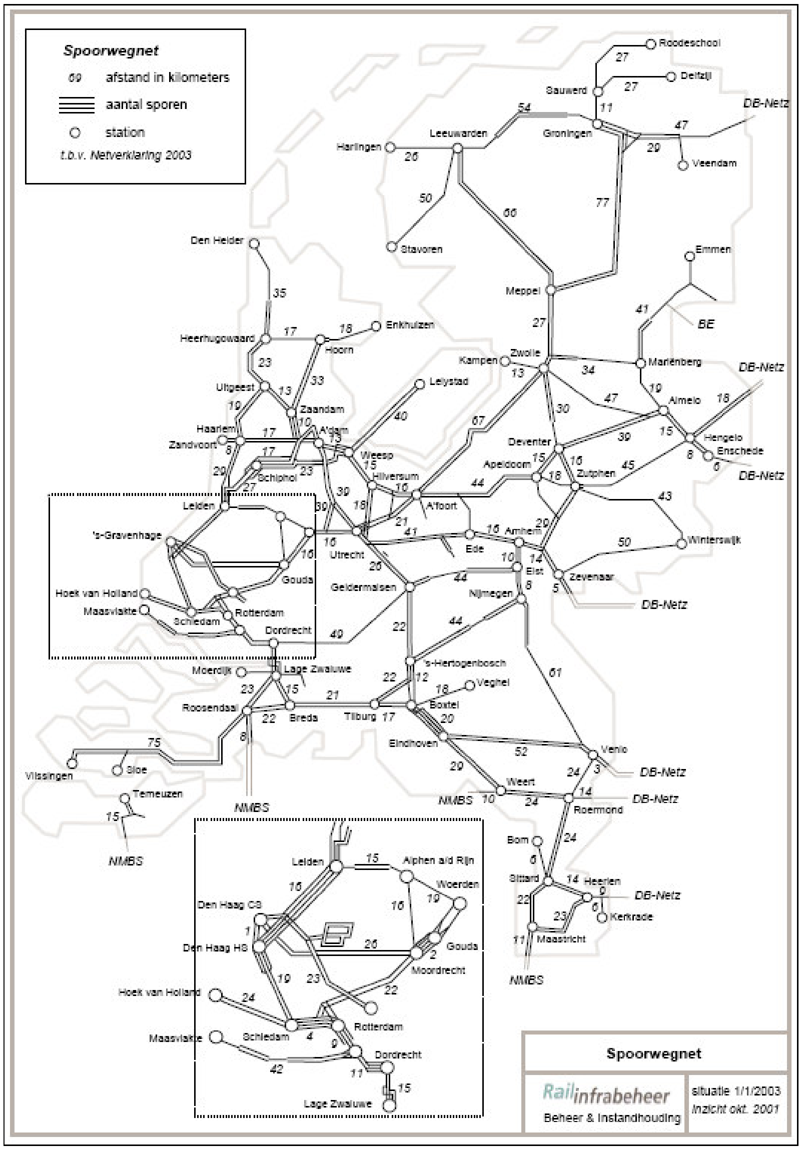
No questionnaire responses were received from Luxembourg, therefore there is no available information on the types of trains used or the number of shunting or marshalling yards. However, it is likely that due to the high percentage of electrification that there are few or no emission hotspots.

[15] http://www.cia.gov/cia/publications/factbook/geos/lu.html#Trans

8.17 THE NETHERLANDS

Netherlands Railway operates 6,500 kilometres of which diesel operations account for approximately 34% of gross-tonne kilometres hauled (WP1 report, 2005). According to 'Netherland's Holdings' this figure only relates to freight volume transported and that only 6% of passenger trains use diesel. A map of the railway network is shown in Figure 8.17 below.

Figure 8.17: Rail map of the Netherlands



Source: http://www.prorail.nl/NR/rdonlyres/4791FAB2-85FC-43D2-9386-85F41AD9BAC1/0/Spoorwegnet.pdf

The European railway stock data reports that there are 128 DMUs and 232 locomotives currently in service in the Netherlands. The rail fleet is fairly young, with the average age of a DMU being 13.6 years, and the average age of a locomotive being 19 years (European Railway stock list, 2005).

Due to the high percentage of electric lines in the Netherlands, liquid fuel consumption is low. For example in 2003, only 1,535 Tera Joules were consumed (UNFCCC, 2004).

ProRail (the Dutch rail infrastructure company) report that no complaints have been made to them with regards to air pollution. They also think that the information is complete and that members of the public are not complaining to other authorities.

ProRail believes that the highest source of pollutant emissions on their rail network are shunting yards followed by locations with restricted air exchange and lastly line sections. More detail and the number of locations relevant to each emission source in the Netherlands is provided in Table 8.17 below.

Table 8.17: Source of emissions from the rail network as identified by ProRail.

Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	2	
Shunting operations	1	Leeuwarden, Arnhem
Locations with high emissions from line sections with diesel traction	3	
Other		

The train operators in the Netherlands do not have to comply with any emission requirements. Given the high percentage of electrification and that no complaints have been received it is likely that there are few, if any, emission hotspots. However it is suggested that the two shunting yards at Leeuwarden and Arnhem are likely to give rise to the highest level of emissions.

8.18 NORWAY

Norway operates 4,077km of railway track[16] of which diesel operations account for approximately 45% of gross-tonne kilometres hauled (WP1 report, 2005). The Norwegian rail company NSB operates 68 DMUs and 74 diesel locomotives, the majority of which entered into service after 1980 (European Railway stock list, 2005). In 2003, 590 Tera Joules of liquid fuel were consumed. This is the fourth smallest fuel consumption of the EU27 countries.

Figure 8.18 Rail map of Norway

Source: http://www.jernbaneverket.no/jernbanenettet/Jernbanekart/

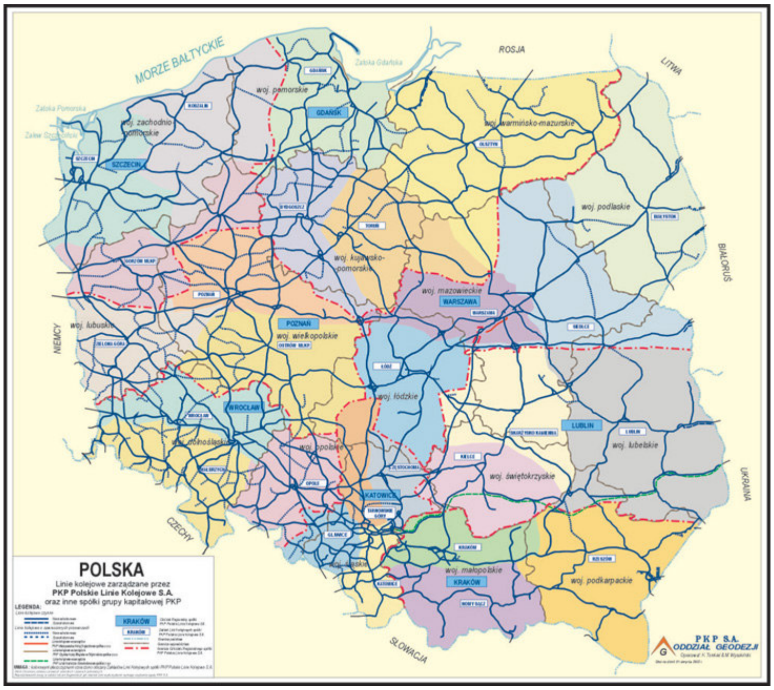
No information regarding pollution hotspots was provided by NSB or the Government Environment departments. It is most likely that any hotspots that do exist would be in the vicinity of the cities of Oslo, Bergen and Trondheim.

[16] http://www.cia.gov/cia/publications/factbook/geos/no.html#Trans

8.19 POLAND

Figure 8.19 provides a map of the main rail routes in Poland.

Figure 8.19 Poland railway map



Source: http://www.plk-sa.pl/en/00spolka/mapa/plk_mapaPolski.html

PKP Polish Railway Lines JSC administers more than 23,000 kilometres of railway lines in Poland, however, at the moment there are only 19,200 kilometres that are in operation[17]. Diesel operations account for approximately 9% of gross-tonne kilometres hauled (WP1 report, 2005).

The fleet consists of 4,150 diesel locomotives and 67 DMUs (European Railway stock list, 2005). The 2004 consumption of diesel fuel was approximately 108,000 tonnes (No information was provided by the UNFCCC to enable a direct comparison with other countries).

Limited information has been obtained about the possible contribution of rail operations to potential emission hot spots in Poland due to a lack of response to requests for data. It is likely that if any emission hotspots do exist that they would be in the vicinity of the main cities.

[17] http://www.plk-sa.pl/en/03infrastruktura/01.php

8.20 PORTUGAL

The Portuguese rail network extends for 2,850km, and diesel rail traffic accounts for approximately 35% of gross-tonne kilometres hauled (WP1 report, 2005).

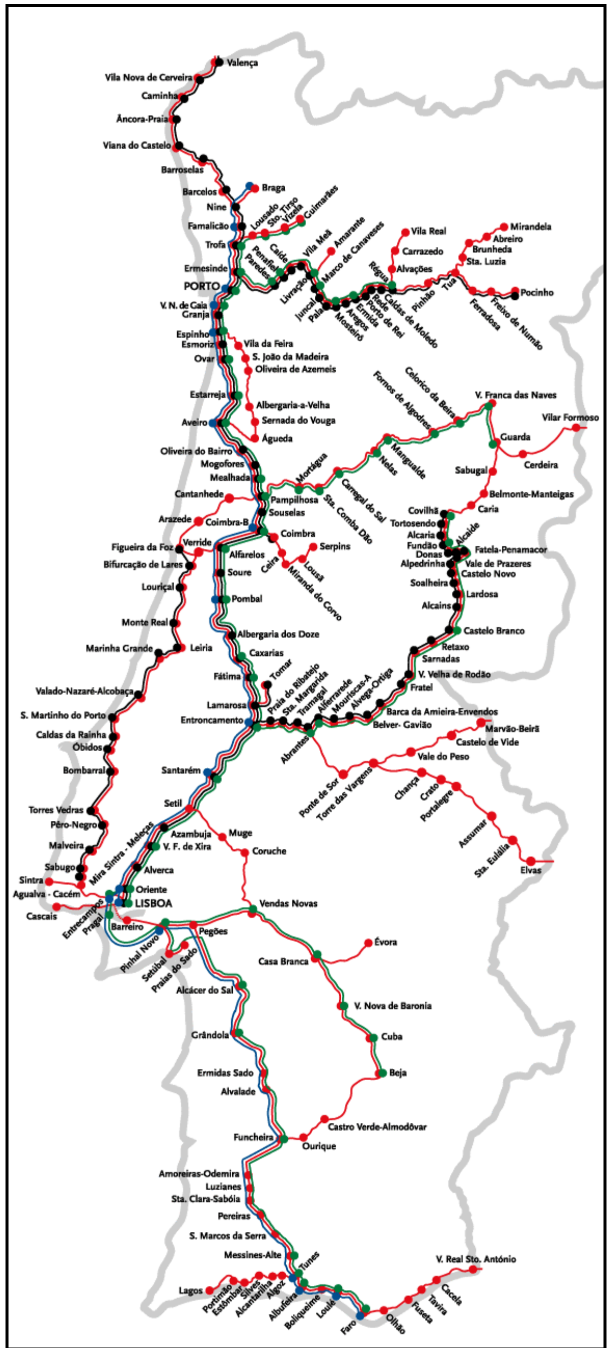
There are currently 81 DMUs in operation and 128 diesel locomotives. With an average age of 31.9 years, the DMU fleet is much older than the European average. At 33.4 years, the locomotive fleet is slightly younger than the European average(European Railway stock list, 2005) This fleet of trains consumes some 1,521 Tera Joules of diesel fuel a year (WP1 Report) with a sulphur content of 350ppm.

The rail company states that they have received no complaints from the public relating to air quality problems. However they identified the Poceirão and Barreiro rolling stock maintenance depots as potential pollution hotspots, within 50m of housing, and the following locations as susceptible to high emissions from line sections with diesel traction:

- Alcântara – Terra
- Godim
- Gaia
- Pampilhosa
- Mangualde;
- Vilar Formoso.

A map showing the diesel network in Portugal can be found at: **http://bueker.net/trainspotting/maps_iberian-peninsula.php**

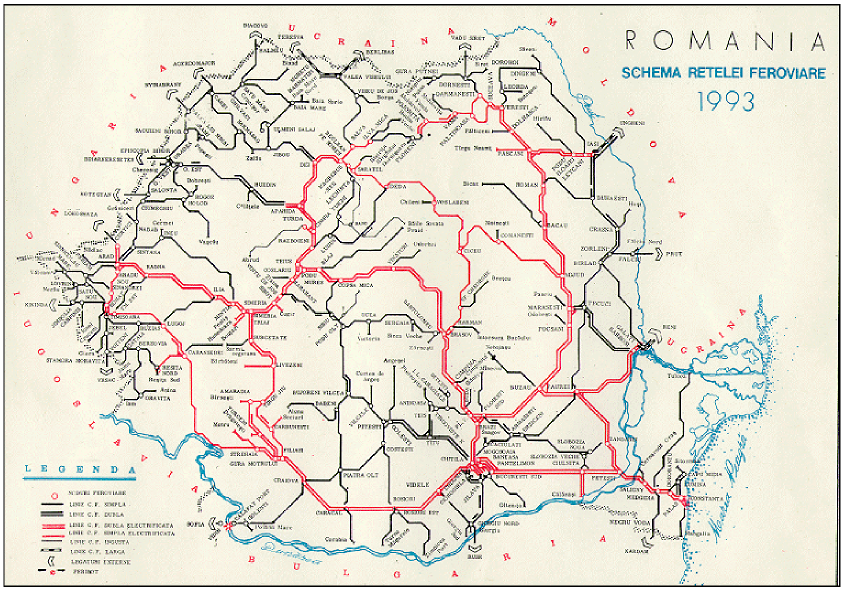
Figure 8.20 Rail map of Portugal



Source: http://www.cp.pt/servicos/e_mapa.html

8.21 ROMANIA

Figure 8.21 The Romanian rail network



Source: http://www.worldbank.org/transport/rail/sys_maps/rail30.gif

The Romanian rail network is 11,385 kilometres in length[18] and diesel operations account for approximately 27% of gross-tonne kilometres hauled (WP1 report, 2005). In Romania the railway system is split among several railway operators. The Romanian Company for Passengers Transportation operates the locomotives.

The Romanian Company for Passengers Transportation has to comply with the following national guidelines relating to pollutant emissions:

- Ministerial Order 592/2002 for approval the norms concerning the limit values, the warning threshold values, criteria and methods of evaluation of SO_2, NOx, PM, lead (Pb), CO and ozone (O_3) in the air;
- Law 655/2001 to approve Governmental Ordinance 243/2000 on Atmosphere Protection
- Ministerial Order 756/1997 for the Regulation approval concerning the environmental pollution assessment
- Ministerial Order 462/1993 to approve the technical conditions concerning the atmosphere protection and methodological norms to set the atmosphere polluting emissions
- STAS 12574/1987, for ambient Air Quality in protected areas

In 2004, the railways consumed 11,272 Tera Joules of diesel (Third party assessment of WP1 report, 2005) with a sulphur content ranging from 38ppm to 280ppm. This is the third highest consumption in the EU27 countries.

The fleet consists of 2,155 diesel locomotives and 281 diesel railcars. With an average age of 42.7 years, Romania has the oldest locomotive fleet in the EU Railway 27. At 38.1 years, the average age of the DMU fleet is significantly older than the European average (European Railway stock list, 2005).

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[18] http://www.cia.gov/cia/publications/factbook/geos/ro.html#Trans

There are six main shunting yards in Romania. These are in:

- Bucuresti
- Ploiesti
- Brasov
- Coslariu
- Dej
- Palas-Constanta

The biggest is in Bucuresti, which was built between 1910-1913 under the name Chitila Triaj.[19]

The Romanian Company for Passengers Transportation (S.N.T.F.C.) has not received any complaints related to air quality.

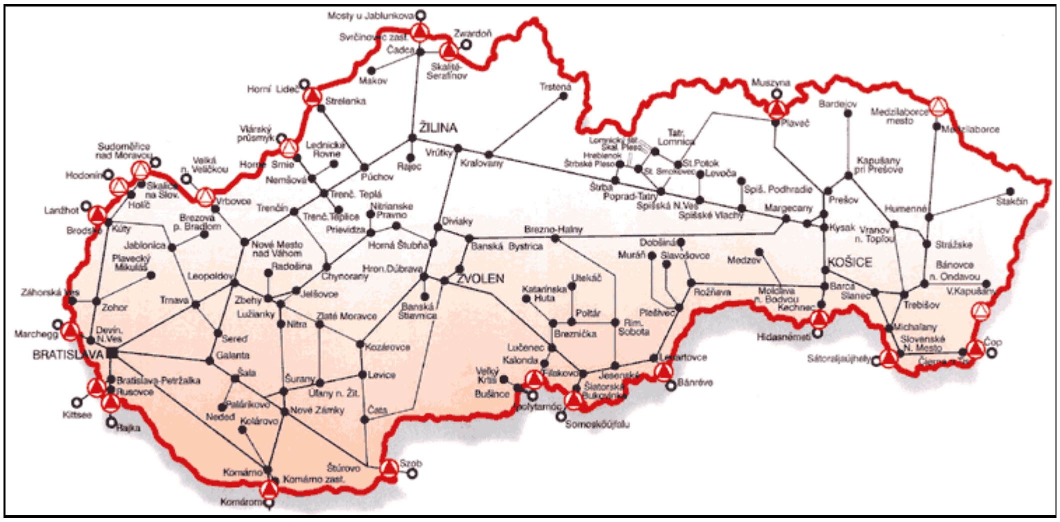
The emission results of their maintenance units showed no significant emission levels. The concentrations of pollutants (CO, NOx, SO_2) fall below the maximum limit permitted (Suceava Depot). The average short term concentrations (averaged over 30 minutes) of a range of pollutants (PM, NO_2, SO_2, CO) measured during typical operating conditions conditions were also found to fall below the maximum concentrations allowed (Medgidia and Galati Depot). The air pollution generated by depot activities is intermittent and the emissions are very localised (Pitesti Depot) but at Lasi Depot, the limit for PM was exceeded, but this could be as a result of the proximity to road traffic.

[19] http://www.cfr.ro/CFR_new/Eng/triaje.htm

8.22 SLOVAKIA

Figure 8.22 shows the main railway lines and junctions in Slovakia

Figure 8.22 The Slovakian rail network.



Source: http://www.interrailnet.com/images/companies/l_carte22.gif

The Slovakian rail network covers 3,657 km of track[20] and diesel traffic accounts for approximately 14% of gross-tonne kilometres hauled (WP1 report, 2005).

The Slovakian railway is run by three operators:

-
- ZSSK - Zeleznicná Spolocnost Slovensko, a.s.,
- ZSCS - Zeleznicná Spolocnost Cargo Slovakia, a.s.,
- BRKS - Bratislavská Regionálna Kolajová Spolocnost.

ZSSK, and ZSCS were both formerly part of the same company (ZSR), but in January 2005, the former ZSR was broken up into three companies (ZSSK, ZSCS, and ZSR). ZSSK is responsible for passenger operations, ZSCS handles freight operations, whilst ZSR is now purely an infrastructure company and does not operate any trains. BRKS is a relatively new operator that took over some rural lines that were formerly operated by ZSR.

The Slovakian trains run on diesel with a sulphur content less than 50ppm. This is classed as ultra low sulphur fuel. There are estimated to be 175 DMUs and 610 diesel locomotives operating in Slovakia (European Railway stock list, 2005). Results from WP1 shows that the Slovakian rail fleet is fairly old; DMUs have an average age of 29.2 years, whilst locomotives have an average age of 34.7 years.

According to the SHMI – (Department of Air Quality) there are four main railway regions: Bratislava, Zilina, Kosice and Zvolen.

- Bratislava: 138 diesel locomotives and 49 diesel railcars in 2003 (activity: locomotives and wagons together 6 649 648 km in 2003)
- Zilina: 83 diesel locomotives and 46 diesel railcars in 2003 (activity: locomotives and wagons together 2 963 920 km in 2003)

[20] http://www.cd.cz/static/sr/CD_rocenka2003_ang.pdf

- Kosice: 176 diesel locomotives and 78 diesel railcars in 2003 (activity: locomotives and wagons together 7 535 608 km in 2003)
- Zvolen: 191 diesel locomotives and 66 diesel railcars in 2003 (activity: locomotives and wagons together 9 596 250 km in 2003).

The following railway routes cross through Bratislava:
- Bratislava – Břeclav (ČD)
- Bratislava – Marchegg (OBB)
- Bratislava – Rajka (MÁV)
- Bratislava – Komárno
- Bratislava – Szob (MÁV)
- Bratislava – Žilina.

At the moment a second direct railway connection between Bratislava and Vienna via Kittsee is being completed.

The following rail routes cross through Žilina:
- Žilina – Čadca s pokračovaním Zwardoň (PKP) alebo Mosty u Jablunkova (ČD)
- Žilina – Bratislava
- Žilina – Rajec
- Žilina – Košice.

The following rail routes pass through Košice:
- Košice – Žilina
- Košice – Zvolen
- Košice – Hidasnémeti (MÁV)
- Košice – Čop (UŽ)
- Košice – Trebišov
- Košice – Muszina (PKP).

The following rail routes pass through Zvolen:
- Zvolen – Margecany
- Zvolen – Košice
- Zvolen – Čata
- Zvolen – Nové Zámky
- Zvolen – Vrútky.

The railway operator, ZSCS has not received any complaints related to air quality.

No information is available on the number of shunting yards in Slovakia. It is likely that the shunting yards together with the four cities named above, where there are potentially busy junctions, would have the highest pollutant concentrations surrounding them.

The infrastructure manager of ZSR plans to introduce a separate charge for use of the railway energy system alongside the total charge for infrastructure use. This would mean that electric trains will become less advantageous than before and so it is likely that there will be further expansion of diesel traction.

8.23 SLOVENIA

Slovenia has a relatively small rail network with a total length of 1,228 kilometres of track. Diesel operations account for approximately 17% of gross-tonne kilometres hauled (WP1 report, 2005).

Slovenian railways operate 80 DMUs and 110 diesel locomotives, of which all but one were brought into service before 1986 according to the European Railway stock list, 2005. Data provided by Slovenske Železnice suggests the following however; 70 DMUs and 80 diesel locomotives. The diesel railcar fleet has an average age of 29.1 years, whilst the locomotive fleet has an average age of 35.1 years (European Railway stock list, 2005). This data is 27 years and 29.1 years respectively according to Slovenske Železnice.

In 2003 the railways in Slovenia consumed 525 Tera Joules of liquid fuel (Third party assessment of WP1 Report, 2005) with a sulphur content of 30ppm. This is the third smallest amount of fuel consumption of the EU27 countries.

Figure 8.23: Rail map of Slovenia

Source: http://www.slo-zeleznice.si/en/infrastructure/railway_network/

There are four major marshalling yards in Slovenia at: Ljubljana Zalog, Maribor Tezno, Celje tovorna, and Koper tovorna. There are also another 98 stations which deal with freight traffic. Slovenske Eleznice (the Slovenian rail operator) has not received any complaints from the public with regards to air pollution. Slovenske Železnice believe that the highest source of pollutant emissions on their rail network are shunting yards followed by stretches of open track. More detail and the number of locations relevant to each emission source in Slovenia is provided in Table 8.23 below.

Table 8.23: Source of emissions from the rail network as identified by Slovenske Železnice.

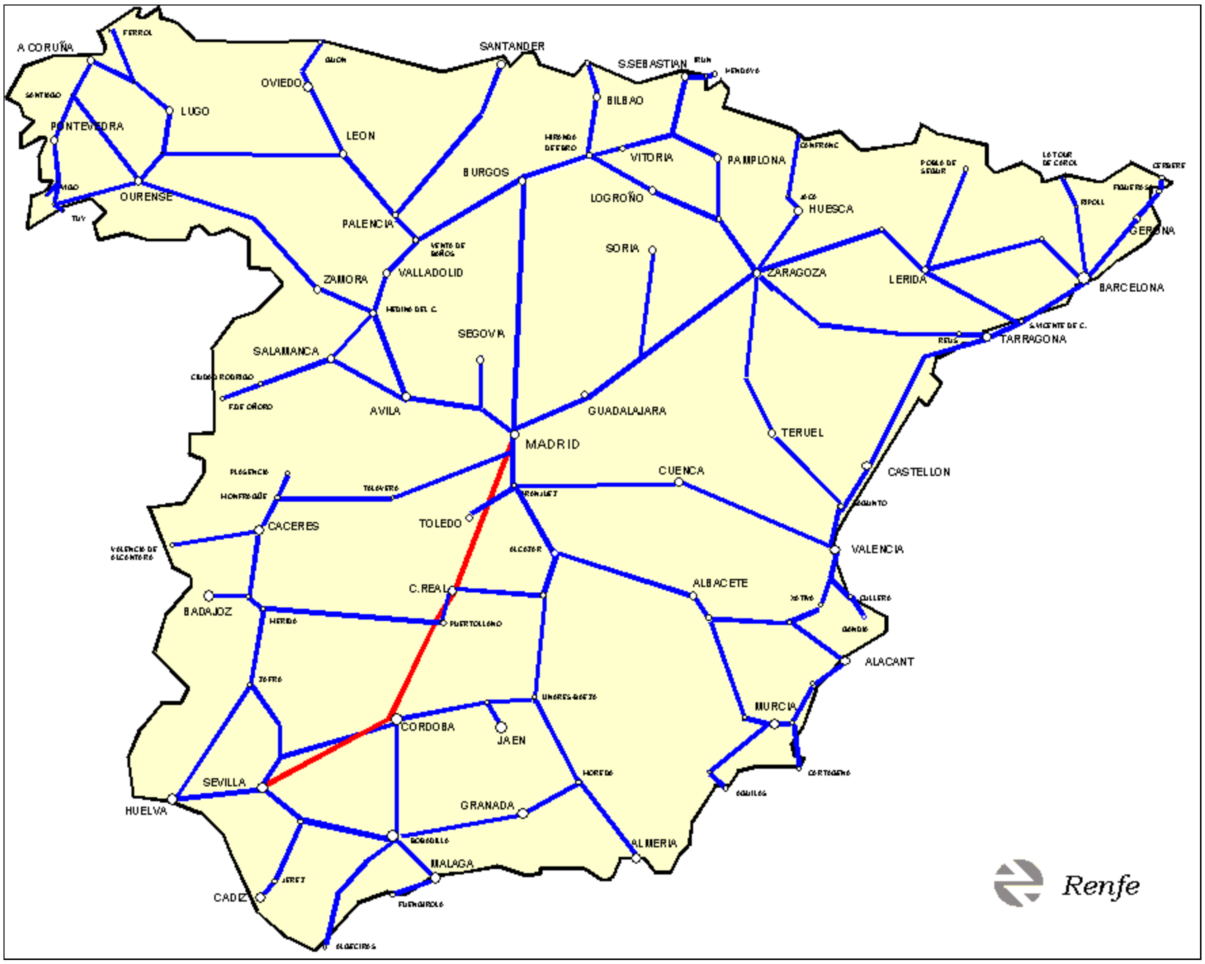
Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	2	0
Shunting operations	1	0
Locations with high emissions from line sections with diesel traction	1	3
Other		

Due to the small size of the diesel railway network in Slovenia it is likely that there are few, if any, emission hotspots. If there are any, they will occur along the three highly used line sections identified in Table 8.23 above.

8.24 SPAIN

Spain operates 14,781 kilometres of railway[21] and diesel rail traffic accounts for approximately 13% of gross-tonne kilometres hauled (WP1 report, 2005). A map of the main rail routes is provided in Figure 8.24 below.

Figure 8.24 Rail map of Spain



Source: http://www.interrailnet.com/images/companies/l_carte8.gif

According to UIC information, approximately 582 diesel locomotives and 241 diesel railcars are currently in operation. The average age of a DMU in Spain is 17.7 years and the average age of a locomotive is 26 years (European Railway Stock list, 2005). Compared to the other European countries in this study, Spain has a relatively young rail fleet. The Spanish rail operators do not have to comply with any emissions legislation.

Liquid fuel consumption by rail operators in Spain was 4,181 Tera Joules in 2003 (UNFCCC, 2004). This is the sixth highest fuel consumption out of the EU27.

The Spanish rail infrastructure company, ADIF, reports that between one and ten complaints are received from the public annually with regards to air pollution. Most of these are also associated with noise complaints. Complaints relating to locations with restricted air

[21] http://www.cia.gov/cia/publications/factbook/geos/sp.html

exchange occur in tunnels in Madrid and Barcelona. Complaints relating to idling trains occur in Madrid and in Provincial capitals.

ADIF believe that the highest source of pollutant emissions on their rail network are idling trains followed by locations with restricted air exchange. More detail and the number of locations relevant to each emission source in Spain is provided in Table 8.24 below.

Table 8.24: Source of emissions from the rail network as identified by ADIF.

Type of location or operation	**Rank order of importance ("1" for the largest source of emissions, "2" for the next largest, etc)**	**Please give the number of locations where these operations occur with significant emission levels that are less than 50 metres away from**
Locations with restricted air exchange (e.g. covered train stations, stations in tunnels etc.) and diesel traffic	2	5
Shunting operations		
Locations with high emissions from line sections with diesel traction		
Other (idling trains)	1	25

In the absence of further information being available it is suggested that the emission hotspots are likely to be located at the five locations with restricted air exchange and 25 locations close to idling trains as identified in Table 8.24 above.

8.25 SWEDEN

The Swedish rail network extends over 11,481km[22], and diesel operations account for approximately 8% of operator SJ AB's gross-tonne kilometres hauled and 4% of Green Cargo's (WP1 report, 2005). A map showing the main rail routes in Sweden is shown in Figure 8.25.

Figure 8.25 Rail map of Sweden

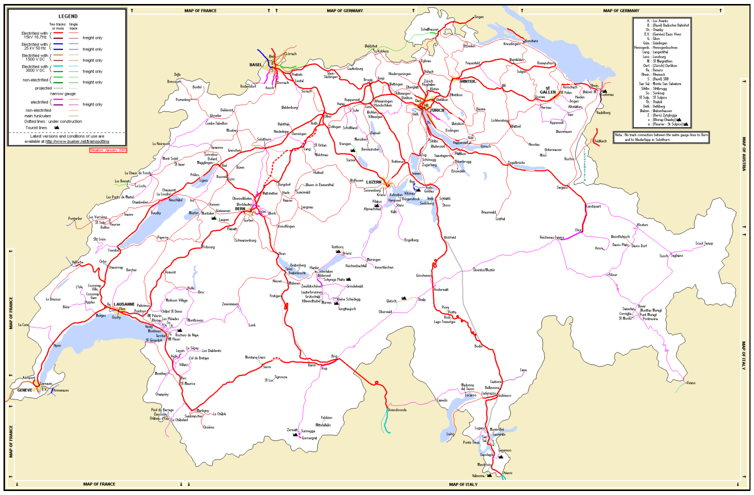
There are currently 201 DMUs and 393 diesel locomotives operating in Sweden. The average age of a DMU is 36.2 years and the average age of a locomotive is 33.2 years (European Railway stock list, 2005).

Due to the high proportion of electric traction, liquid fuel consumption by the railway sector in Sweden in 2003 was small at 936 Tera Joules (UNFCCC, 2004). This suggests that there are likely to be few emission hotspots. Pollution hotspots, if there are any, are likely to be located in and around the capital city of Stockholm and the large port of Malmo. However, no

[22] http://www.cia.gov/cia/publications/factbook/geos/sw.html#Trans

specific hotspots were identified by the Swedish Environmental Protection Agency who are responsible for monitoring air quality, and no questionnaire responses were received from the rail operators.

8.26 SWITZERLAND



Source: http://www.spec2000.net/rr_site_pages/swissmap.gif

The Swiss raiway network is 4,533 kilometres in length[23]. The commercially used railway lines in Switzerland are all electrified. Thus, diesel emissions from railways are of minor importance in Switzerland. Diesel cars are only used for shunting and maintenance operations. The number of diesel locomotives and diesel railcars are 873 and 4 respectively. The average age of DMUs in Switzerland is 25.8 years, whilst the average age of diesel locomotives is 41.5 years (European Railway stock list, 2005).

The diesel fuel consumed by the railways in Switzerland was all classed as sulphur free fuel and in 2003, 358 Tera Joules of liquid fuel was consumed (UNFCCC, 2004). This is the second smallest amount of fuel consumption after Luxembourg in the EU27 countries.

No complaints relating to air quality have been received by the rail operator, BLS Lőtschbergbahn AG. This is because they operate few diesel trains and shunting yards. In contrast however, the operator SBB, receive between one and ten complaints annually as a result of areas with limited air exchange and line sections where there is the occasional use of diesel locomotives for cargo delivery. SBB identified two locations with restricted air exchange that have housing within 50 metres.

There is the possibility that activities at shunting yards could lead to significant emissions but BLS Lőtschbergbahn AG and SBB have reported that there are no shunting yards that have housing within 50 metres. Due to electrification of the network busy line sections will not give rise to emission hotspots. It is therefore likely that there are no rail emission hotspots in Switzerland.

[23] http://www.cia.gov/cia/publications/factbook/geos/sz.html#Trans

8.27 UNITED KINGDOM

The UK's rail network is the oldest in the world, and since the privatisation of British Rail in 1996 has been split from one state owned network into around 30 independent rail companies as listed in table 8.27A below. In addition to the train operating companies (TOCs) there is Network Rail, which is the operator of the railway infrastructure.

Table 8.27A: Train operating companies (TOCs) in the UK

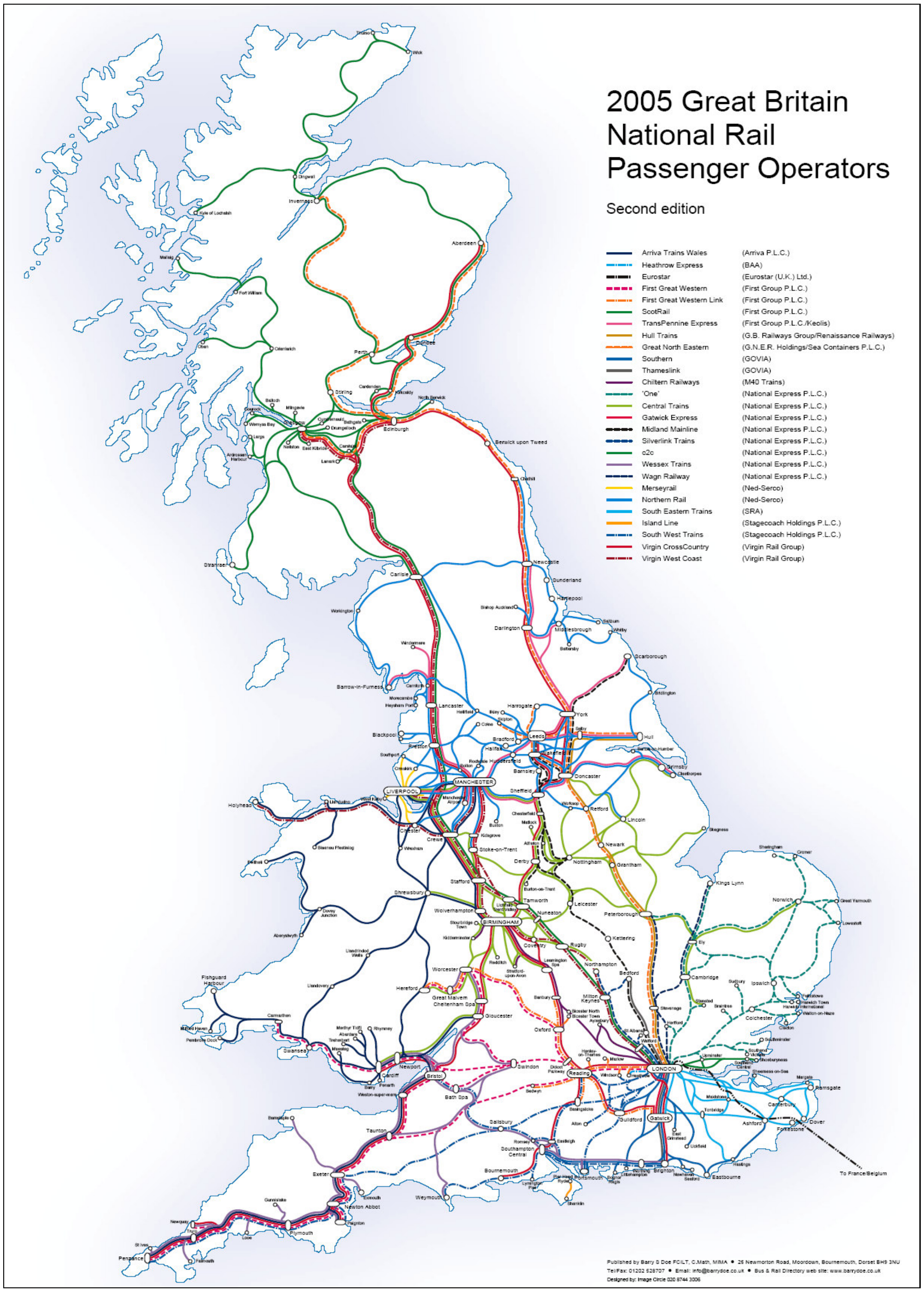
Arriva Trains Wales	Island Line
C2C	London Underground
Central Trains Limited	**Midland Mainline**
Chiltern Railways	**Northern Rail**
Docklands Light Rail	NI Railways
Eurostar	One Railway
English Welsh and Scottish Railways	Silverlink Train Services
First Great Western	Stansted Express
First ScotRail	**Southern Trains**
First TransPennine Express	South Eastern Trains
Freightliner	South West Trains
Gatwick Express	Thameslink Rail
Great North Eastern Railway (GNER)	**Virgin Trains**
Heathrow Express	West Anglia Great Northern Railway
Hull Trains	**Wessex Trains**

Note: those names in bold are those companies which provided information for this study.

The UK network is 17,274 km long[24], and diesel rail traffic accounts for around 43% of gross-tonne kilometres hauled (WP1 report, 2005). Figure 8.27 below demonstrates the complexity of the UKs rail network. The Northern Ireland network can been seen from the map in the Ireland section (Section 8.12).

[24] http://www.cia.gov/cia/publications/factbook/geos/uk.html#Trans

Figure 8.27: Map of the UK rail network (http://www.nationalrail.co.uk/maps.htm)



Source: http://www.nationalrail.co.uk/maps.htm

It has been estimated that there are 1,116 DMUs and 975 diesel locomotives in operation in the UK. Based on data from the European Railway Stock List, the average age of the DMU fleet is 13.7 years and the average age of the locomotive fleet is 22.2 years (European Railway stock list, 2005). The fleet is fairly young compared to the other European countries studied.

In 2003, the UK rail operators consumed 14,469 Tera Joules of liquid fuel (UNFCCC, 2004). This is the second highest consumption after Germany in the EU Railway 27 countries.

8.27.1 The Local Authority Review and Assessment process in the UK

Under the UK's Environment Act 1995 and subsequent Regulations, Local Authorities are required to review and assess air quality in their area from time to time. The role of the review and assessment process is to identify areas where it is considered likely that the air quality objectives will be exceeded. Where a likely exceedance is identified, Local Authorities should declare an air quality management area (AQMA) and an Action Plan should be produced. In some locations the likelihood of rail operations exceeding the air quality objectives have been assessed. These are summarised below.

Summary of UK rail company responses:

Arriva Wales

No complaints from the public have been made against the company relating to air pollution issues, and no pollution "hotspots" can be identified.

Midland Mainline:

Midland Mainline has received no complaints relating to air pollution from their train operations.

Northern Rail:

Northern Rail used to receive complaints relating to air quality from the area around the Neville Hill depot in Leeds, however after improvements such as fitting extra air lines such complaints have ceased.

Southern Rail:

Southern Rail has received one complaint from Victoria Station due to idling trains, but no further details are available. All locations where operations could result in significant emission levels are more than 50 metres from housing implying the Victoria complaint arose from within the station itself.

Wessex Trains:

Penzance Station in Cornwall has been identified as a location where complaints relating to air quality have been received. No Air Quality Management Area has been declared in this area.

First Great Western:

First Great Western periodically receive complaints about noise and air quality from residents of properties adjacent to railway lines. These tend to be in the summer when doors and windows are open and usually relate to stations or sidings where trains are stationary.

These reports come via a variety of routes, for example the local manager, telephone inquiry and letters of complaint to the Managing Director. No definitive numbers or locations have been provided. However there have been consultations between First Great Western, local authorities and Network Rail about emissions from London Paddington station, Weston-super-Mare station, Hereford station, and the Alstone sidings at Cheltenham. The relevant Local Authorities have assessed the impact of rail emissions on air quality concentrations and in each case they were deemed to be below the air quality objectives. Therefore no air quality management areas (AQMAs) have been declared as a result of train movements.

Great North Eastern Railway (GNER):

GNER have received complaints from local residents who live adjacent to the Craigentinny depot in Edinburgh for both air and noise pollution. No further information is provided, but no AQMA has been declared in this area. Therefore Edinburgh City Council do not perceive railway operations as causing emission hotpots at this location.

Virgin Trains:
Virgin report that no air quality complaints have been received.

Air Quality Management Areas declared due to railway activities:
In addition to the air quality limit values outlined in Section 3.1.5, the UK government has implemented their own SO_2 15 minute mean objective of 267 µg/m^3 not to be exceeded more than 35 times a year.

Only one UK local authority (Charnwood Borough Council in Leicestershire) has declared an AQMA due to pollution specifically from rail sources. The source is the Great Central Railway (GCR) locomotive sheds in Loughborough. There are 189 domestic properties within approximately 15 metres of the locations where steam locomotives are stationary for periods greater than 15 minutes.

The Great Central Railway is a private limited company and registered charity whose main business objective is to recreate the experience of travelling on steam locomotives, and is a such the only mainline steam railway in the UK. Both steam and diesel locomotives operate on the line, which runs for approximately eight miles from Loughborough to Birstall with two stations in between. As this is a tourist railway line, that is not representative of typical passenger and freight services. This example of a railway line exceeding the air quality limit values should be treated as an exception, and it is unlikely that other, more mainstream routes would lead to the declaration of an AQMA for sulphur dioxide.

It is evident from the UK railway company responses that some air quality complaints are received. However, Local Authorities do not perceive air quality surrounding railway activities as being poor and therefore in few cases have investigated further. Where air quality problems are perceived to exist, it is the exceedance of the SO_2 objectives that is of most concern. Air quality within station environments (i.e. locations with restricted air exchange) is not however investigated by Local Authorities, as generally this is private property. It is therefore likely that if rail emission hotspots do occur in the UK that they occur in locations with restricted air exchange.

9 Appendix C

9.1 THE DISPERSION MODEL - ADMS

ADMS V3.0 (Atmospheric Dispersion modelling System) is described as a "new generation" model. The model describes the state of the atmospheric boundary layer using two parameters: boundary layer depth and Monin – Obukhov length. The vertical concentration distribution is Gaussian in neutral and stable atmospheres but is skewed in Gaussian in convective conditions. As with the "old generation" models, a gaussian distribution is assumed in the crosswind horizontal direction for all stabilities.

ADMS has been developed in the UK and is widely used internationally by industry, consultants and regulatory bodies. ADMS has been extensively validated during its development against field data sets and wind tunnel data sets. Special features include the ability to treat both wet and dry deposition, building wake effects, complex terrain and coastal influences. ADMS – 3 can model releases from point, area, volume and line sources and can predict long term and short term concentrations. Calculations of percentile concentrations are also possible.

For the modelling of the different railway activities the main input data that was required was as follows: source type (line sources, area sources and point sources depending on the subject modelled), height and diameter of the emitting source, the co-ordinates of the source, the momentum flux and buoyancy flux, and the emissions of the pollutants in grams per second.

There are essentially five different types of meteorological data that can be used in ADMS. In this study, hourly sequential data for 2003 obtained from a UK weather station was used to calculate annual and daily average concentrations. The results of these are presented as contour plots.

The model has been extensively validated against field data and wind tunnel data sets. Studies have covered a range of meteorological conditions. Further detail is provided in the ADMS user guide. There are many factors that affect the performance of dispersion models. It is important that the relevant processes are properly incorporated into the model to allow an accurate simulation. The model output will be strongly dependent on the model input in which there will be uncertainties. This includes for example data on train movements and train types that are used in conjunction with emission factors to determine emission rates. The emission factors will be subject to some uncertainty due to having been derived from a relatively small number of rail engines. In addition it is likely that emission factors will vary depending on the age of the engine and driver behaviour. The meteorological data used will also have an impact on the predicted pollutant concentrations. Various studies have indicated that inter-annual variations in meteorology impact predicted annual average concentrations by no more than about 15%. In the modelling carried out for this study, only one set of meteorological data has been used. This will therefore lead to model uncertainties. However, the results will still provide a good indication of whether rail movements give rise to emission hotspots.

All dispersion models include simplifications in the dispersion algorithms to describe complex atmospheric processes. The user has little interaction with these algorithms. ADMS includes a range of user defined parameters, for example, the Monin – Obukhov length, roughness length and emission source height. Sensitivity analysis of model performance related to model set up parameters tend to indicate a much lower sensitivity compared to other factors such as the emissions data discussed above.

In addition to the above uncertainties there is the additional uncertainty of converting between NOx and NO_2 (see Section 5). The majority of the NOx emission release is in the form of NO which is oxidised to NO_2, largely dependent on the availability of ozone. The contour plots are provided in terms of NO_2 concentrations so that a comparison can be made with the air quality limit values. However, this provides an added uncertainty.

It must be remembered that models are approximate and that they are prone to those uncertainties discussed above. However, in the absence of monitoring data, model output will give an indication of the pollutant concentrations and provide good spatial coverage.

Table 5 in Section 5 shows the input data used by ADMS to calculate the pollutant concentrations. In addition, the following input data has been used:

Table 9.1. Additional input data used in the ADMS model runs.

Input data	Value
Emission height	4.5 metres
Temperature of emitting source	40
Exit velocity	1 m/s

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