ERTAC Rail Emissions Inventory
Part 3: Class II and III Locomotives

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Introduction

Air protection agencies from twenty-seven states, coordinated through the Eastern Regional Technical Advisory Committee (ERTAC) and headed by the Lake Michigan Air Directors Consortium (LADCO), identified a need to better quantify and characterize rail-related emissions inventories. Traditional locomotives utilize large diesel engines, resulting in emissions of NO_x, diesel PM, hydrocarbons, greenhouse gases, and other air pollutants. These emissions are sometimes concentrated in areas exceeding National Ambient Air Quality Standards. No cohesive nationwide railroad emission estimates based on local operations are known to have been made previously. Inventory development methods for locomotive emissions estimates vary from state to state and, in general, lack the spatial or temporal resolution needed to support air quality modeling and planning [1-5].

The ERTAC Rail Subcommittee (ERTAC Rail) was established with active representatives from twelve member states, three regional planning offices, and the US EPA. The subcommittee's goals are to (1) standardize agencies' inventory development methods through a collaborative effort, (2) improve the quality of data received and the resulting emission inventories, and (3) reduce the administrative burden on railroad companies of providing data.

With support from the Rail industry and assistance from the ERTAC Rail Data Workgroup (Appendix A), ERTAC Rail has developed 3 inventories of locomotive emissions (Table 1) for Class I line-haul, Shortline (Class III) and Regional (Class II) Railroads, and Class I railyard switchers. Because of the difficulty in obtaining data and differences in states' needs for inventory years, sources from both 2007 and 2008 were utilized (Appendix B.)

Line-haul locomotives travel long distances (e.g. between cities) while switcher locomotives largely operate in railyards, splitting and joining rail cars with varying destinations. Shortline railroads often transport freight between Class I railroads, ports, or other freight carriers and individual industries, provide local switching in a railyard, and/or own and operate a terminal facility (act as "Switcher and Terminal" providers). Passenger and Commuter Rail, industrial locomotives, and associated non-locomotive equipment are not included in these inventories. More information on ERTAC Rail, Railroad participation, the Rail industry, and effects of rail on air quality are available elsewhere[6].

The Surface Transportation Board (STB) defines Class I Railroads as having had minimum carrier operating revenues of $401.4 million (USD) in 2008, Regional Railroads (Class II) as having had at least 350 route miles of track and/or revenue between $40 million and the Class I threshold, and Shortline Railroads (Class III) as having less than 350 route miles of track, less than $40 million in revenue[7], and include all 'Switching and Terminal' companies. There are 8 Class I Railroads operating in the United States, about 33 Regional Railroads (Class II), and approximately 540 Shortline Railroads (Class III) (Appendix C). While categorized as a Class I Railroad, Amtrak was excluded from these inventories because of significant differences in equipment and operational characteristics.

Table 1. Summary of ERTAC Rail Inventories: U.S. Locomotive Emissions and Fuel Use for either 2007 or 2008*.

	Fuel Use** (gal/yr)	Emissions (tons/yr)						
		NO_x	$PM_{2.5}$	HC	SO_2	CO	NH_3	CO_2
Class I*** line-haul	3,770,914,002	754,443	23,439	37,941	7,836	110,969	347	42,305k
Class I switcher	301,046,290	74,431	2,042	4,867	624	9,230	28	3,367k
Class II and III	157,800,000	47,035	1,065	1,737	327	4,631	14	1,765k

*See Appendix B for a description of the year and source of data utilized for each inventory.
**Locomotive grade diesel
***Excluding Amtrak and including work train fuel use

This paper documents the data sources and methodologies used for calculating the Class II and III emissions inventory. Class II and III activities account for an estimated 4% of the total locomotive fuel use in the combined ERTAC inventories and for approximately 32% of the industry's national freight rail mileage[8]. These railroads are widely dispersed, though more concentrated in the eastern United States (Figure 1), and often utilize older, higher emitting locomotives than their Class I counterparts. These railroads provide services to industries requiring consistent transportation of large amounts or very heavy freight, small towns, and/or provide switching and terminal services at complex rail and intermodal intersections (Figure 2).

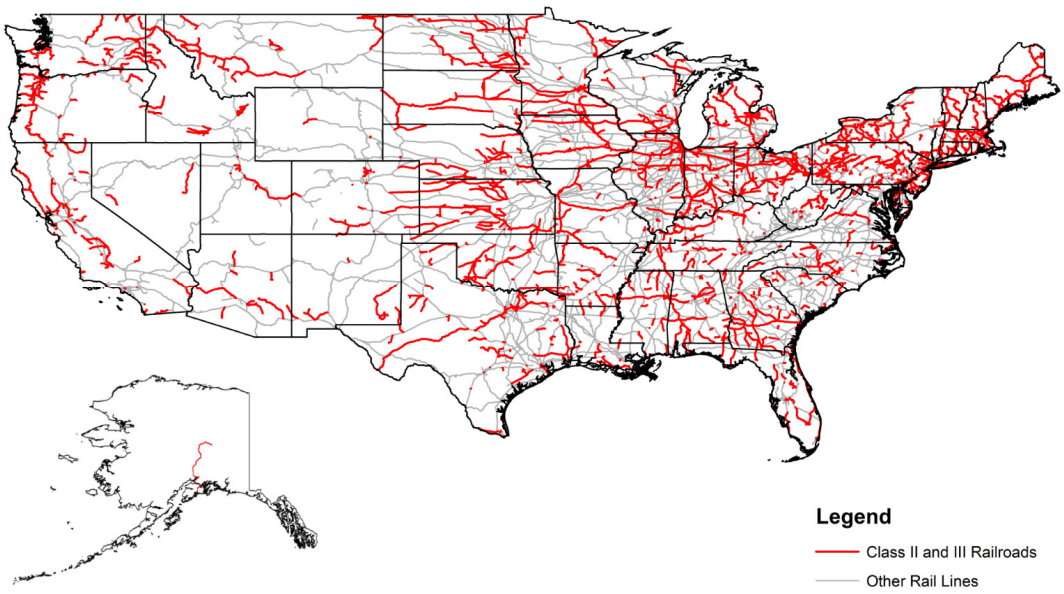

Figure 1. Class II and III railroad links from FRA dataset extracted by ERTAC Rail [9 and Appendix D]

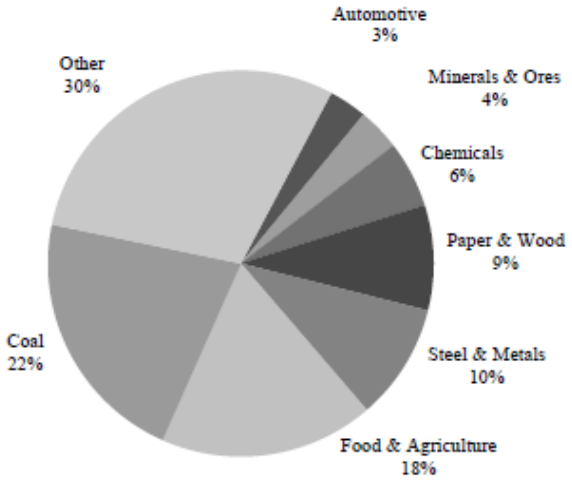

Figure 2. Carloads shipped by Shortline and Regional Railroads by commodity group[7]

Method

There are approximately 570 Class II and III Railroads operating in the United States, around 450 of which are members of the American Shortline and Regional Railroad Association (ASLRRA)[7]. In general, while information on Class II/III link locations and many fleet characteristics are available online, a significant effort would be required to compile this data into a usable format and check the data for reliability. In addition, the Class II and III sectors of the railroad industry have been in considerable flux since partial deregulation from the 1980 Staggers Act. States with relatively large numbers of Class II and III railroads, such as Maine, Pennsylvania, North Carolina, and Massachusetts, have independent surveys and emission inventory estimates available, but no regional or national level cohesive electronic datasets have been previously developed.

To calculate a nationwide Class II/III emissions inventory, ERTAC Rail first surveyed existing data sources, compared states' methods and data used for existing inventories, and contacted members of the Class II and III Railroad communities for guidance, including the ASLRRA, the FRA, and Genesee & Wyoming, RailAmerica, and Omnitrax (large holding companies of Class II and III railroads). In particular, Mr. Steve Sullivan from ASLRRA and Mr. David Powell from Genesee & Wyoming were able to provide significant assistance in identification of an appropriate nationwide dataset of Class II and III railroads with links and total locomotive fuel use, the development of a calculation method, and guidance on appropriate assumptions such as fleet average locomotive Tier classification. Data sources, calculations, and assumptions used to develop the resulting inventory are described below.

1. Locate Class II and III Railroads.

Identification and correct placement of Class II and III railroads was an important first step, requiring a comprehensive electronic dataset. A GIS database was obtained from the Federal Railroad Administration (FRA) with links identified as owned or operated by specific Shortline or Regional Railroads using "Reporting Marks", which are brief identification abbreviations. The full list of Reporting Marks is included with the inventory. The locations of these links with associated data including reporting mark, railroad name, class, number of links and route miles owned and/or operated, and total route miles of links were extracted by ERTAC Rail (Matt Harrell, Appendix D.) While this dataset contains confidential data for the Class I railroads, the geographical allocation of Class II and III links (Figure 1) and related information is public[9]. A similar public database compiled by the Bureau of Transportation Statistics is also available[10]. Data from this source will not match the confidential data exactly but will be very similar.

2. Select/Calculate Emission Factors.

While some Class II and III railroads purchase more recent locomotives, locomotives often serve 30 to 40 years in Class I line-haul service before being transferred to switching service or sold to Class II or III railroads. Through guidance from the Class II/III Railroad community, it was agreed that the EPA Non-regulated (pre-1973) emission factors[11] best represent most operating Class II and III locomotives. In addition, although the fuel use and route miles data obtained represent both switching and line-haul activities by the Class II and III railroads, the US EPA line-haul duty cycle was selected as most representative along with the "Small Line-Haul" conversion factor[11] to obtain gm/gal emission factors for hydrocarbons (HC), oxides of nitrogen (NOx), particulate matter (PM),and carbon monoxide (CO) (Table 2).

Table 2. Emission factors over the standard operating line-haul duty cycle using a conversion factor of 18.2 bhp-hr/gal [11].

	Line-Haul (gm/gal)			
	HC	NOx	PM	CO
Non-regulated (pre 1973)*	8.736	236.6	5.824	23.296

Other emission factors are not engine specific. For locomotives, $PM_{2.5}$ is assumed to be 97% of PM_{10} [11], and emission factors applied for SO_2 and NH_3 are 1.88 g/gal [11] and 83.3 mg/gal [12] respectively. VOC emissions are be calculated as 1.053 times the HC emissions for locomotives [13]. Note that non-road engine and fuel specific information is sparse for these conversions. Greenhouse gases are estimated using emission factors shown in Table 3.

Table 3. EPA greenhouse gas emission factors for locomotive diesel fuel (grams/gal). [14]

	CO_2	N_2O	CH_4
Locomotive diesel	1.015E4	0.26	0.80

3. Calculate Emissions.

The ASLRRA compiles data from the Class II and III railroads every few years[7], including total industry fuel use for locomotives and total Class II/III Route Miles. The FRA dataset also provides route miles. These values can be used to calculate an average Fuel Use Factor (FUF) for the industry (Eqn 1).

$$FuelUseFactor = \frac{TotalIndustryFuelUse_{ASLRRA}}{TotalClassII/IIIRouteMiles_{FRA}} = \frac{157{,}800{,}000\,gal}{52{,}367\,miles} = 2814.64\,\frac{gal}{mile} \qquad \text{Equation 1}$$

Some data was available from the ASLRRA to distinguish between the Shortline and Regional Railroad fuel use and miles of track, however the resulting fuel efficiency factors were not intuitively correct so ERTAC Rail chose to keep their emissions inventories combined until the discrepancies can be improved or explained.

ERTAC Rail chose to use the Total Class II/III Route Miles values with non-zero activity from the FRA dataset for this calculation, 52,367 miles, as shown. This way, if a railroad is known to have ceased operations, those route miles are not counted while the total fuel used estimate remains the same. In addition, this dataset was available in GIS format for mapping purposes, the data is also used for the Class I line-haul and switcher inventories, and it is part of a more comprehensive, managed inventory.

For comparison, ERTAC Rail has actual fuel use data and route miles for approximately 50 shortline railroads, which result in an overall average FUF of 2560.10 gal/mile, very close to the nationally calculated FUF. The average of the independently calculated FUFs in the inventory is 3001.09 gal/mile, with the maximum being 15953.78, the minimum being 67.97, and a standard deviation of 3393.08 gal/mile. As can be seen, while the averages are in good agreement, there is a wide range of potential individual FUFs per railroad which can depend on many factors such as frequency of trips, tonnage hauled, terrain, distance, locomotives used, and others. This wide potential range indicates the importance of using specific fuel use data when possible. There are also discrepancies between the FRA route miles assigned to railroads and route miles reported by the railroads. Because of the GIS linkages available with the FRA database, the FRA route miles rather than reported route miles are used in the inventory. These should also be verified when possible and, if necessary, corrected both in the FRA database and the emissions inventory.

The Fuel Use Factor calculated for use in this inventory (2814.64 gal/mile) was multiplied with the route miles listed for each Class II and III railroad in the FRA database, resulting an estimate of gallons of fuel used in 2008 for each railroad. The annual gallons of fuel used were then multiplied with pollutant emission factors for a mass of pollutant emitted for the year.

Further modifications were made to the estimates to reflect actual fuel use collected for specific class II/III railroads, including entries of '0' for railroads known to be out of operation. In particular, specific fuel use data was entered for railroads owned by Genesee & Wyoming and for some Class III railroads operating in Pennsylvania, Massachusetts, and North Carolina. These modifications were accounted for in the Fuel Use Factor calculation applied to the remaining railroads so that the national total fuel use is equal to the total estimate by the ASLRRA (157,800,800 gal) and the Fuel Use Factor is calculated only using fuel and track data for railroads with no known fuel use information.

Limitations, Conclusions, and Future Work

This ERTAC Rail Class II/III inventory provides a cohesive nationwide inventory with data for where Shortline and Regional Railroads operate and who owns them, and provides a comprehensive geographical allocation of their locomotive emissions bounded by what is reported as nationwide Class II/III fuel usage by the ASLRRA. This inventory will be useful for regional and some local modeling, helps identify where railroads may need to be better characterized, and provides a strong foundation for future development of a more accurate nationwide Shortline and Regional railroad emissions inventory.

Major areas for future improvement include distinguishing between switching and hauling operations and updating fleet Tier characteristics where appropriate. More accurate annual fuel use estimates, rather than using the estimated Fuel Use Factor would greatly improve the inventory. For example, 2006 Class II/III fuel use reported to the ASLRRA was 309 million gallons, almost double what was reported only two years later in 2008. It is unlikely that the industry halved fuel use in two years, but no other activity indicators have been found for comparison. Another area of uncertainty that can be improved is estimates of temporal variability. Emissions inventory preparation guidance from the U.S. EPA describes locomotive activity as constant throughout the year (e.g. no daily, weekly, or seasonal variability), though weekly or seasonal variation is highly likely for the Class II and III lines.

States or other areas with local, direct Class II and III data including temporal activity, fleet characteristics, or annual fuel use should use that information in place of this inventory. This inventory was designed to incorporate refinements from industry or state agency representatives, and we request that any data collected be submitted to ERTAC Rail so that the inventory can be continuously improved.

It must be noted that freight-related rail activity is not always routine and no annual emissions inventory will ever be able to capture the innate variability of the source. However, as other large emission sources are better characterized and reduced, and if rail activity increases as expected, it is important to standardize a methodology for estimating the emissions and to include our best reasonable representation of these sources and their potential variability in air quality analysis. In the future, on-line data loggers and other tracking technologies, combined with ambient studies and detailed modeling, will hopefully provide more insight to the emissions of locomotives and other rail-related sources.

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Key Words

Transportation emissions, freight movement, railroad emissions, locomotive emissions, emissions inventory, emission factors, photochemical modeling, dispersion modeling, air quality modeling, diesel.

Appendices

Appendix A: ERTAC Rail Data Workgroup

REPRESENTATIVE	ORGANIZATION
Matt Harrell	IL EPA
Michelle Bergin (Co-Chair) and Byeong Kim	GA EPD
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Robert Fronczak	AAR
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Erika Akkerman	CN
M. John Germer	UP
Brent Mason and Richard Russell	NS
David Powell	G&WY
Joanne Maxwell	Amtrak

Appendix B: Source and Year of Data Utilized for Each Inventory

Data	Year	Source
Class I Line-Haul		
Annual Line-Haul Fuel Use and Gross Ton-Miles	2007	STB R-1 Reports (CP data for D&H is for 2008.)
Line-haul fleet mix for emission factors	2008	Each Class I railroad
Link-level tonnage	2007	FRA confidential database
Class I Railyards (Switcher Locomotives)		
Annual Switcher Fuel Use	2008	R-1 Reports
Switcher fleet mix for emission factors	2008	Each Class I railroad
Link-level tonnage or Density Code (for activity estimate)	2007	FRA confidential database
Class II and III Locomotives		
Annual Total Fuel Use	2008	ASLRRA Annual Report (2008)
Track length and railroad	2007	FRA confidential database
Estimated fleet mix for emission factors		Discussions with ASLRRA and Class II and III representatives.

Appendix C: Railroad Companies Operating in the United States

Railroad	
Class I	
BNSF	
Canadian National	
Canadian Pacific***	
CSX	
Kansas City Southern	
Norfolk Southern	
Union Pacific	
Amtrack	
***Regional (Class II)**	
	Mileage
Alabama and Gulf Coast Railway	435
Alaska Railroad	506
Buffalo and Pittsburgh Railroad	699
Central Oregon and Pacific Railroad	447
Dakota, Missouri Valley and Western Railroad	534
Florida East Coast Railway	386
Great Lakes Central Railroad	396
Indiana Rail Road	602
Indiana and Ohio Railway	692
Iowa Interstate Railroad	608
Kansas and Oklahoma Railroad	869
Kyle Railroad	554
Missouri and Northern Arkansas Railroad	583
Montana Rail Link	905
Montreal, Maine and Atlantic Railway	527
Nebraska Kansas Colorado Railway	559
New York, Susquehanna and Western Railway	357
Northern Plains Railroad	486
Paducah and Louisville Railway	290
Pan Am Railways	1165
Portland and Western Railroad	587
Providence and Worcester Railroad	568
Red River Valley and Western Railroad	575
San Joaquin Valley Railroad	351
South Kansas and Oklahoma Railroad	398
Texas Northeastern Railroad	665
Texas Pacifico Transportation	393
Utah Railway	430
Wheeling and Lake Erie Railway	878
Wisconsin and Southern Railroad	837
Shortline (Class III)	
See www.aslrra.org/our_members/Railroad_Members or http://www.railsusa.com/links/Shortline_Railroads/	

* These railroads were classified as regional by the AAR in 2007 as reported in Wikipedia (http://en.wikipedia.org/wiki/Regional_railroad#cite_note-2 , accessed Oct. 7, 2011.) Railroads known to have been purchased by Class I railroads after 2007 have been removed from this list.

Appendix D. ERTAC – Class 2/3 Shapefile Documentation (Matt Harrell, 13 Jul 2009)

Introduction

This document outlines the methods and procedures used to compile a shapefile representing the links in the FRA 1:100,000 railroad dataset that are owned or operated by Class II and III railroad companies. It is important to note that there is a considerable amount of overlap between the Class II's and III's and the Class I and passenger railroads. Class II's and III's can operate on Class I or passenger rail links and vice versa. Although the final shapefile specifically represents Class II and III links, there are many Class I and passenger railroads represented as well.

Procedure

1. Started with all proprietary FRA links where "NET = 'M' and "STCNTYFIPS" <> ' ' (this definition query selects all active mainline links located within the United States).

2. Ran 12 queries, one for each ownership and trackage rights field, to select all links not associated with a Class I freight railroad or Amtrak and not containing a null value (e.g., "RROWNER1" <> 'AMTK' AND "RROWNER1" <> 'BNSF' AND "RROWNER1" <> 'CN' AND "RROWNER1" <> 'CPRS' AND "RROWNER1" <> 'CSXT' AND "RROWNER1" <> 'KCS' AND "RROWNER1" <> 'NS' AND "RROWNER1" <> 'UP' AND "RROWNER1" <> ' '). The first query was setup as a new selection. Each of the 11 subsequent queries were setup to add records to initial set of records. 26,261 links were selected and exported to a new shapefile.

3. Due to the multitude of railroad codes used to represent commuter rail operations across the country, additional processing was required to remove any links that were not operated by a Class II or III freight railroad. Each commuter railroad was queried out of the new shapefile and the links analyzed to eliminate all links where no Class II or III operations were occurring. The following commuter rail operations were evaluated: NJT (New Jersey Transit), MNCW (Metro-North Commuter Railroad), LI (Long Island Railroad), CDOT (Connecticut DOT), MBTA (Massachusetts Bay Transportation Authority), SEPA (Southeastern Pennsylvania Transportation Authority), MARC (Maryland Area Rail Commuter), VRE (Virginia Railway Express), MTRA (Northeastern Illinois Regional Commuter Railroad), CSS (Northern Indiana Commuter Transportation District), DART (Dallas Area Rapid Transit), SCRA (Southern California Regional Rail Authority – including also SCAX, LACM, LAPT, and LATC), TCRA (South Florida Regional Transportation Authority), PJPB (Caltrain), and ACE (Altamont Commuter Express). Approximately 1581 links were identified with no Class II or III operations and were deleted from the Class 2/3 shapefile.

4. The remaining Class II and III links were then compared to the regional maps contained in the July-August issue of The Official Railway Guide to assess the completeness of the Class 2/3 shapefile. Six specific edits were made to the shapefile to correct the most glaring errors:

1) BMLP links deleted (Black Mesa & Lake Powell, an electric coal hauling railway in Arizona); 2) DSNG links deleted (Durango & Silverton steam tourist railroad in Colorado; 3) CIC haulage rights links on CN from Chicago to Omaha deleted; 4) DMIR links deleted (Duluth, Missabe & Iron Range, now owned and operated by CN in Minnesota; 5) EVWR's ex-CSXT links coded from Evansville, IN to Okawville, IL (Evansville Western Railroad); 6) INRD ex-CP links coded from Chicago, IL to Louisville, IN (Indiana Rail Road).

5. During the course of reviewing the FRA dataset, 555 "active" links were found to have no ownership or trackage rights codes. 1005 links have no codes listed in the 3 ownership fields. In most cases these links are very short and scattered across the country. Only the links representing the EVWR and INRD spanned large distances and were fixed. The other problem links were deemed to be insignificant. A listing of these links will be provided back to the FRA to assist with their coding in 1:100K railway shapefile.