Final Report

ASSESSMENT OF AVAILABLE TOOLS AND METHODOLOGIES TO QUANTIFY REGIONAL AND PROJECT LEVEL AIR QUALITY EFFECTS FOR FREIGHT RAILROADS

Prepared for
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1.0 INTRODUCTION

In Texas, each nonattainment area maintains an air quality model that includes emission inventories for on-road motor vehicles and off-road equipment. The Environmental Protection Agency (EPA) provides emission rate models for vehicles and off-road equipment, but EPA does not provide models for locomotive emissions. Current practice is to model freight rail as a separate source category using special studies to estimate emissions from this category usually at a regional or nonattainment area scale.

Improvements to rail operations may not be fully reflected in such regional modeling. These improvements are usually specific projects proposed, so the project level analysis needs to be consistent with the regional emissions analysis. At a project level, the emission effects of a proposed action need to account for all incurred changes due to the action. The impact of an individual project may be small, but the collective impact of all projects in a region may be significant.

The purpose of this research project was to determine what tools, models, and/or methodologies are being used to calculate freight baseline and forecasted emissions inventories and the air quality benefits associated with improvements to freight rail infrastructure and operations, on both the regional and project levels, and identify areas of improvement to model inputs and modelling itself. The tasks included the following:

- Review of federal air quality regulations/requirements regarding freight railroads.
- Review of the current air quality modeling of freight railroads for conformity and State Implementation Plans in Texas and other states.
- Document existing locomotion emission models/methodologies and how freight railroads currently quantify emissions. Currently railroad companies use different emissions calculations.
- Assess the state of the practice as to how other agencies and/or nonattainment areas in Texas and the US are analyzing air quality for railroad infrastructure and operational improvements.
- Document and evaluate existing computer models and methodologies for assessing air quality for freight railroad improvements. Include data needs, data fields, level of effort, and confidence level of the analysis. Define the pros and cons of each.
- Recommend model and input enhancements for both project and regional level analyses and cost analysis.

This report outlines the relevant emission standards for locomotives in Section 2, how regional emission inventories have been prepared in Section 3, how project level emission estimates and emission reductions have been estimated in Section 4, and an overview of rail activity models used to assist in planning rail networks in Section 5.

2.0 FEDERAL EMISSION STANDARDS

EPA promulgated locomotive emissions standards in 1997 and added further regulations in 2008 as shown in Tables 1 and 2. The 2008 emission standards for locomotives were combined with similar marine engine regulations, but there are significant differences for marine engines in terms of test procedures, implementation years, and other factors compared with locomotive standards. Only the locomotive standards and not the marine standards are described here.

For locomotives, these standards depend on the duty cycle chosen to certify the engines – either line-haul or switching engine duty cycles. The duty cycle for line-haul engines typically leads to lower emissions on a gram per horsepower-hour (hp-hr) basis because the switching engine duty cycle has a considerable idling time (no hp-hr generated). In some cases the uncontrolled emissions were much lower than some of the emission standards, so no emission reduction would be expected from those standards, especially for HC and CO emissions.

Table 1. Locomotive – Emission standards (g/hp-hr) for line-haul (duty cycle) engines.

Emission Standard	Applicable Year	HC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	PM (g/hp-hr)
Uncontrolled Emissions	**Pre-1973**	**0.48**	**1.28**	**13.0**	**0.32**
Tier 0 – original	1973 – 2001	1.00	5.0	9.5	0.60
Tier 0 – final[1]	2008 / 2010	1.00	5.0	8.0	0.22
Tier 1 – original	2002 – 2004	0.55	2.2	7.4	0.45
Tier 1 – final[1]	2008 / 2010	0.55	5.0	7.4	0.22
Tier 2 – original	2005	0.30	1.5	5.5	0.20
Tier 2 – final[1]	2013	0.30	1.5	5.5	0.10
Tier 3	2012 – 2014	0.30	1.5	5.5	0.10
Tier 4[2]	2015	0.14	1.5	1.3	0.03

1-These are remanufacture standards at the time of rebuild and phased in as retrofit kit availability. The original Tier 0 standard was applied as a retrofit for model years 1973 – 1999 and phased-in as those engines are rebuilt.

2-The Tier 4 NOx standard can be a 1.4 NOx + HC standard.

Table 2. Locomotive – Emission standards for switching (duty cycle) engines**.**

Emission Standard	Applicable Year	HC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	PM (g/hp-hr)
Uncontrolled Emissions	**Pre-1973**	**1.01**	**1.83**	**17.4**	**0.44**
Tier 0 – original	1973 – 2001	2.10	8.0	14.00	0.72
Tier 0 – final[1]	2008 / 2010	2.10	8.0	11.80	0.26
Tier 1 – original	2002 – 2004	1.20	2.5	11.00	0.54
Tier 1 – final[1]	2008 / 2010	1.20	2.5	11.00	0.26
Tier 2 – original	2005	0.60	2.4	8.10	0.24
Tier 2 – final[1]	2008 / 2013	0.60	2.4	8.10	0.13
Tier 3	2011 – 2015	0.60	2.4	5.00	0.10
Tier 4[2]	2015	0.14	2.4	1.30	0.03

1-These are remanufacture standards at the time of rebuild and phased in as retrofit kit availability allows. The original Tier 0 standard was applied as a retrofit for model years 1973 – 1999 and phased-in as those engines are rebuilt.

2-The Tier 4 NOx standard can be a 1.3 NOx + HC standard.

The 1997 regulations only encompassed Tier 0, 1, and 2 emission standards, while the 2008 regulations added the Tier 3 and 4 emission standards. Both regulations included engine remanufacturing as a feature of the regulations. The 1997 regulation included remanufacturing the 1973 – 1999 model year engines to the Tier 0 standards with new engines produced in 2000 and 2001 meeting the Tier 0 standards initially at the time of manufacture. The 2008 regulations now include remanufacturing of the Tier 0, 1, and 2 engines to meet lower standards than originally promulgated in 1997, and include some pre-1973 locomotives in the Tier 0 standard when remanufactured.

The term “remanufacture” means one of the following: To replace, or inspect and qualify, each and every power assembly of a locomotive or locomotive engine, whether during a single maintenance event or cumulatively within a five-year period. The term ‘power assembly’ means the components of an engine where the combustion of fuel occurs, and it consists of the cylinder, piston and piston rings, valves and ports for admission of charge air and discharge of exhaust gases, fuel injection components and controls, cylinder head and associated components.

In addition, all Tier 3 and Tier 4 locomotives must be equipped with automatic engine stop/start that must be set to shut off the main locomotive engine(s) after 30 minutes of idling (or less).

The smoke opacity standards specified in Table 3 apply only for locomotives certified to one or more Particulate Matter (PM) standards or family emission limits (FEL) greater than 0.05 g/bhp-hr. The smoke opacity method provides a measure of when the engine is out of maintenance, and could be used to determine when the engine is producing excess particulate matter.

Table 3. Smoke Standards for locomotives.

Standard	Steady-State	30 second peak	3 second peak
Tier 0	30%	40%	50%
Tier 1	25%	40%	50%
Tier 2	20%	40%	50%

Emission diagnostics will detect significant malfunctions in their emission-control systems. Included in the diagnostics requirements are that engines equipped with selective catalytic reduction (SCR) systems using separate reductant tanks must detect when those tanks are empty.

As with many EPA engine rules, there is an element to allow averaging, banking, and trading (ABT) of emissions between engine families. A manufacturer may use or buy credits to meet the overall standards for its engines. Therefore a specific engine model may exceed (usually would only slightly exceed and within limits set by EPA) the emission standard to which it was certified.

Lastly, EPA (2004) in other rules has promulgated that 15 ppm sulfur fuel be used in locomotives starting June 2012. The low sulfur fuel will have a beneficial impact on direct particulate matter emissions, but the primary benefit is that the low sulfur fuel permits aftertreatment controls to work more effectively.

3.0 REGIONAL EMISSION ESTIMATES

3.1 National EPA Estimates

EPA has estimated locomotive emissions for the nation that include Class 1 (larger railroads comprised of BNSF, Canadian National, Canadian Pacific, CSX, Kansas City Southern, Norfolk Southern, and Union Pacific) line-haul and switching locomotives separately, Class 2/3 (shortline and switching) railroads, and passenger railroads (AMTRAK and commuter). EPA (2008) based their estimates on detailed data on fuel consumption, fleet size, and fleet composition available from industry sources. Load factors and emission factors were developed in the previous rulemaking (EPA, 1997) that used instrumented and laboratory test data. EPA

(1997) provided the baseline (uncontrolled) locomotive emission factors as shown in Table 4. These estimates are national in scope, or at most detailed for individual railroads' overall operations. EPA (2001) in their National Emissions Inventory (NEI) estimated county emissions by allocating these national emissions using general mainline activity in terms of approximate gross tonnage by line segment from a Bureau of Transportation Statistics (BTS) report to determine county level emissions.

Table 4. Locomotive emission factors for calendar years 1999 and earlier (EPA, 1997).

Locomotive Type	HC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	PM (g/hp-hr)	Fuel Consumption (hp-hr/gallon)
Line-Haul*	0.48	1.28	13.0	0.32	20.8
Switch**	1.01	1.83	17.4	0.44	20.8

* Line-haul locomotives over the line-haul duty-cycle

** Switch locomotives over the switch duty-cycle

EPA provided two assessments on the national impact of its rulemakings for the original rule (EPA, 1998) and the more recent rule (EPA, 2008) that encompass the final standards for Tier 0, 1, 2, 3, and 4 locomotives shown in Tables 1 and 2. EPA (2008) presented two methods to forecast locomotive emissions: (1) Emission rates incorporating only the 1997 locomotive rule benefits and (2) Emission rates incorporating both the 1997 and 2008 locomotive rule benefits both with growth included.

EPA (2008) in their analysis of the rulemaking estimated emission reductions due to the latest rulemaking by combining the emission reductions of the original locomotive emissions standards developed in EPA (1998) with the later rulemaking. EPA (1998) provided emission reductions of the benefits of the 1997 rulemaking for all future years for the initial rulemaking. The beginning year for the comparison that EPA (2008) provided was calendar year 2006. Therefore by combining the emission reductions from EPA (1998) for calendar years 1999 to 2006 and from the EPA (2008) analysis for 2006 and later calendar years, the comprehensive emission reduction can be estimated and used to adjust the uncontrolled 1999 locomotive emissions rates shown in Table 4. This calculation yields a control factor used to determine the emission rate reduction due to the rule implementation and fleet turnover. By applying the emission reductions from the combination of the EPA (1998 and 2008) studies with the growth in activity, the future year emissions can be predicted from a base calendar year. EPA (2009) has recently included the benefits of the combined rules into forecasted emission factors.

3.2 Texas Locomotive Emissions (HARC H-18 Project)

ERG (2006) as part of the HARC H-18 Project collected activity data and prepared a locomotive emissions inventory for the Houston-Galveston-Brazoria (HGB) and Dallas-Ft. Worth (DFW) nonattainment areas. The additional detail added in this inventory effort was to identify individual train types and determine emission rates specific to those train types on specific track segments. The result was emissions estimates by county with specific effort for the HGB and DFW nonattainment areas. The remainder of Texas' counties was estimated using the national Bureau of Transportation Statistics (BTS) data of approximate tonnage by rail link.

The level of effort provided by the high level of cooperation of the Texas railroads in supplying specific activity data cannot always be found in other states, so alternative approaches are often required to provide comprehensive estimates. These alternative approaches are described in Section 3.3.

3.3 Other State Locomotive Emission Inventories

Several alternative methods are being used to determine locomotive emissions. These include special studies with a growing interest in a national approach to rail activity identification and emissions estimates.

The first method used to determine locomotive emissions for specific states was to identify the railroads operating in the area and to survey those railroads for individual activity in terms of fuel consumption, gross ton-miles, and switching hours. ENVIRON (2007) used this approach for several states including Illinois, Indiana, Michigan, Ohio, Wisconsin, Arkansas, Wyoming, and Arizona. STI (2004) used this approach to collect fuel consumption data from railroads operating in the central states. Fuel consumption can then be converted to emissions using EPA emission rates from EPA (1997) with the control factors determined from EPA (1998, 2008).

Since these state inventories were prepared, a working group of the Eastern Research Technical Advisory Committee (ERTAC, see reference link) has been working with the larger Class I railroads to make mainline and switching engine activity data available. This data is currently only collected for mainline gross tons activity by rail link and considered proprietary, so railroads that supplied data must sign letters to allow release of the data. (Raquel Wright, 2009)

The California Air Resources Board (ARB) has been working with the California railroads to identify specific locomotive activity along major rail lines to revise their statewide emissions inventory. The results of the study are not yet public, but the approach that ARB is using identifies activity in ton-miles by train type and track link to estimate emissions. (Todd Sax, 2009)

One of the difficulties with these approaches is identifying the local and short line railroad data sources. Smaller railroads cannot always supply specific activity data for the region of interest. Some of their activity along the main lines may be captured by the larger Class I railroads, but these railroads may operate their own lines along with performing switching engine operations. Because switching locomotives may also perform short haul functions, care must be exercised to avoid double counting that activity when using an approach that gathers data from individual railroads.

4.0 PROJECT LEVEL EMISSION ESTIMATES

4.1 Infrastructure

There have been few rail infrastructure projects that quantify emissions benefits. This lack of information is primarily because historically the railroads in question were interested in obtaining a permit for construction and only needed to show that the project would provide a net benefit for air quality and not specifically quantify the emission reductions. The benefits of infrastructure projects can be varied and widespread because reducing train and highway congestion would save people and freight time as well as improve safety, reduce land use, and increase economic activity besides air quality benefits.

The Texas Tower 55 Texas Emission Reduction Plan (TERP) application (http://www.tceq.state.tx.us/implementation/air/terp/erig_apps.html) has been one of the few projects that have provided a detailed quantification of emissions benefits of a rail infrastructure project. While the recent Tower 55 infrastructure TERP application that claimed 68 tpy (0.2 tpd) NOx reduction from locomotives (in addition to an additional 96 tpy in truck emissions) was a fraction of the three-county DFW locomotive emission inventory of 5,346 NOx tpy for calendar year 2003 (ERG, 2006), this project would have been a smaller fraction of the TERP emissions reductions. TERP reductions for projects funded from 2004 – 2008 totaled 22.4 tpd in DFW and 31.0 tpd in HGB, and, for 2008 funded projects alone, totaled 5.3 tpd in DFW and 4.6 tpd in HGB. Likewise, the Voluntary Mobile Source Emission Reduction Programs (VMEP) for DFW totaled 2.48 tpd NOx reduction and for HGB totaled 2.82 tpd. So the State Implementation Plans (SIPs) for DFW and HGB claimed much more emission reduction from TERP and VMEP programs than the Tower 55 project application. (TCEQ, 2009)

An agency coalition had quantified benefits for the general Chicago Region Environmental and Transportation Efficiency Program (CREATE, 2005) plan. But the specifics of the air emissions benefits were not detailed in this report, and many of the individual projects have already been completed. From further discussions with the project proponents, the emission reductions used a combination of detailed surveys and modeled expectations. For road/rail grade separations, actual closure time was combined with vehicle traffic volumes to estimate time and idle emissions reductions. For other gate crossings, the Illinois Commerce Commission (ICC) modeled the improve traffic flows with the CREATE projects to estimate the avoided vehicle idle time. For locomotives, the reduced fuel consumption was modeled using the Berkeley Simulation Software Rail Traffic Controller model, and EPA emission factors used to estimate emissions benefits.

4.1.1 Locomotive emissions

Rail infrastructure projects benefit locomotive emissions by preventing extended idling while waiting for mainline congestion to clear. While many locomotives have automatic idle reduction devices, locomotive in service on mainlines often need to maintain brake pressure and be ready when cleared to proceed, so the engine must continue to idle while delayed. Therefore congestion delay improvements can be determined in terms of fuel consumption benefits useful to estimate emission reductions.

Among other infrastructure projects, track straightening and grade reductions can have a beneficial impact. Train drag increases with track curvature, and the benefit of reducing grade will also reduce overall fuel consumption. It takes sophisticated models to determine the impact of those improvements, such as those outlined in Section 5.

One potential improvement is for the train routes to be more direct thereby reducing mileage, fuel consumption, and emissions. The fewer miles that a train needs to travel are a straightforward effect to justify emission reductions. An example in Texas would be Kansas City Southern's (KCS) reopening of the Rosenberg line, reducing the overall miles traveled between Rosenberg and Victoria by up to 70 miles. (http://fortbendcounty.org/documents/KCSR_Opens_Rail_Line_From_Ros_to_Victoria_6-10-09.pdf)

In California, a similar project to Tower 55 where the BNSF and Union Pacific mainlines would be grade separated was evaluated. (http://www.sanbag.ca.gov/projects/grade.html, or http://www.coltoncrossing.com/) To date, the analysis has only estimated the delay time that could be used to estimate emission reduction, but the final analysis has not yet been prepared.

4.1.2 Highway – Rail crossing emissions

Railroads do not intend to block at grade road crossings with their trains, but in congested regions grade separation projects may provide an air emissions benefit by reducing the vehicle idling. Grade separation projects also provide for improved safety by reducing interaction between trains and vehicles, and allow for higher vehicle and train speeds as additional benefits beyond air emission reductions.

For the Tower 55 project, ENVIRON, at the request of BNSF, estimated the benefit of higher speed train traffic. The higher train speeds through the area would reduce the number and duration of vehicles at idle waiting for the intersections to clear. This calculation used the vehicle average daily travel with a normal diurnal progression to determine how many vehicles would be stopped while a train passed and on average how long the vehicles would be stopped. Using the idle emission rate, the emissions reductions from the higher train speeds were calculated.

The Tower 55 application approach may underestimate the benefit of rail infrastructure projects, especially when the project involves grade separation, because vehicles would not be required to brake and accelerate for every train but only idle emission reduction benefits were claimed.

4.1.3 Truck diversions

Railroads in general have only one competing alternative mode, on-road trucking. Rail infrastructure projects are often needed to improve service in order to reduce truck traffic in congested regions. Union Pacific in its Tower 55 TERP application estimated the number of truck trips and routes that would be taken to supply the equivalent freight movements if rail congestion reduced the ability of railroads to serve the demand. On-road truck emissions are determined using the miles driven multiplied by the average heavy-duty truck fleet emissions under freeway speeds. These emissions were compared with the rail locomotive emissions to move the equivalent freight.

Rail and truck (or water) modal comparisons need to account for the individual routes that would be used by mode choice based on the supplier and customer. Depending upon the trip origination and termination, each mode might have different mileage based on the preferred routes regardless of the number of rail, truck, or barge movements.

4.2 Engine Replacement/Retrofit

There have been several locomotive engine retrofit/replacement programs many of which can be found online (http://www.westcoastdiesel.org/wkgrp-loco.htm). These include early engine upgrades mandated by EPA rules, replacement of older, primarily switching locomotives with ones using engines meeting the current emission standards, or meeting standards lower than those applicable for new engines. There have been many attempts at retrofit of existing engines, but most of these projects are still being evaluated in the demonstration stage of technical development.

The California Air Resources Board (ARB, 2008) performed an extensive review of emission control and other mitigation options to reduce air quality impacts from rail yards. In its report, engine replacement and retrofit options figured prominently and usually centered on replacing locomotives with new and advance control options including hybrid and generator set designs. The ARB review includes a number of other options associated with other rail yard activities including truck and offroad equipment programs, area and screen buffers, as well as other options.

The State of Georgia has coordinated funding for replacing up to 30 switching locomotive with generator set locomotives. This is a similar approach to those funded by Texas TERP program but with the primary emphasis in Georgia on reducing PM emissions.

4.3 Idling Reduction Programs

One of the first locomotive emission reduction programs was to implement automatic Start/Stop and auxiliary power units (APU). In EPA's region V, several devices were installed and tested especially for the Chicago area switching engines (http://www.epa.gov/smartway/transport/what-smartway/idling-reduction-available-tech.htm), and similar programs have been funded across the US (http://www.swcleanair.org/pdf/EPA_LocomotiveCaseStudy.pdf). The Texas TERP program also funded idle reduction device installations. In colder climates, idle reduction devices are specially designed to avoid engine block freezing and may therefore not be as effective during winter months because either the engine must be operating more or an alternative source, usually burning fuel in an auxiliary power unit, must be used to supply heat and air brake pressure.

California ARB (2005) and the major railroads (Union Pacific and BNSF) agreed in a 2005 MOU to an idle shut off program that included operator action as well as automatic devices to shut off engines within 15 minutes of idling within a rail yard. This idle reduction program was extensive applying to nearly all rail yards in California. The benefits of the program were incorporated into mitigation plans of selected rail yards.

5.0 LOCOMOTIVE ACTIVITY MODELING

5.1 Introduction

ENVIRON investigated two computer models that could be used for analysis of freight railroad activity: the Rail Traffic Controller (RTC) by Berkeley Simulation Software (BSS) and the Train Energy Model (TEM) by the Transportation Technology Center Inc. (TTCI). Both models could be used to derive information on rail projects that can then be used for determining air emissions from rail vehicles considering the effects of specific projects. Both models are proprietary and require licenses.

The RTC costs US$45,000 per desktop (or laptop). For an annual maintenance fee (currently US$5,000), BSS provides program upgrades, bug fixes, and technical support. Additional support services can be purchased on an hourly basis. The TEM is no longer marketed by TTCI, however, TTCI performs studies for clients using the model.

Because of the cost for the use of the models, actual use and trials of the models was beyond the scope of this project.

5.2 Rail Traffic Controller (RTC)

The RTC is used to represent characteristics of the rail infrastructure and simulate train movements similar to a human dispatcher. Accordingly, it is used to represent a number of trains operating over a specified network. Discussions with a representative of BSS[1] were useful in evaluating the capabilities of the model.

In addition to evaluating train movements, the model has the ability to estimate the impact of changes to rail infrastructure and train movements. This model is commonly used to develop operating plans, diagnose bottlenecks and recommend schedule changes, evaluate various improvements to the rail infrastructure, and assess the impact of adding new trains to a network. Both cost and performance are continuously recomputed for a given track configuration to minimize cost of delay for trains involved. The model requires the creation of a track and signal network configuration that includes the nodes that represent switches, signals, speed changes etc.; data on the types and characteristics of the locomotives; and directional links between locations including speed limits, grade, curvature, and operating rules.

The model uses spreadsheets as input files to allow entering and modifying train data. The model can provide several outputs including run times (ideal and simulated), dwell times (for planned work), wait time (for schedule departure), average speed (with and without dwell), delay times (waiting on schedule, switch delays, stop delays, hold times and time spent accelerating and decelerating) and fuel consumption including fuel burned while idling. Using information on train characteristics, train speeds and fuel consumption, air emissions can be calculated outside the model. The model has been used for providing potential locations for main track improvements, sidings, turnout speeds, turnout locations, train-control system improvements and train operation changes. The model is used by many freight railroads including a majority of Class I railroads for operations planning and capacity analysis.

Calculating activity impacts using the RTC requires the establishment of several data inputs and data outputs. The two main data inputs are the “train file” and the “track file”. The train file contains historical data on trains operated over the territory (length, tons, train type, Number of locomotives, etc). The track file contains information on the track structure (track speeds, elevations, switch locations, signal system, etc). Table 5 below provides a summary of the basic data inputs and data outputs.

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[1] Personal conversation with Eric Wilson of Berkeley Simulation Software on July 7, 2009

Table 5. RTC model inputs and outputs[1].

Input Files	Data Description
Nodes	Node number; node name; RTC milepost; field milepost; node time zone; elevation (in feet); X & Y coordinates for display purposes; switches; signals; equipment detector indications and linkages to other nodes; etc.
Links	Track number; track class; direction; distance; grade; allowable nodes (i.e. next available nodes for traversal); equations; speed limits; degrees of curvature; etc.
Train Flies	Train symbols; train types; origin locations (head and tail end nodes); intermediate stop locations (head end nodes), destination locations (head end nodes); prescribed dwell times; crew changes; consist changes; departing loads, direction, trailing tons, trailing feet; position, quantity and type of locomotive(s) running at each location specified, maximum authorized speed; gallons burned per hour at various throttle positions from locomotive performance charts provided by manufacturers.
Other	Option, Label, Division, Crew, Equation, Line, Signal Aspect, Signal Block, Permit, Form A, Form B, Track Occupancy, Locomotive, Fleet, Run Times, Field Data, Track Profile, Workstation, Geography, Environment, and Node Conversion.
Output Files	**Data Description**
All (including Fuel Consumed)	Train counts, velocity, ideal run times, total elapsed times, train miles, delay per 100 train miles and resulting cumulative gallons of fuel consumed

1 Descriptions of inputs and outputs are described in more detail below

The Train Performance Calculator (TPC), a part of the RTC model, keeps a log of how long the throttles are in each position for each unit and accumulates the fuel consumption by multiplying the rate by setting times by the time spent in a setting. Knowing the fuel consumption at each throttle position allows the use of calculating total emissions.

An example of such a calculation was the evaluation of rail relocation and improvements by BNSF Railway Company and Union Pacific (UP) Railroad Company[2]. In this evaluation, BNSF and UP evaluated the delay time and fuel consumption impacts from adding capacity through the Tower 55 crossing, including rebuilt connecting tracks, cross-overs and signaling, siding track extensions, and double track extensions. Using the railroads timetable and track information, nodes and links were used to construct a suite of different cases between build and no-build cases. The difference between the build and no-build cases provided the information required to construct the track file. Train files were held constant for this project.

The RTC model is described in more detail below.

5.2.1 RTC Model Summary

This model is used to represent the characteristics of the rail infrastructure, realistically simulated train movements and identifying dispatching conflicts. The Software package uses the same elements as a human dispatcher but on a larger scale with greater distances and longer periods of time. The model was designed as a tool to be modified and upgraded. It provides the ability to evaluate operational and infrastructure improvements and includes the following elements:

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[2] TCEQ (2008), Emissions Reduction Incentive Grant Application for Rail Relocation and Improvement for Tower 55 at Grade Improvement Project Fort Worth, Texas by BNST Railway Company and Union Pacific Railroad Company, submitted to the Texas Commission of Environmental Quality June 26, 2008.

- “Meet-pass N-train logic™” which facilitates dispatch operations and capacity analysis
- RTC dispatches trains at the network level
- Integrated train performance calculator (TPC) accounts for different equipment types, train consists, terrain and track conditions
- Graphical displays of simulation results
- Validated results using real-world networks

Common uses for the model include developing operating plans, diagnosing bottlenecks and recommending schedule changes, evaluating various improvement scenarios and assessing the impact of adding new trains to a network. The model is also cost-based. As the model dispatches, each train’s cost and performance are continuously recomputed to ensure that trains stay on schedule to the extent possible for a given track configuration to minimize costs of delay to the trains involved.

This model has become the standard among freight railroads and is becoming the standard for passenger operations[3]. The majority of Class I railroads, including the UPRR, BNSF, CSX, Amtrak, KCS, TFM (Mexico) and others, have selected RTC for operations planning and capacity analysis.

5.2.2 Features of the RTC Model

The RTC has several features for operations planning and capacity analysis. These include:

Evaluating Train Performance – Contains a train performance calculator (TPC) to compute minimum run times for trains running from one specified point to another over a specified route without interference from other trains. This feature could be used to determine whether infrastructure or track improvement projects would result in less train delay and hence an estimate of the impact this would have on air emissions could be made.

Developing Realistic Operating Plans –Train movements can be simulated to predict actual train movements within a specified definition of infrastructure and physical characteristics.

Adding New Service – Evaluates the effects of adding new trains to the corridor as well as the aggregated level of all trains over the entire route.

Evaluating Passing Sidings – Allows the evaluation of passing sidings or long segments in a multiple track territory to determine whether sidings are of appropriated length and location for the size and speed of trains being operated or identifies the optimal train sizes and operating speeds to match a specific track configuration.

Stringlines and Track Occupancy Charts – Capable of generating stringline graphs (time/distance plots) as well as track occupancy charts that display which trains occupy specific tracks at any time through a simulation. This is useful in identifying “slots” at station platforms, and for evaluating track utilization in yards and intermodal facilities

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[3] Northwestern Pacific Railroad Financial Feasibility Study, Draft Final Report, Parsons-Brinckerhoff, July 2002

5.2.3 Dispatching Simulation

The simulation “dispatcher” resolves conflicts between trains, similar to an actual railroad dispatcher. However, all trains on the territory are evaluated at the same time. Following are some of the capabilities of the simulation:

- Service crews are limited to 12 hours under federal law. Prior to exceeding that limit, either the crew is displaced or train removed from the main track
- General preference is given to passenger trains over freight trains unless the train is badly delayed. Priorities are determined by the freight railroad and incorporated in the meet-pass logic used to resolve train conflicts
- Expedited trains are higher-priority freight trains, generally carrying intermodal traffic (“Piggyback”) or automobiles.
- Manifest trains have priority lower than Expedited and carry general freight, in equipment like boxcars, tank cars or gondolas.
- Local freights perform retail handling of freight, gathering and distributing cars from a customer’s track, and are of lower priority than Expedited or Manifest trains

The RTC decision process is based on many factors involved in a train’s performance. These include:

- Priority
- Type of Train
- Time available for crew to legally work
- Train length and weight
- Locomotive power
- Scheduled work

All other elements being equal, when making a decision about a conflict between trains, the RTC will generally minimize the total cost of delay to the trains involved. This is done for all trains until a satisfactory resolution occurs.

5.2.4 Model Inputs

Following are key inputs to the RTC model:

Network Creation and Modification

This requires the creation of the infrastructure configuration that replicates the physical characteristics and control system of the railroad to be modeled. It also allows modifications of the parameters in existing networks such as installing a grade separation or track straightening.

Location Interface

Locations are defined in RTC networks as nodes. Nodes can represent switches, signals, detectors, speed change points or operations relevant to train movements.

Locomotives

RTC allows the specification of locomotive data. This is particularly useful for evaluating which locomotive types are best suited for a given territory and train type.

Track Interface

Track between locations is defined as directional links. The links have characteristics such as speed limits, grade, curvature, and operating rules.

Train Spreadsheet

RTC contains a spreadsheet interface for entering and modifying train data. All entries are cross-referenced with previously entered data to catch errors.

Logic

The meet-pass N-Train logic simultaneously encompasses multiple conflicting trains. The logic reroutes and delays trains, as needed, to minimize total delay costs at the system-wide level. Trains are initially assigned user-defined delay costs. As conflicts are resolved, train delay costs are varied dynamically within bounds that are also set by the user. The delay cost for a train as a function of whether it is early or late

5.2.5 Model Outputs

RTC output provides a variety of operating statistics that are useful in evaluating the overall impact of changes to an operating plan and/or changes in track infrastructure. The metrics available can be at several levels of detail including:

- System level (entire railroad network performance)
- Train group (Passenger, Expedited, Manifest, or other types of freight)
- Train type (Manifest, Intermodal, Local, Coal, etc.)
- Individual train level

With the exception of true delay (defined below), all metrics are also available by corridor and subdivision.

Following are measurements that can be obtained from the RTC

Ideal minimum run time - This is the minimum amount of time that it would take for a train to go from origin to destination assuming that all switches and signals are lined favorably.

Simulated run time – This is the time it takes for a train to get from origin to destination with other traffic present. It accounts for conflict resolution, switch delay, acceleration and deceleration.

Minimum dwell time – Minimum dwell is the minimum amount of time that a train stops at a point for planned work: switching an industry or entraining or detraining passengers at a depot. It is user specified for each train at en route locations.

Time waiting on schedule – This is the time spend waiting for a scheduled departure time. It is distinguished from minimum dwell as well as meet-pass delay. This generally limited to passenger trains, as they don't want to leave the depot early.

Switch delay – This is the time associated with lining a switch that requires manual intervention, pulling a train forward to clear the switch, and then holding while a crewman walks back to the locomotive

Stop delay – This is the amount of time a train spends at a speed 0 waiting for conflicts to be resolved. It does not include acceleration or decelerating.

True delay – This is the difference in time between the simulated run time and the ideal run time. It encompasses stop delay as well as time spent accelerating and decelerating.

Origin hold time – This is the time that a train is held at its origin location for traffic to clear so that a slot becomes available. It is distinguished from en route hold delay because a train experiencing origin hold may or may not be crewed, and therefore the statistics might be counted differently

Entry delay time – This is the time that a train is held out of the network at its origin location for traffic to clear so that a slot becomes available. It is distinguished from origin hold delay because a train experiencing entry hold cannot find an available initial track.

Average speed without dwell – This speed gives an indication of average speed when a train is actually en route and hopefully moving.

Average speed with dwell – This speed gives an indication of how fast the actual trains are moving through a network. This includes management specified dwell time to perform work.

Meet-pass delay percentage – This is the percentage of time that a train experiences delay while en route. It excludes management mandated stop time for dwells and waiting departure times.

Delay minutes per 100 train-miles – This is a delay that occurs in a "basic day" for crews (nominally 8 hours). This is an older measurement and is not meaningful for complex terminal areas such as Chicago.

Fuel consumption – This includes fuel burned while idling at meet-pass hold locations. Since RTC has a built-in Train Performance Calculator, it also accounts for acceleration and deceleration after holds. Several performance measures may be used. For example the following measures were used for the Gilroy-Salinas Railroad Capacity and Performance Analysis[4].

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[4] Railroad Capacity and Performance Analysis, Draft Final Report, Prepared for Transportation Agency for Monterey County, Union Pacific Railroad, URS Corporation, March 7, 2008

Number of trains per day-the average number of trains per day operated and measured over the simulation period

On time percentage – the percentage of trains that complete their overall schedule run on or ahead of schedule. If a train is late at any measuring point, it is considered late

Delay hours per day – time spend for meets and passes. Does not include Dwell or Wait on schedule. A decrease is considered “good”.

Delay ratio, or meet-pass delay percentage – the proportion of running time that a train is stopped for meets and passes with other trains, not for station work (dwell) or waiting on schedule.

These output variables may be accompanied with other output information and displays, some of which are listed here.

- Animation of traffic flow
- Time-distance diagrams (stringlines)
- Train performance profiles displaying elevations, speed, throttle, brake settings, cumulative distance and run time
- Track occupancy chart
- Detailed train status
- Timetables-at various levels of detail (from traditional list of stations and train departure times to complete meet/pass plans
- Operating statistics at the individual train level or summarized by train type or at a system-wide level

Recent uses of the model[5] include projects for the Dakota, Minnesota & Eastern (DM&E), Austin’s Capital Metropolitan commuter line and Nevada Power. For DM&E, HDR, a consulting firm studied various questions related to the design of its Powder River Basin coal line (e.g., the location and length of sidings and two main track sections, cycle times, and fuel burn). For Austin Capital Metropolitan, the RTC was used to examine changes in curve super-elevation and unbalance to improve speed. The RTC was also used to assist Nevada Power to estimated costs for its 100-mile proposed Nevada Northern Railway construction.

5.3 Transportation Technology Center Inc. (TTCI's) Train Energy Model (TEM)

TTCI has several vehicle and train dynamic models that have the ability to model the behavior of rail vehicles, components, track, structures and systems. Data collected during full scale testing was used to build, refine and validate the models under a variety of conditions. The model has the ability to study new concepts, vehicle/track components, vehicle/track dynamic interaction, train operations, and train energy consumption. The models available from TTCI include NUCARS (simulation of dynamic interaction of railway vehicles and track), TEM (predict energy consumption for specific trains, routes and speed profiles), RTLM (track and track component degradation analysis, maintenance planning and life-cycle cost analyses), WRTOL

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[5] Hale,S., Hemphill, M., Burgel, B., HDR’s Powerful Rail Modeling Tool, Rail Line, May 2008

(assessing vehicle performance, wheel/rail wear, and rolling contact fatigue) and TOES/STARCO (simulate train operations and energy simulator).

Of these models, the TEM model appears to be most appropriate for evaluating the air emissions from rail operations because fuel consumption is estimated. The model uses an Automatic Train Handling Algorithm (ATA) to attain the desired motion of the train for the desired duration of the train movement. The model predicts fuel consumption, train control duty cycles and train speed distribution for a single train configuration. As with the RTC model, this information can be used outside the model to calculate emissions. Validation tests using actual test trains have been run to determine the accuracy of the model. The tests verify that the fuel consumption predictions are accurate, that the model can account for statistical variability in fuel consumption and that the ATA is able to match actual speed distribution of the test trains. Accuracies of the fuel consumption from the TEM compared to the test trains were within the 90% confidence level.

ENVIRON contacted a representative of TTCI[6] who indicated that TTCI is no longer selling the TEM model. However TTCI performs studies for clients using the model. Ron Lang of TTCI cautioned that the model is based on older locomotives and would need to be updated if a client wished to conduct a study.

5.3.1 Overview

TTCI's vehicle and train dynamics modeling tools have the ability to model the behavior of rail vehicles, components, track, structures and systems. Data collected during full-scale testing at the TTC, as well as on railroads, is used to build, refine and validate models that predict behavior under a variety of conditions. This model enables the study of new concepts, vehicle/track components, vehicle/track dynamic interaction, train operations, and train energy consumption in an analytical environment, thereby reducing the cost of field testing. Modeling capabilities include:

- Optimize new wheel and railhead profile designs
- Predict the effects of wheel/rail profile design on wear rates and rolling resistance
- Investigate mechanisms that promote rolling contact fatigue and rail corrugations
- Evaluate new trucks for service condition ranging from bulk commodity loads to ride quality sensitive applications
- Improve passenger car suspensions
- Optimize train operations for minimum energy consumption
- Evaluate new turnout designs
- Investigate derailments
- Calculation of in-train forces (buff/ draft)
- Predict the effects of lubrication on train rolling resistance and wheel/rail forces
- Estimate the remaining service life of bridges
- Evaluate innovative designs such as flange bearing frogs in crossing diamonds
- Speed up the research and development of new products

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[6] Personal conversation with Ron Lang of TTCI on July 14, 2009

5.3.2 Models Available from TTCI

NUCARS® is a simulation model for evaluating the dynamic interaction of railway vehicles and track. NUCARS® is can simulate the response of any type of rail vehicle (locomotives, freight, passenger, and transit vehicles, including multiple and articulated cars) while running on a variety of track geometries, including special track work such as turnouts, crossings, and tracks with guardrails. The software package includes pre and post processing programs for preparing vehicle and track inputs and analyzing simulation results. Simulations include a wide range of non-linear effects such as springs and dampers, air suspensions, stick-slip friction, traction, and braking. A recently developed capability simulates the track structure in full detail, including rails, ties, fasteners, and ballast. This feature is being used by TTCI engineers for fundamental vehicle/track interaction research and consultancy work.

TEM™ (The Train Energy Model) predicts energy consumption for specific train consists, routes, and speed profiles. As examples, this model may be used for scheduling, train operation, and operating cost analyses, or predicting exhaust emissions for operations with given equipment operating under certain schedule constraints.

RTLM™ (Railway Track Life-cycle Model) is a software package for track and track component degradation analysis, maintenance planning, and life-cycle cost analyses. The program is designed so that the latest Association of American Railroads (AAR) research results can be incorporated under a common platform for enhancing existing models and developing new models. Seven track component degradation models are integrated within the program to predict rail wear rate, rail defect rate, wood tie degradation, turnout life, ballast degradation, and track roughness growth. Maintenance costs are calculated based on degradation rates, maintenance policies, component replacement costs and discount rates.

WRTOL™ (Wheel/Rail Tolerance) is a software package that assesses wheel/rail contact parameters to predict vehicle performance, wheel/rail wear, and rolling contact fatigue.

TOES™ / STARCO™ **(**Train Operations and Energy Simulator and Simulation of Train Action to Reduce Cost Operations), allow users to predict and analyze train dynamics. These software packages are used for studying train dynamics and derailment prevention. They allow users to predict and analyze train dynamics as generated from given operation and environmental parameters. Both TOES™ and STARCO™ include detailed train air brake models, non-linear models of inter-car coupling characteristics, locomotive traction/braking characteristics, and train resistance calculations. Both packages are primarily designed for analysis of freight trains; however, they are also useful for passenger and transit systems because of their capability of predicting braking system response and stopping distance.

5.3.3 Train Energy Model (TEM)

The Train Energy Model (TEM) was developed under the AAR Energy Program. This model is a train performance simulator used to predict fuel consumption for a train on any route. As opposed to the RTC model, this model predicts the behavior of a single train rather than a network of trains. The train and performance in TEM is governed by the Automatic Train Handling Algorithm (ATA) which is a form of “artificial intelligence” that seeks to attain some desired motion of the train (e.g., maintain train speed close to the posted speed, if the power to do so is available) for the duration of a train movement. Among the outputs from the TEM are the following:

- Fuel Consumption
- Which locomotive contributed to fuel use (when multiple locomotives used)
- Where fuel is used or distributed
- Numeric models for each individual aspect such as braking etc.
- Train Control Duty Cycle
- Train Speed Distribution
- Average trip speed
- Time in notch (which can give you acceleration and deceleration)

5.3.4 TEM Validation Projects[7]

Several validation projects were conducted to test the validity and accuracy of the model. A summary of these projects will provide some insight as to its accuracy and use.

Unit Coal Train Test

A test train was derived from a dedicated unit coal train which runs in a fixed locomotive power and trailing and tonnage service. This test was compared to revenue trains for both loaded and empty configurations. Following is a summary of the test:

The data was collected for one round trip of the test train, a total of 570 miles. The test route for the loaded trip, which covers 287 miles, is undulating and sinuous, with grades that range between -2.1% (downhill) and +3.0 % (uphill), and track curves up to 11.0 degrees.

To simulate the field test, an “off-the-shelf” TEM was run using the ATA. Since all the locomotives in the train were in synchronous (multiple unit) operation for virtually all of the time, this record (along with the fuel meter tickets, that bracket the test round trip) provided sufficient data to validate TEM for the test round trip.

The TEM and recorded (event recorder) train control duty cycles for the entire round trip were compared. The engineers who ran the coal train used dynamic braking 29% of the time, low motive power 41% of the time, and high motive power 30% of the time. The ATA used low motive power 48% of the time, rather than 41% of the time because the ATA tries to maintain the reference speed with the throttle in idle as much as possible (tries to coast as much as possible).

Before the validation test was conducted, the member railroad provided AAR with round trip fuel consumption records for more than a year of operation of the revenue train. A statistical analysis of the records (78 total) shows the round trip fuel consumption values are normally distributed. It was thus concluded that it is appropriate to apply standard statistical procedures to this set of values. Therefore the TEM simulations were used to compare to normal distributions.

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[7] Train Energy Model Validation Overview-TEM test of railroad train performance simulator for predicting fuel consumption, Railway Age, Dec 1992.

Using a baseline or mean fuel consumption case as well as a low and high fuel consumption case the TEM results were then compared to the standard distribution sample which had a sample mean of 7,413 gallons and a sample standard deviation of 430 gallons. The TEM prediction for the mean (base case) was 7,373 gallons which is well within the 90% confidence level with less than 1% error in the mean.

Mixed Intermodal Train Validation

A test train consisting of three SD40-2 locomotives, one-and two-trailer flatcars, and articulated flatcar, articulated double stack cars and autorack cars in four different modes as cars were set out along the route. The test train traveled a total distance of 355 miles from Point A to Point E. The test route was undulating and essentially tangent, with grades that range from -2.0% (downhill) to +1.7% (uphill) and maximum track curves of 6.0 degrees. The average speed limit for the test route was 62 mph.

The TEM simulations for the intermodal test used the same nominal SD40-2 vehicle parameters, tractive and dynamic braking effort characteristics, and fuel consumption rates for all three locomotives. The TEM simulations for the intermodal test were created on the basis of train movements were identified in the test data and information from the test log. Several simulations were performed. The total fuel consumption for the intermodal test was 2,307 gallons. The locomotive parameters, characteristics, and fuel consumption rates were provided by the manufacturer.

The simulations provided the operating conditions, number of stops, distance traveled, elapsed time, mean over-the-road speed, and fuel consumption for each of the six simulations. The total elapsed time of 13 hours and 15 minutes matched the measured total elapsed time extremely well. Without taking switching moves into account, the TEM predicted a value of 2,186 gallons for the intermodal test, which is about 5% less than the actual value.

The ATA train controller was able to match the actual speed distribution extremely well. It was concluded that the ATA is a realistic train controller, since it achieves the same fuel consumption and train speed distribution.

Based on the results of both tests, the following conclusions were reached

- TEM fuel consumption predictions were accurate
- TEM could account for the statistical variability in fuel consumption values for a dedicated train service
- The ATA was a realistic train controller
- The ATA train controller was able to match the actual speed distribution for the unit coal train as well as the intermodal test trains

Based on these conclusions, users in the railroad industry expressed confidence in the results obtained from simulating train movements using TEM.

5.4 RAILS2000

Another program called RAILS2000 incorporating, the ‘Railway Analysis & Interactive Simulator,’ is a modeling tool that measures the impact of proposed plant, rolling stock, operational and maintenance program enhancements. The Railway Analysis & Interactive Simulator is a modeling tool that measures the impact of proposed plant, rolling stock, operational and maintenance program enhancements. Like other models, this model contains a Train Performance Calculator (TPC) that drives the movements of individual trains within the simulation. The software also contains a Train Dispatching Simulator (TDS) which simulates the dispatching and control of trains over a defined route or network of lines. The TPC is a useful tool for evaluating the performance of a single train over a given track whereas the TDS is used for multiple trains over a network of tracks. The software is logic based, with optimizing capabilities deliberately restricted to emulate real-world limitations of train dispatching. The model is capable of handling multi-track mainline corridors and signals for both freight and transit operations. The software is owned by CANAC which was founded as the international railway consulting arm of Canadian National Railway Company (CNR), and is currently a wholly owned subsidiary of SAVAGE Companies. The model was developed in 1992 by Corporate Strategies Inc. (CSI) and was acquired by CANAC Inc. thereby including all rights to the model.

RAILS2000 generates a variety of standard statistics (similar to other models) which can be exported to a database for other types of custom analyses. The model also has the capability to generate time-distance graphs for plotting or importing into another program. The TPC allows the user to build and edit data files of track descriptions and train characteristics including commuter, inter-city passenger, freight, or light rail) and calculates fuel use. The TDS creates additional files, performs the simulation (moves all trains for a defined period over a specified route or network) and creates a variety of train performance and delay reports, graphical displays and animation of operations. The model has the capability to duplicate any kind of activity that a train, class of train or line may experience. For example, tracks may be removed from service for specified times for maintenance or construction. Tracks may also be modified to evaluate the impact of modifications on overall train performance. The model can be calibrated to match historical operations based on actual experience to reflect new operations, revised plant configuration, or any combination of events. While the TDS does not calculate fuel use, this feature is currently being added to the model outputs.

As an example, The RAILS2000 model was used by CANAC to conduct an assessment of the physical plant of the Toronto Union Station Rail Corridor (USRC) in anticipation of adding a new shuttle service between the station and Lester B. Pearson International Airport. With projected growth in commuter and intercity services, the capacity of the USRC to accommodate the additional Toronto Air Link (TARL) trains was in doubt. Operational simulations were performed to assess the capacity of the corridor, and to quantify track and platform usage and their ability to accommodate the TARL service. Computer simulations overlaid the proposed TARL service, with scenarios assuming 15-minute and 20-minute headways, onto the projected volumes of commuter and intercity trains. Simulations also incorporated alternate station platform allocation plans.

When compared to other similar models such as the BSS RTC, the RAILS2000 model allows the user to tool up easier and as a result allows the user to begin seeing results faster[8]. The difference between the two models is that the RTC model requires the input all data such as switch, elevation and curve data for each node and link, which can often be thousands of data inputs. The RAILS2000 TPC enters curve, elevation and speed data into a separate layer which then is interpolated between locations. For example when comparing the coding necessary for a 200 mile track would take about a week to input data whereas the RTC model would take two to four weeks due to the complexity of the inputs. Output of the RAILS2000 model can be summarized in MS Excel spreadsheets on a second-by-second basis and includes throttle position, speed, resistances acceleration and deceleration and fuel consumed for each output separate from the nodes. Overall costs for the model are approximately $30,000 for the first license, $15,000 for the second license and about $5,000 to $7,000 for subsequent licenses.

5.5 Other Models

Ron Lang of TTCI indicated that a model developed by the Missouri Pacific called the Train Performance Model (TPM) may be available in the public domain. ENVIRON found a description of the TPM in a study of rail vs. truck fuel efficiency. (Abacus, 1991) The fuel consumption output from the study was based on older locomotives and therefore the model would need to be updated for a modern fleet.

6.0 SUMMARY AND RECOMMENDATIONS

In summary, the methods used for a detailed investigation of the rail operations and especially infrastructure projects using complex computer models may be consistent with regional emission inventories. However, the computer models are significantly more sophisticated and require more detailed input data than the approaches used to estimate regional inventories. In addition, projects that used computer model scenarios were specific to the situation analyzed. However, the emissions impact of an individual rail improvement project would usually be a fraction of the potential voluntary emission reduction projects and a much smaller fraction of the area emissions, so the results of the project analysis could be consistent with the overall emission inventory methods. Some projects would affect current operations, or may affect the rate of growth in activity, which is more uncertain. Using the detailed project analysis approach for rail improvements is similar to many other mobile source project approaches (such as those used in the TERP or voluntary VMEP projects) that use project-specific benefits to adjust emission inventories created using general activity indicators.

It would be difficult to incorporate the detailed computer models into the emission inventories because the input data specifications would need to be constantly updated by the affected railroads as their scheduled operations change. So average activity indicators (gross ton-miles and typical fuel consumption rates, switching hours, etc.) should be sufficient to prepare emission inventories. Nationally, the Federal Railroad Administration is collecting such information for dissemination to states preparing emission inventories beginning with the line-haul activity. The large Class I railroads (which comprise the overwhelming majority of the locomotive activity) provide annual reports of their fuel consumption, rail movements (gross and revenue ton-miles), and other performance indicators useful for verifying historic growth estimates. Therefore, the activity data can be updated year by year without significant effort.

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[8] August 13, 2009, Personal conversation with Michael Samario of CANAC

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Harold Holmes, California Air Resources Board, August 10.

Todd Sax, California Air Resources Board, August 11.

Raquel Wright, Federal Railroad Administration, July.

Bill Thompson, Association of American Railroads, CREATE Coordinator, August 26.

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