LADCO
Task 2 - Evaluation of Growth Methodologies for Stationary Point, Area, and Mobile Sources

Draft Report

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TABLES

ACRONYMS AND ABBREVIATIONS

AEO	Annual Energy Outlook
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BTS	Bureau of Transportation Statistics
CAFE	corporate average fuel economy
CMV	commercial marine vessel
CO_2	carbon dioxide
D-W	Durbin-Watson
DOE	Department of Energy
EGAS	Economic Growth Analysis System
EGU	electrical generating unit
EIA	Energy Information Administration
EMA	Engine Manufacturing Association
EPA	United States Environmental Protection Agency
FHWA	Federal Highway Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
hp	horsepower
IAQR	Interstate Air Quality Rule
LADCO	Lake Michigan Air Directors Consortium
LOE	level of effort
MAD	mean absolute deviation
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
NEMS	National Energy Modeling System
NH_3	ammonia
OTAQ	Office of Transportation and Air Quality
Pechan	E.H. Pechan & Associates, Inc.
PSR	Power Systems Research
REMI	Regional Economic Models, Inc.
RPO	Regional Planning Organization
SCC	source classification code
SI	spark ignition
SIC	standard industrial classification
VMT	vehicle miles traveled
WEFA	Wharton Econometric Forecasting Associates

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CHAPTER I. INTRODUCTION

A. OVERVIEW

E.H. Pechan & Associates, Inc (Pechan) is supporting the Lake Michigan Air Directors Consortium (LADCO)'s efforts to review growth methodologies for all emissions inventory sectors except electrical generating units (EGUs). The primary geographic area of interest is the 5-State Midwest Regional Planning Organization (RPO) region (i.e., Indiana, Illinois, Michigan, Ohio, and Wisconsin). To assess progress for attaining air quality goals, LADCO requires methodologies to forecast emissions from a 2002 base year inventory to several future years of interest. These future years are likely to include, but not be limited to, 2010 (expected attainment date for moderate ozone nonattainment areas) and 2018 (first milestone for regional haze reasonable progress demonstrations).

Under Task 1, Pechan summarized alternative stationary point and area source and on-road and nonroad mobile source growth methodologies for LADCO's consideration (Pechan, 2004). The Task 1 report provides a summary of the emission projection methodology information obtained from each Midwest RPO region State agency and provides the following information on each approach:

- Background/overview of the method/data;
- Geographic and source category coverage; and
- Cost and availability of documentation.

Pechan recommends that the reader should be familiar with the material in the Task 1 report to better comprehend the evaluations provided in this report.

The purpose of this report is to assess the growth methodologies summarized under Task 1 using a set of evaluation criteria selected in consultation with LADCO. This report is organized into this Introduction and chapters specific to the evaluations conducted for each major source sector. Chapter II presents the evaluation of alternative emission activity projection methodologies for stationary point and area sources. Chapter III describes the assessments conducted on methods for forecasting vehicle miles traveled (VMT) for onroad mobile sources. Chapter IV provides the evaluation of alternative approaches for forecasting nonroad source emission activity levels. Chapter V presents the information sources that were consulted in preparing this report.

B. EVALUATION CRITERIA

To provide a consistent method for evaluating each of the emission projection methods, Pechan identified a set of four criteria. These criteria, which are described in this section, were used to assess the strengths and weaknesses of each of the projection methods/data sources.

1. Availability

The first criterion of importance is to identify any licensing, data availability, or resource constraints that limit LADCO's potential use of the data/methodology. Questions to be answered for this criterion include: (1) is the forecasting model/data proprietary; (2) are there licensing/ cost issues associated with use of the model/data; (3) are there data availability issues associated with implementing the methodology throughput the Midwest RPO region; and (4) is there a substantial level of effort associated with compiling the data and/or implementing the methodology?

2. Coverage

The second criterion pertains to the coverage of the data/methodology. The questions that are answered in this section include: what is the scope of the model with respect to: (1) emission source categories/industry sectors; (2) geography, (3) time horizon; and (4) pollutants? For the first two topic areas, both the comprehensiveness and the specificity of the forecasts will be evaluated. In evaluating the geographic topic area, for example, the following questions will be answered: are the projections available for the entire Midwest RPO region (comprehensiveness) and for what level of geographic detail (specificity)? The following specific data/methodology coverage information will be developed in evaluating this criterion:

Category	*Source Classification Codes (SCCs)* *Standard Industrial Classification (SIC) codes*
Geographic	*Metropolitan Statistical Area (MSA), County, State, Regional, National?*
Time Period	*Forecast period for which data are reported?* *Forecast baseline-latest year of actual historical data?*
Pollutants	*(if applicable, methodology covers which criteria, toxic, greenhouse gas pollutants)*

3. Validity

The theoretical validity and, where applicable, empirical validity, are evaluated for each alternative growth methodology under this third criterion.

a. Theoretical

First, the general soundness of the theoretical basis for each projection methodology is evaluated. Questions that were asked in evaluating this criterion, include: (1) are the projections based on a defensible and generally accepted forecasting technique; (2) are the projections likely to be representative of activity for the category of interest; (3) are the projections likely to be representative of activity for the specific geographic area of interest (e.g., are National inputs used to develop county-level growth estimates); and (4) are the key inputs to the methodology based on recent or outdated information?

b. Empirical

In order to test the empirical validity of alternative growth methodologies, a retrospective analysis was conducted that compares the past performance of these methods in projecting emission activity. Because of the level of effort associated with evaluating this criterion, retrospective analyses were conducted for a sub-set of stationary point, area, and nonroad emission source categories ("priority categories"). These priority source categories were identified in consultation with LADCO.

The mean absolute deviation (MAD) is a statistic that can be calculated to determine the accuracy of various projection methods. The MAD is defined as the average of the absolute deviations of the observed values from the predicted values. For each non-energy emission activity, Pechan calculated MADs from the actual 1990-2001 activity levels and the historical activity levels projected from 1990-2001 using each projection method. Because 1995 was the first year for which the Department of Energy (DOE) developed energy forecast data on a consistent basis (EIA, 1996; EIA, 1997), the energy category and VMT MAD calculations were performed for the 1995-2001 period.

To calculate the MADs for each source category, the absolute difference between predicted and actual activity levels is computed, and these differences are summed and divided by the number of observations (in this case, the number of years). The following equation is used:

$$MAD_i = \frac{\sum_{y=1}^{n} |A_y - F_y|}{n} \tag{1}$$

where:
- MAD_i = mean absolute deviation for emission activity i
- A_y = actual activity level for each year analyzed
- F_y = forecasted activity level for each year analyzed
- n = number of years analyzed

4. Documentation

The final criterion evaluates how well each methodology's algorithms and input data are documented, whether each methodology has undergone peer review, and to what extent LADCO can access additional methodology background information and forecast updates.

CHAPTER II. STATIONARY POINT AND AREA

The following lists the stationary point and area (non-point) SCCs for which emission activity growth factors are required under this contract.

2415xxxxxx	Degreasing	2401xxxxxx	Surface Coating
2420xxxxxx	Dry Cleaning	2102xxxxxx	Industrial Boilers
2440xxxxxx	Adhesives	2104008xxx	Residential Wood Combust.
2461xxxxxx	Pesticide Application	2501060100	Stage 2
2465xxxxxx	Commercial/Consumer Solvents	2610xxxxxx	Open Burning
2102xxxxxx	Industrial Fuel Combustion	20700xxx	Pulp and Paper
10200xxx	Industrial Boilers	31000xxx	Natural Gas Production
20500xxx	Petroleum Refineries	30301xxx	Iron and Steel Production

The Task 1 report (Pechan, 2004) identified the following six alternative stationary point and area source growth methodologies/sources:

- Bureau of Economic Analysis (BEA);
- Bureau of Labor Statistics (BLS);
- Economic Growth Analysis System (EGAS)/Regional Economic Models, Inc. (REMI);
- EGAS/DOE;
- Industry/Market Research forecasts; and
- Empirically-derived estimates.

The purpose of this section is to summarize the comparative evaluations performed on each of these methodologies/sources. Section A discusses the derivation of empirically-derived growth factors for "priority" emission activities. Section B discusses the past performance evaluations that were performed to compare the validity of the alternative methods. Section C describes the evaluations of stationary point and area source growth methodologies and data relative to each of the evaluation criteria presented in Chapter I. Section D presents additional relevant forecast information for LADCO's consideration.

A. DETERMINATION OF EMPIRICALLY-DERIVED ESTIMATES

One of the alternative emission activity forecasting methodologies evaluated in this study is empirically determined projections. This method, which is used in EGAS 4.0 for a select set of source categories, relies on the identification of a statistically verified historical correlation between emission activity and one or more variables.

To evaluate this method, it was necessary for Pechan to conduct multiple regression analyses to test the relationship between historical emission activities and historical values for variables available from the latest version of the REMI model (version 5.5), which will be incorporated into EGAS 5.0 (Houyoux, 2004). Pechan performed analyses that regressed national/regional emission activity data against national/regional data for variables identified as potentially correlated with the activity.

Because of the level of effort associated with conducting the regression analyses, Pechan conducted analyses for a sub-set of the emission activities covered by this contract. Pechan assisted LADCO in compiling a list of the emission activities (priority activities) for which these analyses would be performed. Table II-1 displays this list and identifies the data sources that were consulted in obtaining historical data for these activities. Pechan generally obtained historical data from 1990-2001 (exceptions are noted in Table II-1). Because Midwest RPO region-specific data were often not readily available, Pechan obtained national historical data for most activities. However, Pechan compiled data specific to the Midwest RPO region states for the following activities:

Livestock: Swine; Poultry; Milk Cattle; and Heifer Cattle;
Pesticides: Pesticides (Agricultural);
Industrial Fuel Combustion: Natural Gas; Coal; and Distillate;
Industrial Boilers: Natural Gas; Coal; and Distillate;
Residential Wood Combustion: Fireplaces; Woodstoves; and
Natural Gas Production.

Table II-2 presents the REMI variables identified as potentially correlated to emission activity levels. The first row in each section of this table identifies the emission activity; subsequent rows display the REMI variables that were evaluated in the regression analyses. In addition, Pechan tested a one-period lagged dependent variable in the regression analyses. Linear, squared, and cubic equation forms were tested. Pechan identified the best statistical fit by comparing each equation's adjusted coefficient of determination (i.e., R^2), while ensuring that the t-statistic for each independent variable in the equation is greater than 2.

Because autocorrelation is a particular concern when performing regression analysis on time series data, it was necessary to investigate whether autocorrelation was a problem for each equation. Autocorrelation, which exists when error terms corresponding to different points in time are correlated, leads to misleadingly high R^2 values. The Durbin-Watson (D-W) statistic is calculated and compared to acceptable upper and lower limits to identify the presence of positive or negative autocorrelation. In many cases, the D-W test indicated the presence of autocorrelation for the best fit equation developed from the initial regression analyses. In these cases, Pechan conducted additional regression analyses after stationarizing the variables (i.e., converting the emission activity and REMI values into first differences or logarithms). Pechan also included one-period lagged independent variables in each analysis conducted on the first difference and log variables. Linear, squared, and cubic equation forms were tested on the series of variables and the best functional form was selected.

Table II-3 presents the best-fit emission activity estimation equation for each source category as determined from a review of each equation's adjusted R^2, t-statistic, and D-W values. Because of the constraints of the methodology (e.g., sole reliance on variables available from economic models developed by REMI), the regression analysis was not always successful in identifying variables that strongly correlated with emission activity levels. In a few of these cases, Pechan has defaulted to an equation that was developed from regression analyses conducted over a longer time-frame in support of the development of EGAS 5.0 (these instances are identified in Table II-3 with shading). Because of concerns with weak correlation results for some categories, Pechan recommends that LADCO only consider using the empirically-derived approach for a sub-set of priority activities (i.e., categories noted with a “Yes” in the first column in Table II-3).

B. PAST PERFORMANCE EVALUATIONS

The validity of each method with respect to the ability to forecast changes in activity can be evaluated qualitatively or quantitatively. This section describes the quantitative analyses that were performed for the priority emission activities. These analyses were performed for each of the alternative methods except for the Industry Estimates/Market Research (Freedonia Group) approach. It was not possible to conduct a past performance analysis of this approach because Freedonia Group forecast data were not available from the early to mid-1990s.

The first step in the analysis was to identify the growth indicator surrogates that would be used to conduct the past performance evaluations for each priority emission activity. These growth indicators, which are presented in Table II-4, were identified from the variables available from the following projection data sources: BEA, BLS, DOE, and REMI. Next, Pechan compiled forecast data from earlier versions of these sources. The forecasts from these earlier versions, which were based on historical data up through 1990 or early 1990s, were used in calculating the MAD values for each alternative method (BEA, 1995; BLS, 1991; EIA, 1996; EIA, 1997; and REMI, 1999).

1. Non-Energy Category Evaluation Results

Table II-5 summarizes the results of the past performance MAD analyses at the emission activity level. The summaries are separated into energy and non-energy activities because the DOE projections do not apply to the non-energy activities and the empirically-derived projections were not evaluated for the energy activities. As expected, the results indicate that the empirically-derived estimation method provided the closest approximation of the historical trend in activity. In particular, the overall average MAD for this method was 9.2. Note that the average MAD drops to 5.6 if two of the EGAS 5.0 equations (Sulfate Pulping and Automotive Refinishing) are eliminated from use as Pechan recommends. The next best overall method for non-energy categories was REMI data, which provided an average MAD of 20.2.

2. Energy Category Evaluation Results

With a considerably lower average MAD value (10.2) than the alternative growth indicators (next best indicator, BLS, provided a MAD value of 16.0), the DOE forecasts provided the best fit for energy emission categories. The empirically-derived forecasting approach was not quantitatively evaluated for the energy categories because the DOE projections have higher theoretical validity than all of the alternative methods, including the empirically-determined approach.

C. EVALUATION OF ALTERNATIVE METHODS

Table II-6 displays a summary of the evaluations of stationary point and area source growth methodologies and data relative to these evaluation criteria. The following identifies the methodologies/data sources with particular strengths and/or weaknesses in relation to each of the four evaluation criteria.

1. Availability

The cost and level of effort for obtaining the necessary data/implementing the methodology is minor for most of the approaches evaluated. Two major exceptions are the Industry/Market Research approach, which requires purchasing each forecast data set, and the empirically-derived approach, which requires a substantial LOE for compiling each category's historical activity data and conducting each category's regression analysis.

2. Coverage

The coverage criterion highlights significant strengths and weaknesses of the various forecasting approaches. While the majority of the methods provide state-level data (BEA, REMI, Empirically-Derived), DOE develops regional-level forecasts, while the BLS only provides national projections. In addition, the BLS forecasts are only provided for one year, the Industry/Market Research projections are for the fifth and tenth beyond the base year, and the BEA forecasts were developed for select years through 2045. All other forecast approaches are annual, with DOE providing estimates through 2025 and the REMI and empirically-derived methods through 2035. The source category coverage of the methods differs as well with the BEA methods based on 2-digit SIC code (approximately 53 sector) data, the REMI on 3-digit SIC code (172 sector) data, and the BLS on 293 industry sectors. In addition, DOE provides forecasts specific to energy sectors and fuel types that are not available from the other methodologies.

3. Validity

When comparisons are made between the alternative approaches, a few of the methodologies/data sources provide clearly superior/inferior theoretical and empirical validity. For energy categories, the DOE data provide the best theoretical and empirical validity. The theoretical validity of the DOE methodology is superior because it is the only approach that explicitly models energy supply and demand markets by sector and fuel type. The least theoretically valid methodology for non-energy categories is the BEA approach because these forecast data are outdated, and were developed using historical data up through the early 1990s. Structural changes in the economy since that period render these forecasts the least defensible of the non-energy methods analyzed. The most theoretically and empirically valid method for non-energy categories is the empirically-derived approach. Unlike the other methods, this approach is based on the identification of a statistically determined correlation between historical emission activity and one or more variables. All other methods rely on a judgmentally determined crosswalk that is used to link forecast variables to emission activities.

4. Documentation

With the exception of the Industry/Market Research forecasts from the Freedonia Group, each of the forecasting methodologies is well-documented. Unlike the quantitative modeling approaches used by the other forecasting methodologies, the Freedonia Group apparently uses a substantial amount of ad hoc information/judgment in preparing their forecasts.

D. ADDITIONAL CONSIDERATIONS

As part of this task, Pechan evaluated the possibility of incorporating forecast data from REMI models supplied to the State of Michigan. Based on the information received, population forecasts are available for each county in Michigan from a previously licensed REMI model (Grimes, 2004). However, the current Michigan REMI model is no better resolved geographically (State) or sectorally (53-sector) than the REMI models that Pechan is planning to use in EGAS 5.0. Therefore, Pechan plans to use forecast data from the REMI Michigan model that Pechan recently obtained for incorporation into EGAS 5.0 (Houyoux, 2004). Pechan will consult further with the State of Michigan about the validity of incorporating the county population projections from the REMI model previously licensed by the State.

For the Architectural Coatings category, Pechan has identified an equation for estimating total coatings use. Because the emission activity for this category is a function of the solvent content of the coatings used, Pechan plans to recommend that an adjustment factor be applied to the output of this equation to account for the projected proportion of total coatings consumption that is solvent-based. Projections for this adjustment factor are available from the Freedonia Group, Inc. An overview of the approach is provided below:

Emission Activity	Dependent Variable in Equation	Proposed Adjustment to Regression Output	Source of Proposed Adjustment
Architectural Coating Solvents	Architectural Coating Shipments (gallons)	Solvent-based architectural coating shipments per total architectural coating shipments	Freedonia, 2002: "Table V-8. Architectural Paint Shipments by Type & Application"

If this approach is adopted by LADCO, Pechan will extend the adjustment factor beyond the 2011 date available from Freedonia.

LADCO requested that Pechan provide an evaluation of the potential for identifying future solvent chemical consumption/substitution trends due to employee health concerns (e.g., elimination/reduction in toluene and acetone consumption). Pechan recommends that relevant records from the April 2003 Freedonia report "Solvents: Green & Conventional to 2007," be purchased for information relevant to this issue. This report analyzes the U.S. solvents industry, presenting historical data for 1992, 1997 and 2002 and forecasts to 2007 and 2012 by product (e.g., alcohols, hydrocarbons, ethers, ketones, esters, chlorinated solvents, propylene glycol, terpenes, butanediol, vegetable oils, tetrahydrofuran, hydrogen peroxide); by function (e.g., vehicle/carrier/thinner, antifreeze and deicers, cleaners, extraction agents); and by market. In addition to purchasing relevant information from Freedonia, Pechan suggests that additional information may be available from contacting trade associations such as the Halogenated Solvents Industry Alliance and the Synthetic Organic Chemical Manufacturers Association.

Table II-1. Priority Stationary Point and Area Source Emission Activities

Emission Activity	Emission Activity Units	Years	Data Source(s)
	Non-Energy Categories		
	Surface Coating		
Architectural Coatings Paint Shipments	Thousand Gallons	All	USCB, 2003a
Automobile Refinishing	Thousand Metric Tons	All	Pechan, 2001a
		All	USCB, 2003a
Wood Furniture	Thousand Gallons	All	USCB, 2003a
Miscellaneous Manufacturing	Thousand Gallons	All	USCB, 2003a
Other Special Purpose Coatings	Thousand Gallons	All	USCB, 2003a
Metal Cans	Thousand Gallons	All	USCB, 2003a
Industrial Maintenance Coatings	Thousand Gallons	All	USCB, 2003a
Electronic and Other Electrical	Thousand Gallons	All	USCB, 2003a
	Pesticide Application		
Pesticide Application	Thousand Lbs of Active Ingredient	All	NASS, 2004a
	Consumer/Commercial Solvents		
All Adhesives and Sealants	Value of Shipments in Constant Dollars was used as proxy of change in volume of adhesives and sealants used)	1980-1996	NBER-CES, 2000
		1992-1996	USCB, 1998
		1992, 1997	USCB, 2000
		1994-2001	BLS, 2004
		1997-2001	USCB, 2003b
All FIFRA Products	Millions of Lbs of Active Ingredient	All	EPA, 2002
All Coatings and Related Products	Thousand Gallons	All	USCB, 2003
	Stage 2: Gasoline Marketing		
Stage II Gasoline	Thousand Barrels	All	EIA, 2003a
	Open Burning		
Residential Household Waste	Pounds/Person/Day	All	EPA, 2003
	Livestock		
Swine Production Composite	Number of Livestock	1987, 1992, 1997	NASS, 1999
		1987-2002	NASS, 2004b
Cattle and Calves Waste Emissions, Milk Cows	Number of Livestock	1987, 1992, 1997	NASS, 1999
		1987-2002	NASS, 2004b
Poultry Waste Emissions, Layers	Number of Livestock	1987, 1992, 1997	NASS, 1999
		1988-1992	NASS, 1995
		1993-1996	NASS, 1998
		1997-2002	NASS, 2004c
Cattle and Calves Waste Emissions, Heifers and Heifer Calves	Number of Livestock	1987, 1992, 1997	NASS, 1999
		1987-2002	NASS, 2004b

Table II-1 (continued)

Emission Activity	Emission Activity Units	Years	Data Source(s)
Fertilizer Application			
Urea	Thousand Metric Tons	All	ACS, 2003
Nitrogen Solutions	Thousand Metric Tons	All	ACS, 2003
Pulp and Paper			
Plywood Operations, Waferboard Dryer	Million Square Feet	All	USDA, 2004
Sulfate (Kraft) Pulping	Thousand Short Tons	1971-1982	API, 1984
		1983-1993	AF&PA, 1994
		1994-2000	AF&PA, 2001
Sulfite Pulping	Thousand Short Tons	1971-1982	API, 1984
		1983-1993	AF&PA, 1994
		1994-2000	AF&PA, 2001
Iron and Steel Production			
Titanium, Other Not Classified	Metric Tons	All	USGS, 2004
Energy Categories			
Industrial Fuel Combustion			
Natural Gas	Million Cubic Feet	1990-2001	EIA, 2004a
		2001-2003	EIA, 2004b
Bituminous/Subbituminous Coal	Thousand Short Tons	All	EIA, 2004a
Distillate Oil	Thousand Barrels	1990-2001	EIA, 2004a
		2001, 2002	EIA, 2003b
Residential Wood Combustion			
Fireplaces: General	Thousand Cords of Wood	All	EIA, 2004c
		1991/1993/1997/1999	USCB, 2002
Woodstoves: General	Thousand Cords of Wood	All	EIA, 2004c
		1991/1993/1997/1999	USCB, 2002
Industrial Boilers			
Bituminous/Subbituminous Coal	Thousand Short Tons	All	EIA, 2004a
Natural Gas	Million Cubic Feet	1990-2001	EIA, 2004a
		2001-2003	EIA, 2004b
Distillate Oil	Thousand Barrels	1990-2001	EIA, 2004a
		2001, 2002	EIA, 2003b
Petroleum Refineries			
Catalytic Cracking Units, Fluid Catalytic Unit	Million Barrels	All	OGJ, 2002
		1972-1991	Pechan, 2001a
		1992-2002	EIA, 2003c
Process Heaters, Gas-Fired	Thousand Barrels	All	EIA, 2003a
Process Heaters, Oil-Fired	Thousand Barrels	All	EIA, 2003a
Natural Gas Production			
Other Not Classified	Million Cubic Feet	All	EIA, 2004d

Table II-2. REMI Variables Evaluated in Empirical Analysis

Architectural Coatings	Auto Refinishing	Wood Furniture	Miscellaneous Manufacturing
Population	Automobile parking, repair, and services - SIC 752 - 754 Output	Furniture & Fixtures - SIC 25 Output	Miscellaneous Manufacturing Industries - SIC 39 Output
Real Disposable Personal Income	Automobile parking, repair, and services - SIC 752 - 754 Employment	Furniture & Fixtures - SIC 25 Employment	Miscellaneous Manufacturing Industries - SIC 39 Employment
Housing Expenditures	Auto Repair, Services and Parking - SIC 75 Value Added	Furniture & Fixtures - SIC 25 Value Added	Miscellaneous Manufacturing Industries - SIC 39 Value Added
Construction- SIC 15, 16, 17 Output	Vehicle and Parts Expenditures	Durables Manufacturing - SIC 24, 25, 32-39 Output	Total Manufacturing - SIC 20-39 Output
Construction- SIC 15, 16, 17 Employment	Gasoline and Oil Expenditures	Durables Manufacturing - SIC 24, 25, 32-39 Employment	Total Manufacturing - SIC 20-39 Employment
Construction- SIC 15, 16, 17 Value Added	Real Disposable Personal Income	Durables Manufacturing - SIC 24, 25, 32-39 Value Added	Total Manufacturing - SIC 20-39 Value Added
Paints and allied products - SIC 285 Output	Automobile parking, repair, and services - SIC 752 - 754		Total Output
Paints and allied products - SIC 285 Employment			
Chemicals and Allied Products - SIC 28 Output			
Chemicals and Allied Products - SIC 28 Employment			

Table II-2 (continued)

Other Special Purpose Coatings	Metal Cans	Electronic and Other Electrical	Industrial Maintenance Coatings
Total Manuf. - SIC 20-39 Output	Metal cans and shipping containers - SIC 341 Output	Electronic components & accessories - SIC 367 Output	Total Manuf. - SIC 20-39 Output
Total Manuf. - SIC 20-39 Employment	Metal cans and shipping containers - SIC 341 Employ	Electronic components & accessories - SIC 367	Total Manuf. - SIC 20-39 Employment
Total Manuf. - SIC 20-39 Value Added	Fabricated Metal Products - SIC 34 Value Added	Electronic Equip, except computer equipment - SIC 36 Value Added	Total Manuf. - SIC 20-39 Value Added
Total Output		Electronic Equip, except computer equipment - SIC 36 Employ	Durables Manuf. - SIC 24, 25, 32-39 Output
Real Disposable Personal Income		Electrical industrial apparatus - SIC 362 Output	Durables Manuf. - SIC 24, 25, 32-39 Employment
Paints and allied products - SIC 285 Output		Electrical industrial apparatus - SIC 362 Employment	Durables Manuf. - SIC 24, 25, 32-39 Value Added
Paints and allied products - SIC 285 Employ		Paints and allied products - SIC 285 Output	Petroleum refining - SIC 291 Output
Chemicals and Allied Products - SIC 28		Paints and allied products - SIC 285 Employment	Petroleum refining - SIC 291 Employment
Durables Manuf. - SIC 24, 25, 32-39 Output		Chemicals and Allied Products - SIC 28 Employment	Petroleum & Coal Prods - SIC 29 Value Added
Durables Manuf. - SIC 24, 25, 32-39 Employ			
Durables Manuf. - SIC 24, 25, 32-39 Value Added			

Table II-2 (continued)

Pesticide Application: Agricultural, All Processes	All Automotive Aftermarket Products	All Adhesives and Sealants	All FIFRA Related Products
Farm- SIC 01, 02 - Value Added	Population	Population	Population
Farm- SIC 01, 02 Employment	Total Output	Construction - SIC 15, 16, 17 Output	Farm - SIC 01, 02 Value Added
Population	Automobile parking, repair, and services - SIC 752 - 754 Output	Construction - SIC 15, 16, 17 Employment	Farm - SIC 01, 02 Employment
Total Output	Automobile parking, repair, and services - SIC 752 - 754 Employment	Construction - SIC 15, 16, 17 Value Added	Agricultural chemicals - SIC 287 Output
Agricultural chemicals - SIC 287 Output	Auto Repair, Services and Parking - SIC 75 Value Added	Total Manuf. - SIC 20-39 Output	Agricultural chemicals - SIC 287 Employment
Agricultural chemicals - SIC 287 Employment	Chemicals and Allied Products - SIC 28 Value Added	Total Manuf. - SIC 20-39 Employment	Chemicals and Allied Products - SIC 28 Value Added
Chemicals and Allied Products - SIC 28 Value Added	Vehicle and Parts Expenditures	Total Manuf. - SIC 20-39 Value Added	
Agricultural Services- SIC 07 Output		Durables Manuf. - SIC 24, 25, 32-39 Output	
Agricultural Services- SIC 07 Employment		Durables Manuf. - SIC 24, 25, 32-39 Employment	
Agricultural Services- SIC 07 Value Added		Durables Manuf. - SIC 24, 25, 32-39 Value Added	
		Nondurable Manuf. - SIC 20-23, 26-31 Output	
		Nondurable Manuf. - SIC 20-23, 26-31 Employment	
		Nondurable Manuf. - SIC 20-23, 26-31 Value Added	

Table II-2 (continued)

All Coatings and Related Products	Stage 2: Total	Residential, Household Waste	Swine Production
Population	Gasoline & Oil Expenditures	Population	Farm - SIC 01, 02 Value Added
Housing	Population	Nondurable Manuf. - SIC 20-23, 26-31 Output	Farm - SIC 01, 02 Employment
Total Output	Crude petroleum, natural gas and gas liquids -SIC 131, 132 Output	Nondurable Manuf. - SIC 20-23, 26-31 Employ	Food & Kindred Products - SIC 20 Employment
Paints and allied products - SIC 285 Output	Crude petroleum, natural gas and gas liquids -SIC 131, 132 Employment	Nondurable Manuf. - SIC 20-23, 26-31 Value Added	Food & Kindred Products - SIC 20 Output
Paints and allied products - SIC 285 Employ	Total Output	Total Output	Food & Kindred Products - SIC 20 Value Added
Chemicals & Allied Prods - SIC 28 Value Added	Real Disposable Personal Income	Housing Expenditures	Meat Products- - SIC 201 Output
	Vehicle and Parts Expenditures		Meat Products- - SIC 201 Output
	Petroleum Refining- SIC 291 Output		Total Output
	Petroleum Refining- SIC 291 Employment		Food & Bev Expenditures
	Petroleum & Coal Prods. - SIC 29 Value Added		

Cattle and Calves Waste Emissions, Milk Cows	Poultry Waste Emissions, Layers	Cattle and Calves Waste Emissions, Heifers and Heifer Calves	Urea	Nitrogen Solutions
Farm - SIC 01, 02 Value Added	Farm - SIC 01, 02 Value Added	Farm - SIC 01, 02 Value Added	Farm - SIC 01, 02 Value Added	Farm - SIC 01, 02 Value Added
Farm - SIC 01, 02 Employ	Farm - SIC 01, 02 Employ	Farm - SIC 01, 02 Employ	Farm - SIC 01, 02 Employ	Farm - SIC 01, 02 Employ
Food & Kindred Prods - SIC 20 Output	Food & Kindred Prods - SIC 20 Output	Food & Kindred Prods - SIC 20 Output	Population	Population
Food & Kindred Prods - SIC 20 Value Added	Food & Kindred Prods - SIC 20 Value Added	Food & Kindred Prods - SIC 20 Value Added	Agricultural chemicals - SIC 287 Output	Agricultural chemicals - SIC 287 Output
Food & Kindred Prods - SIC 20 Employ	Food & Kindred Prods - SIC 20 Employment	Food & Kindred Prods - SIC 20 Employ	Agricultural chemicals - SIC 287 Employment	Agricultural chemicals - SIC 287 Employment
Dairy products - SIC 202	Meat Products- - SIC 201 Output	Meat Products- - SIC 201 Output	Chemicals and Allied Products - SIC 28 Value Added	Chemicals and Allied Products - SIC 28 Value Added
Dairy products - SIC 202	Meat Products- - SIC 201 Output	Meat Products- - SIC 201 Output	Food & Bev Expenditures	Food & Bev Expenditures
Total Output	Total Output	Dairy products - SIC 202		
Food & Bev Expenditures	Food & Bev Expenditures	Dairy products - SIC 202		
		Total Output		
		Food & Bev		

Table II-2 (continued)

Plywood Operations, Waferboard Dryer	Sulfate (Kraft) Pulping	Sulfite Pulping	Titanium, Other Not Classified
Millwork, plywood and structural members- SIC 243 Output	Pulp, Paper, and Paperboard mills, SIC- 261-263 Output	Pulp, Paper, and Paperboard mills, SIC- 261-263 Output	Primary nonferrous smelting and refining- SIC 333 Output
Millwork, plywood and structural members- SIC 243 Employment	Pulp, Paper, and Paperboard mills, SIC- 261-263 Employment	Pulp, Paper, and Paperboard mills, SIC- 261-263 Employment	Primary nonferrous smelting and refining- SIC 333 Employment
Lumber and Wood Products - SIC 24 Value Added	Paper and Allied Products - SIC 26 Value Added	Paper and Allied Products - SIC 26 Value Added	Primary Metals Industries - SIC 33 Value Added
Construction - SIC 15, 16, 17 Output			Durables Manuf. - SIC 24, 25, 32-39 Value Added
Construction - SIC 15, 16, 17 Employment			Durables Manuf. - SIC 24, 25, 32-39 Output
Construction - SIC 15, 16, 17 Value Added			Durables Manuf. - SIC 24, 25, 32-39 Employ
Housing Expenditures			Total Output

Table II-3. Empirically-Derived Forecasting Analysis Results

Equation to Be Used?	Sector	Comments	Years	Equation	coeff (y-int.)	coeff (b1)	coeff (b2)	REMI Variable	R2	R2 adjusted	R2 prediction	t-stat (y-int.)	t-stat (m1)	t-stat (m2)	F-stat	D-W
Surface Coating																
Yes	Architectural Coatings	EGAS equation noted at right	1981-2001	y = b0 + b1x7 + b2yLAG	-0.017	0.614	0.437	Housing Expenditures	0.964	0.959	0.950	-0.23	2.84	2.29	237.63	1.93
Yes	Auto Refinishing	EGAS equation noted at right	1972-2002	yLOG = b0 + b1yLAGLOG + b2x3LOG	0.087	0.542	0.401	Auto. Parking, Repair & Services-SIC 752-754 Output	0.813	0.799	0.764	2.97	3.64	2.14	56.70	2.10
Yes	Wood Furniture		1993-2002	yDIF=b0 + b1x2DIF^3	0.060	3024.3		Furniture Fixtures - SIC 25 Employ	0.925	0.914	0.891	2.43	9.29		86.37	1.94
Yes	Miscellaneous Manufacturing		1993-2002	y=b0 + b1x3^3	0.997	-.110		Misc. Manuf. Industries - SIC 39 Value Added	0.824	0.799	0.723	24.44	-5.73		32.85	2.20
	Other Special Purpose Coatings	No statistically valid equation identified														
	Metal Cans	No statistically valid equation identified														
	Industrial Maintenance Coatings	Not used - poor adjusted R2	1993-2002	yLOG=b0 + b1x1LOG	0.075	-1.007		Total Manuf. - SIC 20-39 Output	0.442	0.349	-0.163	1.36	-2.18		4.75	2.08
Yes	Electronic and Other Electrical		1993-2002	yLOG=b0 + b1x2LOG^3	-0.005	-204.01		Elect. Components & Accessories - SIC 367 Employ	0.757	0.722	0.649	-0.11	-4.67		21.78	1.91
Pesticide Application																
	Pesticide Application: Agricultural, All Processes	Not used - poor adjusted R2	1990-2002	yLOG=b0 + b1x2LOG	-0.026	-5.877		Farm - SIC 01, 02	0.397	0.337	0.140	-0.31	-2.57		6.58	1.33
Consumer/Commercial Solvents																
	All Adhesives and Sealants	No statistically valid equation identified														
Yes	All FIFRA Related Products		1990-1999	yLOG=b0 + b1x1LOG^3 + b2x1LOG^2	-0.005	2290.7	- 128.97	Population	0.944	0.926	0.755	-1.15	7.17	-8.20	50.94	2.29
Yes	All Coatings and Related Products		1993-2000	y= b0 + b1x6	2.317	-1.111		Chemicals & Allied Products - SIC 28 Value Added	0.918	0.902	0.841	13.74	-7.49		56.03	2.01
Gasoline Marketing																
Yes	Stage 2: Total	EGAS equation noted at right	1990-2002	LOG(y) = b0 + b1x2LOG^2	0.006	7.419		Gasoline and Oil Expenditures	0.901	0.890	0.839	2.22	9.05		81.81	1.71
Open Burning																
	Residential, Household Waste	No statistically valid equation identified														

Table II-3 (continued)

Equation to Be Used?	Sector	Comments	Years	Equation	coeff (y-int.)	coeff (b1)	coeff (b2)	REMI Variable	R2	R2 adjusted	R2 prediction	t-stat (y-int.)	t-stat (m1)	t-stat (m2)	F-stat	D-W
Livestock																
Yes	Swine production composite		1990-2002	yLOG=b0 + b1x5LOGLAG	0.003	-1.600		Food & Kindred Prods. - SIC 20 Value Added	0.877	0.864	0.830	0.29	-8.02		64.33	2.31
Yes	Cattle and Calves Waste Emissions, Milk Cows		1990-2002	y=b0 + b1x2	-1.175	2.187		Farm-SIC 01, 02 Employ	0.907	0.899	0.874	-0.74	2.65		107.82	1.49
Yes	Poultry Waste Emissions, Layers		1990-2002	y=b0 + b1yLAG + b2x5	-0.386	0.584	0.794	Food & Kindred Prods - SIC 20 Value Added	0.994	0.992	0.990	-6.35	10.04	7.94	726.57	2.30
Yes	Cattle and Calves Waste Emissions, Heifers/Heifer Calves		1990-2002	y=b0 + b1yLAG^3 + b2x7^2	0.944	0.254	-0.196	Meat prods - SIC 201 Employ	0.974	0.968	0.953	10.21	6.14	-3.86	165.52	2.53
Fertilizer Application																
	Urea	No statistically valid equation identified														
	Nitrogen Solutions		1995-2002	yLOG = b0 + b1x2LOG^3	0.057	155992.418		Farm - SIC 01, 02- Employment	0.871	0.845	0.810	11.20	5.816		33.83	1.422
Pulp and Paper																
Yes	Plywood Operations, Waferboard Dryer		1990-2002	y=b0 + b1x5	-1.869	3.22		Construction - SIC 15, 16, 17 Employ	0.94	0.934	0.909	-6.39	12.53		157.05	1.31
Yes	Sulfate (Kraft) Pulping	EGAS equation noted at right	1971-2000	LOG(y) = b0 + b1x3LAGLOG^3 + b2yLAGLOG	0.063	-21.562	0.816	Pulp, paper, and paperboard mills-SIC 261 Employment	0.961	0.958	0.944	2.94	-2.25	11.98	305.41	1.93
Yes	Sulfite Pulping		1990-2000	y=b0 + b1x3	1.994	-1.022		Paper & Allied Prods. - SIC 26 Value Added	0.886	0.873	0.818	14.55	-8.36		69.89	1.98
Iron and Steel Production																
	Titanium, Other Not Classified	Not used - poor adjusted R2	1990-2002	yDIF=b0 + b1x1DIFLAG^2	0.143	-26.63		Primary nonferrous smelting & refining-SIC 333 Output	0.63	0.588	0.44	2.57	-3.91		15.29	1.87

Table II-4. Past Performance Evaluation Growth Indicators for Priority Stationary Point and Area Source Categories

Category	Subcategory	Growth Indicator: BEA	BLS	REMI	DOE
		Non-Energy Categories			
Surface Coating	Architectural Coating	Chemicals and Allied Products - SIC 28	Paints and Allied Products - SIC 285	Paints and Allied Products - SIC 285	n/a
	Automobile Refinishing	Auto Repair, Services, and Parking - SIC 75	Automobile Parking, Repair, and Services - SIC 752 - 754	Automobile Parking, Repair, and Services - SIC 752 - 754	n/a
	Electronic and Other Electrical	Electronic Equipment, except computer equipment - SIC 36	Electronic Equipment, except computer equipment - SIC 36	Electronic Equipment, except computer equipment - SIC 36	n/a
	Industrial Maintenance Coatings	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	n/a
	Metal Cans	Fabricated Metal Products - SIC 34	Metal Cans and Shipping Containers - SIC 341	Metal Cans and Shipping Containers - SIC 341	n/a
	Miscellaneous Manufacturing	Miscellaneous Manufacturing Industries - SIC 39	Miscellaneous Manufacturing Industries - SIC 39	Miscellaneous Manufacturing Industries - SIC 39	n/a
	Other Special Purpose Coatings	Chemicals and Allied Products - SIC 28	Paints and allied products - SIC 285	Paints and Allied Products - SIC 285	n/a
	Wood Furniture	Furniture & Fixtures - SIC 25	Furniture & Fixtures - SIC 25	Furniture & Fixtures - SIC 25	n/a
Pesticide Application	Pesticide Application: Agricultural	Chemicals and Allied Products - SIC 28	Agricultural Chemicals - SIC 287	Agricultural Chemicals - SIC 287	n/a
Consumer/ Commercial Solvents	All Adhesives and Sealants	Population	Population	Population	n/a
	All FIFRA Products	Population	Population	Population	n/a
	Al Coatings and Related Products	Population	Population	Population	n/a
Stage 2: Gasoline Marketing	Stage 2: Total	Petroleum and Coal Products - SIC 29	Petroleum Refining- SIC 291	Gasoline & Oil Expenditures	n/a
Open Burning	Residential, Household Waste	Population	Population	Population	n/a
Livestock	Swine Production Composite	Farm - SIC 01, 02	Livestock and Livestock products- SIC pt. 01, pt 02	Farm - SIC 01, 02	n/a
	Cattle and Calves Waste Emissions, Milk Cows	Farm - SIC 01, 02	Livestock and Livestock products- SIC pt. 01, pt 02	Farm - SIC 01, 02	n/a
	Poultry Emissions, Layers	Farm - SIC 01, 02	Livestock and Livestock products- SIC pt. 01, pt 02	Farm - SIC 01, 02	n/a
	Cattle and Calves Waste Emissions, Heifers and Heifer Calves	Farm - SIC 01, 02	Livestock and Livestock products- SIC pt. 01, pt 02	Farm - SIC 01, 02	n/a
Fertilizer Application	Urea	Farm - SIC 01, 02	Other Agricultural Products- SIC pt 01, pt 02	Farm - SIC 01, 02	n/a
	Nitrogen Solutions	Farm - SIC 01, 02	Other Agricultural Products- SIC pt 01, pt 02	Farm - SIC 01, 02	n/a

Table II-4 (continued)

Category	Subcategory	Growth Indicator: BEA	BLS	REMI	DOE
Pulp and Paper	Plywood Operations, Waferboard Dryer	Lumber and Wood Products - SIC 24	Millwork and Structural Wood Members, nec- SIC 2431, 4, 9 + Veneer and Plywood- SIC 2435, 6	Millwork, Plywood and Structural Members- SIC 243	n/a
	Sulfate (Kraft) Pulping	Paper and Allied Products - SIC 26	Pulp, Paper, and Paperboard Mills, SIC- 261-263	Pulp, Paper, and Paperboard Mills, SIC- 261-263	n/a
	Sulfite Pulping	Paper and Allied Products - SIC 26	Pulp, Paper, and Paperboard Mills, SIC- 261-263	Pulp, Paper, and Paperboard Mills, SIC- 261-263	n/a
Iron and Steel Production	Titanium	Primary Metal Industries - SIC 33	Primary Nonferrous Smelting and Refining- SIC 333	Primary Nonferrous Smelting and Refining- SIC 333	n/a
	Energy Categories				
Industrial Fuel Combustion	Natural Gas	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	Industrial, Total Natural Gas
	Bituminous/Subbituminous Coal	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	Industrial, Total Coal
	Distillate Oil	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	Industrial, Total Distillate
Residential Wood Combustion	Fireplaces: General	Population	Population	Population	Residential, Renewable Energy
	Woodstoves: General	Population	Population	Population	Residential, Renewable Energy
Industrial Boilers	Bituminous/Subbituminous Coal	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	Industrial, Total Coal
	Natural Gas	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	Industrial, Total Natural Gas
	Distillate Oil	Total Manufacturing- SIC 20-39	Manufacturing- SIC 20-39	Total Manufacturing- SIC 20-39	Industrial, Total Distillate
Petroleum Refineries	Catalytic Cracking Units, Fluid Catalytic Unit	Petroleum and Coal Products - SIC 29	Petroleum Refining- SIC 291	Petroleum Refining- SIC 291	Refinery Petroleum Products Supplied, Total
	Process Heaters, Gas-Fired	Petroleum and Coal Products - SIC 29	Petroleum Refining- SIC 291	Petroleum Refining- SIC 291	Refinery Petroleum Products Supplied, Total
	Process Heaters, Oil-Fired	Petroleum and Coal Products - SIC 29	Petroleum Refining- SIC 291	Petroleum Refining- SIC 291	Refinery Petroleum Products Supplied, Total
Natural Gas Production	Other Not Classified	Oil and Gas Extraction - SIC 13	Crude Petroleum, Natural Gas and Gas Liquids- SIC 131, 132	Crude Petroleum, Natural Gas and Gas Liquids- SIC 131, 132	Natural Gas Production, Dry Production

Table II-5. Past Performance Evaluation Results

Source Category	BEA	BLS	REMI	DOE	REGRESS
Non-Energy Categories					
Pesticides	41.3	62.1	42.8		
Stage II	7.9	18.8	3.0		7.0
Swine production	13.9	4.9	20.1		2.4
Cattle and Calves, Milk Cows	15.9	5.3	19.9		1.8
Poultry	10.3	17.3	6.4		5.0
Cattle and Calves, Heifers and Heifer Calves	12.5	3.4	18.4		2.0
Urea	19.4	25.4	10.9		
Nitrogen Solutions	9.4	19.7	7.4		7.1
Plywood, Waferboard	74.4	62.1	43.0		19.1
Sulfate Pulping	8.2	7.5	6.2		29.1
Sulfite Pulping	28.2	12.6	25.1		3.8
Titanium	21.7	20.1	22.0		
Architectural Coatings	6.0	9.7	38.4		3.4
All Adhesives and Sealants	7.6	11.7	18.5		
All Coatings and Related Products	12.6	22.0	18.7		1.7
All FIFRA Related Products	13.5	17.6	1.9		1.0
Electronic and Other Electrical	42.2	2.0	20.6		10.0
Industrial Maintenance Coatings	18.2	36.0	61.0		
Metal Cans	29.7	53.8	7.4		
Miscellaneous Manufacturing	14.6	6.4	13.3		9.1
Wood Furniture	16.4	12.2	3.3		5.6
Residential Household Waste	1.8	14.7	12.8		
Auto Refinishing	28.0	14.0	43.3		38.9
Other Special Purpose Coatings	59.6	37.4	20.6		
AVERAGE	**21.4**	**20.7**	**20.2**		**9.2**
Energy Categories					
Natural Gas Production	38.9	16.7	21.0	4.8	
FCCU	4.2	14.6	1.7	25.3	
Process Heaters- Oil Fired	19.6	9.3	22.1	3.7	
Process Heaters- Gas Fired	2.3	8.9	5.1	2.5	
Industrial Fuel Combustion- Coal	29.6	16.8	35.1	3.2	
Industrial Fuel Combustion- Natural Gas	7.1	5.5	12.7	8.6	
Industrial Fuel Combustion- Distillate Oil	11.1	5.6	16.6	5.5	
Industrial Boilers- Coal	29.6	16.8	35.1	3.2	
Industrial Boilers- Natural Gas	7.1	5.5	12.7	8.6	
Industrial Boilers- Distillate Oil	11.1	5.6	16.6	5.5	
Woodstoves	44.6	43.4	44.4	25.7	
Fireplaces	44.6	43.4	44.4	26.1	
AVERAGE	**20.8**	**16.0**	**22.3**	**10.2**	

Notes: Due to poor performance over the 1990-2001 period, Pechan recommends that the categories in gray shading use data for the REMI variable with the best MAD over the 1990-2001 period rather than the estimated equation from EGAS (Pechan had recommended use of EGAS equation because there was no statistically valid equation identified from the 1990-2001data). If these two categories are removed from the calculation, the average MAD for the regression approach drops to 5.6.

Table II-6. Evaluation of Alternative Stationary Point and Area Source Growth Methodologies/Data Sources

Availability	Coverage	Validity	Documentation
Bureau of Economic Analysis			
BEA projections are available for free. Only substantial level of effort (LOE) is in developing crosswalk between BEA variables and SCCs (draft crosswalk exists)	*SCCs* - can be used for each emission source category via crosswalk between SCCs and BEA variables that are assumed to represent a valid surrogate for changes in emission activity (most BEA variables reported by 2-digit SIC code) *Geographic* - state *Time period* - 1998, 2000, 2005, 2010, 2015, 2025, and 2045 (Pechan has an in-house database of BEA-based 1998-2045 growth factors developed from interpolating between these projection years). *Pollutants* - not applicable	*Theoretical* - Poor–projections data are outdated (were released in 1995), unlike REMI data incorporated into EGAS, there are no equations available that relate BEA data to changes in emission activity levels. *Empirical* - ***Non-energy categories***: worst method ***Energy categories***: 3rd best method	Well-documented methodologies (see Task 1 report for summary)
Bureau of Labor Statistics			
BLS projections are available for free Only substantial LOE is in developing crosswalk between BEA variables and SCCs (no draft crosswalk exists)	*SCCs* - can be used for each emission source category via crosswalk between SCCs and BLS variables that are assumed to represent a valid surrogate for changes in emission activity (variables include output and employment projections for 293 industry sectors and employment projections for 725 occupations; BLS also forecasts gross domestic product, real disposable personal income, a small number of components of personal consumption expenditures, and population) *Geographic* - national *Time period* - 2012 only *Pollutants* - not applicable	*Theoretical* - Fair–projections are based on recent data (and are updated every two years); however, data are national and may not reflect trends in the Midwest RPO states; unlike REMI data incorporated into EGAS, there are no equations available that relate BLS data to changes in emission activity levels. *Empirical* - ***Non-energy categories***: 3rd best method ***Energy categories***: 2nd best method	Well-documented in a series of reports, see: http://www.bls.gov/emp/home.htm.

Table II-6 (continued)

Availability	Coverage	Validity	Documentation
Economic Growth Analysis System (EGAS)/Regional Economic Models, Inc. (REMI)			
Pechan has access to REMI data for both EGAS 4.0 and 5.0 (raw data can not be released to LADCO, but can use data to develop growth factors for LADCO). Updating of existing crosswalk may be required depending on whether any non-energy SCCs included in Midwest RPO base year inventory are not in EGAS 4.0; minor LOE to implement.	*SCCs* - can be used for each source category via crosswalk between SCCs and REMI variables that are assumed to represent a valid surrogate for changes in emission activity (most variables are constant dollar output data by sectors that are equivalent to 3-digit SIC codes). *Geographic* - state for EGAS 5.0; regional (Midwest RPO region States are all included in the Great Lakes regional model) for EGAS 4.0. *Time period* - annual through 2035 *Pollutants* - not applicable	*Theoretical* - Good for REMI data that will be included in EGAS 5.0; Fair for REMI data in EGAS 4.0. Many sectors in EGAS do not use equations that relate REMI data to changes in emission activity levels, therefore, crosswalk assumptions are key to validity. *Empirical* - ***Non-energy categories***: 2nd best method ***Energy categories***: worst method	A reference manual and user's guide document the data sources, algorithms, and operation of EGAS (Pechan, 2001a and 2001b).
EGAS/Department of Energy			
DOE projections are available for free. Updating of existing crosswalk may be required depending on whether any energy SCCs included in Midwest RPO base year inventory are not in EGAS 4.0; minor LOE to implement.	*SCCs* - can be used for each energy source category via crosswalk between SCCs and DOE variables that are assumed to represent a valid surrogate for changes in emission activity (energy sectors in EGAS 4.0 rely on DOE projections released in 2001; for EGAS 5.0, DOE projections data are circa 2004). *Geographic* - regional (Midwest RPO region States are all included in the East North Central Census Division) for most indicators, national for a few less important sectors. *Time period* - annual through 2025 *Pollutants* - not applicable	*Theoretical* - Excellent for DOE data circa 2004 (EGAS 5.0); Good for DOE data circa 2001 (EGAS 4.0); methods (National Energy Modeling System [NEMS]) peer reviewed/undergo periodic refinements. *Empirical* - ***Nonenergy categories***: not applicable ***Energy categories***: **best method**	Documentation of the DOE forecast assumptions and modeling approaches is available at the following EIA web site: http://www.eia.doe.gov/oiaf/fore_pub.html.

Table II-6 (continued)

Availability	Coverage	Validity	Documentation
Industry/Market Research (Freedonia Group, Inc.)			
Research reports are $4,000 to $5,000. Can purchase individual chapters for approximately $500 to $2,500, while individual "records," which contain either tabular data or supporting text describing historical and future trends in supply, demand, and prices, are available for $30.	*SCCs* - limited to specific non-energy emission sectors (e.g., paints and coatings) for which Freedonia publishes reports. *Geographic* - national. *Time period* - forecasts provided for 5^{th} and 10^{th} year beyond base year of research report. *Pollutants* - not applicable	*Theoretical* - Unclear. Nonenergy sector projections are more specific to emission processes than other methods. Projections are generally updated on a triennial basis. However, methods are unclear (see Documentation criterion) *Empirical* - unable to evaluate (projections circa 1990 not available).	Methods not well documented-developed by "scouring trade publications, government source books, proprietary databases, product literature, and annual and industry reports to find out what industry professionals have to say, adding information gained by extensive interviews with major players as well as knowledgeable industry participants."
Empirically-Derived Estimates			
Require access to REMI or other forecast data for variables incorporated into equation (Pechan has access to latest REMI forecasts) Significant effort associated with obtaining historical activity data/conducting regression analyses	*SCCs* - same as EGAS/REMI (dependent on REMI or other forecast data source). *Geographic* - same as EGAS/REMI. *Time period* - same as EGAS/REMI. *Pollutants* - not applicable	*Theoretical* - Excellent (short-run); Unclear (long-run). Projections are specific to emission processes and account for recent historical relationship between activity trends and socioeconomic trends. *Empirical* - ***Nonenergy categories***: **best method**.	Dependent on study author; Pechan has developed extensive documentation of data, assumptions, and results of regression analyses for this study.

CHAPTER III. ONROAD MOBILE SOURCES

The following lists the onroad mobile source SCCs for which emission activity growth factors were examined .

2201xxxxxx Gasoline-powered highway vehicles, trucks, buses, and motorcycles
2230xxxxxx Diesel-powered highway vehicles, trucks, and buses

The primary activity indicator used currently with onroad mobile sources is VMT. VMT is the activity needed to calculate emissions using onroad emission factors from EPA's MOBILE6.2 model. As EPA continues its development of the MOVES model, other activity factors may be used for onroad mobile sources, such as time of travel or fuel consumption. However, a replacement of the MOBILE6 model with MOVES is not expected until about 2007. Therefore, the focus of this evaluation is on VMT.

The VMT forecast methods included in the Task 1 report included:

- Transportation Demand Module of the NEMS used in the Annual Energy Outlook (AEO);
- Federal Highway Administration (FHWA) VMT projections;
- methodology used for EPA's draft Section 812 VMT projections; and
- time series regression analysis.

The purpose of this chapter is to summarize the comparative evaluations performed on each of these VMT projection approaches. Section A discusses the past performance evaluations that were used to compare the empirical validity of the alternative methods. Section B summarizes the evaluations of the VMT forecast methods and data listed above, relative to the evaluation criteria presented in Chapter I. Section C provides information on ways that the above approaches could be modified or combined to best meet LADCO's needs.

The Task 1 report also summarized the VMT projection methods used by various Metropolitan Planning Organizations (MPOs) within the Midwest RPO States. These RPOs generally use transportation planning models to project VMT. Such models use local inputs including land use, employment, population, and road networks. Where these models are used and VMT projections are available, we assume that these projections would be used in the areas covered by these MPOs. The methodologies described in this report focus on methodologies that would be applied in areas without local VMT projections.

A. PAST PERFORMANCE EVALUATIONS

To determine the empirical validity of the various VMT forecast methods evaluated in this report, a set of past performance analyses were performed. To fairly compare the methods, the past performance evaluations were designed to review data available to all of the methodologies. No past performance evaluation was performed for the FHWA VMT forecasting approach because past projections were not available with this methodology. The sections below discuss how the MAD analyses were performed for each of the three other VMT projection methodologies along with the results. Table III-1 summarizes the MAD evaluation results.

The performance evaluations described below should not be used as an absolute determinant of the best methodology for predicting VMT. When projecting emissions, the split between light duty vehicles and heavy duty vehicles and between gasoline-powered vehicles and diesel-powered vehicles is very important. For example, if one of the described methodologies closely predicted total VMT, but overpredicted light-duty gasoline VMT and underpredicted heavy-duty diesel VMT, PM and possibly NOx emissions would likely be underestimated while VOC and NH_3 emissions would likely be overestimated. Unfortunately, sufficient data were not available to prepare vehicle type-specific past performance evaluations.

1. AEO MAD Evaluation

Projected VMT were obtained from the 1997 AEO for all vehicle types combined for each year from the base year of 1995 through 2002. Growth factors for each year were then calculated by dividing the projected VMT by the 1995 base year VMT. For each of the five Midwest RPO States, similar growth factors were calculated using historical VMT from FHWA's Highway Statistics using 1995 as the base for each year through 2002. A MAD value was then calculated for each State by comparing the absolute value of the difference between the AEO growth factor and the actual growth factor based on the historical Highway Statistics data for each year from 1995 through 2002. The average of these values from 1995 to 2002 was then determined for each State. The average MAD value based on the AEO projections for these five States was 2.3.

2. Draft Section 812 MAD Evaluation

A simplified Section 812 approach was developed to estimate its past performance. Inputs to this included historical State-level and national population from 1995 through 2002 from REMI, the 1997 AEO VMT projections for the years 1995 to 2002, and the historical State-level total VMT data for each of the five Midwest RPO States from 1995 from Highway Statistics. Projected VMT were then calculated for each State by multiplying the 1995 base year VMT by the ratio of the State-level population growth factor to the US population growth factor and also by the ratio of the national AEO projected VMT to the 1995 base year VMT. Once these calculations were performed for each of the five States for each year from 1995 to 2002, the MAD calculations were prepared as discussed above, comparing these Section 812-based growth factors to the historical Highway Statistics VMT growth factors. This methodology resulted in an average MAD value for the five Midwest RPO States of 3.7.

3. Regression MAD Evaluation

A regression of the historical State-level VMT from Highway Statistics was performed based on data for each year from 1980 through 1995. Using this regression equation, VMT were then projected to the years 1996 through 2002. The resulting projected VMT for each of the five States was then compared to the historical Highway Statistics VMT data for these States from 1995 to 2002. The regression-based forecast approach resulted in a MAD value of 2.5.

4. Limitations of Past Performance Evaluations

As discussed in the next section, the regression approach is expected to perform better in near-term years and worse in long-term projection years. Pechan performed a regression analysis on the historical VMT to project VMT from 1990 through 2002. Separate MAD calculations were then performed on the 1990 through 1996 projected VMT and the 1997 through 2002 projected VMT. The 1990 through 1996 calculations resulted in an average MAD value of 1.71, while the 1997 through 2002 projections resulted in a MAD value of 3.54, more than double the value for the earlier years.

The Section 812 MAD evaluation is dependent upon the population data used in the calculations, as well as the AEO VMT projections. The resulting population ratios are all less than one, indicating that population growth in these five States was less than the national population growth in the years analyzed. This led to underpredicting the VMT. Thus, the population data also needs to be carefully examined, along with the VMT data.

The AEO projections are recalculated each year, with occasional changes in methodology. Therefore, examining how the projections from the 1997 AEO performed may not be a good indicator of empirical validity of the 2004 version of the AEO VMT projections.

B. EVALUATION OF ALTERNATIVE METHODS

Table III-2 summarizes the evaluations of VMT growth methodology approaches according to the selected criteria. The discussion below compares and contrasts the different VMT growth approaches by each of the four primary evaluation criteria, identifying approaches with notable strengths or weaknesses in these areas.

1. Availability

The existing VMT projection data are publicly available free of charge for all of the VMT projection approaches included here. However, different levels of effort would be involved in customizing the models used. The approach with the lowest expected LOE would be the regression approach. This approach requires historical VMT data. Although this report focuses on a State-level regression approach, the regression approach could also be applied at a finer level of detail, such as by State and roadway class, if the State has consistent historical VMT data available at this level. The draft Section 812 approach would have the next highest LOE. Pechan has already developed simple programs to apply this approach. These programs could easily be customized to represent the level of detail desired of the growth factors (such as the number of vehicle categories desired). The growth factors could also be tailored to the county level if the Midwest RPO States have reliable county-level population projections. Next would be the FHWA approach. The report for this methodology includes the equations used for each of the five vehicle categories modeled by FHWA. However, developing all of the input data needed to apply these equations would require a significant amount of effort. The AEO approach is expected to have the highest LOE, but only if the Midwest RPO States wish to customize this approach. The transportation module of NEMS is a Fortran-based model and could be run by users familiar with Fortran. A significant amount of effort would be needed to review or modify the inputs or to make changes to the program code to develop growth factors at a finer level of detail. However, if national VMT growth factors for each of the three AEO vehicle categories is considered to be sufficient, DOE performs the work necessary to update these projections each year so that the latest available VMT growth factors could always be used and using these data would then require only a negligible LOE.

2. Coverage

The draft Section 812 VMT growth factor methodology currently provides growth factors at the greatest level of detail, with growth factors varying by county and 28 vehicle types. In contrast, the AEO VMT projections are only available nationally and by 3 vehicle categories. The FHWA VMT projections fall between these two approaches with VMT projections available by State and five vehicle categories. The regression approach described in this report would produce VMT growth factors at the State level, with no distinction by vehicle type. However, depending upon the historical VMT data available in a given State, this approach could produce VMT growth factors that differ by geographic areas within a State or by vehicle type. All of these projection methodologies have the weakness of not providing VMT growth rates that differ by roadway class, although the regression and draft Section 812 approaches could be adapted to include growth factors that differ by roadway class.

All of the projection approaches discussed here provide the ability to obtain VMT growth factors annually. The currently existing AEO and FHWA projections both provide VMT projections through the year 2025, and the draft Section 812 projections have been prepared through 2020.

3. Validity

The theoretical validity of AEO VMT projections ranks high in three out of the four subcategories of theoretical validity (use of defensible techniques, representativeness of activity for category, and validity of key inputs). However, this approach is lacking in the area of the geographic representativeness of the projections, as the data are only available nationally. The draft Section 812 approach attempts to build upon the strengths of the AEO projection methodology by using the national AEO VMT projections as a starting point, and then improving the geographic representativeness and category specificity of the projections by incorporating REMI population projections and MOBILE6 projections of national VMT fractions by vehicle category. This improvement to the geographic and vehicle category representativeness endows the draft Section 812 methodology a superior theoretical validity compared to the other methods. The FHWA approach has a higher theoretical validity than the AEO approach in terms of category and geographic representativeness. However, this approach has a lower level of theoretical validity than the AEO approach in terms of using defensible techniques (because it has not been as widely circulated, tested, or peer reviewed as the AEO approach) and in terms of the inputs, as they are not annually updated. The theoretical validity of VMT projections based upon regression techniques would vary depending upon the specificity and validity of the historical data used in the regressions. In general, though, the theoretical validity of the regression approach would be better for short term projections and poorer for long-term projections.

The past performance evaluation discussed in the previous section indicates that the AEO VMT projection approach has a higher level of empirical validity than either the draft Section 812 approach or the regression approach. Nonetheless, all three of these approaches performed very well in the past performance evaluation. It should be noted, however, that a more useful past performance evaluation would have evaluated the empirical validity of these approaches by vehicle subcategory and at a finer level of geographic detail. However, data were not available to perform a consistent evaluation of this type for these approaches. Additionally, sufficient data were not available from the FHWA approach to evaluate its empirical validity.

4. Documentation

The AEO VMT projection approach is the most fully documented of the four approaches. Nonetheless, documentation exists for the FHWA and draft Section 812 approaches at a level sufficient to understand how the projections were made. Because the FHWA approach is fairly complex, the existing documentation may not be sufficient to allow an outside user to reproduce FHWA's results. No specific documentation exists for the VMT regression approach, but these projections can be prepared by anyone familiar with regression techniques.

C. ADDITIONAL CONSIDERATIONS

In addition to the four VMT forecasting methodologies evaluated here, LADCO should give consideration to variations of the evaluated approaches and/or combinations of the evaluated approaches. Since it is expected that MPO-based VMT projections will be used in most of the metropolitan areas, it will be important to find an approach that best fits with the expected VMT projection trends that will be experienced in the more rural areas that remain once the metropolitan areas are removed from the VMT projections. It will also be important to make sure that the VMT projections are not dominated by the expected VMT growth in the metropolitan areas. For example, if State-level VMT growth factors are derived and the metropolitan and rural portions of the State experience different VMT growth rates, then using the State-level growth factors will either under predict VMT growth in the rural areas or over predict it, depending upon whether the metropolitan are VMT growth factors are lower or higher than the VMT growth rates in the rural areas.

Although the draft Section 812 approach had a lower MAD value than the other approaches examined, the Section 812 approach could be refined to use county-level population projections, if they are available from the States. Using county-level population projections could improve the projection performance in areas outside of the metropolitan areas.

Another possible approach would be to modify the NEMS model used in the AEO projections to produce results that are a more detailed geographic level of detail. It may also be possible to obtain results for a greater number of vehicle categories than the three categories currently reported in the AEO. However, the resources budgeted in this current contract are not sufficient to perform these program modifications.

Table III-1. Past Performance Evaluation Results for Onroad Vehicles

	AEO	Section 812	Regression
Illinois	1.2	2.9	1.5
Indiana	1.4	2.9	3.3
Michigan	4.1	6.7	2.1
Ohio	2.1	1.6	3.7
Wisconsin	2.6	4.2	1.8
Average	2.3	3.7	2.5

Table III-2. Summary of Onroad Mobile Source Growth Projection Methods

Availability	Coverage	Validity	Documentation
DOE–Transportation Sector Model of NEMS			
AEO projections are available free; underlying model is also available free LOE to develop projections specific to Midwest RPO States would be high	SCCs - covers all onroad SCCs, in three vehicle type groupings; no distinction by road class Geographic - national, with projections calculated using regional inputs Time period - projections made at annual level, recalculated annually, can obtain all years from present through 2025 Pollutants - not applicable	Theoretical – Very Good, except in category of geographic representativeness. The projections are updated annually. The underlying model has been reviewed by independent experts and the documentation provides references to the findings of independent reviewers (DOE, 2004a). The overall NEMS model attempts to balance energy supply and demand across all sectors and the transportation module also considers expected technology changes over time, along with regulatory emission requirements and corporate average fuel economy (CAFE) standards. Empirical – **best method evaluated**	The methodology and data are fully documented. The transportation sector module documentation can be found at: http://tonto.eia.doe.gov/FTPROOT/modeldoc/m070(2004).pdf. This documentation separately describes and details the algorithms used in the light duty vehicle module, the commercial light truck module, and the freight transport module. The transportation sector model can be downloaded at: ftp://ftp.eia.doe.gov/pub/oiaf/aeo/tranonly.zip
FHWA VMT Projections			
VMT projection data are available free from FHWA LOE to obtain necessary input data to revise or update projections would be high	SCCs - covers all onroad SCCs in five vehicle type groupings; no distinction by road class Geographic - national, with projections available at State level Time period - projections available for each year through 2025, with 1998 most recent historical year used in development of projection equations Pollutants - not applicable	Theoretical - Good. The underlying models are specific to each of the five vehicle categories and account for the factors most likely to influence VMT in the future. However, inputs may be outdated. Empirical - not available-sufficient data are unavailable for past performance evaluation.	The analysis and methods used in the FHWA VMT projections were documented by WEFA (WEFA, 2003).

Table III-2 (continued)

Availability	Coverage	Validity	Documentation
Draft Section 812 VMT Projections			
Methodology available publicly Method was developed by Pechan, so only low level of effort needed to modify methodology or develop additional projection years	SCCs - covers all SCCs, with factors by the 28 MOBILE6 vehicle categories, but no road class distinctions Geographic - county-level Time period - projections currently available for 2007, 2010, 2015, and 2020, currently based on 1999 historical VMT data; approach can be applied to any base year to any projection year through 2025 Pollutants - not applicable	Theoretical - Best of evaluated methods. These projections build upon the DOE projections, using the DOE data for overall VMT growth rates. Other factors affecting the validity of this methodology are the accuracy of EPA's vehicle type fraction forecasts and the REMI population projections. Each of these components have been independently reviewed and are expected to have good theoretical validity. The validity of combining these factors in VMT projections has not yet been thoroughly examined, but this methodology provides the greatest level of detail in the growth factors which is important when projecting emissions (e.g., distinguishing different growth rates for different vehicle categories, as well as for different geographic areas.) Empirical - worst past performance of models evaluated, but in comparison to other sectors, this is still a good level of past performance.	This projection methodology has been documented for EPA (Mullen and Neumann, 2004).
Regression-based Projections			
For best results, would need consistent historical VMT data for Midwest RPO States LOE may differ for each individual State	SCCs - depends upon basis of historical VMT data Geographic - depends upon basis of historical VMT data Time period - depends upon basis of historical VMT data Pollutants - not applicable	Theoretical - Very Good for short-term projections. Validity decreases as length of projections decreases. Also, the more robust the historical VMT data set is, the better the validity of the regression-based growth factors will be. Empirical - Second-best past performance of models evaluated.	Will depend on individual study

CHAPTER IV. NONROAD MOBILE SOURCES

Table IV-1 presents a list of nonroad SCCs identified by LADCO to be SCCs of interest for this analysis. With the exception of diesel commercial marine vessels (CMVs) and locomotives, the remaining categories are included in EPA's NONROAD model.

The following sections describe an evaluation of nonroad source growth methodologies and tools according to the specified evaluation criteria. Section A discusses the derivation of empirically-derived growth factors. Section B discusses the past performance evaluations that were conducted to compare the validity of the alternative methods for locomotive and commercial marine vessel categories; a past performance of the NONROAD model categories was not conducted. Section C describes the evaluations of nonroad sector growth methodologies and data in the context of the evaluation criteria presented in Chapter I. Section D provides additional discussion of EPA's NONROAD model as the projection tool of choice for NONROAD model categories.

A. DETERMINATION OF EMPIRICALLY-DERIVED ESTIMATES

Similar to the point and area source sector analysis, Pechan evaluated empirically determined projections for the commercial marine and locomotive categories. This method relies on the identification of a statistically verified historical correlation between emission activity and one or more variables. Pechan performed multiple regression analyses to test the relationship between historical emission activity levels and historical values for variables available from the REMI model. Pechan obtained national historical fuel consumption data for the 1990-2001 time period from the sources listed in Table IV-2. To provide the most meaningful comparison with the alternative growth methods, which generally contained historical data up through the early 1990s, Pechan correlated the regression analyses using data up through only 1996. This approach was used so that the empirically-derived approach would not have the advantage of incorporating additional years of data in the actual procedure.

Pechan regressed each emission activity against a series of potential explanatory REMI variables to identify the equation with the best statistical fit. Values from the EGAS 4.0 version of the REMI model were used in the analyses because this version contained historical data up through 1996 (i.e., all post-1996 values are projections). Table IV-3 presents the best-fit emission activity estimation equation for each source category.

Because this methodology relies solely on variables available from economic models developed by REMI, the regression analysis was not always successful in identifying variables that strongly correlated with emission activity levels. For example, a suitable equation could not be developed for residual-fueled commercial marine vessels.

B. PAST PERFORMANCE EVALUATIONS

The validity of each method in forecasting changes in activity was evaluated quantitatively by conducting past performance evaluations for the rail and commercial marine vessel categories. For the NONROAD model SCCs, Pechan did not perform a retrospective analysis to determine which projection method would be the best determinant of past activity levels, because when compared to any alternate projection method, the NONROAD model growth rates, which are taken directly from the model's underlying Power Systems Research (PSR) data, will always be the best predictor of historic activity levels. Alternate projection methods could have potentially been compared among each other, but Pechan believes that the limited available data would make any empirical validity conclusions difficult to justify.

Pechan first identified the growth indicator surrogates that would be used to conduct the past performance evaluations for each priority emission activity. These growth indicators, which are presented in Table IV-4, were identified from the variables available from BEA, BLS, DOE, and REMI. It was not possible to conduct a past performance analysis of the Industry/Market Research Approach because Freedonia Group forecast data were not available from the early to mid-1990s. Next, Pechan compiled forecast data from earlier versions of these sources. The forecasts from these earlier versions, which were based on historical data up through 1990 or early 1990s, were used in calculating the MAD values for each alternative method (BEA, 1995; BLS, 1991; EIA, 1996; EIA, 1997; and REMI, 1999).

Table IV-5 summarizes the results of the past performance MAD analyses at the emission activity level. Because the list of rail and commercial marine SCCs that will be included in the base year inventory is not yet final, Pechan evaluated the results across all SCCs. In addition, since a best-fit equation could not be developed for the residual fueled commercial marine category, the results for this category were not included in calculating an overall MAD for any of the alternative methods. In comparing the overall average MAD results for each methodology, the DOE and empirical approach (REGRESS) provide comparable MAD values, with REGRESS being slightly lower (6.2 compared to 6.6). Although this may seem to support the use of REGRESS over DOE, it is not clear that these two methods are equally valid theoretically, which is explained further in Section C.3. The next best overall method was REMI data, which provided an average MAD of 9.4. BEA and BLS were the least empirically sound.

C. EVALUATION OF ALTERNATIVE METHODS

Pechan evaluated the following methods for projecting nonroad sector emissions:

- EPA's NONROAD Model;
- BEA;
- BLS;
- REMI;
- DOE;
- Empirically-derived estimates; and
- Industry/Market Research Forecasts.

Table IV-6 displays a summary of the evaluations for each of the above listed methodologies. Note that the empirical validity comparisons only relate to the rail and commercial marine categories. The following identifies the methodologies/data sources with particular strengths and/or weaknesses in relation to each of the four evaluation criteria. Where appropriate, these comparisons are discussed separately for NONROAD model categories and the locomotive and commercial marine vessel categories.

1. Availability

The cost and level of effort associated with most of the approaches is minimal. There are two exceptions: 1) the Industry/Market Research approach, which requires purchasing each forecast data set; and 2) the empirically-derived approach, which requires a significant level of effort for collecting historical activity data and conducting regression analysis for each category.

2. Coverage

In evaluating the coverage criterion, the majority of the methods provide state-level data (BEA, REMI, Empirically-Derived), while the BLS and DOE methods provide national projections. The DOE provides annual estimates through 2025, the REMI/Empirically-Derived approach provides annual estimates through 2035, and the remaining forecasts represent only one year or several select years. The source category coverage of the methods differs as well with the BEA methods based on 2-digit SIC code (approximately 53 sector) data, the REMI on 3-digit SIC code (172 sector) data, and the BLS on 293 industry sectors. In addition, DOE provides forecasts specific to energy sectors and fuel types that are not available from the other methodologies. Until the final list of rail and commercial marine SCCs is established for the Midwest RPO, the SCC coverage criterion cannot be completely evaluated. The NONROAD model covers many diverse equipment and application types that, prior to its inception, were not represented in emission inventories.

3. Validity

In comparing the alternative approaches for categories not included in the NONROAD model, the DOE approach is believed to provide the best combined theoretical/empirical validity. Although the past performance results for the rail and commercial marine categories are about equal for the empirically derived approach and the DOE (MAD of 6.2 and 6.6), there are other theoretical validity considerations that lend support to the DOE data as the preferred method. Theoretically, the DOE methodology is superior since it explicitly models changes in energy intensity. All other methods do not explicitly forecast changes in energy intensity, which may be particularly important in projecting activity for sectors such as commercial marine and rail freight.

There are theoretical limitations in the NONROAD model forecasting methods, including the assumption that past trends affecting historic equipment populations will hold in the future. However, NONROAD accounts for equipment scrappage wherein existing nonroad equipment is retired and replaced with new equipment that emits at lower levels due to new emission standards. The effects of emission standards are reflected in the NONROAD model emission factors. So the theoretical validity of the NONROAD model as a comprehensive tool for projecting activity and emissions is very high. Forecast data obtained from industry groups and market research firms may more accurately reflect industry trends, but these are typically projected engine sales data, which do not provide an accurate estimate of in-use nonroad equipment populations/activity.

4. Documentation

All of the forecasting methodologies are well-documented, with the exception of the Industry/ Market Research forecasts from the Freedonia Group. The data inputs and algorithms of the NONROAD model are explained by EPA in a series of technical reports that are updated as needed with each draft model release.

D. ADDITIONAL CONSIDERATIONS

Pechan focused the past performance analysis and empirical validity evaluation on the locomotive and commercial marine vessel categories. For the NONROAD model, EPA has incorporated recommended growth rates in the model for projecting forecasted equipment populations. The NONROAD model average annual growth rates by fuel are presented below:

Sector	Diesel	Gasoline	LPG	CNG
Construction	3.2	0.2		
Farm	3.0	1.8		-10.2
Industrial	3.7	-4.0	3.8	
Lawn & Garden	6.8	2.4		
Light Commercial	4.5	3.8	8.7	4.2
Logging	-1.0	5.0		
Railway	4.4	1.4		
Recreational	3.3	0.6		

Because these growth rates are based on historical changes in equipment populations, the empirically- derived forecasting approach would likely result in a more defensible set of growth factors. However, the resources to implement this approach for the listed NONROAD model categories exceed this project's budget.

In addition, since the development of the Task 1 report, Pechan reviewed comments provided by the Engine Manufacturing Association (EMA) on the NONROAD model growth rates, suggesting the use of DOE's diesel fuel projections for agriculture, construction, industrial and commercial sectors (Heiken, 2004). DOE also prepares projections for recreation boats, which was identified as an SCC of interest to LADCO. However, the average annual growth rates estimated by DOE for these categories are the same for all fuel types, indicating that their projections do not differentiate among fuel types like the NONROAD model does. Based on the historic growth rates, growth rates should be expected to differ by fuel type. Therefore, Pechan recommends using the default NONROAD model growth rates for all model categories.

In May 2004, EPA released an updated draft version of the NONROAD model (NONROAD2004), (EPA, 2004). Primary changes from NONROAD2002 include the following:

- Accounts for the final Tier 4 nonroad diesel engine standards.

- Revised exhaust emission factors to reflect the final rulemaking for large spark ignition (SI) engines (>25 horsepower [hp]), recreational equipment, and recreational marine diesel engines (>50 hp). Recreational marine populations, median life, and deterioration factors were also revised. [Revised evaporative emissions (permeation, hot soak, running loss, and diurnal) for recreational and large SI engines, to account for the provisions of the November 2002 rulemaking are not expected until the final version of NONROAD]

- Updated base year diesel populations from 1998 to 2000, based on newer sales data.

- Revised PM2.5 fraction of PM10 for diesel engines from 0.92 to 0.97, based on updated analysis of diesel engine data.

Due to these enhancements, the NONROAD model contains the information needed to model all existing Federal standards, with the exception of the evaporative standards mentioned above.

Table IV-1. Nonroad SCCs of Interest

SCC	Description
2260004xxx	2-Stroke Gasoline Lawn and Garden
2265004xxx	4-Stroke Gasoline Lawn and Garden
226000102x	2-Stroke Gasoline Snowmobiles
2270002xxx	Diesel Construction Equipment
2270005xxx	Diesel Agricultural Equipment
2280002xxx	Diesel Commercial Marine Vessels
2282005xxx	2-Stroke Gasoline Recreational Marine - Outboards and Personal Water Craft
2285002xxx	Diesel Locomotives

Table IV-2. Source of 1990-2001 Activity Data for Past Performance Analysis

SCC	Description	Source of Historic Data
2285002006	Diesel, Line Haul Locomotives: Class I Operations	Table 4-5 (Rail, Class I, in freight service, Diesel Fuel Consumption) from the Bureau of Transportation Statistics' (BTS) "National Transportation Statistics 2003," accessed from http://www.bts.gov/publications/national_transportation_statistics/2003/, March 2004.
2285002007	Diesel, Line Haul Locomotives: Class II/III Operations	Subtracting Class I Freight (see above) from Table E-8 (Class I, II, and & III Locomotive Diesel Fuel Consumption) from EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001," April 15, 2003.
2285002008	Diesel, Line Haul Locomotives: Passenger Trains (Amtrak)	Table 4-5 (Amtrak, Diesel Fuel Consumption) from BTS's "National Transportation Statistics 2003," accessed from http://www.bts.gov/publications/national_transportation_statistics/2003/, March 2004.
2285002009	Diesel, Line Haul Locomotives: Commuter Lines	Table 34 (Commuter Rail Diesel Fuel Consumption) from American Public Transportation Association's "Public Transportation Energy Consumption and Environmental Benefit Statistics," accessed from http://www.apta.com/research/stats/energy/fosfuel.cfm
2280002000	CMV; Diesel	Table 4-5 (Water, Diesel Fuel Oil) from BTS's "National Transportation Statistics 2003," accessed from http://www.bts.gov/publications/national_transportation_statistics/2003/, March 2004.
2280003100	CMV; Residual	Table 4-5 (Water, Residual Fuel Oil) from BTS's "National Transportation Statistics 2003," accessed from http://www.bts.gov/publications/national_transportation_statistics/2003/, March 2004.

Table IV-3. Empirically-Derived Forecasting Analysis Results

Sector	Years	Equation	coeff (y-int.)	coeff (b1)	REMI Variable	R2	R2 Adjusted
Diesel, Line Haul Locomotives: Class I Operations	1990-1996	y=b0+b1x4^2	0.402	0.559	Total GDP	0.942	0.930
Diesel, Line Haul Locomotives: Class II/III Operations	1990-1996	y=b0+b1x3	-0.327	1.344	Total Manufacturing - SIC 20-39	0.811	0.773
Diesel, Line Haul Locomotives: Passenger Trains (Amtrak)	1990-1996	y=b0+b1x1^3	1.378	-0.362	Railroad Transportation - SIC 40	0.770	0.724
Diesel, Line Haul Locomotives: Commuter Lines	1990-1996	y=b0+b1x4	-2.363	3.363	Population	0.896	0.875
CMV; Diesel; Port/Underway Emissions	1990-1996	y=b0+b1x1^3	0.795	0.205	Water Transportation - SIC 44	0.864	0.837

Note: CMV; Residual; Port/Underway not displayed because no REMI variable was identified as strongly correlated with this activity.

Table IV-4. Past Performance Evaluation Growth Indicators for Nonroad Locomotive and Commercial Marine Vessel Categories

		Growth Indicators			
Category	**Subcategory**	**BEA**	**BLS**	**REMI**	**DOE**
Locomotives	Class I Operations	Railroad Transportation - SIC 40	Railroad Transportation - SIC 40	Railroad Transportation - SIC 40	Freight Rail, Distillate
	Class II/III Operations	Railroad Transportation - SIC 40	Railroad Transportation - SIC 40	Railroad Transportation - SIC 40	Freight Rail, Distillate
	Passenger Trains (Amtrak)	Railroad Transportation - SIC 40	Railroad Transportation - SIC 40	Railroad Transportation - SIC 40	Rail Transportation, Intercity Rail (diesel)
	Commuter Lines	Local and Interurban Passenger Transit - SIC 41	Local and Interurban Passenger Transit - SIC 41	Local and Interurban Passenger Transit - SIC 41	Rail Transportation, Commuter Rail (diesel)
CMV	Diesel, Port and Underway Emissions	Water Transportation - SIC 44	Water Transportation - SIC 44	Water Transportation - SIC 44	Domestic + International Shipping, Distillate
	Residual, Port and Underway Emissions	Water Transportation - SIC 44	Water Transportation - SIC 44	Water Transportation - SIC 44	Domestic + International Shipping, Residual

Table IV-5. Past Performance Evaluation Results for Locomotives and Commercial Marine Vessels

Source Category	BEA	BLS	DOE	REMI	REGRESS
Diesel, Line Haul Locomotives: Class I Operations	16.3	17.1	2.2	2.7	7.1
Diesel, Line Haul Locomotives: Class II/III Operations	10.7	22.2	4.1	6.2	6.8
Diesel, Line Haul Locomotives: Passenger Trains (Amtrak)	32.4	3.8	10.7	17.8	0.9
Diesel, Line Haul Locomotives: Commuter Lines	7.7	11.1	9.5	7.1	3.6
Commercial Marine Vessels; Diesel	14.9	15.0	6.4	13.0	12.4
Commercial Marine Vessels; Residual	6.9	6.9	10.9	32.0	NA
Average MAD*	**16.4**	**13.8**	**6.6**	**9.4**	**6.2**

*Average MAD excludes CMV residual since the regression approach did not yield a statistically significant equation.

Table IV-6. Evaluation of Alternative Nonroad Sector Growth Methodologies/Data Sources

Availability	Coverage	Validity	Documentation
NONROAD Model			
NONROAD is a non-proprietary EPA model. No licensing or costs for use.	SCCs - most nonroad engine SCCs, excluding aircraft, commercial marine, and locomotives Geographic - National, state, county, subcounty Time period - 1970 to 2045 Pollutants - criteria pollutants, NH_3, CO_2	Theoretical - Fair-growth factors developed by nonroad application and fuel type. Developed by extrapolating from a linear regression of Power Systems Research (PSR) National equipment population estimates for 1989-1996. Approach assumes that the underlying factors that affected equipment populations during this short time frame will continue to affect future engine populations. Sub-national growth rate differences are not reflected. NONROAD does, however, account for equipment turnover and the effects of controls. Empirical - Past performance not conducted; see section IV.C discussion	The draft NONROAD model has been peer-reviewed and been well documented by EPA.
Bureau of Economic Analysis			
No cost for BEA projections. Level of effort (LOE) needed for developing crosswalk between BEA variables and SCCs (draft crosswalk exists)	*SCCs* - can be used for each emission source category via crosswalk between SCCs and BEA variables that are assumed to represent a valid surrogate for changes in emission activity (most BEA variables reported by 2-digit SIC code) *Geographic* - state *Time period* - 1998, 2000, 2005, 2010, 2015, 2025, and 2045 (Pechan developed growth factors for all years in 1998-2045 time series by interpolation). *Pollutants* - not applicable	*Theoretical* - Poor–projections data are outdated, and have not been updated since 1995. *Empirical* - Least preferred method	Well-documented methodologies (see Task 1 report for summary)
Bureau of Labor Statistics			
No cost for BLS projections. LOE needed for developing crosswalk between BEA variables and SCCs (no draft crosswalk exists)	*SCCs* - can be used for each emission source category via crosswalk between SCCs and BLS variables that are assumed to represent a valid surrogate for changes in emission activity. *Geographic* - national *Time period* - 2012 only *Pollutants* - not applicable	*Theoretical* - Fair–projections are based on recent data (and are updated every two years); however, data are national and may not reflect trends in the Midwest RPO states *Empirical* - 2nd least preferred method	Well-documented, see reports at: http://www.bls.gov/emp/home.htm.

Table IV-6 (continued)

Availability	Coverage	Validity	Documentation
/Regional Economic Models, Inc. (REMI)			
Pechan currently has access to REMI data for both EGAS 4.0 and 5.0 Minor LOE may be needed to update existing crosswalk.	*SCCs* - can be used for each source category via crosswalk between SCCs and REMI variables that are assumed to represent a valid surrogate for changes in emission activity (most variables are constant dollar output data by sectors that are equivalent to 3-digit SIC codes). *Geographic* - state for EGAS 5.0; regional (Midwest RPO region States are all included in the Great Lakes regional model) for EGAS 4.0. *Time period* - annual through 2035 *Pollutants* - not applicable	*Theoretical* - Good for REMI data that will be included in EGAS 5.0; Fair for REMI data in EGAS 4.0. *Empirical* - 2nd best method	A reference manual and user's guide (including data sources and algorithms) are available.
Department of Energy			
No cost for DOE projections; updated annually.	*SCCs* - fuel consumption forecasts available for: 1) Diesel/Residual Domestic/International Freight Shipping; 2) Diesel Freight Rail; 3) Diesel Passenger Rail; and 4) Gasoline Recreational Boats. These variables are assumed to represent a valid surrogate for changes in emission activity. *Geographic* - National *Time period* - annual through 2025 *Pollutants* - not applicable	*Theoretical* - Excellent-projections account for changes in energy efficiency; National Energy Modeling System (NEMS) is periodically updated. However projections are only available at the national level. *Empirical* - **Best method** (tie with empirically-derived)	DOE forecast assumptions and modeling approaches are documented at: http://www.eia.doe.gov/oiaf/fore_pub.html.
Empirically-Derived Estimates			
Pechan has access to latest REMI forecasts needed for this approach. Significant effort to obtain historical activity and to perform regression analyses	*SCCs* - dependent on REMI or other forecast data source. *Geographic* - dependent on REMI or other forecast data source. *Time period* - dependent on REMI or other forecast data source. *Pollutants* - not applicable	*Theoretical* - Excellent (short-run); Unclear (long-run). Projections are specific to emission processes and account for recent historical relationship between activity trends and socioeconomic trends. *Empirical* - **Best method** (tie with DOE)	Dependent on developer of regressions; Pechan has documented the data, assumptions, and results.

Table IV-6 (continued)

Availability	Coverage	Validity	Documentation
Industry/Market Research (Freedonia Group, Inc.)			
Research reports are $4,000 to $5,000. Individual chapters are $500 to $2,500, while individual "records," which describe historical and future trends in supply, demand, and prices, are $30.	*SCCs* - limited to specific emission sectors (e.g., diesel engine demand for marine, construction and farm equipment) for which Freedonia publishes reports. *Geographic* - National *Time period* - forecasts provided for 5^{th} and 10^{th} year beyond base year of research report. *Pollutants* - not applicable	*Theoretical* - Fair/Poor. Estimates engine sales, not total in-use populations. Only national in scope. *Empirical* - could not be evaluated	Not well documented- developed based on trade publications, proprietary information, as well as interviews with industry.

CHAPTER V. REFERENCES

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