Geographic Allocation and Growth In EPA's NONROAD Emission Inventory Model

for December 1998 Air and Waste Management Association Conference

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ABSTRACT

The purpose of this paper is to discuss two critical input variables that are anticipated to be used in the final version of the EPA nonroad mobile source emissions model. The NONROAD model, as it is called, uses these inputs to geographically allocate national equipment population estimates to State or county modeling domains, and for projecting nonroad equipment populations and emissions for future years. This model will provide a tool for EPA, States, regional air pollution organizations, and local air pollution control agencies to use in estimating pollution from nonroad vehicles and equipment for State Implementation Plans (SIPs), as required by the 1990 Clean Air Act Amendments, and other regulatory needs.

INTRODUCTION

The NONROAD model is the EPA's first major emission inventory guidance update for nonroad engines and equipment since the early 1990s. A draft version of the model was released for public review in June 1998. The model is currently being revised in response to the comments received and to correct known deficiencies. A final version of the model will be released in 1999.

The model estimates past, current, and future inventories for all non-road equipment categories with the exception of commercial marine, locomotive, and aircraft. Future model updates will include modules for these remaining sources. Exhaust pollutants are reported for all criteria pollutants, plus carbon dioxide (CO_2). Non-exhaust hydrocarbon (HC) pollutants include diurnal, refueling, spillage, and crankcase emissions. The model calculates emission inventories on an annual, seasonal, or daily basis.

In order to serve as a useful tool for the preparation of State Implementation Plans (SIPs) and other purposes, the NONROAD model must be able to estimate nonroad emissions at the county level and it must be able to project emissions in future years. The first part of this paper (entitled "Geographic Allocation") contains a discussion of how NONROAD takes existing estimates of national populations of nonroad equipment and allocates them to the county level. The last part of this paper (entitled "Growth") contains a discussion of how NONROAD takes existing estimates of current equipment populations and adjusts them to reflect projected growth.

GEOGRAPHIC ALLOCATION

The NONROAD model uses national equipment population data from Power Systems Research (PSR), a company that tracks the sales and populations of all types of nonroad equipment sold in the U.S. It should be noted that PSR also matches the engines to the equipment in which they are used, so a simplifying assumption is made in this paper that the word "equipment" also includes engines. We believe that the PSR information is the only comprehensive, nationwide source of nonroad equipment populations currently available. PSR updates these data on a yearly basis.

The PSR database also geographically allocates equipment populations from the national to the county level and then aggregates the county-level populations to generate state totals. However, the methods and data that PSR uses to perform these allocations have only been explained in general terms, since PSR considers their methods to be proprietary information. Since we want the methods that are used to allocate equipment populations in NONROAD to be fully transparent, publicly available data was used as much as possible to allocate the national PSR equipment populations to the county level. State and local users are encouraged to substitute well-documented, specific local (e.g., county, nonattainment area) equipment population data in place of the model's default inputs to increase the accuracy of the resultant inventories. This locally derived information may be gathered by conducting surveys or taken from some other data source.

Allocating Equipment Activity Versus Population

One central feature of the NONROAD model is that it uses the same methods to allocate equipment populations, activity, and therefore, emissions to specific geographic areas. To the extent that each type of equipment is operated at the same power level and for the same number of hours in all areas, the distribution of equipment populations will match the distribution of equipment activity and emissions. In general, population, activity, and emissions will tend to track one another, since emissions are a direct function of equipment activity and the conditions that stimulate increased equipment activity are likely to stimulate increased equipment populations.

In reality, however, the geographic distribution of nonroad equipment may differ from the geographic distribution of emissions. The amount of activity that each piece of nonroad equipment of a given type experiences can vary from area to area as a result of variations in local economies, weather patterns, or other local conditions. For example, agricultural equipment and residential lawnmowers may experience more use per year in areas with longer growing seasons; construction equipment is likely to be used more intensively in areas experiencing an economic boom and less intensively where the economy is not as robust.

Currently, the NONROAD model is capable of handling only one activity level for each equipment type across all parts of the U.S. As a result, the model uses the same factors to allocate equipment populations and their associated activity. Wherever possible, we have tried to use indicators of equipment activity, since it is equipment activity that results in emissions (except for diurnal and hot soak emissions, which are more closely related to equipment populations). In some cases, however, suitable activity indicators were not identified, and population indicators were used as a surrogate.

For some equipment categories, finding either suitable activity or population indicators was especially difficult. These categories include recreational, railway maintenance, and AC/refrigeration equipment. State and local air quality agencies may wish to substitute adequately documented local data for model's default estimates for these categories.

In order to facilitate the collection and use of local activity and population data, we hope to initiate an effort to develop methods of determining nonroad equipment activity at the county level that state, regional and local air agencies may use as input into NONROAD. Previously, as part of the Emission Inventory Improvement Program (EIIP), the EPA's Office of Mobile Sources (OMS) oversaw the development of a methodology for conducting surveying lawn and garden equipment.[1] Future efforts may initially focus on recreational equipment and recreational marine vessels. These categories comprise a significant portion of the total nonroad emission inventory. The initial pilot project is envisioned to include three parts:

1) performing a review and analysis of known methods that have been used by state and local air agencies to collect local nonroad equipment activity data,
2) choosing one of the methods reviewed and analyzed in part 1 or developing a new method to be included in EPA guidance to state and local air agencies, and
3) applying the chosen method to selected areas to ensure that it works properly and produces reasonable and useful results.

If this effort proves to be successful, methods for creating improved local population and activity estimates for other categories, such as construction and lawn and garden equipment may be undertaken. We also welcome information from our stakeholders and other interested parties about surveys of nonroad equipment that have been conducted in the past or are presently being conducted.

Geographic Allocation Methodology

Since the NONROAD model only has the ability to allocate equipment populations from the state to the county level, the national PSR population data for each equipment type must be processed outside of the model to allocate these data to the state level. The same equation and allocation factors that NONROAD uses to allocate equipment populations from the state to the county level are applied to the PSR national equipment populations to allocate them to the county level, since these allocation factors are county-based. The county equipment populations are then aggregated by equipment type for each state to produce the total state equipment population input files used in the model. Due to the large amount of data that needs to be manipulated, modifying the model so that it could do all of this processing would increase the time it takes NONROAD to run a scenario beyond reasonable limits.

The NONROAD model uses information related to equipment population or activity to distribute the state equipment populations and their associated activity to the county level. This information constitutes a geographic allocation factor. The model can use a single allocation factor for entire categories of nonroad equipment, or it can use separate factors for one or more equipment types within a category. The model multiplies the state population of the equipment type by the ratio of the county level allocation factor to its state total. In essence, the allocation factor serves as a surrogate for population or activity. Mechanically, the model assumes that each type of equipment experiences the

same annual activity, which reduces the allocation problem to one of allocating equipment populations. The basic calculation is as follows in Equation (1).

$$\text{equip. population}_{county} = \text{equip. population}_{state} \times \frac{\text{surrogate}_{county}}{\text{surrogate}_{state}} \quad (1)$$

where

equip. population$_{state}$ = total population of given equipment type for state
surrogate$_{county}$ = value of surrogate indicator for a given county
surrogate$_{state}$ = value of surrogate indicator for a given state

Sources and Types of Geographic Allocation Data

There are three basic types of data that are potentially useful as allocation factors: population, business activity, and geographic data. Most of these data are available from the U.S. Census Bureau or other federal agencies, with the exception of the dollar value of construction at the county level, which was procured from a private source. Information from the U.S. Census Bureau is especially attractive for use in the NONROAD model because census data undergo rigorous statistical analyses and quality assurance reviews.

Population Data

The U.S. Census Bureau conducts a nationwide census on a decennial basis. The census includes data on population, housing (e.g., number of homes by type and number of occupants per home), and income. The most recent census occurred in 1990. The Census Bureau produces updated human population estimates on an annual basis, but does not produce an annual update for housing or income data.

Business Activity Data

The U.S. Census Bureau publishes an annual report called County Business Patterns (CBP), which tracks the number of establishments and employees for various types of businesses and industries at the national and county level using Standard Industrial Codes (SICs). The most recent CBP data covers 1995. County Business Pattern indicators were used previously by the EPA to allocate state-level populations to the county level for the 1991 Nonroad Engine and Vehicle Emissions Study[2] (NEVES).

Geographic Data

Geographic data include factors related to an area's location or physical characteristics. Such factors include water or land surface area, weather-related statistics, and land use data. This information is available from government agencies such as the U.S. Census Bureau, the National Oceanographic and Atmospheric Administration, and the U.S. Geological Survey.

Allocation Factors For Specific Equipment Categories/Types

Table 1 contains the geographic allocation factors used in the draft version of NONROAD and those that we plan to use in the final version of the model. In some cases, the factors for the final version of the model have been changed. For example, although the state populations and allocation factors for snowmobiles and snowblowers were set to zero (not including the national populations) in the draft version of the model because of time and resource constraints, we want to incorporate factors that preclude these types of equipment from being allocated to areas with little or no snowfall. The allocation factors used in the draft model for recreational equipment, railroad maintenance equipment, and AC/refrigeration equipment are still under review and may be changed in the final version of NONROAD if better factors are found. In addition, for the final version of NONROAD, the allocation factors for residential lawn and garden equipment that are based on 1990 Census counts of single and double unit homes have been adjusted by 1997 human population estimates to attempt to account for the growth of suburbs. Lastly, we plan to incorporate more accurate allocation factors for aircraft ground support, logging and underground mining equipment into the final version of the model.

Table 1. Data used in deriving NONROAD surrogate allocation factors.

Nonroad Equipment Category/Type	Allocation Factor Draft Version	Allocation Factor Proposed For Final Version
Lawn and Garden Residential	Number of single and double (duplex) family housing units from 1990 Census by county.	Adjusted by 1997 county human population estimates from U.S. Census Bureau.
Lawn and Garden Commercial	Number of employees in landscape and horticultural services, County Bus. Patterns (CBP), Standard Industrial Code (SIC)78.	Same as draft version.
Residential Snowblowers	Snowblowers set to zero pending implementation of proper allocation based on snowfall.	Same as residential lawn and garden, adjusted by annual average snowfall.
Commercial Snowblowers	Snowblowers set to zero pending implementation of proper allocation based on snowfall.	Same as commercial lawn and garden, adjusted by annual average snowfall.
Construction	Total dollar value of construction by county.	Same as draft version.
Agricultural	Harvested cropland (U.S. Census Bureau, USA Counties database).	Same as draft version.
Recreational Marine	Ratio of county water surface area to total national water surface area.	Same as draft version.

Nonroad Equipment Category/Type	Allocation Factor Draft Version	Allocation Factor Proposed For Final Version
Recreational (except snowmobiles and golf carts)	Number of camps and recreational vehicle park establishments (CBP SIC 7030).	Might be revised for final version, pending review.
Snowmobiles	Snowmobiles set to zero pending implementation of proper allocation based on snowfall.	State level populations from registration data compiled by the International Snowmobile Manufacturers Association, then allocated to counties using same factors as other recreational equipment.
Golf Carts	Number of public golf course employees (CBP SIC 7992).	Number of public golf courses. (CBP SIC 7992)
Aircraft Ground Support Equipment	Number of employees in air transportation (CBP SIC 4500).	Revised to be based on number of landings and takeoffs (LTOs) of commercial aircraft.
Light Commercial	Number of wholesale establishments (CBP SIC 50).	Same as draft version.
Industrial	Number of employees in manufacturing (CBP SIC 20)	Same as draft version.
Logging	Number of employees in logging plus saw and planing mills (CBP SIC 2410 and 2420).	Number of employees in logging only (CBP SIC 2410).
Oil Field Equipment	Number of employees engaged in oil and gas extraction (CBP SIC 1300).	Same as draft version.
Railroad Maintenance Equipment	1990 Human Population	Might be revised for final version, pending review.
Underground Mining Equipment	Number of employees engaged in metals mining(CBP SIC 1000).	Number of Employees in Coal Mining (CBP SIC 1200).
AC/Refrigeration Equipment	1990 Human Population	Might be revised for final version, pending review.

GROWTH

The emissions inventory for nonroad engines is essentially a function of the emission factors and the amount of work or activity levels of these engines. Projections of future nonroad engine inventories must take into account expected changes in these parameters. Future changes in emission factors will primarily be the result of future regulations or technical advances and will not be discussed here. Future changes in activity level will be the result of complex interactions between human population growth,

changes in national and local economic factors, and changes in the markets for nonroad engines and the products they are used to produce.

Historically, EPA has often used projections of economic indicators as surrogates for growth in activity for the purpose of estimating future emissions for a wide variety of sources. When applying this approach to nonroad equipment, the underlying assumption is that engine usage is a constant proportion of earnings for a given sector. The most commonly used compilation of economic indicators is provided by the Department of Commerce's Bureau of Economic Analysis (BEA). The most recent projections were published in July, 1995[3]. BEA provides economic indicators by state or as a national average for numbers of employees, inflation adjusted national dollars of earnings, and inflation adjusted aggregate gross state products (GSP) dollars of earnings. In the past, BEA growth forecasts for major sectors of the economy (e.g., construction, farm, forestry, manufacturing, etc.) have been applied to all nonroad equipment that might be used in that sector of the economy.

However, the use of economic indicators to predict growth in nonroad activity has some potential drawbacks. Economic indicators may not be able to adequately predict the effects of substitution of equipment for labor in the market. Also, economic models in recent years have tended to under-predict growth in the national economy. As a result of both of these factors, economic indicators may tend to under-predict growth in nonroad equipment populations and activity. An indication that this may be the case can be found in an analysis done by E.H. Pechan and Associates[4] which compared BEA estimates of growth between 1990 and 1996 to estimates of actual 1990 and 1996 populations of nonroad equipment from the Power Systems Research (PSR) PartsLink database. The Pechan analysis indicated that the projected 1996 population based on the BEA growth estimate under-predicted the estimates of actual population developed by PSR in 1996 by 7.4%. Overall, the total projected BEA growth from 1990 to 1996 was 9.3%, while PSR estimated that actual nonroad equipment populations grew 18.1% over that same period.

There is a second drawback to using economic indicators that may be as important to estimation of emissions projections as the possibility of under prediction. Because economic indicators at best can only predict growth in broad sectors of the economy, they cannot be used to identify market trends within sectors. For example, economic indicators would not predict differential rates of growth of diesel equipment relative to gasoline equipment in nonroad applications, or changes in the horsepower distribution within nonroad applications. Because diesel and gasoline engines have very different emissions characteristics, the accurate prediction of changes in the relative distribution of different types of engines is very important to the accurate estimation of future emissions.

An alternative approach which would be able to factor in market trends would be to base growth estimates on the historical trend in growth in nonroad equipment activity. Because total activity is never directly measured, the historical trend in population must be used as a surrogate. This seems reasonable given that capital costs of nonroad equipment are high compared to operating costs, in general. As a result, owners of such equipment have a strong incentive to get the most out of the equipment they own and a disincentive to purchase new equipment that will not be fully utilized. Therefore, nonroad equipment populations are likely to correlate well with nonroad equipment activity.

Although the use of historical population growth may have limitations, it is the only approach that will allow estimation of the impact of market shifts on emission projections. For these reasons, we

have chosen to base growth projections in EPA's NONROAD emissions model on a time series analysis of historical nonroad engine populations.

Growth Methodology

We analyzed historical engine population estimates for 1989 through 1996 taken from the PSR PartsLink database, the same source used to determine 1996 baseline engine populations in NONROAD. The PSR database contains detailed information about each engine family sold in the United States. This information could be used to segregate nonroad engines for purposes of growth estimation at by several different factors, including market sector (agricultural, construction, etc.), application type (farm tractors, combines, etc.), fuel type (gasoline, diesel, etc.), and horsepower. As a result, we could in principle estimate separate growth factors for each combination of application type and fuel type, in discrete horsepower categories. However, there are some limitations to this approach. In many cases, equipment populations become small enough, when broken down by all of these factors, that even small errors in the PSR database would result in large errors in growth estimation. In addition, the number of individual growth rates would become unwieldy considering the number of different application types, fuel types, and horsepower categories, as well as the fact that each state would have its own unique set of growth factors.

Given those concerns, for the current version, we have chosen to segregate nonroad engines only by market sector and fuel type. Individual applications in the PSR database were assigned to broad market sectors. For example, excavators, graders, backhoes, dozers, etc. were all assigned to the Construction market sector. A total of eight market sector populations, segregated by fuel type, were calculated for each year from 1989 through 1996.

For the draft version of NONROAD, released in June 1998, we projected future populations by fitting an exponential curve to the historical populations and extrapolating from that curve to future years. This resulted in projecting very large increases in equipment populations in 2010 and beyond. In response to comments received about this approach, we reviewed the data again and concluded that extrapolating from a simple linear regression of the historical populations would give more reasonable estimates of future populations. Currently, we anticipate incorporating these changes in the growth estimates in the final release of NONROAD.

For two market sectors, we have chosen to deviate from the approach described above. For aircraft ground support equipment, we have become aware that the Federal Aviation Administration has a detailed database that tracks aircraft takeoffs and landings for commercial aviation. Given the accuracy of this database, and since the activity of ground support equipment is directly related to takeoff and landing events from this type of aircraft, we believe that this database may provide a more accurate estimation of equipment population and activity than the PSR database. As such, we also believe it may provide a better basis for estimating growth in this sector. However, we have not yet completed this analysis, so we cannot present results yet.

For oil field equipment, the PSR database indicates a sharp decline in oil field equipment population over the period from 1989 to 1996, which is potentially consistent with trends in the domestic oil production industry over that period. However, if that trend is extrapolated linearly, oil field equipment would disappear completely by 2006. Because there is no indication that domestic oil

production will cease in that time-frame, we have chosen to use BEA economic estimates of gross state product from domestic oil production to estimate growth in this equipment category.

Results

Table 2 compares projected annual growth rates from BEA with those derived from a historical analysis of the PSR database. These growth rates are calculated as the average annual growth expected between 1996 and 2010 (the key period for SIP purposes) as a percentage of 1996 population (i.e., the difference between 2010 population and 1996 population divided by 14 years divided by 1996 population). The numbers that result are different than those presented in the growth technical report referred to earlier because of both the move to a linear extrapolation method and a change to a time period which is more appropriate for SIP purposes, as noted above (the previous report used the period from 1990 to 2010).

With the exception of the recreational and railway sectors, the PSR estimates are significantly higher than the BEA estimates. The PSR database also indicates very large differences in growth rates for different fuel types. In most cases, the rate of growth for diesel equipment is substantially higher than that for gasoline equipment. In the industrial and light commercial categories LPG and CNG engines also show higher than average rates of growth (categories with no growth rates for LPG or CNG had populations that were either zero or negligible; i.e. less than 0.1% of the total population for that category).

For two fuel categories, farm CNG and industrial gasoline, the PSR database indicates a decline in population so rapid that these categories would cease to exist within the usable time-frame of the model. For these categories, we allowed the population to decline to zero and then adjusted the growth of the other fuel types within the market sector so that the sum of the fuel types continues to equal the total projected population for all subsequent years.

Table 2. Projected Average Annual Growth Rate Comparison

Sector	BEA	PSR				
		Total	Diesel	Gasoline	LPG	CNG
Construction	1.2%	2.3%	3.2%	0.2%		
Farm	2.0%	2.6%	3.0%	1.8%		-10.2%
Industrial	1.8%	2.7%	3.7%	-4.0%	3.8%	
Lawn & Garden	0.9%	2.4%	6.8%	2.4%		
Light Commercial	1.8%	4.0%	4.5%	3.8%	8.7%	4.2%
Logging	0.6%	4.5%	-1.0%	5.0%		
Railway	3.4%	2.6%	4.4%	1.4%		
Recreational	0.9%	0.7%	3.3%	0.6%		

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KEY WORDS

nonroad
model
emissions
engine
population
growth