TASK 1B REPORT
METHODOLOGIES FOR ESTIMATING THE POPULATION OF NONROAD ENGINES

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1. INTRODUCTION

This report provides an overview of potential methodologies to estimate the population of vehicles by nonroad category. There are four distinct methods that can be used to make this estimation. These are described in detail, including a discussion of the data requirements and data availability for each, assumptions that must be made in pursuing each, and the relative strengths and weaknesses of each approach when gathering data in each category.

This report follows on Task 1a, which provided an evaluation of the Power Systems Research (PSR) database. That report identified strengths and weaknesses in the PSR database and data gathering approach. This report places the PSR approach in the context of other methodologies available for estimating nonroad engine numbers and characteristics.

The four identified approaches can be defined in general terms as follows:

1. **Sales / production and scrappage data.** Surveys or full census of manufacturers (by private vendors, trade associations, government agencies, etc.) can be conducted to obtain data on their production and/or sales of equipment in a given year. This data, combined with data on engine scrappage, can be used to estimate populations. This is the methodology used by PSR.

2. **Vehicle registration data.** State registration of certain types of equipment is done on an annual basis and often contains detailed information on the characteristics and use of nonroad engines, including vintage, size and fuel type.

3. **Equipment user survey data.** Data on the type, number and characteristics of current equipment holdings can be obtained through large, comprehensive surveys as well as much smaller, stratified sample approaches.

4. **Activity Analysis.** This involves bottom-up analysis of equipment populations based on the usage patterns of the equipment. The numbers and some characteristics of equipment can be estimated based on the nature and size of the job they perform. For example, the number of "golf cars" (motorized golf carts) in an area can be estimated from knowing the number of golf courses times the number of golfers per course, carts used per golfer, etc.

Section 2 of this report provides a general summary of these methodologies, their data requirements, their strengths and weaknesses, and how they can be combined in ways that serve as cross-checks or enhance the coverage of data. Section 3 discusses the potential application of each methodology in each of the various categories of nonroad engines and identifies potential approaches for future data-base construction efforts. Section 4 contains conclusions and recommendations.

The categories used in this report are based on the categories developed by EEA in a previous analysis for the EPA (EEA, 1991). While these categories closely align with those adopted by EPA, there are some differences which will be noted where appropriate. The EEA categories are as follows:

1. Lawn and Garden Equipment
2. Light Commercial Equipment (0-50 hp)
3. Recreational Equipment
4. Industrial Equipment
5. Construction and Mining Equipment
6. Farm Equipment
7. Logging Equipment
8. Airport Ground Support Equipment
9. Pleasure Craft
10. Commercial and Government Vessels
11. Transport Refrigeration Units

The general data requirements for each category are similar. In general, EPA is interested in tracking the following data for each equipment category:

- The population of equipment by engine type, equipment vintage, and location
- Characteristics of each equipment group such as average size, usage patterns and emissions factors
- Rates of equipment sales and retirements for projecting future stocks.

These data requirements are considered in the following discussion of alternative data collection methodologies.

2. DESCRIPTION OF ALTERNATIVE METHODOLOGIES TO ESTIMATE NONROAD ENGINE POPULATIONS

The four identified methodologies for estimating nonroad engine populations vary considerably in terms of their approach, the type of data collected, and the usefulness of each to produce accurate estimates of equipment numbers and other information items of interest. The approaches are discussed in turn. A summary of the strengths and weaknesses of each approach is provided in Table 2-1.

There are two overarching themes to the following discussion. The first is that consideration of estimation methodology cannot be divorced from data needs and available data sources. The best methodology for any engine category will depend to a large degree on the specific characteristics of equipment in the category and the data availability for that category. For example, the relative uniformity in characteristics and usage of most industrial equipment (e.g. forklifts, aerial lifts, sweepers) makes it possible to adequately characterize this equipment through a relatively small-scale user survey. On the other hand, the wide variety of applications of most light commercial equipment (e.g. generator sets, power washers) means that a much larger scale survey of users would be required to adequately characterize this category.

The second theme is that the four methods outlined should not be thought of as mutually exclusive. In most cases no single type or source of data will provide all the information required for EPA's purposes, both in terms of variables and geographic coverage. Further, by combining or comparing data from different sources, collected using different techniques, cross-checks are possible that will enhance the accuracy of the database. As a result, EEA does not believe it is feasible to rank these methods or estimate the cost/time associated with each separately. As discussed in the concluding section, a recommended data-collection approach for each category will generally involve combining two or more of these methods.

2.1 PRODUCTION / SALES AND SCRAPPAGE DATA

Manufacturers generally keep excellent records of production and/or sales of the equipment they produce, and have proven cooperative in sharing this information in most cases. Other groups, such as trade associations, also collect production and sales data. These groups also can provide detailed information on equipment characteristics and have developed scrappage curves based on knowledge of the average life of equipment. These type of data are fairly widely available in most nonroad engine categories. The PSR data base, discussed in the Task 1A report, relies on this method. Besides PSR, a number of other sources of production/sales data are available and are discussed more specifically in this report (see Section 3).

However, there are generally several limitations to the use of this type of data. The most important issues relate to tracking the fate of equipment after it is sold and estimating the pattern and rate of usage by equipment owners and operators.

Perhaps the biggest issue is actually estimating the total population of equipment from sales or production data, as well as the population by vintage. This is generally done by developing engine or equipment scrappage functions using data on expected equipment life. Such data are often available from manufacturers (along with sales or production data). Considerable research has gone into estimating the functional form of retirement rates in order to develop reasonable scrappage curves. A common approach is to assume a normal distribution of retirement around the mean rated equipment life (in use hours). This approach requires addressing what happens at the extreme tails of the distribution, to avoid having some equipment scrapped before zero hours of use. A normal distribution with sigma specified by the mean divided by 2.3 is commonly used, as this avoids having significant scrappage in the initial hours. Some studies have indicated that use of a Weibull or log Normal curve provides a better characterization of retirement rates for heavily used equipment (e.g., Volkswagen, 1977).

Table 2-1
Strengths and Weaknesses of Data Methodologies

Methodology	Strengths	Weaknesses

Production/ Sales and Scrappage Data	• Well developed data base already exists and is updated annually
	• Population estimates are available for nearly all engine categories
	• Data on equipment characteristics and scrappage rates for many categories
		• May provide little data regarding equipment location, usage, and resale patterns
		• Depending on data source and detail, may need to make assumptions regarding:
		  • Production v sales
		  • Pct. of engines exported,
		  • Pct for commercial v. residential use,
		  • Geographic distribution of sales

Vehicle Registration Data	• Reliable data where available • May provide detailed info on vehicle and engine characteristics • Generally provides data on geographic breakout, residential v. commercial use (in cases where both are registered) • Provides population vintage data and can be used to build a reliable stock vintaging model	• Many categories and subcategories are not required to be registered; • In some categories a significant pct of equipment required to be registered is not; some registered equipment is unused. • Availability and compatibility of registration from 50 states • Issue of double counting and missing data due to equipment being moved from one place to another

Surveys of Equipment owners/operators	• Provides data on holdings rather than sales
	• Small stratified surveys can sometimes provide good accuracy
	• Can be tailored to obtain particular information such as
	  • Equipment vintage,
	  • engine size/type and other equipment specifications,
	  • Usage patterns and in-use data,
	  • Resale information
		• A large amount of new survey work, covering a vast array of users, would be necessary to build a complete data base, given the number of categories and subcategories of equipment.
		• There are restrictions on new government surveys
		• Owners may not be able to provide detailed or reliable information on equipment specifications

Activity-Analysis	• Given reliable output data and a good understanding of the relationship between equipment requirement per unit output, this approach can provide reasonable estimates of total equipment stock, and be a good cross-check on other estimation methods. • In many cases this approach can take advantage of known or easily obtainable data, with no survey work required.	• Each category and subcategory may have different underlying activity measures (and data) and require a different approach to calculation. • Some activities do not have a simple relationship between output and number of equipment units. • May be especially difficult to obtain measures from categories without easily measured (or available) outputs, such as recreational equipment. • This method may provide very little data other than overall equipment stock. Vintage data, engine specifications, and other data may not be revealed.

This type of approach has proven adequate for equipment that is used fairly intensively and on a regular basis. However, for equipment used irregularly or only occasionally, the rate of engine retirement is not easily characterized by a distribution function based on use hours. For example, compressors and snowmobiles tend to be used so infrequently that the rate of wear is affected more by the passage of time than by the actual pattern of use. The time period and rate of wear can vary depending on equipment geographic location, storage location, and weather. For such equipment, a "bottom-up" approach to estimating scrappage rates may be better than a use-based model. User surveys of actual equipment failure rates or registration data by model year date can form the basis of such a bottom-up approach.

Another important issue in using sales / production data is establishing the relationship between equipment production and sales. In order to track the number and location of each type of equipment, sales data are generally preferable to production data, especially if the sales data indicates the type of customers, the geographic region of sale, and the number of units exported. In many cases manufacturers report only the production of equipment. This also can create discrepancies in terms of the number of units reported produced v. actually sold per year. In some cases differences can be resolved by checking production data against other types of data that might reflect or include sales data. In most cases, the differences have been found to be small and tend to cancel out over the course of several years.

Finally, the rate and manner in which equipment is used, and its condition, are often not tracked by manufacturers. Thus in order to obtain data on the rate of equipment use (usually hours per year), condition, operating cost data, and fuel consumption, other approaches are necessary.

2.2 VEHICLE REGISTRATION DATA

Many vehicle types in the commercial nonroad categories require registration in most or all states, while much of the personal use equipment does not (e.g. lawnmowers, leaf blowers,

personal watercraft). As a result there is very good population data available for some categories and subcategories but not others, reflecting both the major advantage and disadvantage of using registration data.

When registration data are available, it typically provides information on the physical characteristics of the equipment but not its usage patterns or its condition. Since registration data are usually recorded at the model level, it typically provides good detail on engine characteristics such as size and fuel type. It often also provides equipment vintage and geographic location, at least at the county level, and whether the equipment is for commercial or residential use. Thus, registration data are an excellent source for developing disaggregated population data bases consistent with EPA's data needs.

One concern when using registration data is that in some cases vehicles not actively in use are still registered, while in other cases heavily used equipment is (sometimes illegally) not registered. Another is that equipment is often not used exclusively (or at all) where it is registered. This may be especially true for recreational equipment, such as personal watercraft, which is often transported to distant recreational sites before being used. In addition, there is generally some inaccuracy in aggregating state-level registration data to the national level, due to the missed equipment counts and double counting from equipment movement (and re-registration) from one area to another during the year. Errors of this kind can often be addressed and adjustments made by performing time-analysis of the registration data, comparing the changes in equipment numbers from one year to the next to track the movement of equipment.

Overall, registration data that is uniformly collected across the 50 states is usually superior to sales / production data as the basis for tracking equipment populations by vintage and location. However, it often is not uniformly collected and suffers from spotty coverage of equipment categories and subcategories. Further, any effort to use registration data as the primary basis for

developing a population model will require contacting each state and obtaining the necessary data. This is not technically difficult but can be time consuming. A discussion and list of registration data availability by category are provided in Section 3.

2.3 SURVEYS OF EQUIPMENT USERS

In theory, a comprehensive survey of equipment users (owners/operators) for all categories would provide an opportunity to gain all relevant data for EPA's needs. Of course no such survey exists, and there are several practical reasons why this would be difficult. For example, given the wide array of nonroad equipment types, a comprehensive survey would need to gather somewhat different types of data for each category and subcategory.

However, relatively small scale surveys can also provide useful and accurate data, especially when they are stratified to obtain a reasonable sample for each different type of user and equipment. A stratified sample survey covering only 20 or 30 users (depending on equipment category) can be sufficient to yield reliable data on equipment population, usage rates, and other variables at a very disaggregated level, which can then be aggregated using information on the numbers of each type of user. For example, a relatively small sampling of golf courses might be sufficient to obtain an average figure for the number of golf cars per course, and their average usage per day (this could also be based on membership). Since data on the number of golf courses in the U.S. (and by state and county) is readily available, this small sample can be aggregated to obtain reliable estimates of golf car population and use for any geographic area of interest. In order to isolate differences between regions, a slightly larger sample that is stratified by location may be necessary. Of course the greater the variety of equipment uses and user types, the larger the required sample to adequately cover the equipment category.

A fairly large number of smaller, stratified user-based equipment surveys have been conducted in the past 10 years, and some of these have proven to be important as cross-checks on other sources of data, as well as filling in missing data on equipment holdings, condition, and use patterns. EEA investigated the existence of such surveys in its study for the California Air

Resources Board (EEA, 1995) and found a number of useful ones for California. A similar search at a national level would likely turn up many additional sources of data. Likely sources include trade associations, consumer-oriented magazines, and studies conducted on behalf of state governments.

Although aggregation of user survey data can often be based on average relationships (e.g. average golf cars per course), other times a more rigorous analysis is necessary to establish a relationship with a variable that can be used for aggregation. The use of regression techniques is typical, especially where the relationship between the equipment population and indicator is measured over a range of activity levels, or where there are many factors affecting population. For example, the population of lawn mowers could estimated by taking a simple average of mowers per dwelling, but a much better estimate would be based on the amount of mowable area per region, which in turn might be a function of the number of residences (and offices), the percentage of people who hire out lawn care v. do their own, and the weather (temperature and rainfall). In order to conduct a more rigorous statistical analysis, a more detailed survey and larger sample is generally required.

One concern with data from user-surveys is the ability of respondents to accurately answer questions regarding technical aspects of their equipment. Residential respondents may be especially unable to provide information on equipment specifications (such as lawnmower engine size), or patterns of usage (load factor or annual hours of use on their snowmobiles).

Since it is becoming increasingly difficult for the government to sponsor new surveys, the EPA generally must rely on those surveys conducted and made available by independent organizations. In addition to the many known user surveys, there may be a considerable number of existing but as-yet unknown surveys that would help alleviate this problem.

Examples of coverage of equipment categories by user surveys is discussed in Section 3.

2.4 ANALYSIS OF EQUIPMENT OUTPUT (ACTIVITY ANALYSIS)

Of the four identified data collection methods, activity analysis is perhaps the least utilized to date for estimating equipment populations and characteristics. However, it can be a very useful approach for cross-checking other data or as the primary source of data in cases where registration or survey data are unavailable.

Activity analysis can be differentiated from a user survey approach as follows. User surveys generally obtain data that relates equipment populations to other variables that can be aggregated (or disaggregated). In activity analysis, estimates of the population of equipment are based on the equipment's output. This usually does not require any direct survey work. Instead, information regarding the engineering relationship between the equipment and its output is used, as is data on the amount of output produced. In many cases these two pieces of information are well established. For example, the number of cotton harvesters in a region can be estimated from the total cotton harvest in the region, and the average harvest that is obtained per machine. However, the relationship between output and population is not always well understood or non-variant, and can change with changes in intensity of machine use (both annual hours and load factor). Thus care must be taken when using an output-based approach.

Slightly less direct output measures can also be used to estimate equipment population, when the equipment does not produce a well-known commodity such as cotton. For example, the number of golf cars in an area could be estimated from data on the number of golf games played and the number of cars used per game. In this case, golf games is the "output" of golf cars. However, in such cases, some survey work may be required to obtain data needed to establish the relationship between the equipment and its output. In such cases, activity analysis becomes simply a form of user-survey data analysis.

Activity analysis generally must be tailored to each equipment activity-population relationship. Therefore the specific method and data used for each category (and subcategory) of equipment is likely to vary considerably. The output of some equipment types is particularly difficult to measure, or can only be measured using data that is not readily available. This tends to be especially true for recreational equipment such as personal watercraft.

3. METHODOLOGY AND DATA ISSUES BY ENGINE CATEGORY

3.1 INTRODUCTION

This section outlines the application of the four data methodologies for estimating nonroad engine populations in each of the major equipment categories, and makes reference to the availability and quality of known data sources. A summary of data availability by methodology and engine category is provided in Table 3-1.

Currently the PSR manufacturer data represents by far the most comprehensive source of data for nonroad equipment. However, as their data are predominantly manufacturer-supplied sales / production / scrappage data, it suffers from the shortcomings described in the previous section: it generally does not provide reliable and detailed information on the fate of equipment after it leaves the manufacturer. Equipment location, usage patterns, condition, and scrappage rates must all be assumed or obtained from alternative sources (which PSR does to some extent). This is especially troublesome when information is needed on how engines with different characteristics (e.g. size, technology, fuel type) vary in these respects.

However, in most equipment categories there is the possibility of using one or more of the other three types of data methodologies described in the previous section to add this information, as well as cross-check sales/production data.

3.2 RECREATIONAL EQUIPMENT

The recreational equipment category includes motorcycles and minibikes, motorcycle-like all terrain vehicles (ATVs), snowmobiles, golf cars, and specialty vehicles. This category excludes any type of vehicle that is used off-road but is also registered for on-road use, such as four wheel drive trucks and sport utility vehicles, and dual purpose motorcycles.

Table 3-1
Non-road Engine Data Sources (other than PSR)

Category	Production/Sales Data	Registration	Equipment User Surveys	Activity-based
Recreational Equipment	International Snowmobile Industry Assn (ISIA)	most states: motorcycles and minibikes, ATVs, golf cars, specialty vehicles snowmobiles; Many unregistered vehicles	Tyler California survey; golf magazine surveys	Possible with measurable ouputs, such as golfing; difficult for bikes, snowmobiles
Mining and Construction	Construction Industry Manuf. Assn. (CIMA)	most states do not require construction equipment to be registered, but some do require permits to be obtained in specific instances.	McKay / Construction Equipment annual survey; Census Data: equipment value only	Possible based on mine and construction output data, especailly for mid-size equipment
Industrial Equipment	Industrial Truck Assn (ITA)	Some states require registration of some types under certain conditions (I.e., oper. on hwy for a certain distance or oper on hwy a certain distance away from site)	Possibly available from trade groups	
Lawn and Garden Equipment	Outdoor Power Equipment Institute (OPEI); Booz-Allen Ham. (BAH)	most not required to be registered in virtually all states	OPEI survey, Portable Power Equipment Manufacturing Assn. (PPEMA)	Possible based on number of residences, ownership rate
Farm Equipment	Equipment Manufacturers Institute	Some equipment, such as tractors that could be driven on state roads, require registration in most states.	Ag Census has equipment counts for most farm machinery; Sierra Research survey	Possible based on ag output for harvesters and combines
Light Commercial Equipment	BAH survey for California	Most not required to be registered in virtually all states		Difficult due to wide variety of equipment uses
Logging		Most not required to be registered in virtually all states		Output-based estimates possible if logging techniques differentiated
Airport Ground Support Equipment		Most not required to be registered in virtually all states	EEA conducted a small survey of airlines in CA with excellent results for estimating equipment numbers; could be conducted nationally	Airport traffic type and level can be used to estimate equipment demand
Pleasure Craft		Most, if not all, types are registered with states and/or U.S. Coast Guard	Data on shoreline and water area can be used as correlates for regional estimation	
Transport Refrigeration Units		Registered with most states; Highway Information Statistics	None known but probably available from Railroad corporations	

Most types of recreational equipment are required to be registered in most or all states. The major exception is golf cars and specialty vehicles. However, a relatively high percentage of recreational equipment appears not to be properly registered by consumers, especially nonroad motorcycles, minibikes, and snowmobiles. A 1990 owner survey conducted by Tyler and Associates estimated that in California, there are about five times as many nonroad motorcycles and seven times as many snowmobiles in use as there are registered (Tyler, 1990). On the other hand, the California DMV has reported that nearly half of registered motorcycle and ATV registrations were inactive.

It should be noted that the Tyler estimates may themselves be significantly too high. Although the Tyler study represents an important end-use survey of recreational equipment, it is becoming dated (it was conducted in 1990) and was confined to California. Tyler used a random telephone survey approach which could be replicated on a national level. However, the survey methodology suffered from mixing on-highway and off-highway vehicles, and appears to have poorly allocated VMT between on- and off- highway for those vehicles capable of both. None-the less, it is a useful survey and there may be others like it for other states or at a national level. Perhaps the best way to learn about relevant surveys is through direct contact with equipment manufacturers and industry trade associations. EEA did such a search within California which revealed several useful surveys (EEA, 1995).

As mentioned above, the subcategory of golf cars (motorized golf carts) as well as specialty vehicles may be amenable to estimation using small user-survey based techniques. There is well developed data on the number and location of golf courses, for example, although golf cars are used in a number of other applications as well (e.g. the town of Seaside, FL allows only golf cars on its streets). A potential approach to estimating the number of golf cars at golf courses would be to take a small survey to estimate the average number of cars owned by each course and multiply by the number of courses. Golf car specifications (such as engine size and type) could also be obtained in this manner. Golf car rates of usage could be obtained by surveying the average number of golfer-games per year at different courses and the percentage of games that make use of a car. The number of specialty vehicles (primarily "people movers") could similarly

be estimated by identifying the primary locations for their use (e.g. theme parks and airports), and multiplying estimates of the number of vehicles per location by the number of locations.

The size of the sample needed to obtain reliable data will necessarily increase with the expected degree of regional variation in use patterns. Although the numbers and types of specialty vehicles at airports and amusement parks may vary with the size of the complex, they aren't especially likely to vary by region. On the other hand, golf cars at golf courses may vary significantly by region, depending on weather variations, the percentage of public and private clubs, and other factors that also vary by region.

3.3 CONSTRUCTION AND MINING EQUIPMENT

This engine category is the most diverse in terms of the characteristics of each equipment type. Gasoline and diesel engines from under 15 horsepower to over 250 horsepower are used in the construction and mining industries.

Apart from PSR, the major known source of equipment population / sales data is the Construction Industry Manufacturers Association (CIMA). Neither source is fully adequate for estimating the population of equipment after it leaves the manufacturer, but EEA (1995) found that the CIMA data was particularly suspect in its allocation of equipment sales to the state level and its assumptions regarding equipment life expectancies. However, EEA's previous analyses and contacts with the industry associations suggest that this is a category where PSR's sales/scrappage approach has produced reasonably accurate results.

Registration of construction and mining equipment appears to vary considerably from state to state. In some states, such as Washington, most construction and mining equipment do not need to be registered if "they are used primarily for grading of highways, paving of highways, earth moving, and other construction work on highways and which is not designed or used primarily for the transportation of persons or property on a public highway and which is only incidentally operated or moved over the highway." Georgia requires permits to be issued if the equipment

will be temporarily moved on roads. They designate the days and routes upon which loads and construction machinery may be moved within a county, but do not provide much information about equipment specifications. The permits do not involve recording vehicle specifications, such as equipment vintage or engine type, and thus are not as useful as proper registration data.

The U.S. Census collects data on mining and construction equipment, but only on the total value of this equipment, not the piece count (USCB, 1992). In the case of mining equipment, the relatively small number of firms and equipment populations may make this amenable to survey approaches.

One source of user data is the Construction Equipment annual survey conducted by McKay**.** This contains some data on equipment populations and usage. In cases where machine counts are simply unavailable, an alternative is to infer population data from related indicator variables. (EEA, 1995) did an analysis of regional equipment distribution using construction employment as the indicator of machine counts. A regression of these two variables for California produced an R-squared of 0.89 with a highly significant t statistic. Since construction and mining equipment are heavily used, their scrappage can be reasonably estimated by the Weibull or Normal distributions, if mean life in hours of use is known.

Mining is a category that may lend itself to activity analysis, given the availability of mining output data, the relatively small number and known location of mining operations, and the well understood relationship between mining equipment and output.

3.4 INDUSTRIAL EQUIPMENT

Industrial equipment consists mainly of materials handling equipment such as aerial lifts and industrial lift trucks (i.e. forklifts). Many of these pieces of equipment are used indoors in warehouses and on factory floors. The engines in industrial equipment also cover a wide horsepower range - from under 25 to over 250 horsepower.

The Industrial Truck Association (ITA, 1997) is the best known source of industrial lift truck (i.e.

fork lifts) population estimates. Their estimates are based on sales/scrappage data and are very similar to PSR's except for diesel trucks. Although some geographic data are collected on the number of units shipped, publicly released data cover only total U.S. sales by year. The discrepancy for diesels is partly due to differences in assumptions regarding equipment life expectancies and scrappage rates, indicating that separate user-based data would be useful as a cross-check against these manufacturer data bases. However, the population of industrial equipment of most types appears to be well characterized by this approach.

Registration of industrial equipment appears to be somewhat haphazard. Some types of equipment do need to be registered in some states, but only under certain circumstances. For instance, in California forklifts need to be registered if they are operated on the highway for more than ¼ of a mile. In Washington, forklifts do not need to be registered if "they are operated during daylight hours on public highways adjacent to and within 500 ft of the warehouses which they serve." Industrial tractors, in some states, may just need a permit to operate ("if the tractor is only incidentally operated or moved over a street, road, or highway"). Overall, it appears that registration data suffers from incomplete and non-uniform coverage and therefore probably does not provide a strong basis for developing an equipment data base in this category.

Since most subcategories of industrial equipment contain equipment that is quite uniform in characteristics and purpose (e.g. forklifts, aerial lifts, sweepers, etc.) a relatively small sample of user data covering machine counts, equipment usage patterns, condition, etc. might be sufficient to provide a good complement to the manufacturer data already available. For example, the number of fork-lifts at warehouses may be fairly accurately estimated by knowing the average number present at a sample of warehouses (or better, the average number per square foot of warehouse space). It might also be used to improve the breakout of equipment age and location by engine type. Such survey data might already be available from the relevant trade groups.

3.5 LAWN AND GARDEN EQUIPMENT

Lawn and garden equipment can be considered an especially important category, since it contains over 80% of the total number of nonroad gasoline engines in the U.S.

Experience in analyzing California lawn and garden equipment demonstrates the value of having multiple data sources, especially those that include user surveys. In addition to the PSR data, data are available for California from a study conducted by Booz-Allen and Hamilton, Inc. (BAH, 1990). While PSR data apportioned out to the state level was found to be somewhat unrepresentative for California (due in part to the unusually small lot sizes and arid weather in many parts of the state), the BAH state survey data was found to be in general agreement with information provided by the local equipment manufacturers and other sources. The BAH data also differentiates between commercial and residential equipment.

Virtually no residential lawn and garden equipment is required to be registered at the state level. However, there are a number of other trade association surveys available, including the Outdoor Power Equipment Institute (OPEI) and the Portable Power Equipment Manufacturing Assn. (PPEMA). These groups have surveyed both manufacturers and consumers and have useful data at the engine size/type level, although consumer data on engine specification should be treated with caution. There are likely other studies available that have directly surveyed the users of lawn and garden equipment, given the size and importance of the market. Depending on the survey data available, a model could be constructed that relates lawn mower population to the number of homes, apartments, and office buildings, the temperature and rainfall, and the rate of hired-out lawn care vs. occupant-provided care. A similar model could be constructed to estimate the rate of equipment use. Most of the data necessary for making annual estimates with such a model (numbers of buildings, weather) would be readily available.

This is a difficult category for which to develop activity-based measures, since the output of lawn and garden equipment is difficult to measure.

3.6 FARM EQUIPMENT

There are many different types of farm (agricultural) equipment in use, and some of these are designed for specific applications. However, the vast majority of farm equipment belong to the agricultural tractor and tiller categories.

In addition to PSR, the Equipment Manufacturers Institute (EMI) produces sales data on a national basis. EMI complements their own survey data with data from the U.S. Agriculture Census, which collects data on populations of some types of equipment. The Agricultural Census is taken every 5 years (years ending in 2 and 7; USDA, 1997). There is some concern regarding the fact that in the 1987 census, equipment population counts were much higher than those from PSR or EMI, which may be due to counting equipment no longer in service. Pechan (1997) has made a comparison between PSR's estimates for 1990 and the 1992 Census survey, finding that the 1992 Census data are also considerably higher than the PSR estimates.

Although some farm equipment is registered at the state level, much nonroad farm equipment is not required to be registered. Farm equipment that could be driven on roads needs to be registered in most states. Some states define special cases where farm equipment does not need to be registered. For instance, Washington does not require sprayers or fertilizers to be registered if they are used specifically for agricultural operations. Other farm vehicles, such as tractors and trailers used for animal herding, do not have to be registered if they are operated on roads no further than a fifteen mile radius of the farm.

In its ARB study, EEA tested many combinations of use-indicators for farm equipment, some of which were direct measures of output. The use of aggregate employment data in the farm sector was found to be an inadequate correlate for the presence of specific farm equipment. However, there are a number of types of equipment that should be measurable based on their direct output. These include harvesters, sprayers, and tillers. In addition, Sierra Research has done a detailed bottom-up study of farm equipment in California (Sierra, 1993). They surveyed crop production

in the San Joaquin valley and estimated the required number and type of equipment based on crop output, hourly usage of each equipment type on different crops, and average load factors.

Overall there is a variety of data available for characterizing engine populations in this category, and it appears that through a combination of sales data, census data, and bottom-up survey work, engine characteristics can be adequately characterized.

3.7 LIGHT COMMERCIAL EQUIPMENT

Under EEA's classification system, the light commercial category includes small (mobile) equipment that are generally used in light manufacturing, and various wholesaling and retailing activities, namely generator sets, pumps, air compressors, gas compressors, welding machines, and pressure washers. This is perhaps the most difficult category in which to develop good data collection approaches, due to the wide variety of applications for most of the equipment types in the category. The sales-based scrappage estimation approaches have proven especially problematic, since they are unable to properly take into account the wide variations in equipment function and usage pattern. As a result, scrappage rates in this category are still poorly understood.

Booz-Allen has estimated the overall population of commercial equipment for California as part of its utility and lawn and garden equipment study, but it did not break out commercial equipment by type, and it did not estimate the population of diesel commercial equipment separately from other diesel equipment under 40 horsepower. Most of the equipment in this category is not required to be registered by most states.

The wide variety of equipment applications makes it difficult to rely on small-scale user-surveys to gain data on populations or other characteristics, since there are so many different users and user types; it also makes developing an activity-based approach difficult. For example, although the number of generator sets could theoretically be estimated by knowing their electricity output in different applications, this data would itself be difficult to obtain in any kind of systematic or

reliable fashion. This is one category which may require a fairly large, comprehensive survey in order to develop reliable population estimates.

3.8 LOGGING

The logging category includes both small equipment (e.g. chainsaws and shredders over 5 hp) and larger equipment such as feller/bunchers and skidders.

Although no detailed analysis of the existing sales data for logging (by PSR and others) has been conducted, these data appear likely to provide a fairly accurate set of estimates of equipment population and other characteristics. This is due to the fact that there is a small number of users and a narrow range of applications for most logging equipment, resulting in relatively uniform use patterns and scrappage rates.

Most nonroad logging equipment is not required to be registered in any states. However, this category may lend itself fairly well to using an activity-based approach to estimating equipment population. Estimates of harvested timber correlate well with the amount of equipment needed to produce it, as long as the different types of logging methods used are taken into account. Helicopter and cable logging have very different equipment requirements than traditional logging practices, and lumber harvest data would need to be divided into the percentage using these different techniques in order to obtain reasonable estimates. Since logging is concentrated in a few areas and practices (for a given logging technique) are consistent, a relatively small sample of data should be sufficient to characterize this sector. Such an approach would provide a useful complement to the existing sales/scrappage data

3.9 AIRPORT GROUND SUPPORT EQUIPMENT

Ground support equipment (GSE) are found at all commercial airports, and over 20 different types of GSE have been identified. These include a wide variety of equipment that services commercial aircraft while unloading and loading passengers and freight at an airport. However, there is little population data available for the class as a whole, even from PSR, and practically

none for the individual equipment types by horsepower rating.

Further, ground support equipment is generally not required to be registered by most states. As a result, it appears that a user-survey or activity-based approach may be necessary to obtain reasonable estimates of equipment population in this category. Fortunately, it appears that such approaches yield very good estimates. EEA (1995) conducted a study of the relationships between airplane take-offs / landings and the number and types of different ground support equipment for commercial airliners in California and found very high correlations, as long as the type of aircraft is taken into account (narrow v. wide body). This could be called an activity-based approach, since the output of ground service equipment can be argued to be the numbers of flights assisted. In any case, once a relationship is established between each type of equipment and number of take-offs/landings, data on regional and national flight frequencies can be used to estimate the population of GSE equipment.

3.10 PLEASURE CRAFT

The category of Pleasure craft, or recreational marine vessels, reflects a wide variety of equipment specifications (2 and 4 stroke gasoline and diesel engine boats with a wide range of power output, as well as jet ski - type equipment). Fortunately, states require registration of virutally all engine-equiped pleasure craft. Further, most if not all of states' data on populations is reported annually to the U.S. Coast guard. These reports are compiled in *Report of Certificates of Number Issued to Boats* (USCG, annual), which profiles registered boats by length class and propulsion type.

Most states do not tabulate vessel registration by county, and some states count boats and not engines. Therefore, when using such data, a disaggregation technique must be used to obtain a count of engines. EEA performed such a disaggregation for ARB (EEA, 1995) which involved contacting manufacturers to obtain the expected number and type of engines by length of boat and propulsion system.

Possible sources of data to estimate engine counts at a regional or even county level is the *National Estuarine Inventory Data Atlas* (NOAA, 1988), which provides data miles of public beach, and *Census's Area Measurements Reports* (USCB, 1970), which provides data on inland water-covered surface area.

3.11 TRANSPORT REFRIGERATION UNITS

Transport refrigeration units (TRUs) are gasoline and diesel powered cooling units that are used to preserve produce, meat, dairy products, and other perishables during transport to market. TRUs are found on refrigerated trucks and trailers, and it is reasonable to expect that TRUs use the same fuel as the truck or truck tractor engine.

Most states require reporting of refrigeration on trucks and commercial trailers. However, the registration data does not necessarily provide the characteristics of the units (such as size and fuel type), and so other methods may be necessary for estimating these characteristics. Since it can be assumed that refrigeration units use the same type of fuel as their vehicle, fuel type can be estimated by estimating the share or refrigeration trucks using different fuel.

TRUs are also used extensively on railroad boxcars, but currently no population data for train mounted TRUs has been found other than PSR's. However, contacts with industrial railroad corporations could likely be used to develop such data.

4. CONCLUSIONS AND RECOMMENDATIONS

This report has outlined the four primary methodologies for collecting data to estimate the population of nonroad vehicles, and has discussed specific methodological issues for each of 11 major engine categories. None of the methodologies emerges as an overall "winner" since all have strengths and weaknesses and are applicable in different situations, depending on the type of equipment and users in each category, and the type of data available in each.

In virtually all the categories, it appears that a combination of two or more of the approaches will be necessary to obtain data that is complete and reasonably accurate. A second advantage of using multiple approaches in each category is that they can serve as cross-checks on each other. In cases where the data from two different approaches appears very different, the need for additional investigation becomes clear.

There appears to be favorable data availability in most categories for undertaking a new database development effort. In a few categories, such as logging and truck refrigeration units, the existing (sales/scrappage) data appears to be quite adequate, although it could be augmented with other data if deemed necessary. The light commercial equipment category has perhaps the least scope for developing reliable data with the four approaches outlined. Due to the highly diverse nature of equipment use in this category, it would probably need a new large-scale, comprehensive user survey in order to obtain reliable equipment population and usage data at disaggregate and aggregate levels.

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TABLE OF CONTENTS

LIST OF TABLES

REPORT TITLE:	Methodologies for Estimating the Population of Nonroad Engines
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ABSTRACT:
This report outlines four methodologies for collecting data to estimate the population of nonroad vehicles, and discusses specific methodological issues for each of 11 major engine categories. The four methodology types include production/sales/scrappage data, generally from manufacturers; registration data, generally from states; user-survey data; and activity data, which generally relates equipment population to its output, without the need for survey data. None of the methodologies emerges as an overall "winner" since all have strengths and weaknesses and are applicable in different situations, depending on the type of equipment and users in each category, and the type of data available. For most categories, a combination of two or more methodologies should be able to provide data that is fairly complete and reasonably accurate.

KEY WORKS/DESCRIPTORS: Mobile source, automotive technology, emission modeling, nonroad vehicle.