Attachment 1

OFFROAD MODEL

1. Introduction

Other Mobile Sources include 14 categories of emissions sources such as: off-road recreational vehicles, commercial/industrial mobile equipment, farm and construction equipment, aircraft, trains, ships, commercial boats, and recreational boats. Estimating the emissions from these categories is primarily the responsibility of the ARB, but some categories are estimated by the districts, such as emissions from aircraft and ships. The 1995 emissions from Other Mobile Sources remains unchanged from the previous inventory, however, staff are in the process of developing a new, off-road emission inventory model called OFFROAD. Staff is presenting in this Section the structure and algorithms for revising and improving the emission inventory of other mobile sources using OFFROAD. Staff is not seeking Board approval of an updated inventory at this time, rather staff seeks to inform the Board of efforts underway to improve the inventory in this area. Upon completion of the model, staff will present the revised inventory to the Board under the SB 2174 process and seek the Board's approval prior to the use of the revised inventory in any regulatory process.

The OFFROAD model will represent a vast improvement over the current model because it has many modeling capabilities not available in the current model. The new model will cover a variety of equipment types categorized by nine horsepower groups under 14 distinct categories, not all of which are represented in the current model. OFFROAD will have the capability to estimate exhaust, starting, and evaporative emissions under differing spatial and temporal conditions. OFFROAD will also allow for the estimation of the effects of various emission control strategies through the use of a "control factor module" that allows the user to make changes to population, activity, and emissions factors.

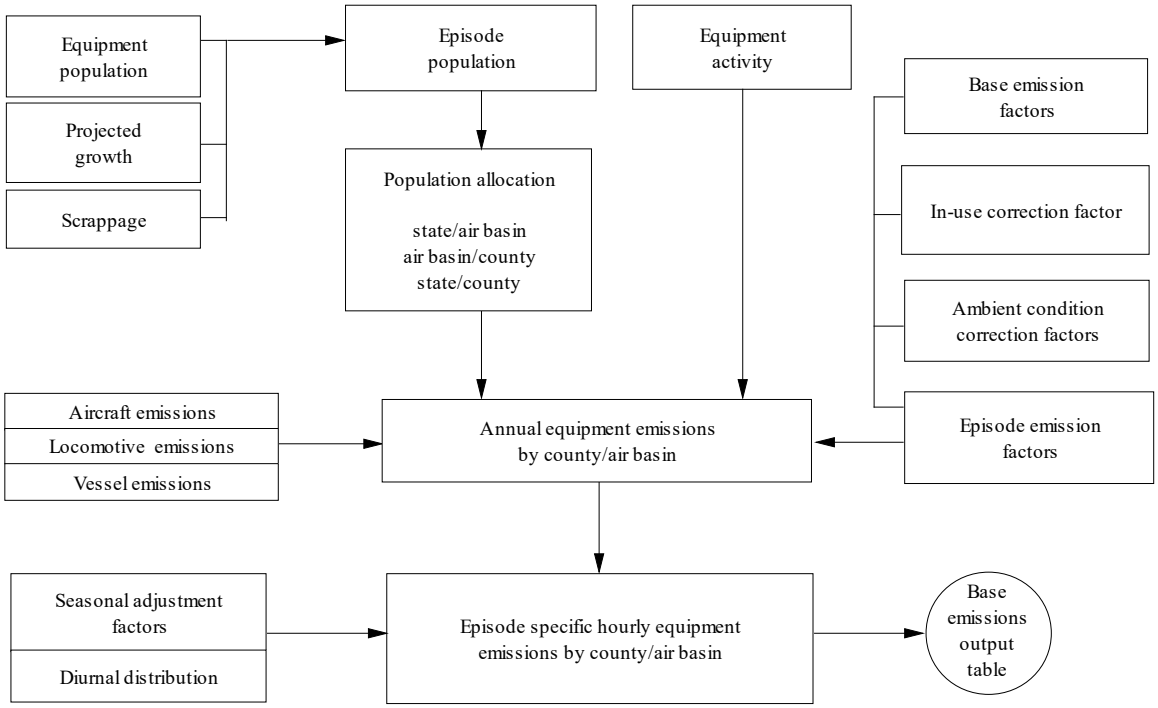
2. The Off-road Model (OFFROAD)

a. Program Structure

The primary emphasis in designing OFFROAD was to provide an overall structure to incorporate the various aspects of off-road source emissions modeling, such as the effects of various adopted and proposed regulations, technology types, and seasonal conditions on emissions. This overall structure is illustrated in Figure 2. Fundamentally, the population, activity, and emission factors are still combined to yield the annual equipment emissions by county, air basin, or state. However, spatial and temporal features have been incorporated, making the new model more accurate in its depiction of emissions.

FIGURE 2

Flowchart of Overall Program Structure of OFFROAD



OFFROAD consists of four main modules: population, activity, emissions, and control factor. The 1990 base year equipment population is adjusted for growth and scrappage, producing model-year specific population distributions for specified calendar years from 1970 through 2020. The statewide population is allocated to each geographic region. The base emission factors are corrected for in-use and ambient conditions. The annual equipment emissions are adjusted for seasonal and diurnal factors producing the base emissions output.

The output tables of OFFROAD have a standard layout that displays activity information and emission data. The activity table includes information regarding the population, use hours per day, starts per day, and gallons of fuel consumed per day. The emission estimates are reported for three processes: exhaust, evaporative, and starts. While the output tables aggregate the information by equipment category for the state, the model can also produce more distinct information such as emission estimates of certain equipment type within a county.

b. Methodology

OFFROAD generates an emission inventory for six pollutants by equipment type, accounting for age and for a given scenario year. The basic equation for OFFROAD is:

$$P_{i,y} = \sum_{i} Pop_{i,v} * EF_{i,v} * Hrs_{i,v}$$

where

P = pollutant (HC, CO, NO_X, PM, CO_2, SO_2)
Pop = equipment population
EF = emission factor
Hrs = annual average use hours
y = scenario year (1970-2020)
I = equipment type
v = vintage (age of equipment)

1) Population Module

This module contains growth factors and scrappage curves that are used to derive an equipment-specific model year population distribution for specified calendar years from 1970 through 2020. The statewide equipment population was obtained through various industry and government agency sources and was divided at the air basin and county level using activity indicators that reflect their usage in those areas.

a) Categories and Equipment Types

There are 95 equipment types aggregated into 14 categories as listed in Table 7. In general, the 14 categories include all equipment types used for a similar purpose or industry. The equipment types are further divided by fuel, engine type, horsepower group, and preempted or non-preempted status to better characterize emissions, adopted and proposed control strategies, and use. According to the Federal Clean Air Act, emissions from certain equipment types can only be regulated by the U. S. EPA and are, therefore, preempted from State regualtions. Table 8 shows the fuel type, engine type, and horsepower groups included in the model.

b) Growth and Scrappage

The growth factors are based on socioeconomic indicators such as housing units and manufacturing employment by category, by county, and with respect to the 1990 base year sales. Scrappage is a static function of equipment age and use which varies by engine type and horsepower group. For all equipment types, except lawn and garden equipment and recreational vehicles, the equipment useful life equals the life of the engine represented in years. The number of model years accounted for are twice the equipment useful life. The maximum useful life modeled is 16 years which translates to 32 model years in a given calendar year. Therefore, the baseline model year distribution is also dependent on the useful life of the equipment. Due to the lack of any other information, the 1990 model year distribution is used for the 1970-1989 calendar years. This distribution is accurate for mature markets such as construction and farm equipment, but may not depict rapidly

growing markets like hand held lawn and garden equipment in the 1980s.

TABLE 7
List of Equipment by Category

a. Lawn and Garden Equipment
1. Trimmers/Edgers/Brush cutters
2. Lawn mowers
3. Leaf blowers/vacuums
4. Rear engine riding mowers
5. Front mowers
6. Chainsaws < 5 HP
7. Shredders < 5 HP
8. Tillers < 5 HP
9. Lawn and garden tractors
10. Wood splitters
11. Snow blowers
12. Chippers/Stump grinders
13. Commercial turf equipment
14. Other lawn and garden equipment

b. Light Commercial Equipment (0-50 HP)
1. Generator sets
2. Pumps
3. Air compressors
4. Gasoline compressors
5. Welding machines
6. Pressure washers

c. Recreational Equipment
1. All Terrain Vehicles (3 & 4 wheel vehicles)
2. Off-road motorcycles
3. Golf carts
4. Specialty vehicles/carts
5. Snowmobiles

d. Industrial Equipment
1. Aerial lifts
2. Forklifts
3. Sweepers
4. Other general industrial equipment
   - Abrasive blasting equipment
   - Industrial blowers/vacuums
   - Marine/industrial winches and hoists
   - Multipurpose tool carriers
   - Other misc. industrial equipment (catch all)

* (Industrial continues next column)

d. Industrial Equipment (cont)
5. Other material handling equipment
   - Conveyors
   - Other misc. material handling (catch all)
   - Industrial tractors

e. Construction and Mining Equipment
1. Asphalt pavers
2. Tampers/Rammers
3. Plate compactors
4. Concrete pavers
5. Rollers
6. Scrapers
7. Paving equipment
8. Surfacing equipment
9. Signal boards
10. Trenchers
11. Bore/Drill rigs
12. Excavators
13. Concrete/Industrial saws
14. Cement and Mortar mixers
15. Cranes
16. Graders
17. Off-Highway trucks
18. Crushers/Processing equipment
19. Rough terrain forklifts
20. Rubber tire loaders
21. Rubber tire dozers
22. Tractor/Loaders/Backhoes
23. Crawler tractors
24. Skid steer loaders
25. Off-Highway tractors
26. Dumpers/Tenders
27. Other construction equipment

f. Agricultural Equipment
1. 2-Wheel tractors
2. Agricultural tractors
3. Agricultural mowers
4. Combines
5. Sprayers
6. Balers
7. Tillers > 5 HP
8. Swathers
9. Hydro power units
10. Other agriculture equipment

g. Logging Equipment
   1. Chain saws > 5 HP
   2. Shredders > 5 HP
   3. Log skidders
   4. Fellers/Bunchers

h. Airport Ground Support Equipment
   1. Airplane tow tractors
   2. Baggage/Cargo tow tractors
   3. Ground power units
   4. Start units
   5. Deicing units
   6. Load lifting and handling
   7. Service utility carts
   8. Pressure washers

i. Pleasure Craft
   1. Inboard powerboats <250 HP
   2. Outboard powerboats
   3. Sterndrive powerboats
   4. Inboard sail-auxiliary
   5. Outboard sail-auxiliary

j. Commercial and Government Vessels
   1. Commercial inboard boats >250 HP
   2. Commercial in/outboard boats
   3. Commercial tug boats
   4. US Coasts Guard boats
   5. Seagoing vessels
      - Motorships
      - Steamships

k. Transport Refrigeration Units
   1. Small units < 25 HP
   2. Large units > 25 HP

l. Locomotive and Rail Operations
   1. Line haul operations
   2. Yard operations

m. Aircraft: Commercial, Military, and General Aviation
   1. Landing and Takeoff Operations (LTO)

n. Agricultural Aircraft
   1. Aircraft operations below 3,000 ft.

TABLE 8

Various Fuels, Engine Types, and Horsepower Groups Used in the OFFROAD Model

Fuel	Engine Type	Horsepower Groups
Gasoline	2-stroke	0-2, 2-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750
Gasoline and CNG/LPG	4-stroke	0-5, 5-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750
Diesel		0-15, 15-25, 25-50, 50-120, 120-175, 175-250, 250-500, 500-750, 750+

2) Activity Module

This module contains information such as annual average use hours, load factor, brake-specific fuel consumption, and starts per year for each equipment type by fuel, engine type, and horsepower group. The activity information reflects seasonal and temporal conditions, as described below.

a) Seasonal and Temporal Parameters

The equipment types from diverse industries such as agriculture, construction, and recreation, are included in the OFFROAD model, and their usage patterns are not identical. These seasonal and temporal influences are resolved by monthly, weekly, and daily use patterns for each type of equipment.

Most of the categories (construction, industrial, light commercial, and airport ground service equipment) have uniform activity throughout the year. Recreational vehicles, lawn and garden, and farm equipment display various seasonal use patterns. Equipment types within a category have the same monthly use pattern except for snowmobiles, snow blowers, chain saws (<=5 HP), and tillers. Although most lawn and garden equipment undergo peak use during the summer, chain saw and tiller use peaks during the winter and spring, respectively. In order to be consistent with the seasonal attributes of reformulated fuels, summertime is defined as May through October while wintertime is considered November through April.

There are three types of weekly use patterns: average, weekday, and weekend. The average, or no peak, use pattern is exhibited by airport ground service and transport refrigeration units. Construction, industrial, and farm display mostly weekday, some Saturday, and less Sunday activity. Instances where weekend use is greater than weekday use would be recreational vehicles and lawn and garden equipment.

The daily activity is distributed into eight 3-hour periods (e.g., 3:00, 6:00, 9:00, etc.). The bulk of the activity occurs between 9 a.m. and 6 p.m., which is the daytime use pattern. Airport ground service equipment is utilized whenever the airport is open, and include servicing of cargo and regular maintenance. Therefore, the use pattern is primarily during business hours with some off-peak activity. In contrast, transport refrigeration units are operated more evenly throughout the entire day because perishables are shipped at night for morning delivery.

3) Emissions Module

This module contains emission factors by model year for HC, CO, NO_X, PM, CO_2, and SO_X emissions. HC emissions are modeled for three types of processes: exhaust, evaporative, and start. The emission factors are a function of new engine emissions expressed in gram per brake horsepower hour (g/bhp-hr), and deterioration rates, expressed as a rate of increase in emissions per useful life consumed.

Since several equipment types use the same engine type, the exhaust emission factors are engine-specific. Equipment-specific emission rates

are obtained by adjusting the appropriate engine emission rate by the duty cycle of the equipment. The model-year-specific emission rates reflect the effect of reformulated fuels and stringent emission standards for regulations adopted by the ARB. Due to the lack of emission data, the deterioration rates are generally based on on-road emissions data[1], except for gasoline engines less than 25 hp which were obtained from emission test results provided by engine manufacturers.

Evaporative emission factors account for refueling, diurnal, hot soak, running, and resting losses. Evaporative emissions are equipment-specific and dependent on fuel systems. Evaporative emissions are only necessary for gasoline equipment since diesel fuel has low volatility and LPG systems are pressure sealed. Due to the lack of data, placeholders are used for hot soak, running, and resting losses. This module also contains correction factors for temperature, reformulated fuels, and volatility. Although no data are currently available, the model is equipped to provide emissions due to start up procedures.

4) Control Factor Module

OFFROAD can also account for regulatory control scenarios as illustrated in Figure 3. The control factor file is a multiplicative adjustment indicated by polluting source, pollutant, beginning year, and ending year. Control factors can be applied to emission rates, activity, and populations. An example of a population control strategy would be to retrofit a particular model year group with an emission control device. Limiting use during peak hours would be an example of an activity control scenario. When this feature is employed, the output consists of both baseline and controlled scenarios.

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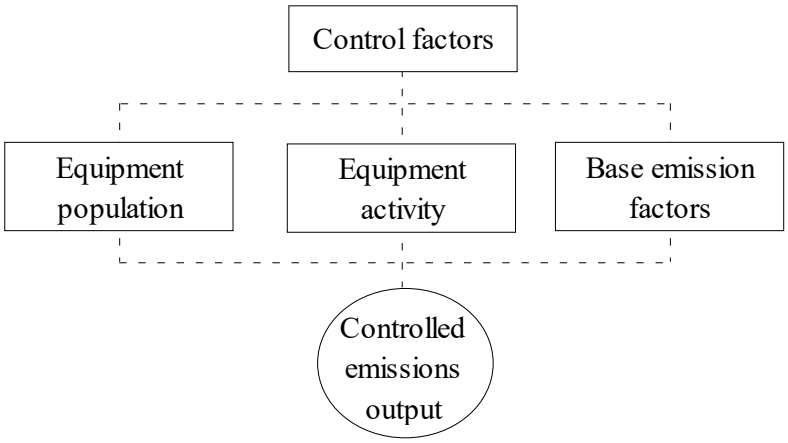
[1] **California Air Resources Board, "Technical Support Document, Derivation of the EMFAC7E Emission and Correction Factors for On-Road Motor Vehicles," July 1990.**

FIGURE 3

Controlled Emissions Output



3. Future Improvements

Staff will present in 1998 the OFFROAD model to the Board for approval. The modular structure of OFFROAD will allow for the evaluation of potential control strategies while the enhanced methodology better characterizes emissions and use.

The new model will aid staff in more accurately estimating emissions from other mobile sources, in identifying categories which emit more, and in quantifying the benefit due to proposed regulations. OFFROAD is merely a first step where emphasis is given to program structure with placeholders if accompanying data are not available. In the future, staff will direct its effort in the further development of aircraft, locomotives, and marine vessels models so that they can be incorporated into OFFROAD. Further emphasis will also be given to obtaining test data for exhaust and evaporative emissions and verifying various activity and emission control information.