Appendix G: Ground Access Vehicles Emission Methodology

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Appendix G: Ground Access Vehicles Emission Methodology

G1. METHODOLOGY

Ground access vehicles (GAVs) produce exhaust, evaporative and idling emissions. The activity of GAVs is separated into two categories: roadway and parking lot. In general, roadway activity consists of the segment of GAV operations that occur on roadways (both on- and off-airport). Parking lot activity refers to the segment of GAV operations that occur in airport and air base parking lots. Parking lot activity does not include vehicles that enter parking lots but are not customers and do not stop (e.g., parking lot and rental car shuttle buses).

The general guidance for calculating emissions from on-road or highway vehicles is provided in EPA's *Procedures for Emission Inventory Preparation*, Volume IV, Chapter 3 (Reference 81). The EPA specifies that the MOBILE and PART5 motor vehicle emissions models be used to develop highway vehicle emission indices and emission inventories. The user guides for EPA motor vehicle emission models (References 72 and 88) also provide additional guidance. Many factors influence motor vehicle emissions including vehicle age, vehicle travel speed and distance, vehicle operating mode, fuel characteristics, control programs, and local ambient conditions. The influence of these factors is constantly changing as technology continues to evolve.

Due to the complex process of determining emission indices, simplified descriptions of the exhaust, evaporative-related, and idling emissions calculation methodologies are provided below. It is possible to estimate both exhaust and evaporative-related emissions using just the exhaust calculation methodology if "combined" emission indices (i.e., combined exhaust and evaporative emission indices) are used. An emission estimate based on combined emission indices will not be as accurate since default assumptions are used in the emission index development. The EPA's *Procedures for Emission Inventory Preparation* should be consulted for a more detailed description of the methodologies. For air bases, the USAF document *Calculation Methods for Criteria Air Pollutant Emission Inventories* (Reference 23) also should be consulted for further guidance.

G1.1 Emissions

G1.1.1 Exhaust Emissions

The exhaust emission calculation methodology can be simply described as multiplying the pollutant emission index for a desired average speed and the designated study year against the distance traveled against the volume of traffic. Emissions must be calculated separately for different years of interest, since emission indices change by year. This calculation can be performed for each EPA vehicle category or for all vehicles using composite inputs. This calculation can be used to determine emissions for any time period (e.g., day, week, month, year) by adjusting the number of trips. Equation G-1 shows the simplified description of the exhaust emissions calculation methodology. As mentioned above, motor vehicle emissions vary based on local ambient conditions (e.g., CO is high in colder weather). If the time period of interest includes both warm and cold weather seasons, the emissions should be calculated for each season to obtain accurate emission estimates.

$$E_i = EI_{isy} \times D \times T \times CF$$

Equation G-1: GAV Exhaust Emissions

Where:	E_i	-	emissions of pollutant i, in pounds, produced by the vehicles of interest in the given time period
	EI_{isy}	-	emission index, in grams per mile, for pollutant i and a specified speed s and year y
	D	-	distance traveled, in miles, by the vehicles of interest
	T	-	number of vehicle trips of interest
	i	-	pollutant type (e.g., HC)
	s	-	average vehicle speed, in miles per hour
	y	-	designated study year
	CF	-	0.0022046 unit conversion factor from grams to pounds
	Note:		Distance traveled (D) times number of vehicle trips (T) also is known as vehicle miles traveled (VMT)

G1.1.2 Evaporative-Related Emissions

In addition to exhaust emissions from GAV operations, there also are evaporative-related emissions of hydrocarbon. There are six types of evaporative-related emissions calculated for GAVs: crankcase, refueling losses, running losses, hot soak, diurnal, and resting losses. The six types of evaporative-related emissions can be divided into two categories: operating or resting. Operating emissions occur while a vehicle is operating, and are applicable to every trip. Operating emissions result from both roadway and parking lot vehicle activity. Resting emissions only occur when the vehicle is at rest, and are applicable to vehicle trips including a vehicle stop. The six types of evaporative-related emissions are listed in the table below by category. Each type of evaporative-related emissions is discussed in more detail below.

Table G-1 : Types Of Evaporative-Related Emissions

Operating Emissions[1]	Resting Emissions[2]
Crankcase	Hot Soak
Refueling Losses	Diurnal
Running Losses	Resting Losses

- **Crankcase -** Crankcase emissions occur while a vehicle is operating and, therefore, are dependent on vehicle miles traveled. Crankcase emissions result from fuel displacement.
- **Refueling Loss -** Refueling loss emissions are the spillage and displacement of fuel vapor from the vehicle fuel tank to the atmosphere when gasoline-fueled vehicles are refueled. Stage II and on-board vapor recovery systems are being implemented to control refueling losses. Refueling loss emissions usually are calculated using the gallons of fuel dispensed. For ground access vehicles that operate and refuel only on the airport, such as fleet vehicles (e.g., parking lot shuttle buses, rental car shuttle buses, airport fleet

[1] Operating emissions occur for every vehicle trip (i.e., result from both roadway and parking lot vehicle activity).

[2] Resting emissions only occur for vehicle trips including a vehicle stop (i.e., only result from parking lot vehicle activity including a park).

vehicles), all fuel consumed is attributable to the airport and the fleet operator typically knows the amount of fuel dispensed and consumed. For other ground access vehicles that also are operated for purposes other than accessing the airport (e.g., passenger vehicles, employee vehicles), attributing the refueling losses of all gasoline in the vehicle tank would overestimate those airport-related emissions. To more accurately estimate refueling losses of those vehicles that also operate for non-airport purposes, emissions are estimated using only the gallons of fuel used to access the airport (as discussed in section G2. Data Sources, below). Refueling emissions also can be calculated based on vehicle miles traveled, but will be less accurate due to inherent assumptions regarding inputs.

- **Running Loss -** Running loss emissions are similar to hot soak emissions; both are heat-related, evaporative emissions that occur while the vehicle is being operated. Running loss emissions are negligible at first, but increase significantly as trip duration lengthens.
- **Hot Soak -** Hot soak emissions occur at the end of each vehicle trip as elevated operation temperatures lead to continued evaporation after a vehicle has been parked (e.g., in an airport parking lot).
- **Diurnal -** Diurnal emissions also occur while the vehicle is parked during periods of rising ambient temperatures. Total diurnal emissions are calculated using two equations: partial/full-day and multiple-day. The partial/full-day equation calculates diurnal emissions from vehicles that are at rest for a day or less (e.g., in a short-term parking lot, employee parking lot, or the first day of a multiple-day parking lot). The multiple-day equation calculates diurnal emission from vehicles that are at rest for multiple days (e.g., in a long-term parking lot). For multiple-day parking lots, emissions from the first day of rest are calculated using the partial/full-day equation. Emissions from the remaining days of rest (i.e., the second day of rest and longer) are calculated using the multiple-day equation.
- **Resting Loss -** Resting loss emissions occur while the vehicle is at rest (e.g., in a parking lot) and result from the permeability of fuel system components. Resting emissions are calculated using the number of hours the vehicles are at rest. Resting evaporative emissions also can be calculated based on vehicle miles traveled, but will be less accurate due to inherent assumptions regarding inputs.

Simplified procedures for calculating these evaporative-related emissions from GAV are presented below. These calculations can be used to determine emissions for any time period of a year (e.g., day, week, month, year) by adjusting the applicable number of trips or miles traveled. As mentioned above, motor vehicle emissions vary based on local ambient conditions (e.g., CO is high in colder weather). If the time period of interest includes both warm and cold weather seasons, the emissions should be calculated for each season to obtain an accurate emissions estimate. In addition, emissions must be calculated separately for different years of interest, since emission indices change by year.

These procedures do not illustrate how to determine the emission indices, which are based on multiple other inputs. See the MOBILE user's guide (Reference 88) for more information on the calculation of emission indices. Similar calculation methodologies are grouped together below, although different emission indices are needed for each type of calculation.

$$E_T = EI \times D \times T \times CF$$

Equation G-2: Crankcase or Running Losses

Where:
- E_T - total hydrocarbon emissions, in pounds, resulting from crankcase or running losses of the vehicle of interest in the given time period
- EI - emission index, in grams per mile
- D - distance traveled, in miles
- T - number of vehicle trips
- CF - 0.00220446 unit conversion factor from grams to pounds

$$E_T = EI_G \times G \times CF$$
or
$$E_T = EI_D \times D \times T \times CF$$

Equation G-3: Refueling Losses

Where:
- E_T - total hydrocarbon emissions, in pounds, resulting from refueling losses of the vehicles of interest in the given time period
- EI_G - emission index, in grams per gallon of fuel dispensed
- EI_D - emission index, in grams per mile
- G - gallons of fuel dispensed (that are used for airport access)
- D - distance traveled, in miles
- T - number of vehicle trips
- CF - 0.00220446 unit conversion factor from grams to pounds

$$E_T = EI \times T \times CF$$

Equation G-4: Hot Soak

Where:
- E_T - total hydrocarbon emissions, in pounds, resulting from hot soak of the vehicles of interest in the given time period
- EI - emission index, in grams per trip
- T - number of vehicle trips for which a soak period exists (i.e., vehicle trips with a stop, such as in a parking lot)
- CF - 0.0022046 unit conversion factor from grams to pounds

$$E_T = EI \times N \times T \times CF$$

Equation G-5: Diurnal (Partial/Full-Day or Multiple-Day of Rest)

Where:
- E_T - total hydrocarbon emissions, in pounds, resulting from diurnal losses of the vehicles of interest in the given time period
- EI - emission index, in grams per vehicle day
- N - number of days of rest (for partial/full-day calculations, number of days equals 1)
- T - number of vehicle trips (i.e., vehicles) for which a diurnal loss period exists (i.e., vehicle trips with a stop, such as in a parking lot)
- CF - 0.0022046 unit conversion factor from grams to pounds

$$E_T = EI_R \times R \times H \times T \times CF$$
or
$$E_T = EI_D \times D \times T \times CF$$

Equation G-6: Resting Losses

Where:

E_T	-	total hydrocarbon emissions, in pounds, resulting from resting losses of the vehicles of interest in the given time period
EI_R	-	emission index, in grams per hour of rest
EI_D	-	emission index, in grams per mile
R	-	days of rest
H	-	hours of rest per day to convert units from day to hours (assumed to be 24 hours/day)
D	-	distance traveled, in miles
T	-	number of vehicle trips for which a resting period exists (i.e., vehicle trips with a stop, such as in a parking lot)
CF	-	0.0022046 unit conversion factor from grams to pounds

G1.1.3 Idling Emissions

Idling emissions are calculated for vehicles with an extended idle time. Only extended idle times are considered, since a normal amount of idle time already is incorporated into the exhaust emission indices. The types of GAV that may have extended idle times at airports are passenger vehicles and taxicabs. At air bases, GAV that may have extended idle times are base transportation vehicles, such as buses or vans. Although the methodology and inputs are generally the same for calculating idling emissions as for exhaust emissions, there are a few minor modifications. These modifications are discussed in EPA's MOBILE5 Information Sheet #2: *Estimating Idle Emission Factors Using MOBILE5* (Reference 75).

G1.1.4 Activity Categories

As mentioned in the above methodology, when calculating emissions from GAVs, vehicle activity is divided into two categories: roadway and parking lot. The EPA procedures described above are applied to both roadway and parking lot activity. Important issues and considerations when applying the above procedures to roadways and parking lots are discussed below.

G1.1.4.1 Roadways

The above methodologies are used to determine GAV emissions from all vehicle roadway trips. Roadway trips are considered to have no significant stops that involve parking (e.g., in a parking lot). As a result, no resting evaporating emissions (e.g., hot soak, diurnal, and resting losses) are calculated for the roadway emission inventory. For vehicles accessing a parking lot as a customer to park (e.g., passenger vehicles, employee vehicles), any emissions generated from the parking lot travel should be included in the parking lot emissions inventory, discussed below. Conversely, for vehicles entering the parking lot but not parking (e.g., parking lot shuttle buses, rental car shuttle buses), parking lot travel is included in the roadway emissions inventory. It is important to apply this distinction consistently when calculating emissions so that emissions are not double counted.

For more accurate results, the procedures should be performed for each roadway segment and summed to determine total emissions. Often this is not an option due to the lack of detailed data inputs required. The alternative option is to perform the procedures for the entire roadway trip using an average trip length.

The applicable methodologies above should be applied separately for each type of private and fleet GAV accessing an airport or air base, since inputs (e.g., average distance traveled) vary by GAV type. GAV types at airports include passenger vehicles, employee vehicles, rental cars, shuttles (e.g., rental car, parking lot, hotel), buses, taxicabs, and trucks. At air bases, GAV types include privately-owned vehicles (POVs), government-owned vehicles (GOVs), and all other vehicles that are not military-registered.

G1.1.4.2 Parking Lots

The above methodologies also are used to determine GAV emissions from all vehicle parking lot trips. Each parking lot trip is considered to have a significant stop that involves parking (e.g., in a parking lot). As a result, unlike the roadway emissions inventory, resting evaporating emissions (i.e., hot soak, diurnal, and resting losses) are calculated for the parking lot emissions inventory. As mentioned above, the parking lot methodology only applies to vehicles accessing a parking lot as a customer to park (e.g., passenger vehicles, employee vehicles). It is important to apply this distinction consistently when calculating emissions so that emissions are not double counted.

For more accurate results, the procedures should be performed for each parking lot and summed to determine total emissions. Parking facilities can be categorized into three types: main terminal, employee, and off-airport public and private parking garages/lots. All parking lots should be considered, including airport rental car parking lots and main taxicab and limousine staging lots. Garage/lot characteristics such as short-term (i.e., two hours or less stay) or long-term parking patterns also should be considered for evaporative and vehicle cold and hot start (discussed below) purposes. Often the detailed data inputs required to perform the calculations on this level are available. For example, the amount of activity entering a parking lot is usually tracked for revenue purposes. If detailed data inputs are not available, the alternative option is to calculate parking lot emissions for all parking lots using average data inputs, although this will result in a less accurate emissions estimate.

G2. DATA SOURCES

The GAV emission calculation requires many inputs. The EPA's *Procedures for Emission Inventory Preparation*, Volume IV, Chapter 3 contains recommendations and suggestions with regard to determining appropriate inputs, although in many cases there is no single correct recommendation that is best for all situations. The EPA procedures document should be consulted for a more detailed description of the numerous data inputs and sources. For air bases, the USAF document *Calculation Methods for Criteria Air Pollutant Emission Inventories* (Reference 23) also should be consulted for further guidance. A current traffic study for the airport or air base may already have determined many inputs to the emission calculation. The airport or the Civil Engineering (CE) Community Planning or Base Development section at an air base should be consulted in gathering the data. Unless otherwise noted, potential sources of the data inputs are the airport or air base operator, an airport or air base study (e.g., airport ground access study), a regional study (e.g., regional vehicle transportation study), and the MPO. Default values for some input data are built into the EPA's motor vehicle emissions models (i.e., *MOBILE5a* and *PART5*). Although the same general methodology and types of inputs are used to calculate the emissions from roadway and parking lot activity, the specific assumptions, data inputs, and default values are different, as discussed below. For many calculation inputs, detailed (e.g. average vehicle speed by roadway segment) or average (e.g., average vehicle speed over all roadway segments) data can be used. In each case, the detailed data inputs produce more accurate results. The following lists only a few of the many calculation inputs.

G2.1 Exhaust Emission Indices

There are HC, CO, NO_x, PM-10, and SO_2 exhaust emission indices applicable to GAVs. In addition, there are fugitive dust emission indices that represent reentrained road dust, which include exhaust emissions as well as brake-wear and tire-wear, applicable to GAVs. Due to a predominance of unleaded and diesel fueled vehicles, of which the lead content of the fuel is negligible, it is assumed that the lead emissions also are negligible. Vehicle emission indices are based on many inputs to the emissions calculation (e.g., cold/hot start percent, speed, study year) not referenced above in the simplified methodology. The EPA specifies that the MOBILE motor vehicle emissions model should be used to develop highway vehicle emission indices for HC, CO, and NO_x. The emission indices incorporate both moving and normal idling operational modes. The EPA specifies that the PART5 model should be used to develop highway vehicle emission indices for PM-10, SO_2, and fugitive dust. Some of the key emission index inputs are listed below.

G2.1.1 Cold/Hot Start Percent

The cold start percent refers to the percent of vehicle miles traveled while operating in "cold start" mode and not yet warmed-up. Any car that is turned off for more than 1 hour operates for a period of time while the vehicle is still cold. This period is typically defined as the first 8-10 minutes of vehicle travel. Conversely, the hot start percent is the percent of vehicle miles traveled in "hot start" mode, when a car is turned off for less than 1 hour. The percent of vehicle miles traveled in cold or hot mode affects emission indices. The cold or hot start occurs at the point of origin for roadways (e.g., a passenger's home) and in the parking lot when restarting the vehicle to exit.

G2.1.2 Speed

The rate of emissions is very sensitive to the vehicle speed. Average speeds must be determined separately for roadways and parking lots. An average speed for each roadway and parking lot results in a more accurate emission estimate.

G2.1.3 Year

The calendar year for which the emissions calculation is being performed defines which emission indices are to be calculated. There are different basic emission rates associated with each model year group, which are defined on the basis of applicable emission standards and emission control technologies. EPA's motor vehicle emissions models have the ability to model emission indices for the years 1960 through 2020.

G2.2 Evaporative-Related Emission Indices

EPA's motor vehicle emissions model *MOBILE5a* calculates GAV HC evaporative-related emission indices. Similar to exhaust emission indices, evaporative-related emission indices are based on many inputs to the emissions calculation (e.g., ambient temperature, fuel characteristics) not referenced above in the simplified methodologies.

G2.3 Vehicle Trips

The number of vehicle trips refers to *round trips*. For roadways, this is from the point of origin to an airport location and then on to the destination, which may be the same as the point of origin. A total number of vehicle roadway trips or total trips per roadway segment can be used depending on other inputs to the calculation. In parking lots a round trip is from the entrance of the parking lot to a parking space to the parking lot exit. As with roadways, the number of vehicle trips can be determined by individual parking lot or for all parking lots depending on other inputs to the calculation. Instead of using an average number of vehicles entering a parking lot, the average number of spaces filled for a parking lot can be used. Since not all vehicles accessing the airport enter a parking lot, the total number of trips input into the calculation is different for roadways and parking lots.

G2.4 Distance

Distance is the distance traveled by vehicles, in miles. For a more accurate emission estimate, the average distance is needed by EPA vehicle type and GAV type (e.g., passenger, employee). If detailed distance estimates are not available, an average for all vehicles can be used, although emission results will be less accurate. For roadways the distance is the average miles traveled from point of origin (e.g., an employee's home) to the airport or air base location (e.g., parking lot) to the point of destination (e.g., an employee's home). As discussed above, for vehicles stopping (e.g., parking in a parking lot), this distance does not include any miles traveled in a parking location. Conversely, for vehicles accessing a parking location but not stopping (e.g., a parking lot shuttle), this distance does include all miles traveled in the parking location. For parking lots, the distance for vehicles stopping in the parking location is the average miles traveled from the lot entrance to a parking space to the lot exit.

G2.5 Days of Rest

The days of rest refers to the number of days that a vehicle's engine is turned off (e.g., in an airport parking lot). For vehicles' trips that do not include a stop, the days of rest is 0.

G2.6 Fuel Dispensed

Using the amount of fuel dispensed in gallons is the EPA-recommended and most accurate method for determining refueling losses. EPA recommends determining the amount of fuel dispensed from total gasoline sales.

As discussed above, for ground access vehicles that only operate and refuel on the airport, such as fleet vehicles (e.g., parking lot shuttle buses, rental car shuttle buses, airport fleet vehicles), all fuel is consumed on the airport and the fleet operator typically knows the amount of fuel dispensed and consumed. For other ground access vehicles that also are operated for purposes other than accessing the airport (e.g., passenger vehicles, employee vehicles), attributing the refueling losses of all gasoline in the vehicle tank would overestimate those airport-related emissions. To more accurately estimate refueling losses of those vehicles that also operate for non-airport purposes, emissions are estimated using only the gallons of fuel used to access the airport. The gallons of fuel used to access the airport can be determined using the applicable average distance traveled (e.g., passenger average distance, employee average distance) and an average miles per gallon (mpg) estimate (e.g., 20 mpg).

G2.7 Age Distribution

The aging of highway vehicles causes deterioration in vehicle engines, vehicle exhaust systems, and catalytic devices, creating higher rates of exhaust emissions. The age distribution of the vehicles accessing an airport by GAV type (e.g., passenger vehicle, employee vehicle) and EPA vehicle type should be determined, especially for airports. The age distribution of airport GAVs is likely to vary from the general population, since flying is an indication of a degree of affluence. If an airport or air base GAV study or regional transportation study has not been conducted, an on-site vehicle survey may need to be conducted in order to collect this data. If site-specific data are not available, Federal Test Procedure (FTP) default values can be used, which are incorporated into the MOBILE model.

G2.8 Idle Time

At airports, vehicles (especially passenger vehicles) often idle for extended periods of time while dropping-off and picking-up passengers at the airport terminal. Although the vehicle emission indices incorporate both moving and *normal* idling operational modes, emissions due to *extended* idling are not included. Extended idling emissions are calculated using idle emission indices developed using the MOBILE model and the average idle time of vehicles. See EPA's MOBILE5 Information Sheet #2: *Estimating Idle Emission Factors Using MOBILE5* for more information.

G2.9 Ambient Temperature Range and Average

Both exhaust and evaporative emissions from vehicles are significantly influenced by the ambient temperatures under which they are operating. A site-specific temperature range and average temperature must be input into the model to accommodate for this effect. Temperature data is available from the National Climatic Data Center (Reference 29).

G2.10 Region

Vehicle emissions also are effected by the local altitude at which they are operating. The type of region, either low-altitude or high-altitude, is input into the model. For most situations, low-altitude is the appropriate choice. For those areas designated as high-altitude by the EPA or that lie substantially above 4000 feet mean sea level, high-altitude should be selected.