Reducing Airport Pollution and Consequent Health Impacts to Local Community

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Hualong Tang, Yu Zhang

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Hualong Tang
Yu Zhang (0000-0003-1202-626X)

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University of South Florida
Tampa, FL, 33620

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16. Abstract

Research shows that air pollution caused by a large airport could be equivalent to that produced by many hundreds of miles of freeway traffic. Airplane air pollution include ultrafine sulfur dioxide, nitrogen oxide and other toxic particles, which not only affect employees and passengers on airport and residents near airport but could spread to as far as 10 miles and cause health concerns of a significant amount of population. This study looks into the sources of local air pollution from aviation activities, for instance, ground access vehicles to and from the airport, aircraft taxiing at airfield surface, landing and take-off (LTO) cycle of aircraft, airport ground equipment etc. and calculate the air pollution inventory of case study airport by using FAA Aviation Environmental Design Tool (AEDT). The natural extension of this study is to estimate the benefit pools of operational improvements due to increased productivity and implementation of emerging technologies/procedures. A simulation-based scenario analysis will be performed to quantify the emission mitigations. The scenarios that are worthy of study include: electrification of ground support equipment (GSE); deployment of alternative aircraft taxiing systems (AATS), and integrated arrival, departure, and surface (IADS) traffic management.

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Hub-based rebalancing, User incentive program, Free-floating bike sharing, Simulation, Multi-objective optimization

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1. Introduction

Research shows that air pollution caused by a large airport could be equivalent to that produced by many hundreds of miles of freeway traffic (Hudda et al. 2014). Air pollutants from aircraft operations include ultrafine sulfur dioxide, nitrogen oxide, and other toxic particles, which not only affect employees and passengers at airports as well as nearby residents but could spread to as far as 10 miles and cause health concerns for a significant amount of population (Hudda et al. 2014). Most existing research focuses on emissions emitting from aircraft during landing and take-off (LTO) cycles, which are assumed to account for a large portion of air pollution from air travel activities, but emissions from other units at airside that support aircraft operation, maintenance, and management, e.g., ground support equipment (GSE), could also significantly contribute to airport-related emissions. However, many of these sources lack adequate attention to impact assessment, among which GSE has attracted the most attention. GSE generally serves the needs of ground power operations, aircraft mobility, and cargo/passenger loading operations for aircraft between its arrival at the apron area and departure for its next flight. GSE is expected to provide fast, efficient, and punctual services to minimize aircraft turnaround time. A few studies quantitatively estimated emissions produced by GSEs (Nambisan et al. 2000, Unal et al. 2005, Schürmann et al. 2007). Nambisan et al. (2000) noted that GSE was associated to approximately 60% of total airport emissions at McCarran International Airport in Las Vegas, and Schürmann et al. (2007) claimed that GSE was responsible for a large part of NO concentrations at Zurich Airport. However, in a study of Atlanta International Airport, the impacts from GSE was estimated to be small compared to that from aircraft operations (Unal et al. 2005). Thus, it is necessary to quantify emissions from GSE and other ground vehicles in understanding the overall picture of airport pollution.

Technology advancements could improve the efficiency and safety of airport operation and could counter adverse impacts by interrupting existing systems. NASA’s Airspace Technology Demonstration 2 (ATD-2): Integrated Arrival/Departure/Surface (IADS) Traffic Management has been tested at several sites, including individual airport and metroplexes. Whereas the operational benefits of ATD-2 have been estimated (Saraf et al. 2017), its environmental benefits have not been studied yet. Alternative aircraft taxiing systems (AATS) discussed in the existing literature will drastically change the aircraft taxiing experience (Guo et al. 2014). The external system, e.g. Wheeltug, would tow aircraft from a gate to the end of the runway, and the on-board system would provide power for taxiing without turning on the main engines. Both AATS systems would lead to significant operational changes and different environmental impacts. Although the existing literature notes the environmental benefit of AATS, the authors used a rough estimation method. In addition, connected and automated vehicle technologies could potentially be implemented for the vehicle fleets of GSE to aid with precisely-scheduled and standard ground service procedures. Advanced information technology could further assist communication between airlines, airports, navigation service providers, and passengers. How to estimate the environmental impacts of these technology advancements is worthy of study.

Using Tampa International Airport (TPA) as the case study, the objectives of this research project were to quantify existing airport pollutant emissions by applying the Federal Aviation Administration (FAA) Aviation Environmental Design Tool (AEDT). This study sets up foundations for scenario analysis of different measures for reducing air pollutant emissions at airport, including electrification of ground support equipment (GSE); deployment of alternative aircraft taxiing systems (AATS), and integrated arrival, departure, and surface (IADS) traffic management..

2. Sources and Types of Air Emissions

According to FAA's Office of Environment and Energy, emission sources associated with aviation are grouped in six categories—Aircraft, Auxiliary Power Units (APUs), Ground Support Equipment, Stationary/Area, Ground Access Vehicles, and Construction (FAA, 2015). Table 1 shows the different emission source types and their corresponding pollutants.

Table 1. Aviation Emission Sources and Their Pollutants

Source		Pollutants
Aircraft	Main engine(s)	CO, VOC, NOx, PM10 PM2.5, SO2, Pb, GHGs (i.e., CO2, CH41, N2O), HAPs2
APUs	Turbine engine	
Ground Support Equipment	Combustion engines (aircraft tugs, air start units, loaders, tractors, fuel or hydrant trucks)	
Stationary/Area	Combustion sources (boilers, heaters); non-combustion sources (fuel storage tanks, painting operations, de-icers)	VOC, PM10, PM2.5, HAPs2
Ground Access Vehicles	Passenger vehicles (private autos, taxis/limos, shuttles, vans, buses, rental cars), airport and tenant employee vehicles, airport fleet, vehicles transporting cargo to/from airport and circulating around airport	CO, VOC, NOx, PM10 PM2.5, SO2, GHGs (i.e., CO2, CH4, N2O)
Construction	Combustion sources (heavy construction equipment, on-road vehicles, and off-road vehicles); non-combustion sources (construction materials staging, demolition)	PM10, PM2.5, VOC

Source: *Aviation Emissions and Air Quality Handbook*, 2015

This study focuses on non-aircraft emissions from airside traffic at an airport, considering only sources from GSE. As defined in *Aviation Emissions and Air Quality Handbook* (2015), GSE is equipment that services aircraft while loading and unloading passengers and freight at an airport. GSE usually consists of aircraft tugs, air start units, forklifts, tractors, air-conditioning units, ground power units (GPUs), baggage tugs, belt loaders, fuel or hydrant trucks, catering trucks, cabin trucks, deicer trucks, water trucks, lavatory trucks, and cargo loaders, among others (CDM Federal Programs Corporation et al. 2012). Different types and models of GSE and number of GSEs in operation would result in different levels of pollutant emissions.

3. Airport Air Quality Modeling

Airport air quality models numerically approximate the physical and chemical processes that occur in the atmosphere. An emissions inventory is produced by estimating the mass (e.g., lbs or kg) of pollutant emissions over a time period from different sources at the airport. Although it is not a very accurate method for quantifying pollutant emissions and cannot capture the dynamics of air pollution dispersion, it provides an understanding of the relative impact from each pollution source and the input to a more sophisticated dispersion model (Arunachalam et al. 2017). To better understand the impact from each emission, it is necessary to know the pollutant concentration (mass per unit volume) at the exposure point. In addition, most criteria pollutant limits are regulated by the government in terms of pollutant concentration.

The air dispersion model, which tracks the atmospheric motion of pollutants from the emission source, is capable of calculating pollutant concentration. Based on different assumptions made by the dispersion model and how plume dynamics are represented, there are various types of air dispersion models. These differences result in their different applications to air quality modeling. Table 2 summarizes four popular air dispersion models and their specific characteristics in modeling methods, range, and targeted emission sources.

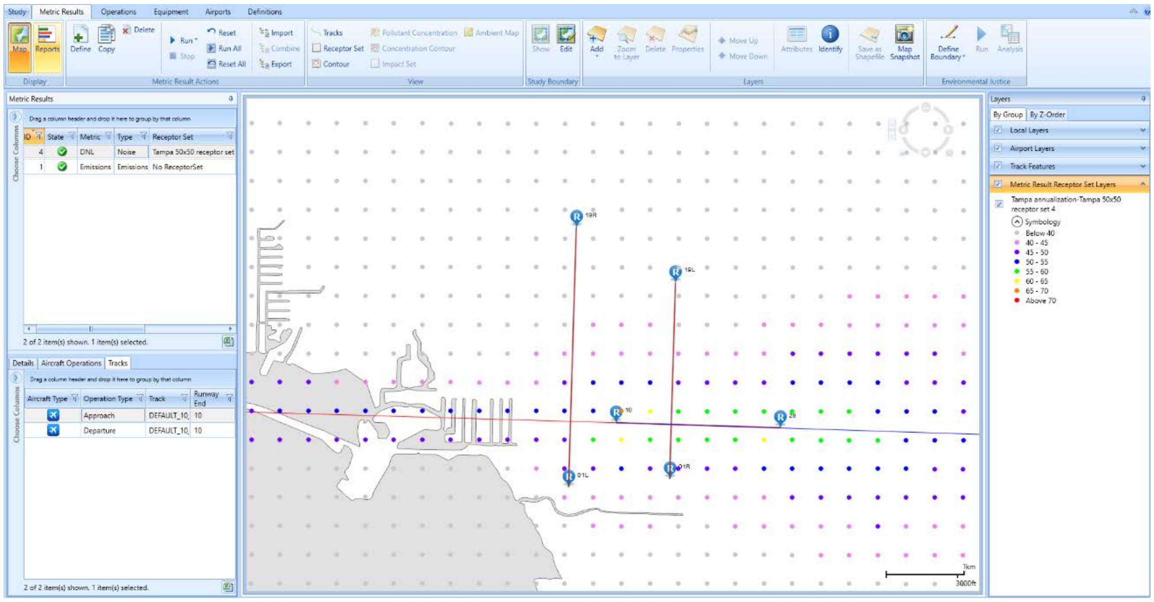
Table 2. Air Dispersion Models and Their Characteristics

Models	Approach	Range	Emission source
AERMOD	Bi-Gaussian puff, steady-state	<50 km	Aircraft, APU, GSE, stationary
CALPUFF	Lagrangian Gaussian puff, non-steady-state	50–300km	Large point sources (plant)
SCICHEM	Lagrangian puff, non-steady-state	Short and long range (>50km)	Large point sources
ADMS-Airport	Bi-Gaussian plume	<50 km	Aircraft, APU, GSE, on-road mobile sources, stationary

Note: AERMOD: American Meteorological Society (AMS)/EPA Regulatory Model
CALPUFF: California Puff
SCICHEM: Second-Order Integrated Puff Model with Chemistry
ADMS-Airport: Atmospheric Dispersion Modeling System at Airports (ADMS-Airport)

FAA’s AEDT is the required model for air quality analyses of aviation sources. The Emissions and Dispersion Modeling System (EDMS) was replaced by the AEDT in May 2015. The American Meteorological Society (AMS)/EPA Regulatory Model (AERMOD) is the standard dispersion model preferred by AEDT (Kenney et al. 2017).

FAA’s AEDT was chosen as the air dispersion model tool in this study because it is suitable for modeling the pollutants spreading out from emission sources in a short-range distance (<50km) and accounts for emissions from aircraft, APU, GSE, and stationary sources. Although AEDT does not cover emissions sources such as vehicles on roadways and in parking lots or construction equipment, these emissions can be estimated through the Motor Vehicle Emissions Simulator (MOVES). AEDT provides functionality for users to import the emissions of these sources and include them for air quality impact analysis. Figure 1 shows an example of using AEDT setting up receptors in a 50x50 nautical mile grid to model the emission concentration at TPA.



ID	State	Metric	Type	Receptor Set
4	✓	DNL	Noise	Tampa 50x50 receptor set
1	✓	Emissions	Emissions	No ReceptorSet

2 of 2 item(s) shown. 1 item(s) selected.

Aircraft Type	Operation Type	Track	Runway End
✈	Approach	DEFAULT_10	10
✈	Departure	DEFAULT_10	10

2 of 2 item(s) shown. 1 item(s) selected.

Figure 1. Receptor set layer at TPA

4. Methodological Approach

There are two methods of calculating the emission inventory for GSE—population-based and aircraft landing and take-off (LTO) cycle-based. The population-based approach accounts for the number of GSE and the operation times of all equipment throughout the year. The LTO-cycle-based method counts the type and number of GSE servicing each aircraft type for an LTO cycle. For the population-based approach, emissions from each GSE type are summed to obtain the emission inventory and does not depend on aircraft type; however, for the LTO-cycle-based approach, the activities of each aircraft type determine the emissions inventory. According to the *Aviation Emissions and Air Quality Handbook*, the preferable method for computing emissions for GSE is the LTO-cycle-based approach because it is more flexible and aircraft activity data are easier to obtain. Thus, in this study, the LTO-cycle-based approach was used to calculate the GSE emissions inventory.

Emissions from GSE are determined by the combination of their type, reference model, and fuel type. The formula used to calculate the emissions of GSE servicing aircraft is shown as follows; each departure and arrival can be modeled by calculating this formula:

$$m_{pa} = \Sigma_{g \in A_a} (E_{pg} P_g L_g t_{ag})$$

where,

m_{pa} = mass (in grams) of pollutant p, emitted from all GSE servicing aircraft a during one operation

A_a = set of GSE servicing aircraft a

E_{pg} = emission factor for pollutant p (in grams per horsepower-hour) for GSE g

P_g = rated power (in brake horsepower) of GSE g

L_g = load factor of GSE g

t_{ag} = for aircraft a, = number of hours GSE g operates during one operation

The data inputs for computing GSE emissions for one LTO include aircraft type, corresponding GSE types, brake horsepower,[1] load factor,[2] usage (in minutes), and emission factors. For existing GSE emission inventory, we used the default value of the GSE brake horsepower, load factor, usage, and emission factor in AEDT. Table 3 shows an example of GSEs assigned to arrival operations executed with aircraft B777-300.

The GSE types, usage time, and operational characteristics are then combined with aircraft activity and fleet mix to obtain the total emissions for an interested inventory period. Aircraft activity levels and fleet mix data were obtained from the FAA Aviation System Performance Metrics (ASPM) database. Within AEDT, GSE usage is dependent upon the size of aircraft assigned. Therefore, aircraft are categorized into four groups (Heavy, Large, Medium, Small), and within each group the GSEs assigned to the aircraft are the same for departure or arrival operation.

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[1] AEDT uses brake horsepower (BHP), the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, differential, water pump, and other auxiliary components such as power steering pump, muffled exhaust system, etc.

[2] Values that represent the ratio of the average energy demand of the equipment (load) to the maximum (peak load) of the equipment.

Table 3. Example of AEDT Default GSE Characteristic for Arrival B777-300

GSE Model	GSE Type	Fuel Type	Duration (mins)	Brake Horsepower	Load Factor
Electric - None - Air Conditioner	Air Conditioner	Electric	7	0	0.75
Diesel - ACE 180 - Air Start	Air Start	Diesel	0	425	0.9
Diesel - Stewart & Stevenson TUG T-750 - Aircraft Tractor	Aircraft Tractor	Diesel	0	475	0.8
Gasoline - Stewart & Stevenson TUG MA 50 - Baggage Tractor	Baggage Tractor	Gasoline	60	107	0.55
Gasoline - Stewart & Stevenson TUG 660 - Belt Loader	Belt Loader	Gasoline	17	107	0.5
Diesel - Hi-Way F650 - Cabin Service Truck	Cabin Service Truck	Diesel	17	210	0.53
Diesel - FMC Commander 15 - Cargo Loader	Cargo Loader	Diesel	40	80	0.5
Diesel - Hi-Way F650 - Catering Truck	Catering Truck	Diesel	10	210	0.53
Diesel - F250 / F350 - Hydrant Truck	Hydrant Truck	Diesel	0	235	0.7
Diesel - Wollard TLS-770 / F350 - Lavatory Truck	Lavatory Truck	Diesel	25	235	0.25
Diesel - F250 / F350 - Service Truck	Service Truck	Diesel	7	235	0.2
Electric - Gate Service - Water Service	Water Service	Electric	0	0	0.2

5. GSE Emission Inventory Results for TPA

Based on the methodology described, annual criteria pollutant emissions produced by GSE at TPA were calculated for 2018. GSE emissions include carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxide (NOx), sulfur dioxide, and particulate matter (PM10 and PM2.5). VOC and NOx are precursors for ozone. The GSE emissions of different pollutants for each month in 2018 are shown in Figure 2 and Table 4.

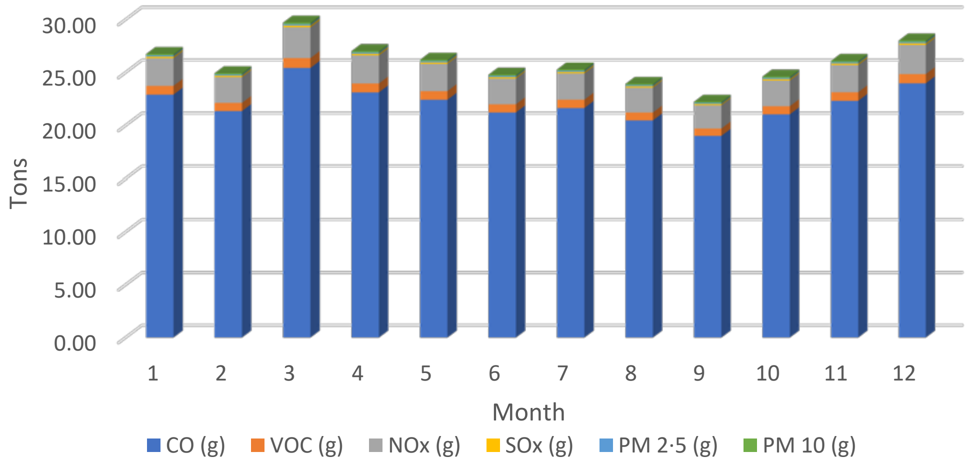

Fig. 2 GSE emissions inventory for months of 2018

Table 4. GSE Emissions Inventory for Months of 2018

Month	CO (ton)	VOC (ton)	NOx (ton)	SOx (ton)	PM2·5 (ton)	PM 10 (ton)
1	22.91	0.83	2.61	0.14	0.12	0.12
2	21.36	0.77	2.44	0.13	0.11	0.12
3	25.43	0.92	2.92	0.16	0.13	0.14
4	23.12	0.84	2.66	0.14	0.12	0.13
5	22.42	0.82	2.58	0.14	0.12	0.12
6	21.23	0.77	2.43	0.13	0.11	0.12
7	21.65	0.79	2.48	0.13	0.11	0.12
8	20.48	0.74	2.35	0.13	0.11	0.11
9	19.02	0.69	2.19	0.12	0.10	0.11
10	21.05	0.77	2.43	0.13	0.11	0.12
11	22.32	0.81	2.57	0.14	0.12	0.12
12	23.98	0.87	2.76	0.15	0.13	0.13

March and December had the most emissions due to the peak air travel activities during those months. The emissions gradually decreased after March, hit their lowest level in September, then increased until December. GSE produced most of its emissions through CO in terms of mass amount, whereas particulate matters were the least.

Figure 3 and Table 5 show the GSE emissions inventory from servicing different aircraft categories. GSE servicing large aircraft contributed most of the emission inventory because these were the largest aircraft fleet and generated the most operations at TPA. It should be noted that GSE emissions associated with heavy aircraft had higher contributions to the emissions inventory in particulate matters (PM2.5 and PM10) than other pollutant sources.

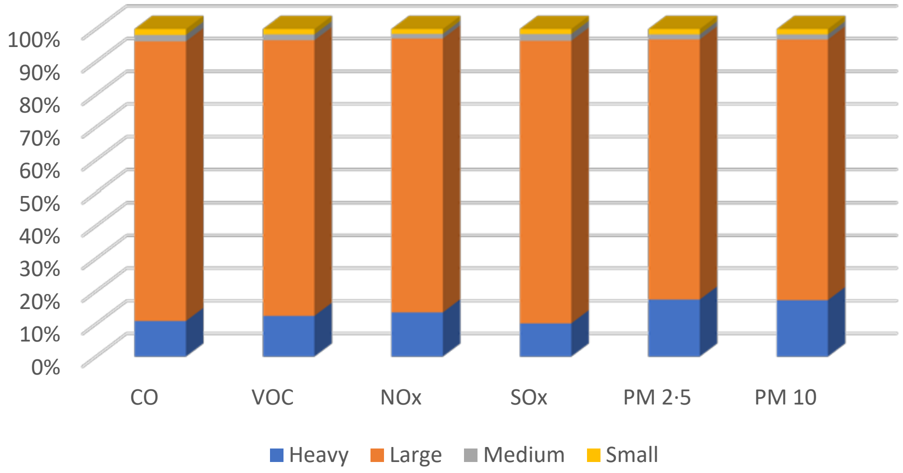

Fig. 3. GSE annual emissions inventory for 2018 by servicing aircraft category

Table 5. GSE Annual Emissions Inventory **for** 2018
by Servicing Aircraft Category

	Heavy	**Large**	**Medium**	**Small**
CO (ton)	28.85	226.15	5.21	4.75
VOC (ton)	1.20	8.10	0.17	0.16
NOx (ton)	4.12	25.44	0.43	0.45
Sox (ton)	0.16	1.40	0.03	0.02
PM 2·5 (ton)	0.24	1.10	0.02	0.02
PM 10 (ton)	0.25	1.16	0.02	0.02

5. Remarks and Future Research

The GSE emissions inventory for TPA in 2018 was calculated using AEDT and the LTO approach, which is based on the type and number of GSE servicing each aircraft type. The aircraft were categorized into four groups (Heavy, Large, Medium, Small) and within each group the GSEs assigned to the aircraft were the same for departure or arrival operation. The AEDT default data for GSE brake horsepower, load factor, usage, and emission factor were used for the inventory calculation. The results show that March and December had the most emissions due to peak air travel activities in those months, and large aircraft contributed the most to the emissions inventory in 2018.

The natural extension of this study is to estimate the benefit pools of operational improvements due to increased productivity and implementation of emerging technologies/procedures. A simulation-based scenario analysis could be performed to quantify the emission mitigations.

The first scenario is to investigate how the improvement of productivity would affect the emissions inventory. For arrivals or departures, if it is assumed that there would be certain reduction in the usage times of different types of GSE, total emissions can be calculated given the same historical operational data.

As shown in Table 3, most GSE are powered by gasoline or diesel. Thus, the second scenario analysis could be to estimate the benefits of electrification of GSE assuming the electrification of each type and the emissions impacts of electrification will be evaluated.

The third scenario looks into AATS, including external and internal systems. External systems include powerful aircraft tractors that can pull an aircraft from a gate to the end of runway; internal systems are on-board systems that can power an aircraft for low-speed push back and taxiing without turning on the main engines on (see Guo et al. 2014). Previous research on environmental analysis of AATS used a simple emission rate formula (Guo et al. 2014). The AEDT tool could be used to evaluate the environmental impacts of different types of AATS for the TPA case. A benchmark will be established, i.e., estimating emissions from both GSE and aircraft taxiing with conventional procedures (departure aircraft being pushed back by aircraft tractor and taxiing with full main engines or half of main engines on, arrivals taxiing to the gate with full main engines on). Then, emissions assuming an external system is implemented will be estimated. Note that external system works only for departures, with an increase in the usage time of aircraft tractors (more powerful than the current ones) but a decrease of the usage time of main engines). Emissions assuming an internal system is implemented will be estimated. With an internal system, there will be no need for an aircraft tractor; aircraft taxiing will rely primarily on power from APU installed on the airplane.

The final scenario is to evaluate the possible impact of integrated arrival, departure, and surface (IADS) traffic management to TPA. The operational benefit of ATD-2 IADS has been estimated for some airports

(Saraf et al., n.d.); however, the environmental benefits of such advanced technologies have not been studied yet.

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