EVALUATION OF AUXILIARY POWER UNIT (APU) AND GROUND SUPPORT EQUIPMENT (GSE) EXHAUST EMISSIONS WITH VARYING ALTERNATIVE TECHNOLOGIES SCENARIOS

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ABSTRACT

This research proposes alternatives to reduce emission due to airports operations using Viracopos (VCP) as a case study. The ground equipment APU and GSE are responsible for significant pollutant inside the airport, although most emissions are from LTO operations, technological advances are getting the plateau of the efficiency. The ground equipment technology available (alternative fuel, hydrogen, or electric powered engines) was presented and simulated using EDMS software develop by the FAA for creating different scenarios and its effects on total pollutant is shown for (NOx) nitrogen oxides, (CO) carbon monoxide, (Sox) Sulfur oxide, and particle mass to prevent health problems.

Keywords: Air Transport Emissions, Air Quality, Airport Emission Modeling, Ground Equipment, Climate change.

1. INTRODUCTION

The impact of social activities affect global health, and the side effect of economic growth brings pollution that affects the people near the emission source, as well the whole planet. Aviation has been used to transport people and provisions, but airport operation is responsible for greenhouse gases emission and other volatile pollutants. So various research and development resources were used to minimize the emission from the main aircraft engine, but it is going to achieve a plateau. Any improve at emission will bring prejudice at noise levels by trade-off at engineering design.

At that point, the airport and aircraft support system can aid to reduce the emission levels. In fact, there a few studies about emissions from GSE (ground support equipment) and APU (auxiliary power unit) to present innovative options, but some result at electrical power, hydrogen, and alternative fuel were presented with data to be imputed at FAA software to study emission.

The case chose Viracopos is an international airport located at Campinas, Brazil, that past years received an increase in the demand, using the aircraft and equipment used at 23 of December of 2013 as a baseline.

2. POLLUTANT AS A SIDE EFFECT OF DEVELOPMENT

The transport system has several externalities (Granger and Kosmodier, 2016), some positive, as mobility for people and ideas exchange leading to innovation with advances in life quality, and some negative, as air pollution and noise. So, a better understanding of "if-then" relationship is needed to enable the system-thinking approach to weight both sides.

The solutions to noise and air quality are behind the growing market of air transportation, (Schäfer and Waitz, 2014). It is stated that a 1% increase in movements yields a 1.05% increase in total environmental effects levels (Grampella et al., 2017) the same effect occurs due to aircraft size increase 1% gives rise to 1,81% increase in environmental effects. Similar results as proposed by (Kesgin, 2006) demonstrate that an increase of 25% in landing and take-off operations represents a range of 31 to 33% rise in emissions.

The technology improvement at last years is incapable to is achieve the threshold expected level settled by NASA (National Aeronautics and Space Administration) (Graham, Hall, and Vera Morales, 2014). Besides, there are several conflicts regarding noise and pollutant emission design with the improvements in one negatively affects the effectiveness of other. So there is a trade-off engineering decision to get along as the By-pass ratio as its increase affects the noise-reduction, nevertheless, it must have ample nacelles that will increase the weight of, and drag on the aircraft, increasing the fuel consumption and therefore the pollution produced prejudicing the public health as below discussed.

3. EFFECTS ON HEALTH

Considering landing and take-off operations - LTO, (Yim et al., 2015) estimated impact at near airport, regional and global scale due to exposure to aviation-attributable mass particle (PM) and ozone, around 16 000 (90%CI: 8300–24 000), premature deaths per year and a cost of around $21 billion per year. However, there is also a lot of non-fatal impacts caused by aviation and airports (Harrison, Masiol, and Vardoulakis, 2015).

As pointed out by full range projects throughout the world (Shepard, 2005), the environmental impact assessment concepts as significance, sustainable and quality cannot be measured and are imprecise linguistics variables sometimes used to camouflage the hidden truth that the neighbors like having this modal accessible but not too close from their homes.

The carbon monoxide (CO) increase caused by daily congestion at ground operation impacts a large area strongly related to respiratory problems and heart disease. At Los Angeles International Airport (LAX), one standard derivation in congestion brings 0,28 deviation levels of CO next to the

airport, and one standard deviation in daily zip-code pollution increases asthma by 17% and heart problems at 9% (Schlenker and Walker, 2016). So it is visible the potential damage caused by congestion at ground operation. The GSE is the primary source of pollution in those circumstances so its functioning can be optimized to reduce emission.

Paradoxically, actions to management air quality take a long time, but short-range meteorological and emissions changes quickly react shifting the pollution to unacceptable levels (Hu et al., 2015). So study and manage the discharge caused by the GSE can help to keep the pollution under control.

4. METHODOLOGY

This research proposes alternatives to reduce emission due to airports operations using Campinas-Viracopos International Airport (VCP) as a case study. To develop an accurate model would be necessary to consider airports internal sources of pollution as well as aircraft sources and car traffic, heating, restaurants and other sources from the facilities, (Masiol and Harrison, 2014), but most of this data are not public.

For the simulation of quantification of pollutants the software EDMS 5.1.4.1 (Dispersion and Emissions Modeling System), developed by the FAA (Federal Aviation Administration), was used to calculate emission using at base scenario the results from (Mello, 2015) obtained the number of take-offs and landing operation aircraft, APUs and GSE inventory at 2013.

As proposed by Postorino and Mantecchini (2014) the composition of the inventory is given by the sum of exhaustion from each pollutant source at four diverse sites, as represented in Figure 1.

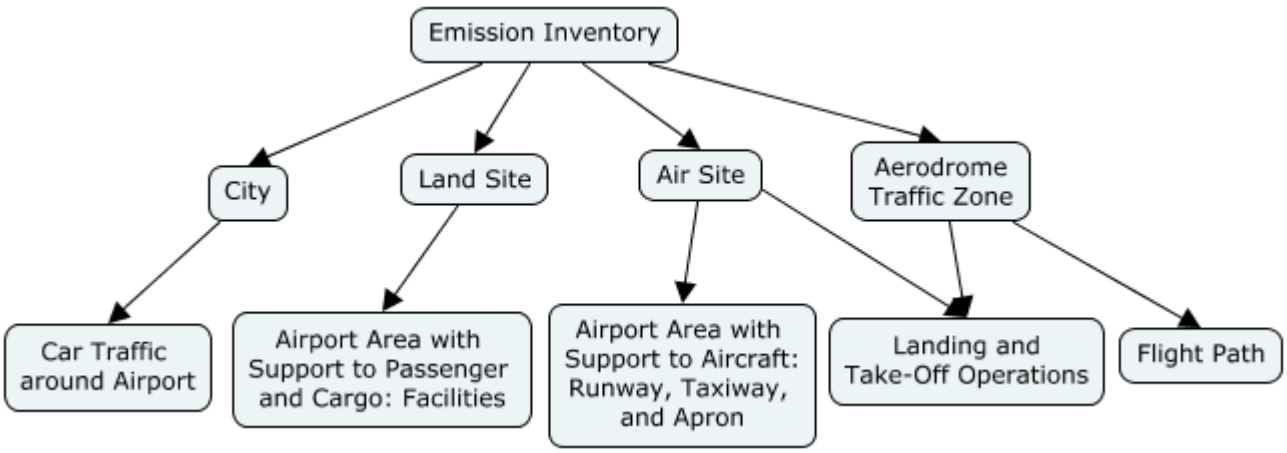


Figure 1: Emission Inventory (adapted from Postorino and Mantecchini, 2014)

For that scenario was used real data from aircraft operation at the busiest day, December, 20 of 2013. The database was presented by International Civil Aviation Organization (ICAO). This database contains air side emission (aircraft, its engines, auxiliary power unit (APU), and ground support equipment (GSE)) and land side (vehicles and its engines). Due to international regulations, aircraft and engine should be tested before start operation, so their emission is inputted at this publicly available database.

Analyzing the study of Winther et al. (2015), Lobo et al. (2015), Testa et al. (2014), and Kinsey et al. (2012), it was generate several APU and GSE user defined to study the effects of several technologies available (alternative fuel, hydrogen, or electric powered engines).

As the APU using a coal-derived Fischer-Tropsch fuel was tested for quite a few exhaust gas temperature (EGT), which was used as an indicator of load factor, it was calculated the linear interpolation between two boundaries of emission reduction. Their results show a decrease of 10% from CO, 30%, from a total of hydrocarbons, 2% from nitrogen oxides (NOx), 90% of sulfur oxide

(SOx), and 90% from Mass Particles. This percentage was applied to each APU emission outputs only (the main aircraft engine emission levels was kept at the same degree), as shown in Table 1.

Table 1: Comparison between standards emissions and estimated emission from APU burning alternative fuel

	Standart emission (Kg/hour) from EDMS 5.1.4					*Alternative Fuel Emission estimated (Kg/hour)*				
APU	***CO***	***THC***	***NOx***	***SOx***	***PM***	***CO***	***THC***	***NOx***	***SOx***	***PM***
GTCP 36-300 80HP	0.2055	0.1050	1.0125	0.1002	0.0620	0.1850	0.0105	0.9973	0.0100	0.0062
GTCP 331-350	0.3822	0.0473	2.0343	0.2055	0.1108	0.3440	0.0047	2.0037	0.0205	0.0111
131-9	0.5645	0.0428	0.7680	0.1157	0.0930	0.5080	0.0043	0.7565	0.0116	0.0093
PW901A	6.5680	0.5871	1.2330	0.3914	1.1238	5.9112	0.0588	1.2145	0.0391	0.1124
GTCP 331-200 (143HP)	0.5019	0.0523	1.1557	0.1215	0.1108	0.4517	0.0052	1.1384	0.0122	0.0111
GTCP 331-500 (143 HP)	0.4595	0.0486	2.7741	0.2431	0.1108	0.4136	0.0049	2.7325	0.0243	0.0111
TSCP 700-4B(142HP)	0.7834	0.0777	1.7284	0.2100	0.1101	0.7050	0.0078	1.7025	0.0210	0.0110
GTCP 36-150	0.4359	0.0412	0.3100	0.0676	0.0620	0.3923	0.0041	0.3053	0.0068	0.0062
GTCP 36-300 80HP	0.2055	0.1050	1.0125	0.1002	0.0620	0.1850	0.0105	0.9973	0.0100	0.0062

The proton exchange membrane fuel cell of hydrogen was another technology tested, and the reduction of 92% in CO, 89% in THC, 90% in NOx, 89% at Sox and 96% at PM10 was applied to several users defined GSE, to simulate hydrogen as a fuel replacement.

From electrical pollutant emission was considered only the emission from the airport, so none gas pollutant or a mass particle was expelled since the emission generated producing electrical power usually is far from the airport area.

5. ANALYSIS OF DATA

The baseline scenario was built using the EDMS 5.4.1 software to emulate the standards emission and presented the results at Table 2 from each pollutant CO, THC, NOx, SOx, PM-10 and PM-2.5 from each category of source Aircraft, GSE, APU, and the total was computed and presented. So this is the start point whereas one can measure the impact of the change in use of technologies to reduce emission.

Table 2: Baseline scenario annual emission from EDMS 5.4.1

	Annual Emission in Kilograms					
Category	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
Aircraft	125,127.876	17,675.031	209,840.407	18,066.580	1,103.114	1,103.114
GSE	109,153.889	0.000	13,493.722	333.378	557.002	533.365
APU	7,646.663	707.963	7,772.402	1,292.318	1,208.569	1,208.569
total	241,928.428	18,382.994	231,106.531	19,692.276	2,868.685	2,845.048

As the THC from GSE is unreported by the EDMS 5.4.1, its value was considered zero. So the ratio of contribution from Aircraft, GSE, and APU can be determined in Table 3, and it is important to establish an input to a compressive indicator of reduction of emission possible.

Table 3: Contribution ration from Aircraft, GSE, and APU to total emission from air site

	Contribution ratio					
Category	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
Aircraft	52%	96%	91%	92%	38%	39%
GSE	45%	0%	6%	2%	19%	19%
APU	3%	4%	3%	7%	42%	42%

At this context was expected the change at GSE power source response at CO emission levels and the APU fuel be responsible for PM reduction.

The aircraft emission was unaltered in every scenario, but the emission from APU and GSE achieved different levels as below represented in Table 4, Table 5, and Table 6.

Table 4: Annual Emission in Kilograms from APU using a coal-derived Fischer-Tropsch fuel scenario

	APU using a coal-derived Fischer-Tropsch fuel scenario					
Category	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
Aircraft	125,127.876	17,675.031	209,840.407	18,066.580	1,103.114	1,103.114
GSE	109,153.889	0.000	13,493.722	333.378	557.002	533.365
APU with alternative fuel	6,957.882	512.832	7,671.301	269.178	233.385	233.385
Total	241,239.647	18,187.863	231,005.430	18,669.136	1,893.501	1,869.864

This technology is independent of the next two technologies options, but as the APU it is an aircraft equipment, so the change in the fuel depends on approval of more stakeholders as industries, airlines and fuel suppliers.

Table 5: Annual Emission in Kilograms from GSE using electrical power scenario

	GSE using electrical power scenario					
Category	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
Aircraft	125,127.876	17,675.031	209,840.407	18,066.580	1,103.114	1,103.114
GSE electrical	0.000	0.000	0.000	0.000	0.000	0.000
APU	7,646.663	707.963	7,772.402	1,292.318	1,208.569	1,208.569
Total	132,774.539	18,382.994	217,612.809	19,358.898	2,311.683	2,311.683

This scenario considers only the emission from the airport, so the emission generated to provide electrical power is not considered because it is usually released far from the airport area.

Table 6: Annual Emission in Kilograms from GSE using proton exchange membrane fuel cell of hydrogen scenario

	GSE using proton exchange membrane fuel cell of hydrogen scenario					
Category	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
Aircraft	125,127.876	17,675.031	209,840.407	18,066.580	1,103.114	1,103.114
GSE hydrogen	31,323.957	0.000	2,760.756	146.827	77.506	77.152
APU	7,646.663	707.963	7,772.402	1,292.318	1,208.569	1,208.569
Total	164,098.496	18,382.994	220,373.565	19,505.725	2,389.189	2,388.835

This technology cannot be implemented together with the solution presented by the third scenario at Table 5, so the administrator must choose between not change the fuel to GSE, use an electrical GSE or use a GSE with hydrogen.

With all this simulated data, it is possible to compare the expected emission with the baseline scenario, the ratio of reduction is presented in Table 7.

Table 7: Reduced ratio consolidated

Scenario	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
APU	0.28%	1.06%	0.04%	5.20%	33.99%	34.28%
GSE electrical	45.12%	0.00%	5.84%	1.69%	19.42%	18.75%
GSE hydrogen	32.17%	0.00%	4.64%	0.95%	16.71%	16.04%

As expected both GSE power supply alternatives lowered CO emission. Naturally the electrical delivers a better response at CO level. Nevertheless, it is remarkable the PM effect, and NOx reduction by both technologies are the almost same result implying either power change might improve the air quality at the airport.

The APU fuel variation had a massive change at PM emission, and it is possible to reduce above 50% the PM emission combining the APU and GSE innovative energy supply.

Therefore, the potential reduction choosing use the best innovative engines technologies could succeed at high levels of quality of health near airports as shown in Table 8.

Table 8: Potential reduction

Pollutant	***CO***	***THC***	***NOx***	***SOx***	***PM-10***	***PM-2.5***
Percentage	45.40%	1.06%	5.88%	6.89%	53.41%	53.02%

At VCP case studied by Mello (2015), the NOx was above the recommended levels, so was proposed a specific strategy for the zoning of emissions based on pollution generated by this pollutant. Consequently, at first sight, a small reduction of 5.88% could represent a lower area with economic and social restriction in the areas immediately surrounding airports.

6. GENERAL DISCUSSION

The huge effect at particle emission changing the APU fuel could stimulate further studies to aircraft design to allow the APU use a separate fuel tank with alternative fuel, despite the supply chain and cost structure difficult the alternative fuel be used as an only power source to the main engine of aircraft.

The electrical GSE could bring autonomy issues, but the result at hydrogen fuel cell gives hope that the airport operator can use a mix of technology adapted at usage time and frequency to its unique needs.

In continuity, the same model could be used to determine the effect at congestion, by specifying user defined aircraft with taxi and authorization to departure and take off wait time. Furthermore, since the emission occurs different locations at the airport and the weather influence a lot the dispersion, it could be analyzed to suggest different levels and solution of personal protective equipment of air service employees, beyond determine the reduction at zoning of emissions proposed by Mello (2015).

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