The analysis of emission values from commercial flights at Dalaman international airport Turkey

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Abstract

Purpose – This study aims to present atmospheric emissions (NOx, CO and HC) of commercial flights at Dalaman Airport for the years between 2016 and 2018.

Design/methodology/approach – Growing up, the potential for domestic and international airports will cause an increase in air transportation. Increasing demand for air transportation will cause adverse environmental impacts as well as positive economic contributions. Finding negative environmental effects and searching for solutions is an essential first step.

Findings – Emissions were calculated under three different groups (as daily, number of flights and per passenger). The maximum CO emission calculated was 1031.71 kg/day in August 2018, 41.55 g/pax. in October 2016 and 6909.27 g/flight in August 2018. The maximum HC emission calculated was 117.22 kg/day in August 2018, 4.78 g/pax. in May 2018 and 796.47 g/flight in May 2018. The maximum NOx emission calculated was 148.63 kg/day in August 2018, 6.04 g/pax. in October 2017 and 995.34 g/flight in August 2018.

Practical implications – The current study intends to show how can emission results differ under three different units.

Originality/value – The originality is the using of the real-time values for all calculations. The value of this study is to be key study for future applications of emission calculation methodologies.

Keywords Aircraft, Emission, Aeronautics, Airport

Paper type Research paper

Introduction

Aviation has been overgrowing worldwide. The demand for air transportation is expected to grow day by day and continue in the future. According to the International Civil Aviation Organization (ICAO), the aviation industry has been increasing as it continues to recover from the recent economic recession (Pham *et al.*, 2010; Sikorska, 2015; ICAO Publications, 2017; Hassan *et al.*, 2018).

There are several civil aviation activities (including or excluding these indicators). Commercial aviation, the part of civil aviation (both general aviation and scheduled airline services), involves operating aircraft for hire to transport passengers or multiple loads of cargo. The air transportation industry includes all civil flying performed by certificated air carriers and general aviation. Over the past years, the air transportation industry has become an increasingly important part of the world economy. Aviation is the most dominant intercity mode of transportation used by most countries for passengers and goods that must be transported quickly and efficiently (Dempsey, 2000; Neufville and Odoni, 2003; Wells and Wensveen, 2004).

Preliminary data, released by the ICAO, show a total of 4.3 billion passengers were carried by air transport on scheduled services in 2018. This indicates a 6.1% increase over 2017. The number of departures rose to approximately 38 million globally and world passenger traffic, expressed in terms of total scheduled revenue passenger-kilometers (RPKs), grew solidly at 6.7% and reached about 8.2 trillion RPKs. This growth is a slowdown from the 7.9% achieved in 2017. Over half of the world's 1.4 billion tourists, who traveled across international borders in the past year were transported by air and air transport now carries some 35% of world trade by value (ICAO, Montréal, December 31, 2018).

The prospects of the Turkish commercial aviation sector remain growth is driven by Turkish and World economies. Turkey has made significant contributions to the development of the civil aviation sector in the world and especially in our region, with the growth it has shown in the past 15 years in the field of civil aviation. In many reports published by international aviation organizations, it is seen that Turkey has been at the top of the world's aviation sector in recent years.

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Many aviation experts believe that environmental impacts constitute the most critical impediment to the future growth of the air transport industry. Globally, concerns about noise and air pollution and their effects on health and quality of life have led to increasingly severe environmentally related restrictions on aviation (Neufville and Odoni, 2003).

There are two sides in airports (landside and airside). Although airports consist of large, immense structures (such as terminal buildings, hangars and fire department buildings) built on large areas (landside), the primary environmental pollutants appear to be airside (because of aircraft). Gas turbine engines, conceived as the prime mover of aircraft, are the main reason for environmental impacts because of their exhaust emissions. Primary pollutants of gas turbine engines are carbon dioxide (CO_2), nitrogen oxides (NO_X), methane (CH_4) and non-methane volatile organic compounds , carbon monoxide (CO), sulfur oxides (SO_X) and particulate matters (PM) (Unal *et al.*, 2005; Altuntas, 2014).

Besides safety and security, to avoid the effects of all pollutants, airports were built away from city centers. After the growth of population, almost all airports end up being located in living areas. For a sustainable future, this case should be managed.

To determine and detect the environment effects of airports, there are several studies in open literature. Schürmann *et al.* (2007) measured some emission parameters (NO, NO_2, CO and CO_2) in Zurich Airport and evaluated them with ICAO parameters. Westerdahl *et al.* (2008) measured PM and NO_x emissions for landing and takeoff (LTO) in Los Angeles Airport. Mazaheri *et al.* (2011) evaluated PM and NO_x emissions of different aircraft for LTO in Brisbane Airport. Song and Shon (2012) used EDSM method to calculate emission parameters in Korea. Yim *et al.* (2013) explored death numbers depending on emissions in the UK airports. Rissman *et al.* (2013) investigated LTO emissions of Atlanta Airport. Pecorari *et al.* (2016) focused on their study regarding the effects of meteorology on aircraft emission (NO_x, HC and CO) for the Marco Polo Airport.

Similar studies have also been conducted for some airports in Turkey. Tınmaz *et al.* (2002) investigated aircraft emissions from Corlu Airport. Kaygusuz (2003) analyzed NO_x and CO emissions, created in LTO, in all Turkish Airports. Kesgin (2006) investigated emission parameters in LTO some of Turkish Airports. Elbir (2008) evaluated NO_x, HC and CO emissions for Adnan Menderes Airport. Ekici *et al.* (2013) calculated NO_x, HC and CO emission parameters for the busiest Turkish Airports. Altuntas (2014) estimated global warming potential for aircrafts used in Turkish Airports.

When all of the studies are examined, it is seen that besides the existence of emission values for airports, it is also essential to determine their effects. In this study, the total amount of NOx, CO and HC emissions, which are produced by commercial flights, of Dalaman airport, which was the seventh largest airport in Turkey between 2016 and 2018, have been calculated.

Materials and method

First, sample airport is described under this section and also methodology used in the framework of the study are presented.

Dalaman airport

Airports consist of immense structures (such as terminal buildings, hangars and fire department buildings) built on large areas. The higher number of passengers and the higher flight numbers are not be directly related to the large-capacity airports. The competence of the company helps to more transport passengers as much as the capacity of airports.

Dalaman, one of the world's leading tourism centers, has always been one of the world's focal points with its geographic location, historical values, social structure and economic potential. Dalaman is an airport terminal established on a business-to-business basis with YDA investment group. As shown in Figure 1, Dalaman Airport covers an area of 1,100–1,200 hectares and is 6 km away from the center of Dalaman. The area given in this range consists of various architectural and urban planning calculations. Ten per cent of this area is reserved for the terminal building and external buildings and 90% is reserved for runway and flight safety, cargo and maneuvers (from the parking position of the aircraft to the taxiway passing the taxiway). It covers the area as open-air spaces with empty fields.

ICAO Airdrome Chart for Dalaman Airport was shown in Figure 2. The airport has a total area of 11,776,961 m^2. The total area of both the international and domestic terminal is 364,500 m^2, the international terminal being 268,000 $m^2$and the domestic terminal being 96,500 m^2. The combined terminal capacity is 17.5 m.pax/year. One of the main elements of the airport is the runways and the others are aprons (DHMİ, 2011).

Methodology

Flight occurs in two parts: ground operations and flight operations. While flight operations include LTO and cruise, ground operations of flight include passenger and luggage unloading/loading, refueling, etc. Flight operations also can be analyzed in two sub-categories, as LTO (below 915 m) and rest. Figure 3 can be explained as follows (right-to-left): landing, taxi-in, parking and engine shutdown in apron, engine start-up, taxi-out, runaway waiting and takeoff until climb-out. About 79% of the flight operation is held in taxi-in, taxi-out and apron.

In this study, the ground time was taken as 2 h for the aircrafts that waited in the apron for a long time or departed after one day. This ground time value was reached as a result of the interviews with aviation experts, ground handling managers and terminal operation managers.

As a result of the interviews, it was determined that activities such as refueling, cleaning, loading and unloading passengers, loading and unloading cargo and maintenance services were performed during this period. Ground handling companies start preparations for new operations at least 1 h before takeoff. Ground handling companies provide aircraft closure times approximately 55 min after the aircraft has moved to the parking position. Therefore, if the aircraft will be on the ground for a long time, the ground time (total time of taxi-in, apron and taxi-out) will be accepted as 2 h.

The standards issued by ICAO for ground operations and flight conditions are an essential parameter for investigating environmental impacts. With these standards, NO_X, CO and HC emissions, which have an indirect effect on global warming,

Figure 1 Geographical view of Dalaman Airport

Figure 2 ICAO airdrome chart for Dalaman Airport

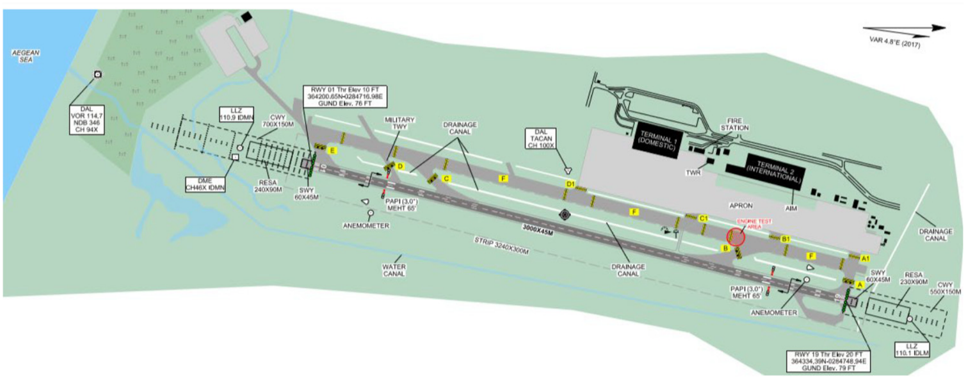
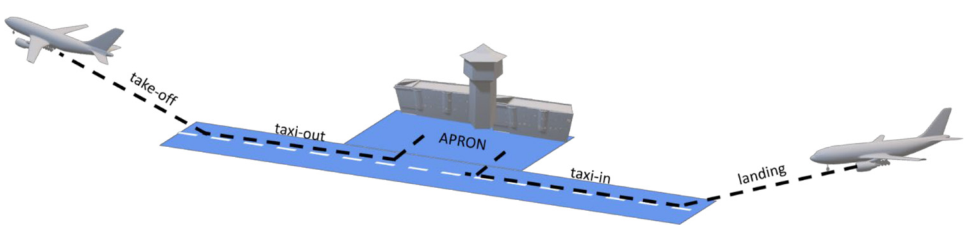


Figure 3 LTO phase of flight operation



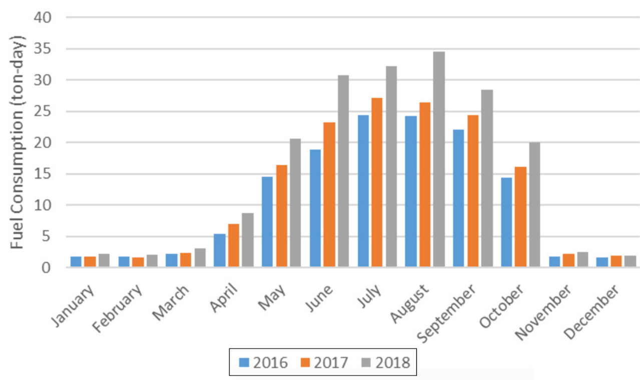
are the emission parameters that are the priority in aviation for a reference LTO at an altitude of 915 m. Three different approaches have been introduced in the calculation of ICAO aircraft engine emissions, simple, advanced and detailed. These are classed according to the combination of aircraft – engine, duration of operating modes and the amount of fuel exhaust emissions (ICAO, 2007; Altuntas, 2014).

All flight operation information recorded between 2016 and 2018 taken from YDA (including the airline name, flight code, landing and takeoff times and the types of aircrafts) is provided as follows. First, the commercial flight operations selected are all in the flight operation parameters. Then, the aircraft types and engine types are cleared. According to the ICAO databank, the emission factors of selected engine types must be selected to

Table 1 Number of flights and passengers in Dalaman Airport between 2016 and 2018 (adapted from ref. [DHMI, 2018])

	2016	2017	2018
Commercial flight			
Domestic	9,513	9,872	10,669
International	11,252	12,628	16,469
Total	20,765	22,500	27,138
Total passenger number			
Domestic	1,279,611	1,461,033	1,615,590
International	1,822,291	2,257,735	2,935,900
Total	3,101,902	3,718,768	4,551,490

Figure 4 Average fuel consumption



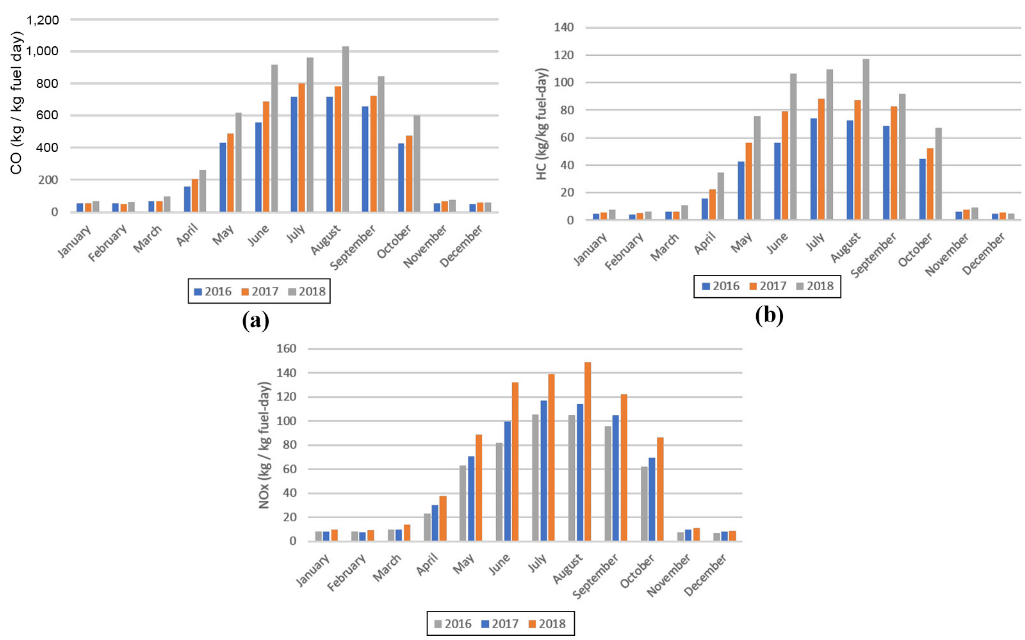
calculate daily/monthly/annual emissions for Dalaman Airport. In this study, more accurate results are obtained because of real-time flight operation information. As the examinations are conducted with the data collected from the ICAO database and real-time flight operation data, this calculation method can be shown as an advanced analysis. Emission calculations were made directly by taking ICAO data. Thus, it was seen that calculations were made with the general approach of ICAO.

Results

According to the knowledge of authors, all flight parameters collected from refs (DHMI [General Directorate Of State Airports Authority], 2018; ICAO, 2018) are showed in this section. Some main number of commercial flights, held in Dalaman Airport between 2016 and 2018, is listed in Table 1.

According to Table 1, in the past three years, there has been a 14.48% increase in the total number of commercial flights and 21.14% increase in the number of passengers. The reason for this increase is undoubtedly because of the new terminal building which opened in 2017. The newly opened terminal building helped increase traffic capacity. In line with this increasing rate, it is inevitable that the total number of commercial flights in 2019 will be approximately 31,000 and the total number of passengers will be 5.5 million. The fact that the airport operator mentioned a similar rate in some of their reports also shows how important it is for the airport to evaluate the emissions from aircraft in ground operations. As a result of the evaluation, the effects of ground operations were investigated in three different ways (daily, commercial flight number and number of passenger). Each approach is a method of evaluation encountered in the open literature. It is seen that many environmental studies have been carried out by the authorities, such as showing the amount of CO_2 generated

Figure 5 Average values of (a) CO/day, (b) HC/day and (c) NOx/day



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during a flight process in ticketing and being mandatory for CORSIA to monitor the environmental impacts of airlines.

In this study, fuel consumption, emission parameters and all flight data are taken from the management of Dalaman Airport and the ICAO database. Daily fuel consumption and NOx, CO and HC production values at Dalaman Airport are given in Figures 4 and 5, respectively.

Figure 4 shows the average amount of fuel consumed at Dalaman Airport. As shown in Table 1, the highest fuel consumption occurs between June and September, with the highest number of flights. When the average daily fuel consumption is considered, the highest fuel consumption is seen in August 2018 with 34.49 tons, in July 2017 with 27.16 tons and in July 2016 with 24.32 tons. The lowest fuel consumption is estimated at around 2 tons in November, December, January and February.

Figure 5 shows the average emission values generated at Dalaman Airport. It is seen that the daily emission values are also high in the months when the highest fuel consumption is realized.

When the average CO values per day are examined, the highest CO value is observed as 1031.71 kg in August 2018, 803.6 kg in July 2017 and 720.21 kg in July 2016. When the average HC values per day are examined, the highest HC value is 117.22 kg in August 2018, 88.22 kg in July 2017 and 73.81 kg in July 2016. When the average NOx values per day are examined, the highest NOx value was observed as 148.63 kg in August 2018, 116.91 kg in July 2017 and 105.09 kg in July 2016.

The average monthly fuel consumption per passenger transported at Dalaman Airport and NOx, CO and HC production values are given in Figures 6 and 7, respectively.

Figure 6 shows the average monthly fuel consumption per passenger at Dalaman Airport. When the calculated values are examined, the highest fuel consumption observed is 1.33 kg/pax in October 2018, 1.4 kg/pax in October 2017 and 1.4 kg/pax in October 2016. As shown in the 2018 values, it is seen that the value is less than 1 kg/pax in November, December and February.

Figure 7 shows the generated emissions per passenger on a monthly basis. When the calculated values are examined, the highest CO value calculated was 39.72 g/pax in October 2018, 41.39 g/pax in October 2017 and 41.55 g/pax in October 2016. The highest NOx value observed was 5.72 g/pax in October 2018, 6.04 g/pax in October 2017 and 6.02 g/pax in October 2016. The highest HC value observed was 4.78 g/pax in May 2018, 4.55 g/pax in October 2017 and 4.33 g/pax in October 2016.

The average monthly fuel consumption and NOx, CO and HC production per flight at Dalaman Airport are given in Figures 8 and 9, respectively.

Figure 6 Average monthly fuel consumption per passenger

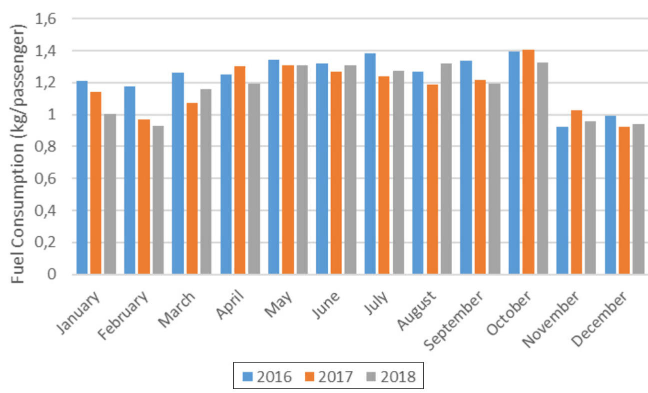


Figure 7 Average values of (a) CO g/pax, (b) HC g/pax and (c) NOx g/pax

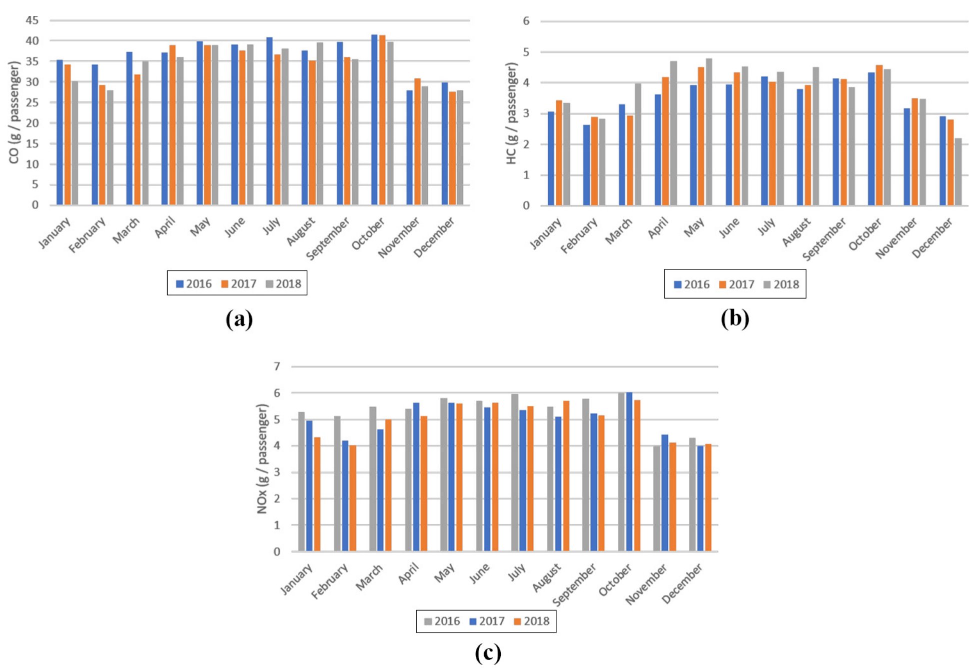
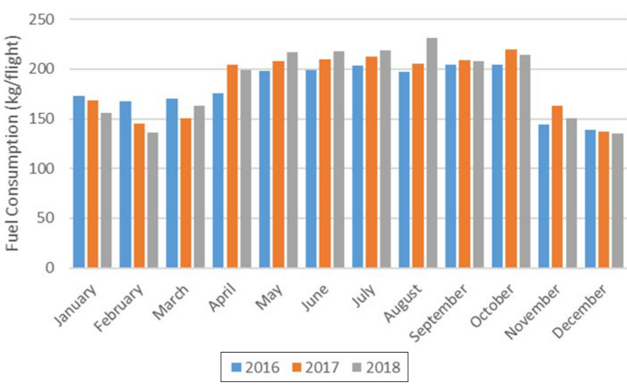


Figure 8 shows the average amount of fuel consumed per flight at Dalaman Airport monthly. When the calculated values are examined, it is seen that the highest fuel consumption is in August 2018 at 230.95 kg/flight, in October 2017 at 219.94 kg/flight and in October 2016 at 204.82 kg/flight.

Figure 9 shows the average generated emissions per flight at Dalaman Airport on a monthly basis. When the calculated values are examined, the highest CO value observed was 6909.27 g/flight in August 2018, 6485.42 g/flight in October 2017 and 6098.28 g/flight in October 2016. The highest NOx value observed was 995.34 g/flight in August 2018, 945.8 g/flight in October 2017 and 883.83 g/flight in October 2016. The highest HC values were in May 2018 with 796.47 g/flight, in June 2017 with 716.68 g/flight and in October 2016 with 635.9 g/flight.

Figure 8 Monthly values for average fuel consumption/flight by years.

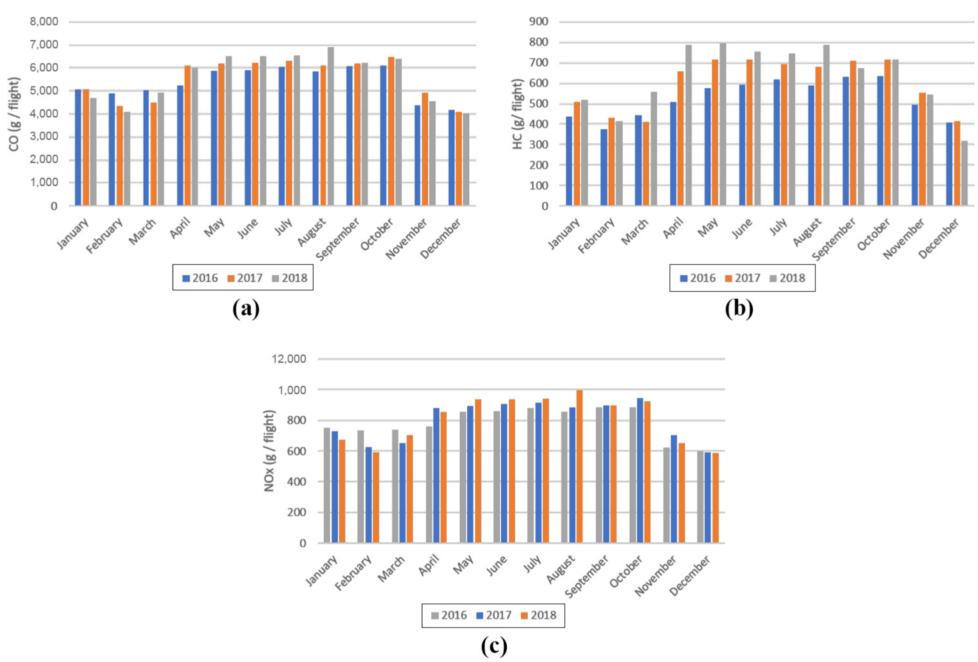


Conclusion remarks

The main conclusions of this study are as listed;

- Though the number of passenger increases about 21.14% per year, the total number of commercial flights increases 14.48%. This increase is a sign of more fuel consumption and also more environmental effects. The lowest fuel consumptions were calculated as 2 tons, 1 kg/pax. Considering climate conditions and results, the lowest fuel consumption will be seen in winter.
- The maximum CO, HC and NOx were calculated as 1031.71 kg/day, 117.22 kg/day, and 148.63 kg/day, respectively, in August 2018. This result is directly related to the number of traffic.
- According to the number of flights and passenger traffic, there is a change in the manner in which total emissions produced are displayed. The maximum daily CO, HC and NOx values were calculated in August 2018. According to passenger values, the maximum CO, HC and NOx values per passenger were found in 2016, 2017 and 2018, separately. The maximum average generated for CO, HC and NOx emissions per flight was calculated in 2018.
- The maximum CO values were found in October 2016 at 41.55 g/pax. and in August 2018 at 6909.27 g/flight. The maximum NOx values found were 6.04 g/pax in October 2017 and 995.34 g/flight in October 2017. The maximum HC values found were 4.78 g/pax in May 2018 and 796.47 g/flight in May 2018. While the total amount of emissions is related to traffic density, it has been noticed that the number of passengers and airplane landing also changes the balance.

Figure 9 Average values of (a) CO g/flight, (b) HC g/flight and (c) NOx g/flight



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