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Using Environmental Cost to Evaluate Air Freight Traffic in a Turkish International Airport

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Abstract

Air freight transportation has major advantages such as rapid and safe transit of goods compared to other transportation modes. As well as other transportation sectors growth rate of air freight transportation is related to global supply chain. Air freight sector fundamentally includes freight forwarders, integrators, warehousing, customs, agents, airport terminal operators, and air freight carriers. Cost of air freight transportation is dependent to carrier expenses including costs of ground and flight crew, fuel, aircraft maintenance and insurance. But environmental prevention costs are usually missed out and disregarded. But environmental costs gained importance for many enterprises as well as airway companies after Kyoto and Paris Agreements. The current paper describes an approach to calculate prevention cost of air freight operations induced air pollutants. For this purpose, air freight traffic in an International Airport located in Isparta, Turkey is considered to present the approach. At the end of the study environmental cost of each air pollutant emissions, annual environmental cost of flight operations in the airport, and annual environmental cost per unit freight are calculated and compared in terms of yearly variation. The presented approach is employed to evaluate environmental costs related to air freight traffic in an International Airport for the first time.

1. Introduction

Regarding the recent advances in global trade and business world supply chain management gains importance. Supply chain management is defined to be planning and management of all sourcing, procurement, conversion, and logistic activities in addition to coordination of suppliers and all other third-party service providers (Stank et al., 2005). Thus, logistics activities are the main element of global trade from of old. In logistic activities railway and intermodal transportation is the most preferred option. But air freight transportation is always the most prominent one among others if rapid and safe transit of goods is required. On the other hand, growth rate of air transportation is closely linked to global supply chain. Air freight industry mainly includes freight forwarders, integrators, warehousing, customs, agents, airport terminal operators, and air freight carriers. Cost of air freight transportation is mainly related to carrier expenses. Here we can consider ground and flight crew, fuel, aircraft maintenance and insurance costs as the major factors of carrier costs (Leung et al., 2000; Chao and Hsu, 2014). Most of the previous studies discussed effect of passenger numbers and fuel prices on air freight costs (Tsoukalas et al., 2008; Takebayashi, 2011; Mayer and Scholz, 2012; Chao and Hsu, 2014;). However environmental cost is mostly disregarded.

After the Kyoto and Paris Agreements climate change and global warming concern of the mankind is comprehended in a better way. So sustainable depletion of sources and deceleration of environmental effects have been the main objective of many industries. Aviation industry has a small percentage among all others with a global average value of 2.5% in 2007 in terms of CO2 emissions. But it is expected to increase 4.8% each year according to ICAO reports (ICAO, 2010).

Lu (2011) focused on economic gains from airports due to environmental costs. In this case Taiwan Taoyuan International airport was evaluated in terms of both environmental and social costs induced by aircraft noise and engine emissions. At the end of the research the economic benefits obtained from the airport operations were found to outweigh the negative side effects. In a former study of Konuralp (2020) showed a particular interest to the environmental degradation caused by commercial aviation. And pricing of carbon via tax was also asserted. Ekici and Sohret (2021) discussed the environmental cost of aircraft emissions at the Antalya Airport during the busiest period of 2018 year. It was concluded that B737 family aircraft has the highest environmental cost with value of 39,723.4 Euros.

Sustainable development problem related to environmental concerns in aviation industry is discussed by a group of researchers (Ekici et al., 2022). In this research how to employ environmental impact and financial values for policymakers and build new regulations is presented.

To understand relationship between environment and economy of aviation sector international organizations and aircraft manufacturers started different projects to decrease emissions. Prevention and elimination of emissions from the environment is another issue. As well as many other processes prevention and elimination of emissions from the environment lead costs. To understand and evaluate this cost environmental accounting is considered as a beneficial tool.

Environmental pollution is linked to in efficiency, and it is associated to economic disadvantage in terms of utilization of sources. So it is an opportunity for business to improve their financial performance by minimization or prevention of pollution. Particularly in last decade this approach plays a key role for sustainable management and development of firms. On the other hand prevention of pollution has a cost but it can be absorbed by winnings from more efficient use of sources. Understanding of this idea has been the driving force for many leading companies that aim to achieve sustainability (Burrit and Christ, 2016; Deegan, 2017). From this point of view environmental accounting attracts attention both industry and academia. In environmental accounting prevention or lamination cost environmental pollutions including air, water, and land pollution induced by each process is considered. The main goal of the environmental accounting is determining environmental cost whereas minimization or absorption of them by winnings from process improvements.

In the current paper the main goal is determination of air pollution cost of emissions from air freight traffic in an International Airport located in Isparta, Turkey. For this purpose, air traffic data is obtained from the Ministry of Transport and Infrastructure of the Republic of Turkey. Obtained air freight traffic data is evaluated in conjunction with aircraft fleet in Turkey with consideration of aircraft and its engine type. At the end of the study achieving environmental cost of air traffic in the investigated airport per carried freight is purposed.

2. Methodology

2.1. Environmental Accounting

Accounting is information and document collection, classification, financially assessment, and reporting of all activities in any enterprise. Account has a responsibility to consider rights of society instead of a person or a part of the society. From this point of view social responsibility accounting merged related to social responsibility of the accounting. Environmental accounting is one of the subsidiary branches of the social accounting. Environmental accounting plays a key role in documentation, reporting, and auditing expenses associated with environmental activities in an enterprise (Ergin and Okutmuş, 2007). Considering recent advances in environmental policy and environmental sensitivity of enterprises environmental accounting has gained significance to evaluate environmental impact and to obtain required information for decision making. Environmental accounting fundamentally aims to describe relation and interaction between economy and environment in addition to developing profile of resources, depletion of resources in the stock, and analyzing balance sheet (Adediran and Alade, 2013; Moorthy and Yacob, 2013; Ascui, 2014; Magablih, 2017).

On the basis of an enterprise, environmental accounting can be considered to appreciate the value of activities at each level of the organization affecting environment in the bad manner. Within this framework environmental impact of an air transportation operation should be considered as activities of flight attendants, activities in airport terminal building, activities during flight operation, and so on. However the flight operation takes the lion's share among all other activities of the airway enterprise due to emitted polluting gases from the aircraft engine during the operation

2.2. Overview of Air Transportation in Turkey

In the last ten years investment on transportation sector has an increasing trend in Turkey. As the most significant digit of this progress Turkey purposes to be the main hub of both air passenger and freight in next years by opening of Istanbul Grand Airport. Carried air freight and passenger from Turkish airports in the years of 2019 and 2020 is tabulated in Table 1. According to the table total passenger number is decreased 60.8% from 2019 to 2020 whereas decrease in flight number and air freight are 45.1% and 10.1%, respectively.

Table 1. Air traffic data in Turkey in the years of 2019 and 2020 (General Directorate of State Airports Authority, 2022).

	2019			2020		
	Domestic	**International**	**Total**	**Domestic**	**International**	**Total**
Flight number	839.894	716.523	1.556.417	572.994	280.756	853.750
Passenger number	99.946.572	108.427.124	208.373.696	49.740.303	31.875.837	81.616.140
Air freight (tons)	65.667	1.456.737	1.522.404	51.043	1.317.533	1.368.577

In Table 2, a detailed air freight data for each airport in Turkey is also presented. In accordance with the table the most freight is transported by Istanbul Grand Airport (ISL) in both years of 2019 and 2020. However, in the current paper Isparta Suleyman Demirel International Airport (ISE) is evaluated despite its low freight amount. Isparta Suleyman Demirel Airport is in the service of West Mediterranean Region of Turkey for air transportation. But a high amount of exported goods from this region is transported by seaway, roadway or railway to East Asia, Europe, and Africa countries. Additionally, role of the Isparta Suleyman Demirel International Airport in the global trading potential of the region increases regarding a project development for a freight village integrated to the airport. If the freight transportation by the airway from Isparta Suleyman Demirel International Airport the air traffic and its environmental impact should be a concern.

Table 2. Air freight data of Turkish Airports in the years of 2019 and 2020 (General Directorate of State Airports Authority, 2022).

Airport (IATA Code)	2019			2020		
	Domestic	International	Total	Domestic	International	Total
ISL	8.662	816.833	825.495	1.965	795.179	797.144
IST	15.814	575.149	590.962	18.292	476.310	494.602
SAW	8.004	52.044	60.048	5.585	34.438	40.022
ESB	8.544	3.310	11.853	5.599	5.350	10.949
ADB	11.775	5.140	16.915	10.616	3.353	13.969
AYT	4.626	3.079	7.705	2.179	745	2.924
GZP	0.2	0.0	0.2	1.0	0.0	1.0
DLM	25	0.1	25	20	11	30
BJV	53	0.1	53	41	0.0	41
ADA	2.884	709	3.593	2.726	615	3.341
TZX	751	2	754	462	8	470
ERZ	190	0.0	190	129	0.0	129
GZT	779	2	781	595	369	964
ADF	64	0.0	64	60	0.0	60
AJI	4	0.0	4	4	0.0	4
MZH	18	0.001	18	16	0.0	16
CII	0.0	0.0	0.0	0.0	0.0	0.0
EDO	1.0	0.0	1.0	0.02	0.0	0.02
BZI	0.0	0.0	0.0	0.0	0.0	0.0
BAL	264	0.0	264	248	0.0	248
BGG	2	0.001	2	8	0.0	8
YEI	45	6.0	51	0.4	0.0	0.4
CKZ	1.0	0.0	1.0	1.0	0.0	1.0
GKD	0.0	0.0	0.0	0.0	0.0	0.0
DNZ	338	0.02	338	288	0.0	288
DIY	423	0.01	423	348	20	368
EZS	128	0.2	128	100	0.5	100
ERC	36	0.0	36	30	0.0	30
AOE	0.0	3	3	0.0	3	3
YKO	0.0	0.0	0.0	0.0	0.0	0.0
HTY	9	1	10	23	1	24
IGD	27	0.0	27	20	0	20
ISE	7	0.01	7	2	0.0	2
KCM	56	0.0	56	21	0.0	21
KSY	21	0.0	21	8	0.0	8
KFS	2	0.0	2	2	0.0	2
ASR	615	15	630	595	11	606
KCO	0.1	7	7	0.0	0	0
KYA	239	0.9	240	222	0.1	222
MLX	141	0.0	141	71	0.0	71
MQM	82	0.0	82	68	0.0	68
MSR	45	0.0	45	38	0.0	38
NAV	17	0.0	17	11	1	12
OGU	123	0.2	123	72	0.0	72
SZF	390	4	393	274	4	278
SXZ	0.4	0.0	0.4	5	0.0	5
NOP	11	0.0	11	6	0.0	6
VAS	29	0.0	29	15	7	22
GNY	109	0.0	109	55	0.0	55
NKT	2	0.0	2	4	0.0	4
TEQ	0.01	430	430	0.0	1.109	1.109
TJK	0.0	0.0	0.0	0.0	0.0	0.0
USQ	0.1	0	0.1	0.0	0	0.0
VAN	305	1	306	218	0	218
KZR	3.5	0	3.5	0.1	0	0.1
ONQ	0.3	0	0.3	0.0	0	0.0

2.3. Conceptual Framework

The flag carrier and the block holder of the air freight transportation in Turkey and operating freight carrier airway in Isparta Suleyman Demirel International Airport is currently Turkish Cargo. Based on the obtained data freight is carried in the years of 2019 and 2020 by 3 and 1 separate flights, respectively. In other words, freight transportation corresponds to 3 and 1 landing and take-off (LTO) count in the

years of 2019 and 2020, respectively According to data provided by Turkish Cargo fleet distribution is given in Table 3. According to the table the widely in-service cargo aircraft type is A330-200F.

Also, in Table 4 main features of A330-200F aircraft are listed. According to the table net cargo payload of the aircraft is 64.48 tones. According to datasheet of Airbus the main power unit of A330-200F is one of these engines: PW4000, Trent700, or CF6 series. In the current paper environmental accounting of emissions is performed regarding CF6-45A2 engine.

Table 3. Cargo aircraft fleet of Turkish Cargo (Turkish Airlines, 2022)

Aircraft Type	Number of Aircraft
A330-200F	10
B777F	6
B747-400F	4
A310-300F	2
A300-600F	1

Table 4. Features of A330-200F type cargo aircraft (Turkish Airlines, 2022)

Net Cargo Payload	**64480 kg / 330 m³**
Main Deck Door Dimensions	358 x 257 cm
Lower Deck Front Door Dimensions	270 x 170 cm
Lower Deck After Door Dimensions	273 x 168 cm
Bulk Cargo Compartiment Door Dimensions	95 x 90 cm
Height Limits in Aircraft	240 cm Max
Maximum Cargo Capacity (Main Deck)	58.532 kg / 242 m³
Maximum Cargo Capacity (Lower Deck Front)	18.869 kg / 52 m³
Maximum Cargo Capacity (Lower Deck After)	16.828 kg / 44 m³
Maximum Capacity (Bulk Cargo Compartment)	2.770 kg / 19 m³

According to the ICAO emission measurement procedure LTO cycle is shown in Fig. 1. In this context approach phase is operated for 4 minutes at 30% engine load, taxi phase is operated for 26 minutes at 7% engine load whereas duration of take-off and climb phases are 0.7, and 2.2 minutes, respectively.

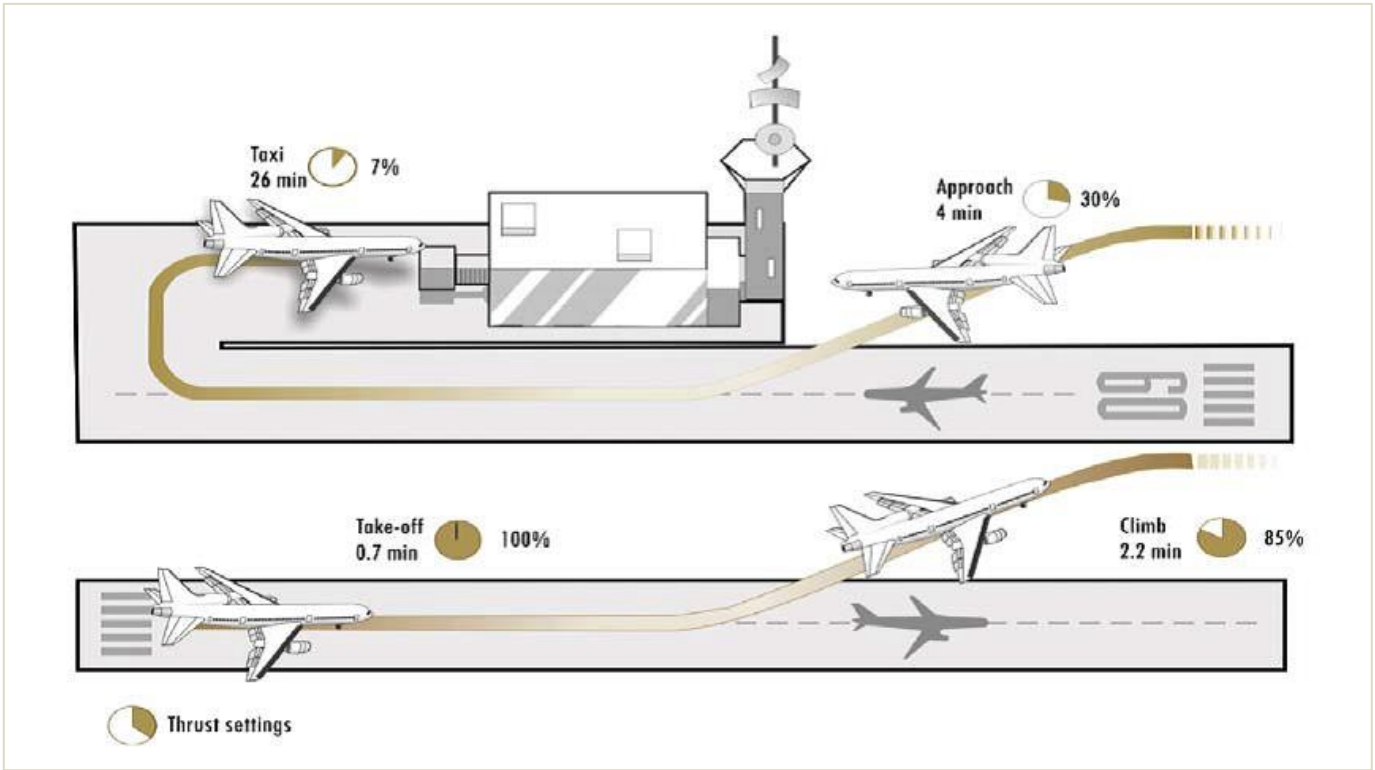

Figure 1. LTO schematic illustration for the ICAO emissions certification procedure (ICAO, 2022)

In Table 5 LTO emissions of CF6-45A2 engine is listed. Herein emissions data is obtained from EASA emissions inventory regarding ICAO emissions certification procedure illustrated in Fig. 1. Here emissions index of each exhaust gas and fuel flow rate is given. In the current study environmental accounting of each exhaust gas is evaluated by considering prevention costs determined by Vogtlander (2019). Within this context prevention cost of CO, HC, and NOx are 0.27 €/kg, 3.538 €/kg, and 6.65 €/kg.

Table 5. LTO emissions characteristics of CF6-45A2 engine (EASA, 2022)

Flight Phase	Emissions Index (g/kg)			Fuel Flow Mass (kg/sec)
	HC	CO	NOx	
Take-off	0.09	0.43	25.45	2.027
Climb-out	0.14	0.54	21.61	1.663
Approach	0.35	5.01	9.36	0.592
Idle	2.72	24.04	3.4	0.163

3. Results and Discussion

In the current paper, environmental accounting of the freight air traffic in the Isparta Suleyman Demirel International Airport is presented. In Table 6 emissions amount of 45A2 engine is given. According to Table 6 the highest emitted gas is NOx during LTO cycle excluding idle phase whereas HC is the least emitted gas.

Table 6. LTO emissions of CF6-45A2 engine

Flight Phase	Emissions Flow Mass (g/sec)		
	HC	CO	NOx
Take-off	0.18243	0.87161	51.58715
Climb-out	0.23282	0.89802	35.93743
Approach	0.2072	2.96592	5.54112
Idle	0.44336	3.91852	0.5542

In Table 7 environmental cost of the engine per second during a LTO cycle is tabulated. According to Table the highest environmental cost per second is calculated as 0.623 €/sec for NOx while the lowest environmental cost per second is determined as 0.0023 €/sec for CO. Additionally environmental cost of HC is found to be 0.00378 €/sec. On the other hand take-off phase of LTO is the main source of the environmental cost per second as it is understood from Table 7.

Table 7. LTO environmental cost of CF6-45A2 engine

Flight Phase	Environmental Cost (€/sec)		
	HC	CO	NOx
Take-off	0.000645	0.000235	0.343055
Climb-out	0.000824	0.000242	0.238984
Approach	0.000733	0.000801	0.036848
Idle	0.001569	0.001058	0.003685

Fig. 2 shows environmental cost of emissions at LTO phases regarding operation durations given in Fig. 1. Here, the highest environmental cost is determined for NOx emissions whereas the lowest environmental cost is found for CO emissions. On the other hand the highest environmental cost is determined for the emissions released at climb-out phase. The lowest environmental cost of emissions is calculated for the approach phase with the value of 9.212 €. At each phase of LTO NOx induced cost is the highest one among all emissions. Also cost related to HC is higher than CO induced cost. If total cost of emissions is evaluted NOx, HC, and CO correspond to 60.546 €, 2.759 €, and 1.885 €, respectively during LTO cycle.

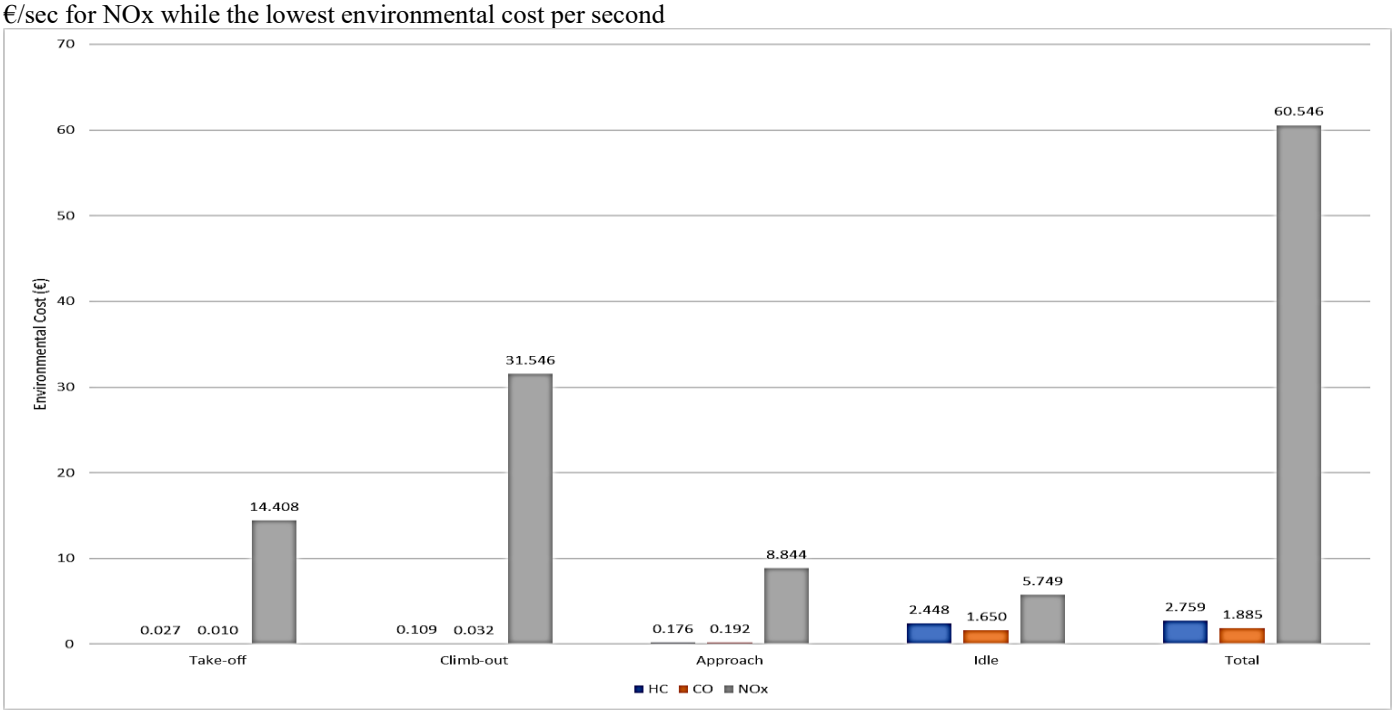

Figure 2. Environmental cost of emissions at LTO phases

In Fig. 3 calculation results are graphed considering annual operation of the freight aircraft and annual LTO count. Regarding higher LTO count in 2019 than 2020 environmental cost in the year of 2019 is found to be higher than the environmental cost in the year of 2020. If the calculation results are compared total environmental cost decreased by 66% from 2019 to 2020. Herein decerase in flight operations is a natural result of the pandemic regulations and restraints.

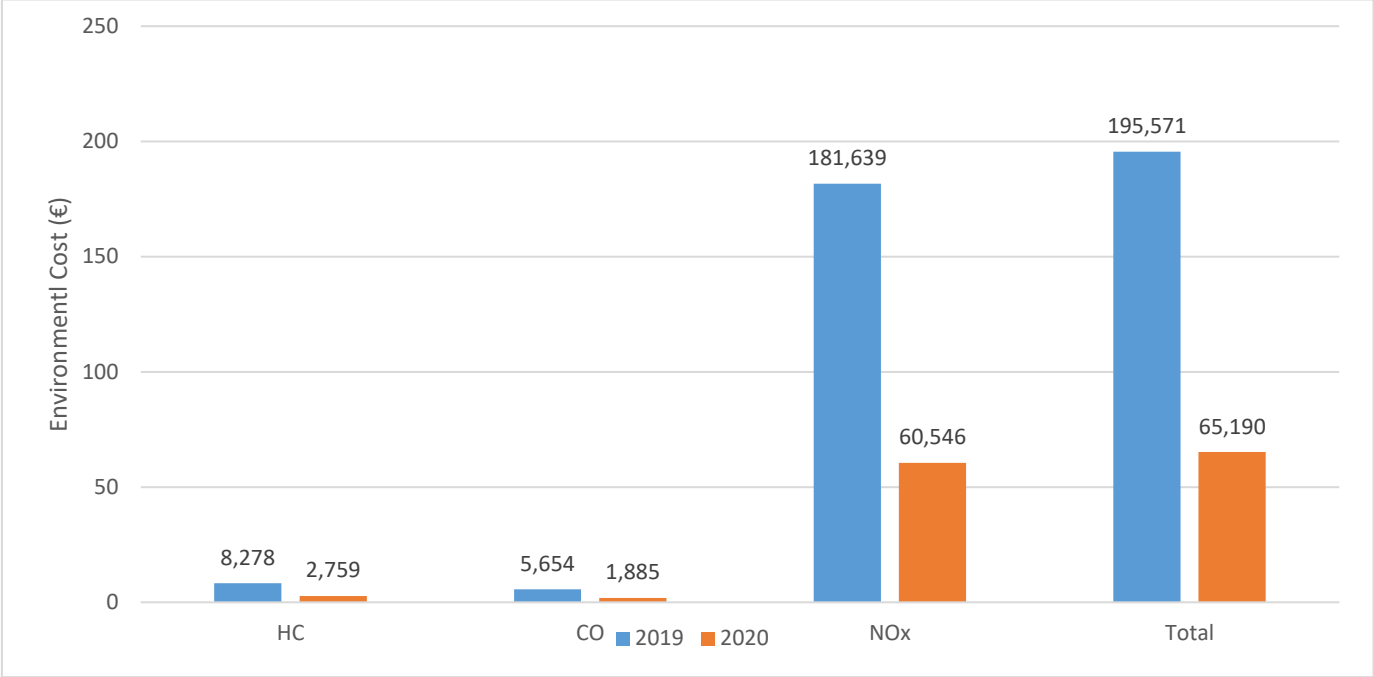

Figure 3. Annual environmental cost of emissions

If Fig. 4 is evaluated environmental cost per unit freight variation with the year can be understood. Environmental cost per unit freight increases from 2019 to 2020 whereas annual environmental cost decreases. Considering carried freight amount in 2019 and 2020 calculation result is meaningfull. Annual environmental cost per unit freight increases from 0.028 €/kg to 0.033 €/kg with an increase rate of 18% while the freight amount is decerased by 71% from 2019 to 2020.

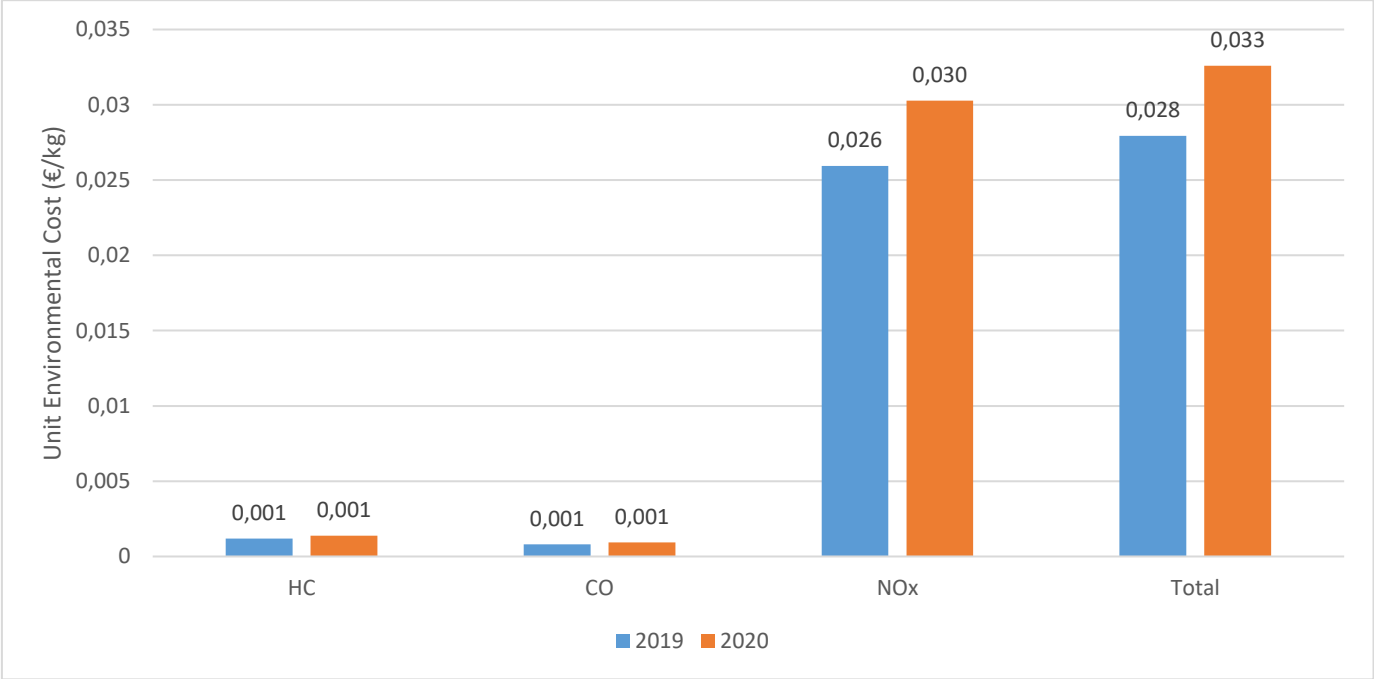

Figure 4. Annual environmental cost of emissions per unit freight

4. Conclusion

The present study asserts an approach to determine air pollution cost of emissions from air freight traffic in Isparta Suleyman Demirel International Airport. In this framework, air traffic data obtained from the Ministry of Transport and Infrastructure of the Republic of Turkey is evaluated considering aircraft and its engine type in terms of environmental cost of each air pollutant emissions, annual environmental cost of flight operations in the airport, and annual environmental cost per unit freight. The main implications can be deduced regarding the results of the study:

- NOx is the highest emitted gas is during LTO cycle excluding idle phase whereas HC is the lowest emitted gas.
- The highest environmental cost per second is calculated for NOx.
- The lowest environmental cost per second is determined for CO.

- Environmental cost in the year of 2019 is found to be higher than the environmental cost in the year of 2020.
- Environmental cost per unit freight increases from 2019 to 2020.

In a future study a comparison of environmental costs of emissions induced by different transportation modes including railway, airway, and roadway is planned by the author.

Ethical approval

Not applicable.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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