Outlines of Sustainable Air Transportation in ICAO Annex Documents: Roots of Sustainability

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Nomenclature

AHP	Analytical Hierarchy Process
BWM	Best Worst Method
FAA	Federal Aviation Authority
FDM	Fuzzy Delphi Method
GRI	Global Report Initiative
ICAO	International Civil Aviation Organization
KPI	Key Performance Indicators
MABAC	Multi-attribute Border Approximation Area Comparison

1 Introduction

Sustainable aviation is a phenomenon that defines the long-term characteristics of the environment, social, and economic domains of a vision. Although Federal Aviation Authority (FAA) defines sustainable aviation with an additional "operational" domain, the literature understands this phenomenon in three domains, "social," "economical," and "environmental," both separately and together (FAA, 2022). Also, Fraport Group published a sustainability report based on Global Reporting Initiative (GRI) on Environment, Financial, and Personnel basis (Fraport, 2019).

However, there should be a better understanding of sustainable aviation metrics. Barros and Dieke (2008) have developed a two-stage semi-parametric model for

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airport economic efficiency. They have defined airports as an interest to contemporary economics due to their increasing strategic importance in the movement of people and goods in a globalized world. Due to airline deregulation and liberalization, the increased competition among airlines has created a much more competitive environment for airports. They analyzed the economic efficiency characteristics of 31 airports and found sustainability indexes such as the number of planes, the number of passengers, general cargo, handling receipts, aeronautical sales, commercial sales, labor costs, capital invested, and operational costs.

Brueckner and Abreu (2017) studied carbon emissions, an item of the environmental domain. They used annual data of airlines in North America between 1995 and 2015. They used the available ton-kilometers, and available seat-kilometers per aircraft rose in their study. They also and revealed the stage length rose by 100 miles, the load factor rose by 5%, aircraft vintage becomes younger, the fuel price rose, and optimal emissions during the flight.

Another study in the literature evaluated the environmental protection performance model (Chao et al., 2017), which used a Fuzzy Delphi Method (FDM), and dimensions, and indicators for assessing airport environmental protection performance were chosen. The first round of a questionnaire survey solicited expert opinions on the summarized indicators, followed by a second questionnaire designed to obtain the weights of the selected environmental rating indicators using the analytic hierarchy process (AHP) and examine the value functions of these indicators. All the environmental indicators have been grouped under green airport design, energy conservation and carbon reduction in airport operations, use of renewable resources, and airport environmental sustainability management.

Key performance indicators (KPIs) are vital to measuring sustainability. Eshtaiwi et al. have determined KPIs to assess airport success (2018). This study seeks to provide a collection of airport key performance indicators (KPIs) that may be used to monitor and assess the operation of Libyan airports. The technique analyzes the opinions of specialists with extensive experience in the airport business in Libya and high levels of knowledge. The results showed 25 KPIs under five domains: passenger service, airside area, financial perspective, safety and security, and environmental.

Contrarily, Indian airports have been examined by the integrated performance evaluation technique by Chakraborty et al. (2020). Using the best-worst method (BWM) and the multi-attribute border approximation area comparison (MABAC) method, the performance of 32 major Indian international airports was evaluated based on eight criteria: annual revenue, total passengers, aircraft movements, total freight, terminal area, number of routes, number of check-in counters, and distance from the city center.

This chapter looks at mediation to find an understandable way to categorize and group around the sustainability domains and indexes to assess annexes. The findings of the chapter were based on the basic methodology used to assess a group of aviation students.

2 Method

This research has planned to assess all subheadings of annex documents to examine according to the specified literature and evaluate all three main sustainability domains. The study comprised three main stages. First stage was the determination of sustainability metrics from the literature. Second stage was browsing of the annexes for possible relations and marking down on a mindmap diagram. Second stage was finalized after a discussion session to ensure the relation. The last stage, third stage, matched the findings with the related annex and sustainability indexes.

The research criteria constructed for the environment domian were obtained using the research created by Chao et al. (2017). There are 19 criteria to be considered in evaluating the sustainability performance and developing performance improvement plans according to the state of the aviation.

2.1 Determination of Sustainability Metrics

The competition caused by aviation liberalization influenced the formation of sustainable and efficient operations in which there is a relevant interest in the modern economy. Skillful aviation companies that find sustainable ways to operate provide guidance to improve aviation industries and society. Then, sustainability in terms of economics, altering the competition caused by the liberalization of airports and airlines, also ensures sustainable efficiency and interest in the modern economy.

It is seen that the utilization rate and the capacity of airports, which are increasing every day with the development of air transportation, do not meet each other according to the Asker and Battal (2017). For this reason, it has been observed that the effective and efficient use of airports will positively affect social, economic, and environmental sustainability. Airports are not the only source of aviation. Airlines are the other vital source of aviation. Tiwari et al. have proven the significance of low costs operations and simplicity as a strategy for a new company in the airline industry necessary to achieve ongoing sustainable profitability in an industry that is failing to turn a profit (2018).

This chapter examined aviation sustainability in three divisions: environmental, social, and economic domains, with the criteria below.

- Environmental domain
  - Waste management
  - Water management
  - Noise management
  - Energy management
  - Emissions and air quality
  - Biodiversity
  - Certifications

- Economic domain
  - Direct
  - Indirect
  - Development
  - Employment
- Social domain
  - Employee satisfaction
  - Customer satisfaction
  - Human rights
  - Safety and hazards
  - Shareholder relations
  - Ethical rules
  - Social accountability
  - Indirect social affects

2.2 Browsing the Annexes

A word-based scan was performed within the 19 annexes and appendix documents for the matching indexes grouped under three domains of sustainability. During this screening, the topic's content was examined by paying attention, and titles were taken. The headings specified in the annexes have been shared in the group to process them efficiently while scanning.

On the other hand, this study has focused to investigate the usefulness of these titles in terms of economic, social, and environmental domains was examined. As a result, the aim is achieved after the discussions are completed on these three domains. The results obtained from the mindmap after all headings and subheadings of annexes were browsed are shown in Fig. 1. The scheme thus created is called "the EYE." Thanks to this, a better understanding of the issue has been achieved.

After the annex subheading is placed under the appropriate sustainability category, a two-dimensional matrix system is generated.

Fig. 1 A mindmap graphic called the EYE of Annexes showing the relationship of sustainability indexes and the annex subheadings

3 Results

The latest versions of ICAO annexes and updates were examined until August 2022. The 29 documents examined containing 4,562 pages with their appendixes show that its contribution to sustainability-related development was found insufficient, considering environmental, economic, and social consequences. Furthermore, there is no direct relation to sustainability in the documents. However, there are indications of previously mentioned groups.

These documents were examined and compared with three domains of economic, social, and environmental sustainability. Sustainability indexes specified under these domains were compared regarding sustainable aviation. The most exciting result was found for the social domain, representing 69% of all connections. Of the results obatined, 28% matched with environmental and only 3% with the economic proportion, which are shown in Fig. 2.

According to the data obtained, the conclusion drawn is that there is an imbalance in the annexes. Imagine that this is a wheel to roll to carry the whole industry; it is pretty impossible to go forward due to the imbalance of the three domains of the sustainability wheel. The progress will not be accessible from a sustainability point of view because rims did not share equally.

3.1 Environmental Domain

Thus far, manufacturers, airlines, and airports have taken many sustainable actions for the environment. However, according to the results of the annexes, there is not much standardization related to the environment. The result were obtained when the

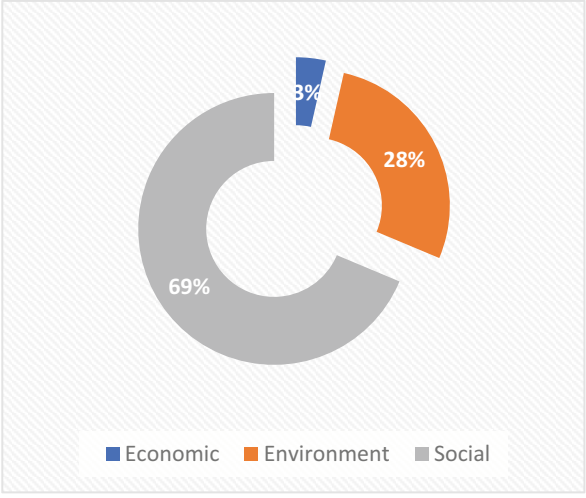

Fig. 2 Proportions of sustainability groups in annexes

research shows the general characteristics of all appendixes, almost one-third of all indexes are confrontation of the environmental domain. This specified ratio should also consider the scarcity of data input. Table 1 shows the environmental finding of sustainability. According to this table, a total of 55 related indexes were found.

There are three crucial index groups noticed in Table 1. The first is "emissions and air quality," which is mentioned 24 times. "Certification" is mentioned ten times and "noise management" nine times. There are 22 sustainability indexes mentioned in Annex 16, and the contents of this annex are related with "aircraft noise". Headings of Annex 16 also cover "aircraft engine emissions." It is seen that these annexes, which tackle the two main sustainability problems of the aviation sector, have an impact on sustainable aviation.

3.2 Economical Domain

The economic aspect is vital in terms of continuing sustainability. Economic efficiency is often at the forefront for airlines and airports. The reason for this is the necessity to stay afloat. From this point of view, it should be understood that achieving economic sustainability is a breakthrough in terms of continuity in the sector and should not be sustainable if there is no economical plans present. In this context, the conclusion drawn from the table is that annexes are more focused on employment. In particular, failure to achieve standardization in terms of direct economic contributions may turn into a problem in terms of keeping the sector afloat.

It is known that these annexes were created from the ensuring standardization. However, it is seen that sustainability has not been mentioned from the economic point and no standardization has been achieved in this regard (Table 2).

The fact that there is little standardization in terms of cost structure shows that there is a high potential for long-term problems in the sector. As a result of the research conducted from this point of view, the necessity of introducing an economic standardization can be critical for aviation rules. ICAO determines direct economic contributions and, at the same time, the employers in the sector will know that they have economic contributions, thanks to this standardization.

3.3 Social Domain

In light of the studied documents, most of the entries were found from a social point of view. It is thought that this is because it has a lot to do with the content. Out of all annex documents, a content-appropriate title was determined with almost seven out of ten. In these indexes, 75 related safety and hazard topics have been found. As is known, "rules in aviation are written in blood." Due to this, serious measures have

Table 1 Findings in the environmental domain of sustainability

Environmental domain								
Annexes	Waste management	Water management	Noise management	Energy management	Emissions and air quality	Biodiversity	Certifications	Total
1				1	1			2
2				1			1	2
3					1			1
4		1						1
5								0
6			4				1	5
7								0
8							1	1
9		1				1		2
10					8			8
11					1			1
12					2			2
13					1			1
14		1		1	1		1	4
15			1	1				2
16	2	1	4	1	9		5	22
17								0
18								0
19							1	1
Total	2	4	9	5	24	1	10	55

Table 2 Findings in the economical domain of sustainability

Economic domain					
Annexes	Direct	Indirect	Development	Employment	Total
1			1	1	2
2		1	1		2
3					0
4				1	1
5					0
6					0
7		1			1
8	1				1
9					0
10					0
11					0
12					0
13					0
14					0
15					0
16					0
17					0
18					0
19					0
Total	1	2	2	2	7

been taken to close any security vulnerability. It is also pervasive for ICAO to standardize these measures.

Table 3 shows that shareholder relations is the second index with a count of 25. The third is the code of ethics with nine indexes. The main findings for this domain come from the sixth and tenth annexes – aircraft operation and aviation telecommunication, respectively. Since miscommunication between stakeholders in the aviation sector leads to significant accidents, ICAO focuses on standardization in this regard.

However, according to the table obtained, there is a serious standardization problem in the field of social responsibility too. It is foreseen that social sustainability studies in the sector can also pave the way if the society understands more on social standards and aviation industry. When we look at sustainability from a social point of view, innovation can be done by realizing the things that need to be improved faster in the sector. At the same time, awareness of important issues such as security can be achieved faster. It is assumed that this study is carried out in order to create an awareness to contribute to the air transportation sector. At the same time, in these rapidly advancing times, Industry 4.0 and Society 5.0 are blended with topics and offer the potential for the sector to become more sustainable.

Table 3 Findings in the social domain of sustainability

Social domain									
Annexes	Employee satisfaction	Customer satisfaction	Human rights	Safety and hazards	Shareholder relations	Ethical rules	Social accountability	Indirect social affects	Total
1		1		4	1	3			9
2		1	1	5		1		1	9
3	1			2		1			4
4				1					1
5									0
6	1	1	1	18	1	3		5	30
7									0
8				2					2
9				2					2
10	2			9	8			1	20
11				7	7				14
12				1	1	1	1		4
13			1	2					3
14	1			5	1				7
15				7	2	4			13
16									0
17				7	1				8
18				1	2				3
19		1	1	2	1	2			7
Total	5	4	4	75	25	15	1	7	136

4 Conclusion

We have examined the the results of the annexes formed by ICAO standards. This research turns out the usefulness of the examined standards. All data indicate that the ICAO needs to achieve greater environmental and economic sustainability standardization. In particular, the results explained in seven topics in the field of economics, leaves a question mark in the heads about the sector's potential to survive in the long term.

The fact that the standard of this commercially made network is almost nonexistent calls into question the continuity of the sector. Organizations such as IATA protects airlines. However, it is known that the rule maker is ICAO. From an economic point of view, sustainability should be ensured and reflected in the documents.

These results show that looking at aviation from a sustainability framework will be very effective. Researchers can take the financial perspective on the economy. The environment, on the other hand, constitutes a category by itself. In this way, we can say that aviation of airport performance increase is directly connected to sustainability.

This study aims to contribute to the literature on sustainable aviation by analyzing the ICAO Annex documents. At the same time, it is necessary to bring sustainability to the sector attention for more reliable and integrated aviation. This research shows that the aviation sector needs to increase awareness of sustainable aviation and increase the number of studies.

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