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An Investigation and Benchmarking Model for Developing Sustainable Material Use Among Turkish Airport Operators

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Abstract

Sustainable material use refers to the capacity of a material to be utilized in a way that does not deplete the Earth's natural resources or harm the ecosystem. This lowering might entail employing renewable or recyclable materials and reducing the overall quantity of material utilized in airport services. Renewable materials, recyclable materials, biodegradable materials, reusable materials, low-impact materials (low-emission materials), natural materials, and non-toxic materials are sustainable materials used in airports. There are 58 civil airports operated in Turkiye. The public information on the airport operators' websites can assess sustainable material use in these airports. Mentioned 58 airports are operated under ten different airport groups. This study offered a novel scoring system called CACS which stands for Clarity, Accessibility, Continuity, and Suitability, to retrieve sustainable material use from sustainability reports of airport operators. The model proposed in this paper will help the readers benchmark a group of airports not present in the literature. The results show that İGA airport is the highest score among the ten airports, followed by TAV airports at 820.6 and 256.3, respectively. The top five airports encapsulate 97.44% after the Normalization of passenger counts of Turkiye. Airport operators' sustainable material usage and other sustainability benchmarking on numerous domains based on sustainability reporting systems would draw the public and increase awareness, allowing operator firms and airport authorities to concentrate on creating a more livable future.

1. Introduction

Sustainable material use refers to the ability of a material to be used in a way that does not deplete the Earth's natural resources or harm the environment. This diminishing can involve using renewable or recyclable materials and reducing the overall amount of material used in airport services. The goal of sustainable materials is to create a closed-loop system where materials are used, recovered, and then used again rather than discarded and contributing to waste and pollution.

Investigating and developing the airport's energy management system is another part of sustainable material usage. Although energy consumption is another aspect of sustainability, the approach must encompass all aspects. The objective is to design a strategy for sustainability to close the gaps. Sustainable strategy plans are critical and identify significant actions to improve sustainability (Bujok et al., 2020; Mathiyazhagan et al., 2019).

Life Cycle Assessment (LCA) is another domain of the material sustainability approach. Material sustainability should assess the disposal and lifetime effects on the environment and economy. Calado et al. (2018) have investigated to find optimal materials for production. Alternative transportation methods can be grouped under sustainability but may relate to the sustainability of the materials; therefore, this must be assessed carefully. The mitigation of raw material used was assessed for alternative transportation research (Wang et al., 2020). Building Information Modelling (BIM) and LCA is effective tool combination for making design decisions for environmental and health consequences of building goods and materials. BIM-LCA integration to aid designers in making sustainable material and product selection decisions from inception. Studies have revealed excellent effects of optimization of sustainable design solutions based on simulations (Asare et al., 2020).

1.1 Material Use and Airport Sustainability

Using sustainable materials in airports can be summarized under renewable materials, recyclable materials, bio-degradable materials, reusable materials, low-impact materials (low-emission materials), natural materials, and non-toxic materials. The Sustainable Airport Manual, being developed by the Chicago Department of Aviation, mentions sustainable materials in the life cycle of an airport development as planning, design and construction, operations and maintenance, and relations with the terminal occupants' sections (Rhee, 2020). The same document has sections describing materials starting with green procurement policy, recyclable materials for conserving resources, waste

management, material reuse, local procurement, certified wood use, maintenance, and low-emission materials.

Çelik and Görgülü (2021) stated that airports have seized the significance of sustainability after the new millennium and drawn an environmentally friendly corporate profile to both reduce the impacts of aviation operations and deal with the pressure. Authors have brought attention to material, building reuse, construction waste recycling, local material use, rapidly renewable material use, and certified wood use as LEED (Leadership in Energy and Environmental Design) certification advises. Nonetheless, terminal sustainable development is crucial for construction material reuse by realizing eco-friendly approaches (Ashley and Lemay, 2008).

However, several airport terminal building evaluation methods are present worldwide. Kacar et al. (2022) evaluated LEED, BREEAM (Building Research Establishment Environmental Assessment Method), and Green Airport Green Company certification methods over seven different certification systems by differential benefits for management staff.

Many studies have dealt with pavement covered by sustainable material use for airports in the design and construction or operation and maintenance phases. Green pavement rehabilitation has been studied by Karadelis et al. (2007), who found that their method will be a solution for sustainable pavement repair. Magnoni et al. (2016) have shared recycling practices for airport pavement construction. Another study has focused on utilizing sustainable runway rehabilitation methods and reviewing the performance results (Moulton et al., 2016). Asphalt pavement performance on friction and material reuse by adding in the mixture has been studied by White (2019). Dyer et al. (2022) have brought the public's attention to the significance of cheaper and sustainable alternative pavement technologies used in railroads, airports, and ships. The literature also has articles focusing on structurally optimized sustainable solutions for airport pedestrian bridge construction methods (Sarkisian et al., 2019).

The abovementioned articles have assessed the airport material used in construction from an architectural point of view. Additionally, there is an economic aspect of material sustainability. There is a diverse effect of using raw materials on the epidemic and pandemic situations. Easily reproducible materials for the disinfection of germs can be possible by supporting reusable materials in airports (Shishkin et al. 2021).

A different study has revealed that acknowledging sustainability reporting is vital from the customers' point of view, and some indicators are critical for the airport industry's sustainability aspects (Karagiannis et al., 2019). However, this study marks sustainable material use as the less significant driver for the airport industry. These remarkable results are the examination of sustainability reports of the world's most used airports. A similar study has focused on the sustainable airport phenomenon for Rome International Airport and the relationship between innovative architectures and materials to achieve Nearly Zero Energy Building design (NZEB) (Falvo et al. 2015). Another approach can be proper planning of airline activities that help to reduce material use by the airline cost reductions (Orhan et al., 2010).

A distinct aspect of sustainable material use is waste management in airports. There is a study financial benefits of recycling the utilization of solid waste in airports (Li et al., 2018). The factors driving the passengers' support for environmental sustainability in aviation have been studied on biofuels, materials, and sustainable manufacturing (Winter et al., 2019). A seperate study highlights that producing aviation fuel from sustainable waste by Fischer-Tropsch synthesis can be a decisive recycling advantage in airports (Sanchez et al., 2022).

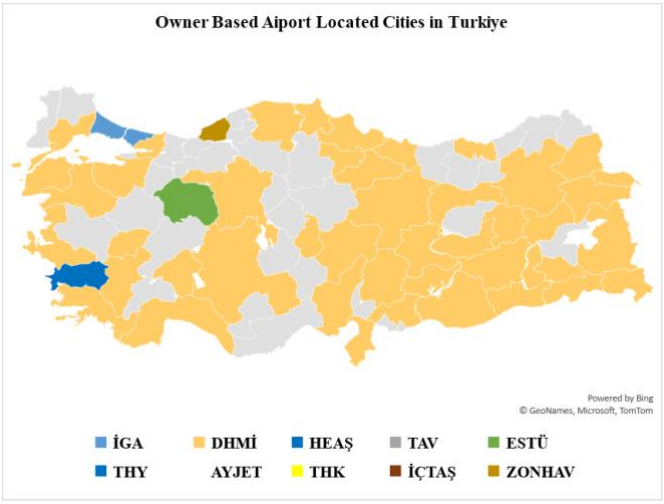
There are many studies in the literature dealing with different aspects of when the topic is sustainable material use in any industry. Nevertheless, airport sustainable material use may be the most condensed form of sustainable material use; unless it has been fully measured. The enormous gap in the literature is that it does not have a gauge to measure how the operators and authorities handle their airports or terminals' sustainable material use. In this study, a proposed approach lets any reader assess sustainability reports to gauge the performance of sustainable material use.

2. Method

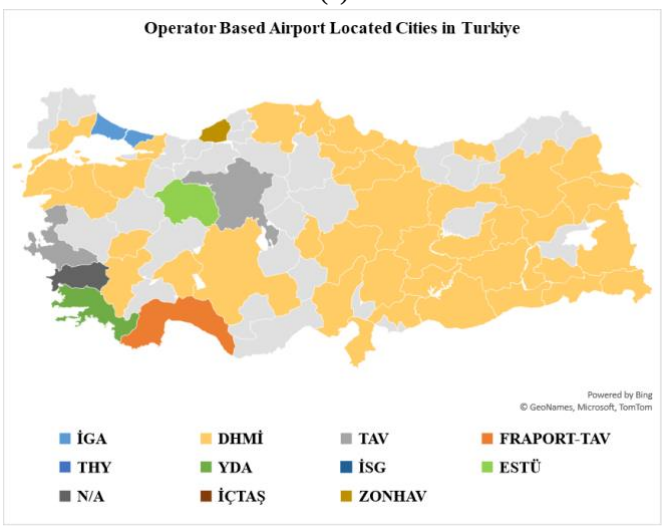
There are 58 civil airports operated in Turkiye as per DHMİ records (DHMİ, 2022a). Figure 1. (a) and Figure 1. (b) demonstrate the Owner-Based Aiport Located Cities in Turkiye and Operator-Based Aiport Located Cities in Turkiye, respectively. Most airports are owned and operated by the DHMİ (DHMİ stands for State Airports Authority). The others are IGA (Istanbul Grand Airport), İSG (İstanbul Sabiha Gokcen), TAV (TAV Airports), Fraport-TAV (Frankfurt Airpot and TAV Airports Venture), YDA (YDA Airports), ESTÜ (Eskisehir Technical University Airport), İÇTAŞ (IC İÇTAŞ), and ZONHAV (Zonguladak Airport Operator) can be found in the DHMİ and SHGM pages. Ordu-Giresun Airport, owned by DHMİ, started operations on 14 May 2022, and the operational figures were reported in the statistics section of DHMİ (DHMİ, 2022a).

There is a distributional difference between the count of owned airports and the total passenger figures served in the airports. Figure 2 (a) and Figure 2 (b) show the differences in this manner—the vast majority of airports, with 74% for DHMİ side. The following airport owners are 6.9% for TAV and 1.72% each for İGA, İSG, YDA, THY, ESTÜ, İÇTAŞ, and ZONHAV. However, the total served passenger figure is slightly changed. The biggest group or airport operator is İGA after the opening at the end of 2018, with 33.78% of total Turkiye air traffic. The following airport operators are Fraport-TAV, İSG, DHMİ, TAV, and YDA, with figures of 16.5%, 16.43%, 15.9%, 14.83%, and 2.43%, respectively. The total of the minor operators covers 0.13% for İÇTAŞ, ESTÜ, THY, and ZONHAV.

These distributional differences define how the problem of developing materials sustainability for airports. The number of airport owners and served passenger count numbers are not aligned. However, how the numbers need to approach to solve is quite challenging. The aviation industry has been changed by unprecedented pandemic news caused by the city of Wuhan, China. Ironically, the virus that started the pandemic has spread throughout the aviation industry and worldwide. The statistics are not reliable, starting with 2020 to the end of 2021. The aviation industry has started to use reliable measurements by the start of 2022. However, the figures are judged and compared by the numbers of 2019 (IATA, 2022). The approach has to be assessed with the approach of catching the series by the average point of 2019 and 2022.



(a)



(b)

Figure 1. Airport distribution among the cities of Turkiye (a) Owner locations, (b) Operator locations (SHGM, 2022a; SHGM, 2022b; DHMİ, 2022b).

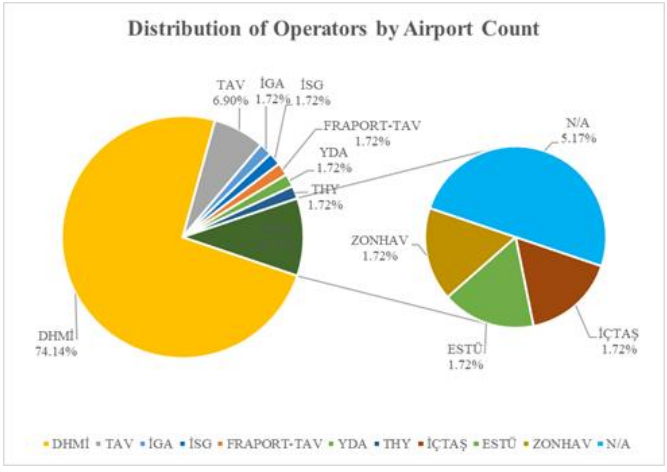
However, the airports of Turkiye cannot be analyzed because of the significant airport change; Istanbul Ataturk Airport has moved to New Istanbul Airport (DHMİ, 2022c; TRT Haber, 2019). This colossal movement action has affected many passenger preferences; airline operations have been affected accordingly. Due to the most significant airport movement and global pandemic effects, it is mandatory to use both 2018 and 2022 data to assess airline distribution.

The research method is based on examining sustainability reports on airport operators. The reason for choosing airport operators is to working methodology of rental and built-operate-transfer agreements in Turkiye. The operator is responsible for the terminal operation and sustainability activities of the airport premises.

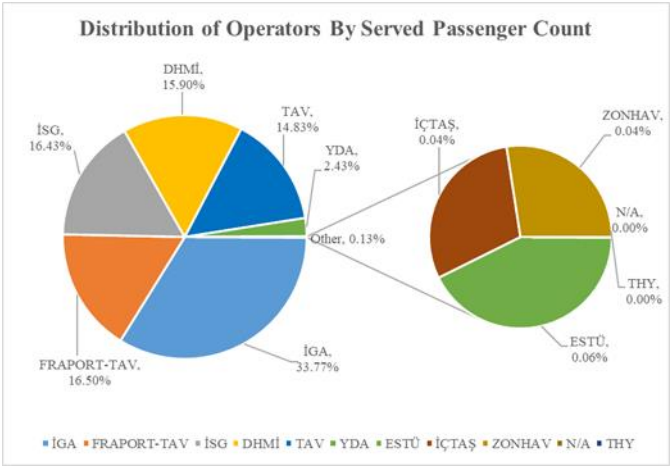
Some studies have assessed sustainability reporting for companies, whether the reporting overlaps with the GRI (Global Reporting Initiative) or not. Karagiannis et al. have studied over 33 reports on the busiest airports of 193, corresponding to 17% of commitment to sustainability issues worldwide (2019). They have described the word “material” as the “importance or applicability” in their study. This applicability study grounds to assessing by a frequency analysis of indices and 2 step approach for identification and prioritization. However, they have not revealed their precise analysis of scoring. Table 1 is a proposed CACS analysis base on gauging for sustainable material use by assessing Clarity, Accessibility, Continuity, and Suitability.

This analysis is to weigh the amount of sustainable material used throughout the airport operation life cycle. The airport operational life cycle starts with the planning phase of airport design and construction; then, it continues throughout the operation and maintenance period with the airport occupants. Figure 3 represents the methodological approach for benchmarking. There is a need to define a normalization approach for the problem to express a comparable magnitude as a gauge for sustainable material use by summarizing public information and reports, and benchmarking calculations were followed through the calculation.

The benchmarking step is multiplying the Clarity, Accessibility, Continuity, and Suitability scores with the normalization index. Normalization is vital to the comprehensibility of the benchmarking grade of the airport’s sustainable material consumption. Normalization can be used yearly to assess the differences throughout the years.



(a)



(b)

Figure 2. Airport operator distributions over Turkiye (a) Counts of operators, (b) Served passenger counts (DHMİ, 2022a).

Figure 3. Methodological approach to solving the problem

Table 1.: Proposed CACS (Clarity, Accessibility, Continuity, Suitability) approach for assessing Sustainable Material Use (SBU)

Gauge	Clarity	Accessibility	Continuity	Suitability
1	SBU is not clearly described	The airport operator web site (web) does not mention any sustainability reporting	The airport operator (AO)has not published any sustainability report	There is no SBU information present in the published report
2	SBU described as a value or significant indicator	There are a value mentioned on the web that sustainable values	AO has announced to publish of a sustainability report	There is only one mention of SBU
3	SBU policy is defined, but no other information is founded	There is more explanation than the values on the web, also approaching and vision plans	AO was published only once years ago	SBU was mentioned more than once
4	SBU policy was defined, and the planning phase announced	There are more explanations than the values on the web have, also specific targets on short-term	AO has published once but announced to publish of the forthcoming version(s)	SBU has been mentioned in many areas but not measured
5	SBU policy defined, and plans mentioned in long-term	Airport operator web site have sustainability reporting/pages but are hard to find	AO has published the reports irregularly for the years	SBU measured
6	SBU policy defined, plans on middle-term were announced or defined	It is possible to find out sustainability reports/pages on the web not easy to find	AO has published the reports irregularly for the years but excuses published in missing years	SBU measured and tracked
7	SBU policy was defined, and short-term and middle-term targets defined	It is possible to find out sustainability reports/pages on the web	AO publishes regularly but stopped because of the pandemic or another force-major	SBU is measured and tracked in many domains
8	SBU policy was defined, short-term and middle-term targets have been defined, announced	It is possible to find out sustainability reports/pages on the web easily	AO publishes regularly but stopped because of the pandemic or another force major, but excuses published on the web	SBU has published as a section
9	Sustainable material use policy defined, plans on short-term and middle-term targets have been defined, latest figures support improvement	Sustainability reporting is present and is offered as a section on the web	AO regularly publishes for years	SBU has published as the main section

Benchmarking grade G_r can be calculated by the below approach:

$$Gr = \frac{i_C\ i_A\ i_P\ i_S\ N}{100} \quad (1)$$

where i_C is the clarity index, i_A is the accessibility index, i_P is the continuity index, and i_S is represents the suitability index. Also, Gr is the grade for the result for the airport, and N represents the normalization value for the airport.

Normalization (N) is used to alter the impact of each development to carry to higher numbers to encourage operators for better applications. The N value represents the share of the commercial passenger count through Turkish airspace. The annual statistics from DHMİ and SHGM were used to calculate the Normalization value. The underlying reason for using N value is to see the actual effect of each sustainable material use development by the passenger share of commercial air traffic served. The score will be more prominent if the share is extensive with each activity.

2.1. Assumptions and Limitations

This study assumpts 'airport owners' and 'airport operators' as two different entities in the airport industry. Although industrial acknowledgment for some definitions of terminal operations is not the same for airport operations, the leading airport owner DHMİ's approach to sustainability points out that the airport operators are the terminal operators. Terminal operators are responsible for the development, building, and investment per the contract. Therefore, DHMİ must be understood as the 'airport owners' category where there is a terminal operator.

Due to the global pandemic adverse effects on the aviation industry, airline metrics have become inconsistent. Therefore, 2020 and 2021 figures were not used for Normalization. On the other hand, the leading airport move in 2019 figures is also unsuitable for this year.

On the other hand, the primary research limitation is publicly announced sustainability reports. There is a worldwide 17% commitment to sustainability reporting per the airport sustainability reporting study (Karagiannis et al., 2019). The Turkish Airports sustainability reporting is based on published reports on the airport operator websites.

This research analyzes sustainability reports' substance and benchmarks public sources. The reports' integrity and impartiality were crucial. The CACS approach created a grade scheme and assessment technique to examine and label the sections of report material carefully. This methodology lets readers assess all sustainability reports subjectively and quantitatively.

The primary constraint of this study was the wide variety of sustainability techniques and definitions. In fact, many reports have neither a section on the usage of sustainably sourced materials nor any discussion of this topic. The second issue involved the consistency of the reporting schedule. In addition, the non-recyclable or non-sustainable material consumption should have been included in the reports. Covid-19, for instance, influenced and compelled airports to use more hygienic materials than reused ones. This specific change also was not discovered in any report. On the other hand, 2022 and 2019 statistics have been used to correlate the difference and consistency of the numbers.

3. Result and Discussion

The methodologic approach item three corresponds to the interrogation of the sustainable material use by the public information throughout the airport operator websites. This task involves searching the airport operator websites, finding the required information, and matching in the scaling step. The reporting information is broadly available for İGA, Fraport-TAV, and TAV airports. The sustainability-related information is present, but no published reports are available for İSG and DHMİ airports. YDA, ESTÜ, and İÇTAŞ airports do not mention any sustainability on their sites, but there are management statements like waste management and targets like zero waste strategy. The airport operator sites for ZONHAV and THY are not reachable. Since no public information is present, their grades have been calculated as a zero, which can be seen in Table 2, Figure 4, and Figure 5.

The results revealed that the CACS score and Normalization are defined in the results in Table 2. Due to the CACS score defined by multiplication, the sustainable material use adaptation score increases rapidly, and the differentiation shows itself broadly.

The graphs shown in Figure 4 and Figure 5 are the results of the CACS benchmarking grade by assessing all aspects as Clarity, Accessibility, Continuity, and Suitability from public reports. Each standpoint developed to a higher level has matched the actions annotated in the airport operators' sustainability reports. CACS indexes i_C the clarity index, i_A the accessibility index, i_P the continuity index, and i_S the suitability index matches with the levels of identical value. Those values and the normalization value of N, which is the share number of total commercial air passenger, represents the grade of airport operator or authority. The vertical scale selected is logarithmic because the normalization value creates incremental growth.

The score for İGA airport is the highest score while comparing the Normalization with other airports. The normalization scores for other big airports are around 15%. The biggest airport operator and prominent airport owner in Turkiye is DHMİ. The DHMİ small airports' total normalization figure is around 15% too. The total for those airport operators in the top five lines reaches 97.44%. Low CACS scores for Fraport-TAV, İSG, and DHMİ are low because their sustainability reports were not published.

Table 2.: Sustainable material use benchmarking scores for airport operators

Airport Operator	Clarity	Accessibility	Continuity	Suitability	Normalization	Grade
	i_C	i_A	i_P	i_S	N	Gr
İGA (İGA Airport, 2022)	9	9	5	6	33.77	820.6
Fraport-TAV (Fraport TAV, 2022)	5	8	1	1	16.50	6.6
İSG (ISG, 2022)	2	5	1	1	16.43	1.6
DHMİ (DHMİ, 2022)	2	3	1	2	15.90	1.9
TAV (TAV Airports, 2022)	9	8	6	4	14.83	256.3
YDA (YDA Dalaman, 2022)	2	2	1	1	2.43	0.1
ESTÜ (ESTÜ HPA, 2022)	2	4	1	1	0.06	0.0
İÇTAŞ	1	1	1	1	0.04	0.0
ZONHAV	1	1	1	1	0.04	0.0
THY	1	1	1	1	0.00	0.0

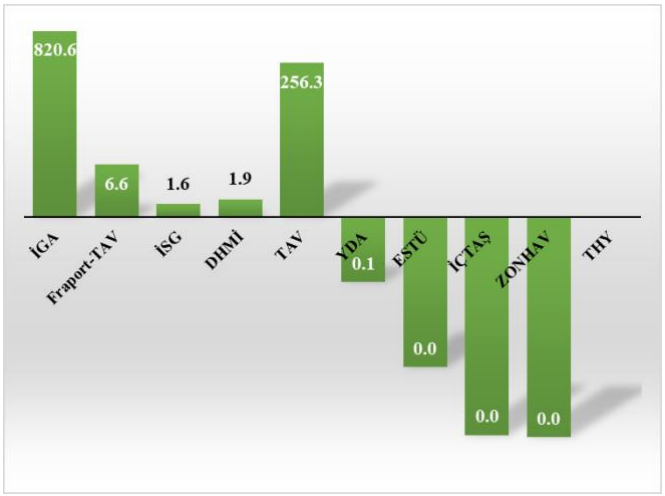


Figure 4. Normalized benchmarking scores among airport operators

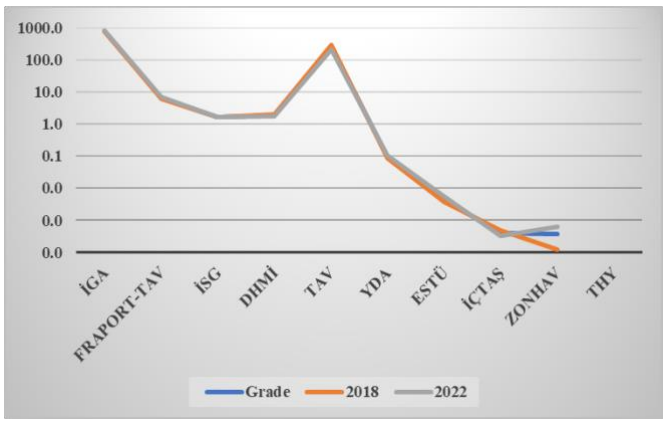


Figure 5. Normalized benchmarking scores among airport operators

The DHMİ has published many annual reports, documents, and statistics, also descriptions on their website, the sustainability reporting is not present. Therefore, their CACS score is as low as the other two airport operators, Fraport-TAV and İSG.

The second highest score was TAV airports which operate four airports in Turkiye. Their normalization score is the lowest in the top five airport operator groups; however, because of their sustainability commitment. İGA and TAV are the most appropriate approaches to sustainability reporting and development for sustainable material use. However, İGA has higher scores in suitability than TAV airports. Figure 4 shows the top five airport operators and other minor airports on a logarithmic scale in a more meaningful way because of the CACS score and Normalization in an exponential manner.

On the other hand, 2018 and 2022 passenger statistics can be slightly different from the normalized results shown in Figure 5. However, as seen in the graphic in logarithmic scales, the differences between the Normalization and 2018 and 2022 figures are almost the same. The changes appear because of the tourist popularity differences and local political results in the neighborhood countries.

The literature has checked for comparing this study with a possible match for sustainable material use in airports. The results of Çelik and Görgülü (2021) listed Adnan Menderes Airport by the LEED criteria of Construction Waste Management, Recycled Materials, Local Material use as 2 points out of 2, and Reuse of Materials as 1 point out of 2. Çelik and Görgülü's measurements are in line with the TAV airports' second position in this study's benchmark. Congruently, the same methodologic approach has been found in the paper of Karagiannis et al. (2019) that benchmarks all airports around the world. There are not any Turkish airport operators assessed in that study; however, the Materials and Sustainability have not been taken seriously by the international airport community as ~%10. Conversely, the same study revealed that Waste Management is recognized as more than %60 important on other indicators.

4. Conclusion

The use of sustainable materials is important because it helps to conserve natural resources and reduce our impact on the environment. The materials used in airports daily, such as plastic, paper, napkins, and materials for any maintenance activity and airport project building phase, affect sustainability. Sustainable material use is one of the most significant parameters in this era.

On the other hand, setting and designing benchmarking systems is crucial for triggering sustainable development in economic, social, and environmental domains. Sustainable material use should start with the definition of a policy statement and the activities of recyclable materials procurement for conserving resources, waste management to reduce environmental impact, reusing of materials to extend the materials life cycle, local procurement alternatives for economic benefits, certified wood use for nature conservation, better maintenance applications for reducing raw materials, and low-emission materials for indoor environmental quality.

Benchmarking systems offered for airport operator sustainability on multiple domains as defined in sustainability reporting systems will attract the public and improve awareness, letting operator companies and airport authorities focus on a more livable future. This study has offered an alternative to benchmarking on sustainability reports to assess sustainable material use under the airport operators of Turkiye.

Acronyms

BIM : Building Information Modelling
BREEAM: Building Research Establishment Environmental Assessment Method
CACS : Clarity, Accessibility, Continuity, and Suitability
DHMİ : Devlet Hava Meydanları İşletmesi, Turkish State Airport Authority
ESTÜ : Eskisehir Technical University Airport
İÇTAŞ : IC İÇTAŞ airports
İGA : İstanbul Grand Airprot
İSG : İstanbul Sabiha Gokcen airport
LCA : Life Cycle Assessment
LEED : Leadership in Energy and Environmental Design
NZEB : Nearly Zero Energy Building
TAV : Tepe Akfen Venture airport
THY : Türk Hava Yolları, Turkish Airlines
TRT : Turkish Radio and Television company
YDA : YDA Airports
ZONHAV: Zonguladak Airport Operator

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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