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Investigating the Mediating role of Infrastructure Requirements for Electric Aviation between Egypt's Initiatives and Tourism Sustainability in Egypt

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Abstract

This study aims to investigate how Egypt's governmental initiatives contribute to the integration of electric aviation at Sharm El-Sheikh International Airport, thereby establishing it as a model for sustainable urban tourism. By concentrating on the essential infrastructure prerequisites for electric aviation, this study investigates the intermediary function of these prerequisites in the realization of the Triple Bottom Line (TBL) sustainability objectives—namely environmental, economic, and social dimensions. The study adopts the (TBL) framework to evaluate the viability and prospective benefits of electric aviation technology in promoting sustainability. A quantitative methodology was implemented to achieve the stated research objectives. Data were gathered from personnel employed at Sharm El Sheikh International Airport. The study employs Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze the data obtained from 220 airport employees. The findings suggest that the infrastructure facilitating electric aviation significantly contributes to the sustainability objectives of the city, presenting an innovative approach for urban tourism advancement in Egypt, thereby rendering it particularly pertinent to practices within urban tourism. Moreover, The findings provide actionable insights for policymakers and urban planners seeking to harmonize aviation strategies with sustainable tourism development in prominent tourism destinations.

Introduction

Tourism sustainability has become increasingly crucial in urban development, particularly in cities where tourism plays a significant role in driving the economy (Guo and Liu, 2024). Over recent years, the aviation industry has progressively embraced sustainable practices, with electric aviation emerging as a promising solution to mitigate the environmental impacts of air travel (Wang, 2024). Sharm El-Sheikh, one of Egypt’s leading tourist destinations, is at the forefront of the nation's green city initiatives, particularly with the transformation of its international airport into a hub for sustainable aviation (ICOC-E, 2022).

The aviation sector continues to expand rapidly. Aviation analysts reported that the total number of aircraft in operation globally reached approximately 23,600 in 2017. Moreover, the International Civil Aviation Organization (ICAO) projects that the size of the global air transport network will double by 2032, relative to its scale in 2017 (Huang, 2023). Air travel now accounts for over 50% of all international tourist movements, with demand rising steadily (Sengur and Altuntas, 2023). In fact, global air passenger traffic surged by 64% in 2022 compared to the previous year, a notable rebound following the downturn caused by the COVID-19 pandemic (Statista, 2023).

Efforts to manage the aviation sector must address its economic, environmental, and social impacts. However, there has been insufficient focus on the sector's sustainability implications (Al Sarrah et al., 2021). While scholars such as Letcher and Scott (2012) have identified inconsistencies in meeting basic sustainability standards, much of the focus remains on the environmental aspects, with less attention paid to the economic and social dimensions of sustainability (Agarwal, 2012). Nonetheless, the aviation industry plays a critical role in fostering economic growth, promoting trade, boosting tourism, and creating job opportunities (Calyurt and Yuksel, 2017). Additionally, aviation provides substantial social benefits by improving access to leisure travel and enhancing transport infrastructure, ensuring greater safety and efficiency in mobility (Al Sarrah et al., 2021; Letcher and Scott, 2012). Egypt's "Sustainable Egypt Vision 2030" further emphasizes the importance of incorporating sustainable development principles across various sectors, integrating economic, social and environmental objectives (NVRSDG, 2016).

Electric aircraft have attracted significant attention in the environmental literature due to their potential to reduce greenhouse gas emissions in the aviation sector (Sengur and Altuntas, 2023; ICAO, 2022 a; Jayant and Brandon, 2022; Rajamani, 2019). Yet, the implementation of the Triple Bottom Line (TBL) framework within the tourism sector remains limited, despite the growing adoption of green airports. This transition not only benefits the environment but also fosters societal progress and economic growth (Petr et al., 2022; WSDOT, 2020; Schwab et al., 2021). The ongoing shift towards electric aviation presents a timely opportunity to explore its broader implications for tourism sustainability.

Several airports worldwide are already enhancing their infrastructure to support electric aviation. Examples include Christchurch Airport in New Zealand, Kansai Airport in Japan, Glasgow Airport in the UK, and Chattanooga Airport in the US, among others (ICAO, 2022a). Some of these airports, such as Umeå Airport (ESNU) in Sweden and Denver International Airport (DEN) in the US, have already begun operating electric flights (Alfredsson et al., 2022; Schwab et al., 2021).

Despite the growing global interest in sustainable aviation, particularly electric aviation, a significant gap remains in the literature regarding its application within the tourism sector, particularly in urban tourism hubs like Sharm El-Sheikh. Most studies have focused on the environmental benefits of electric aviation in isolation, without considering the broader impact on tourism sustainability, which encompasses economic, social, and environmental dimensions. Furthermore, while airports in developed countries are preparing for electric aviation, little research has explored the readiness of airports in developing regions, including the Middle East and North Africa (MENA), to accommodate such technologies. This study seeks to address this gap by investigating the role of Sharm El-Sheikh International Airport in integrating electric aviation infrastructure to support Egypt's sustainable tourism goals in alignment with Egypt's Vision 2030.

This research explores the mediating role of infrastructure requirements for electric aviation at Sharm El-Sheikh International Airport in achieving broader sustainability objectives—environmental, economic, and social—within the Triple Bottom Line (TBL) framework (Elkington, 1994, 2004; Guan et al., 2022; Gupta et al., 2020; Al Sarrah et al., 2020).

By addressing this critical gap, the study contributes to the growing body of research on urban tourism development. Sharm El-Sheikh's transformation into a green city, supported by electric aviation, offers a unique case study on how urban infrastructure can adapt to technological advancements that promote sustainable tourism. Furthermore, this research aligns with Egypt's Vision 2030 (MPED, 2024), which integrates sustainability across economic, environmental, and social dimensions, making it directly relevant to the field of urban tourism and sustainable development.

Literature Review and Hypotheses Development

The concept of "The Third Revolution in Aviation" is utilized to delineate the captivating progression of electric aircraft. The initial revolution encompassed the pioneering powered flight achieved by the Wright brothers; the subsequent revolution entailed the innovation of jet propulsion, enabling enhanced speed and range in air travel. The ensuing advancement in aviation introduced a significant challenge in terms of carbon emissions (Rajamani,2019). The emergence of electric aircraft driven by sustainable electricity signifies a noteworthy shift towards achieving zero carbon emissions in aviation, characterizing the pivotal "third revolution." This revolution has many more benefits than just lowering emissions. (ICAO,2022a)

1. Electric Aviation and Triple Bottom Line Framework:

The Triple Bottom Line (TBL) framework in sustainability emphasises three key elements: the natural environment, society, and economic performance (Elkington, 1994, 2004). Scholars argue the significance of considering both people and the planet alongside profit, leading to outcomes that are more sustainable (Aguilera *et al.,* 2007; Porter and Kramer, 2006). Aviation has environmental impacts like noise, pollutants, and pollution (Gupta *et al.,* 2020).

The tourism sector contributes 8% to global carbon emissions (Tanja, 2023). Transportation , electricity use (in hotels and restaurants), and fossil fuel combustion are major sources (Siyue *et al.,* 2022). Within the tourism sector, transport-related CO2 emissions contribute to 22% of the overall transport emissions. The aviation industry actually accounts for only 2.5% of global CO2 emissions. Fly Net Zero is airlines' commitment to achieve zero carbon emissions by 2050 (IATA, 2022). ICAO and Member States, along with industry stakeholders, aim to reach that target, considering each state's circumstances and capabilities. Achieving this goal will necessitate significant investment and support for developing countries and states with specific needs (ICAO, 2022b).

Airport strategies aim to reduce energy consumption, enhance efficiency, and monitor water quality. Innovation and environmental concerns require new operational approaches (ICAO, 2023). Electric aviation shows promise for sustainable air travel (Gupta *et al.,* 2020; Virginie *et al.,* 2013). Electric aviation, often seen as an innovative practice, holds the potential to position airports as "energy hubs" within transportation networks, providing eco-friendly energy options and charging infrastructure for nearby communities (Grey, 2021; ICAO, 2023). Efforts to reduce carbon footprints involve sustainable energy sources like solar farms and biofuel (ICAO, 2022a). Electric aviation can stimulate economic development and lower operational costs (Gupta *et al.*, 2020). Electric aircraft, characterised by their eco-friendly and efficient attributes, align closely with the sustainability principles of the TBL framework, presenting a potential solution to mitigate the environmental impact of traditional aviation while promoting economic sustainability and social responsibility.

2: Electric Propulsion System: Benefits and Challenges

2.1 Benefits

The global market for electric aircraft achieved a valuation of 7.91 billion USD in the year 2022, and projections suggest a substantial increase to reach 50.86 billion USD by 2032, driven by a remarkable compound annual growth rate (CAGR) of 20.6% from 2023 to 2032 (precedence research, 2023)

-*Reduced Costs*: Electric aircraft are motivated by cost savings and advantages, such as fuel cost reductions of 90% and maintenance cost reductions of 50%. (Howell and Elizabeth, 2019). A study on electrifying routes near Denver Airport revealed that the substitution of fossil-fueled aircraft with electric ones could lead to a substantial reduction in fuel expenses, dropping from around $400 to $50 (Schwab *et al., 2021*).

-*Regional travel market*: The regional travel market is dominated by intra-regional air travel, accounting for 80% of international arrivals. Inter-regional travel, mostly done by air (95%), represents 20% of all travel. (UNWTO,2019). The growth of electric planes is expected in regional markets with trips under 500 km due to limited battery capacity. Regional air mobility currently relies on turboprops and short regional jet flights. A small percentage of airports handle many regional routes, leaving others underused (WEF, 2023). According to the NASA Regional Air Mobility report (Antcliff *et al.*, 2021), only a small number of US airports can accommodate most domestic air travel. Electric aircraft could make currently uneconomical regional destinations profitable, increasing access to flights and reducing passenger travel time (Howell and Elizabeth, 2019).

-*Emissions Reductions*: The primary impetus behind the global embrace of electric aircraft is the reduction in emissions. While various technologies utilizing drop-in replacement fuels like SAF will diminish emissions and enhance air quality for local communities, electric aircraft have the potential to slash CO2 emissions by up to 95% (Jayant and Brandon, 2022).

-*Noise Reduction*: Local communities oppose new airports due to noise and pollution concerns. Regional electric aircraft hold promises in generating less noise with elevated climb and descent profiles. Datey et al. (2023) have highlighted the capability of regional electric aircraft to produce reduced noise levels. Internal investigations conducted by United Technologies Corporation, for instance, propose 60% quieter takeoffs and landings (Schwab et al., 2021).

-*Increased Accessibility*: Electric air travel not only reduces emissions but also alleviates congestion at airport hubs. It offers an eco-friendly alternative for travellers, especially to and from rural areas, reducing travel time and expenses. (Howell and Elizabeth, 2019)

-*Economic Development*: Electric aviation promotes economic development by serving underserved areas, reopening markets, and reducing operating costs (WSDOT, 2020). It also supports innovation, pilot training, and critical community services like medevac and organ delivery (Schwab *et al., 2021).*

2.2 Challenges

Despite the benefits, electric aircraft propulsion systems have a number of challenges. The conversion efficiency and endurance of an electric propulsion system would not be able to support an electric aircraft travelling the same distance as an aircraft powered by a conventional internal combustion engine. This is because batteries in electric propulsion systems are unable to store enough energy. (Huang, 2023) Approximately 45% of all global flights, which are shorter than 500 miles, fall within the range of electric aircraft expected to be commercially viable by 2030 (Schwab et al., 2021).

The second challenge for electric aircraft in the aviation industry is regulations for safety; FAA and EASA must certify new electric aircraft. Regulators face challenges with resources and expertise when certifying over 200 projects. In 2022, FAA's CECI will manage eight programme managers and over 70 projects for electric aircraft certification. (ICAO, 2022a).

The third challenge involves the preparedness of the ecosystem for electric aircraft operation, including clean energy availability for charging (WEF, 2023). Various stakeholders, such as airports, airlines, and the energy industry, are part of this ecosystem. RAM airports mostly use grid electricity, which may not be entirely renewable. (Cedric *et al.*, 2020).

3. Electric Aviation Development

The market has witnessed the emergence of electric-powered aircraft, exemplified by the introduction of the Pipistrel Velis Electro and ongoing research endeavors by companies such as Bye Aerospace, Piper, and eViation, signaling a forthcoming rise in electric aircraft (WILSON, 2023). Specifically, between 2016 and 2022, there has been a proliferation of over 300 electric aircraft projects and nearly 200 electric aircraft start-ups globally, reminiscent of the renaissance of aviation in the early 1900s (ICAO, 2022a). Furthermore, Canada achieved a significant milestone in 2019 by setting a world record with the inaugural fully electric commercial flight conducted by Harbour Air (Edwards and Parker, 2022).

3.1 Near-Term Use Cases

Initially, electric aircraft technology is being used in various applications such as pilot training, general aviation, and business. Companies like Bye Aerospace and Pipistrel are developing electric aircraft for different purposes, with a focus on the general aviation market. These aircraft are suitable for short-haul flights with up to six passengers, with charging times similar to historical refuelling times. NASA is also engaged in electric aircraft development, including a semi-electric aircraft powered by fuel cells and the X-57 Maxwell, its first all-electric experimental aircraft in two decades (Schwab *et al., 2021*). Pipistrel is the only manufacturer with certified aircraft, such as the Velis Electro, which is certified in Europe and operates under the experimental category in the United States (Nicholas *et al.,* 2023).

3.2 Mid-Term Use Cases

Various companies like Bell, Hyundai, Archer, and Beta Technologies are involved in applying electric aircraft technology for regional commuter/air taxis, light cargo transport, and regional air service. Electric vertical take-off and landing aircraft are anticipated to operate up to 50 miles for regional commuter/air taxis with up to four passengers. Ampaire, Beta Technologies, and MagniX are focusing on light-air cargo applications, with plans for electrifying cargo routes by United Parcel Service (Holland, 2021). Companies such as Ampaire, Eviation, and MagniX are working on regional commuter service with different passenger capacities and ranges for their aircraft (Schwab *et al., 2021*). A modified Cessna Caravan 208B with a MagniX engine completed a test flight in May 2020, marking the largest commercial electric plane to fly (Baraniuk, 2020).

3.3 Longer-Term Use Cases

In the forthcoming period (2040–2050), the progression of commercial aviation will involve the investigation of single-aisle aircraft with around 70 seats and electric/hybrid capabilities. These aircraft aim to replace planes like the Bombardier Q400, Bombardier CRJ700, and Embraer EMB135. Wright/EasyJet is presently involved in the development of a 186-seat all-electric aircraft, projected to undergo testing by 2030 (Schwab et al., 2021).

3.4 Preparing Airports for Electric Aviation

Preparing an airport for electric aircraft encompasses various essential procedures. These encompass the installation of clean energy derived from zero-carbon sources such as solar, wind, and hydroelectric power. Establishing charging stations capable of fast-charging electric aircraft, Developing protocols for handling electric aircraft in terms of safety measures, Diagnostic equipment and maintenance technicians, the monitoring of power supply and distribution to charging stations, telecommunications and digital infrastructure, and the evaluation and mitigation of environmental impacts associated with electric aircraft operations (WEF, 2023), ensuring compliance with aviation regulations regarding electric aircraft operations (ICAO, 2022a), and providing training for airport personnel on handling electric aircraft and charging equipment safely (Petrie, 2023) Collaborating closely with electric aircraft manufacturers to understand their requirements and provide necessary support; coordinating with air traffic control authorities to integrate electric aircraft operations into existing airspace management systems (WSDOT, 2020) By addressing these aspects, airports can effectively prepare for the introduction and operation of electric aircraft in their facilities.

Airports are presently linked to power grids and may already have electric ground support apparatus and EV charging facilities in operation. Although enhancements to grid connections and energy storage mechanisms are expected with the increasing adoption of these aircraft, battery-electric infrastructure will be relatively easy to scale up (WEF, 2023).Innovative solutions such as parallel charging, wireless charging, and nonelectrified flow battery technology are being explored to address challenges in charging infrastructure (Schwab *et al., 2021*). Heathrow and Gatwick airports are investigating alternative charging options for hybrid and electric aircraft, including slow chargers, quick plug-in chargers, and battery swap operations (UKPNS, 2022). **[**

4. Sharm El-Sheikh: The First Sustainable Green City in Egypt

Sharm El-Sheikh, situated at the entrance of the Gulf of Aqaba, is a resort city in Egypt known for its biodiversity, making it a popular travel destination (Genina et al., 2023). The hosting of COP27 in Sharm El-Sheikh by Egypt aimed at translating global commitments into tangible actions (UN, 2022). Egypt's National Climate Change Strategy 2050, unveiled during COP26 in Glasgow, outlines key objectives such as reducing emissions across sectors, promoting renewable energy sources, utilizing waste for energy production, and exploring alternative energy options (ICOC-E, 2022).

The vision to transform Sharm El-Sheikh into a green city includes transitioning all public transportation to operate on natural gas or electricity (SIS, 2022), Progress has been made in establishing several new solar power stations in the city, a collaborative effort involving various ministries, the South Sinai Governorate, and the United Nations Development Program (Genina et al., 2023; COP27, 2022). Currently, Sharm El-Sheikh boasts over 40 MW of solar power stations, generating 68 million MWh/year and reducing 35k tons of CO2 emissions (UNDP, 2023).

5- Sharm El-Sheikh International Airport into a Green Airport

Sharm El-Sheikh International Airport serves as the main entry point for tourists, with over 5.96 million passengers and 43.47 thousand flights in 2023 (EMCA, 2024). The transition to an eco-friendly airport is essential for sustainable development, operational efficiency, and environmental harmony, with key features including resource efficiency, environmental sustainability, operational effectiveness, and user-focused design (Xiong et al., 2022). The Egyptian Ministry of Aviation is aligning with the United Nations Sustainable Development Goals to promote sustainable development (Perryman et al., 2022). Efforts are underway to power Sharm El Sheikh International Airport with solar energy to reduce carbon footprint and protect the environment (SIS, 2022). Solar power stations around the airport can provide clean energy, as indicated by Abdul Raouf et al. (2019). According to Genina *et al.'s (*2023) study, the airport has two main power lines: one at "Nabq Station" with 20 MW capacity and one at "Al-Salam Station" with 5 MW capacity. Solar energy is used in the airport from various sources. Emergency indoor stations provide backup power of 300 kVA. A project by ARSC installed a canopy with a 280-kW solar power station at the airport. This station is in front of Terminal 2. Solar energy is also used for lighting poles. Additionally, there are 12 solar water heaters at the airport.

6- Hypotheses development

Based on the literature, the relationships between the key variables—government initiatives (ICO), infrastructure requirements (IR), and Triple Bottom Line (TBL) sustainability—are expected to be interlinked. The development of hypotheses is grounded in the theoretical understanding of how these variables influence one another.

6.1 Government Initiatives (ICO) and Infrastructure Requirements (IR):

It is expected that the initiatives taken by the Egyptian government, especially those that support sustainability and turn Sharm El-Sheikh into a green city, would have a direct impact on how prepared the airport's infrastructure is to handle electric aircraft. These programs include policies that support renewable energy, lower carbon emissions, and stimulate aviation technology advancement (NVRSD, 2016). According to research by Schwab et al. (2021), significant infrastructure modifications, including the installation of charging stations and energy-efficient systems, are frequently necessary for the implementation of sustainable aviation policy. Thus, the first hypothesis (H1) suggests that Government initiatives (ICO) are positively associated with infrastructure requirements (IR) for electric aviation at Sharm El-Sheikh International Airport.

6.2 Infrastructure Requirements (IR) and Environmental Sustainability (TBL):

One of the primary objectives of electric aviation is to reduce the environmental footprint of air travel, including reductions in CO2 emissions and noise pollution (Gupta et al., 2020). The necessary infrastructure, such as the use of renewable energy sources and advanced aircraft technology, plays a pivotal role in achieving these environmental benefits. Studies on sustainable aviation suggest that without proper infrastructure, the environmental advantages of electric aviation cannot be fully realized (Schwab et al., 2021). Thus, the second hypothesis (H2) is that Infrastructure requirements (IR) for electric aviation are positively associated with the environmental dimension of TBL sustainability.

6.3 Infrastructure Requirements (IR) and Economic Sustainability (TBL):

Economic sustainability is reached. when the use of electric aircraft reduces expenses, such as those associated with fuel and maintenance, and boosts regional economies by attracting tourists and encouraging the purchase of eco-friendly products (Howell and Elizabeth, 2019). It is anticipated that the region's economic viability will increase with the development of appropriate infrastructure, like solar-powered charging stations and environmentally friendly airport operations (Al Sarrah et al., 2021). This leads to the third hypothesis (H3), suggesting that Infrastructure requirements (IR) for electric aviation are positively associated with the economic dimension of TBL sustainability.

6.4 Infrastructure Requirements (IR) and Social Sustainability (TBL):

Social sustainability in the context of urban tourism is enhanced when infrastructure improvements benefit the local community and improve the quality of life. Electric aviation, with its quieter operations and reduced environmental impact, is expected to provide social benefits by creating a healthier and more pleasant living environment for residents and tourists alike (Gupta et al., 2020). Additionally, airports with advanced infrastructure can contribute to job creation and community development. Therefore, the fourth hypothesis (H4) proposes that Infrastructure requirements (IR) for electric aviation are positively associated with the social dimension of TBL sustainability.

6.5 The Mediating Role of Infrastructure Requirements (IR):

In addition to the direct associations, it is anticipated that infrastructural prerequisites will serve as a mediating factor in the relationship between governmental initiatives (ICO) and the three dimensions of Triple Bottom Line (TBL) sustainability. Governmental initiatives, when viewed independently, may be insufficient for achieving sustainability outcomes in the absence of the necessary infrastructure to support electric aviation. As the existing literature posits, infrastructure functions as a facilitator, enabling governmental policies to be converted into tangible sustainability benefits (Schwab et al., 2021). Therefore, the fifth to seventh hypotheses (H5, H6, H7) explore the mediating role of infrastructure in linking government initiatives with environmental, economic, and social sustainability.

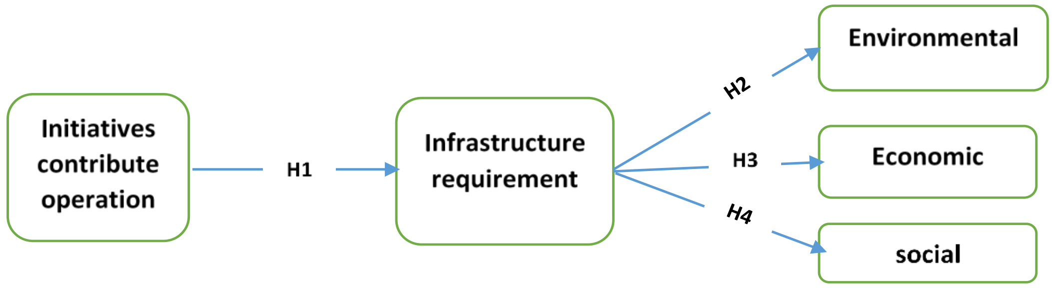
(H5): Infrastructure requirements (IR) mediate the relationship between government initiatives (ICO) and environmental sustainability (TBL).

(H6): Infrastructure requirements (IR) mediate the relationship between government initiatives (ICO) and economic sustainability (TBL).

(H7): Infrastructure requirements (IR) mediate the relationship between government initiatives (ICO) and social sustainability (TBL).

Based on the reviewed literature, a conceptual framework has been developed to explore the relationships between Egypt's governmental initiatives (ICO), the infrastructure requirements (IR) for electric aviation, and the achievement of Triple Bottom Line (TBL) sustainability goals—environmental, economic, and social. This framework (Figure 1) is grounded in the sustainability principles and highlights the mediating role of infrastructure readiness in aligning government initiatives with tourism sustainability outcomes.

Figure (1)The conceptual framework



Notes: *H5*. Infrastructure requirement mediate the relationship between Initiatives contribute operation and Environmental dimension of TBL. H6. Infrastructure requirement mediate the relationship between Initiatives contribute operation and Economic dimension of TBL. H7. Infrastructure requirement mediate the relationship between Initiatives contribute operation and Social dimension of TBL

Research Methodology

This study investigates the influence of the initiatives of the Egyptian government to convert Sharm El-Sheikh into a green city on the achievement of TBL's objectives at Sharm El-Sheikh through a positive contribution to the readiness of Sharm El-Sheikh airport to operate electric aviation flights A comprehensive conceptual framework is formulated following a thorough examination of existing literature. Subsequently, the efficacy of this framework is evaluated utilizing Partial Least Squares Structural Equation Modelling (PLS-SEM) with data gathered from a survey conducted at Sharm El-Sheikh airport. A Likert scale comprising of five points was employed for data collection, ranging from (1) strongly disagree to (5) strongly agree. The method of data collection was a self-completed questionnaire, returned by e-mail or personally collected by the researchers.

Sampling and data collection

The study is conducted on a purposive, non-probability sample selected based on the characteristics of a population and the problem and objectives of the study. From January to March 2024, a survey questionnaire was carried out at Sharm El-Sheikh airport. The investigated population was first guaranteed that the questionnaire would be completely anonymous and confidential. The questionnaire was distributed to a population of 471 respondents as follows: 84 at the operation department, 15 at the conformity and safety department, and 372 at the airport ground services company. As a result of the data cleaning process, there were 220 valid entries for the statistical analysis. Moreover, a pre-study was conducted before distributing the questionnaire with an expert pilot who has great knowledge about electric aviation, as well as the Minister of Tourism's sustainability consultant , The operation manager of Sharm El-Sheikh Airport and Director of the Environment Department and Wildlife of Sharm El-Sheikh Airport. through direct personal interviews. The pre-study aimed to verify the appropriate study population and to ensure that the questionnaire statements were cleared for individuals. Also, as a result of the pre-study, researchers reached an accurate number of employees at each department and chose the judgmental sample approach for the selected departments above.

Research Measures

The research consisted of three phases. The first phase includes measuring the opinions of the respondents about how the initiatives of the Egyptian government to convert Sharm el-Sheikh into a green city contribute positively to operating the electric aviation flights at Sharm el-Sheikh Airport, as measured in (Abdul Raouf *et al.*, 2019; UN, 2022; COP27, 2022; IOC-E, 2022; SIS, 2022; UNDP, 2023) In the second phase, infrastructure requirements for electric aviation at Sharm El-Sheikh Airport were measured. Phrases constituting these requirements were derived from (Schwab et al., 2021; WEF, 2023; ICAO, 2022a; Petrie, 2023; WSDOT, 2020). The final phase explores how the operation of electric aviation flights at Sharm El-Sheikh Airport could achieve the TBL's sustainability objectives in Sharm El-Sheikh city (Elkington, 1994, 2004; Guan *et al., 2022*;Gupta *et al.*, 2020; Al Sarrah *et al.*, 2020).

Data analysis

WarpPLS 7.0 was employed for the examination of the data through the utilization of partial least squares structural equation modeling (PLS-SEM) as indicated by Kock (2021). Within the realm of scholarly discourse on empirical tourism management, PLS-SEM stands out as a frequently employed instrument, as noted by Al-Azab and Al-Romeedy (2023). This methodology proves to be a fitting choice for the scrutiny of intricate structural frameworks characterized by both direct and indirect linkages among multi-item variables, as articulated by Manley et al. (2021)

Results

Participant's characteristics

From 220 respondents there were 23.7% less than 30 years, 31.8% being between 30-40, 25.9% between 40 and 50 years and 18.6% over than 50 years. Moreover, 45.6% of respondents had a bachelor's degree, while the least, 55.4%, did not have a high education. Furthermore, 8.6% of respondents had less than two years of work experience, 20.9% had between two and five years' work experience, 29.1% had between 5 and 10 years' experience, and 41.4% had over ten years' experience (Table 1).

Table (1) Participant's profile

Characteristics	Frequency	%
Age		
< 30 years	52	23.7
30 < 40 years	70	31.8
40- 50 years	57	25.9
>50 years	41	18.6
Education		
Bachelor	98	44.5
Diploma	122	55.4
Experience		
<2 years	19	8.6
2-5 years	46	20.9
5-10 years	64	29.1
>10 years	91	41.4

Measurement model

Loading of an item greater than 0.5 is considered acceptable according to Hair et al. (2010). All item loadings were calculated in the current study and found to be satisfactory, ranging from 0.536 to 0.906. The assessment of convergent validity through the average variance extracted (AVE) and the evaluation of internal consistency through composite reliability coefficients are crucial factors affecting measurement quality (Shrestha, 2021). The composite reliability values for all variables, as displayed in (Table 2), are considered sufficient, exceeding 0.7. Moreover, following the predefined criteria by Hair et al. (2010), the convergent validity of the scales is confirmed by AVE values exceeding 0.5.

For the establishment of discriminant validity, the correlation between two latent variables must be notably lower than one (Franke and Sarstedt, 2019). The study model's discriminant validity is supported by the results presented in (Table 3), showing that each variable's AVE value surpasses the highest common value.

Examination of model fit and quality indices for the research model indicates that prior to hypothesis testing, a review of the model fit was conducted. According to Kock (2021), all model fit findings and quality indices meet the necessary criteria, as outlined in (Table 4).

Table (2) Mean, Std. deviation, factor loading, reliability and convergent validity

		Mean	Std. deviation	Item Loading	α	CR	AVE
	Initiatives contribute operation (ICO)				**0.744**	**0.830**	**0.595**
ICO1	The transformation of Sharm El-sheikh into green city.	3.20	1.039	**0.738**			
ICO2	The reliability of Sharm El-Sheikh on clean energy.	3.03	1.029	**0.649**			
ICO3	Reducing emissions.	3.00	1.053	**0.650**			
ICO4	The reliability of Sharm El-Sheikh airport on solar energy.	3.21	1.018	**0.714**			
ICO5	Launching national climate change strategy 2050	3.13	1.092	**0.762**			
	Infrastructure requirement (IR)				**0.767**	**0.844**	**0.522**
IR1	Providing the airport with a permanent source of clean electricity.	2.61	1.060	**0.733**			
IR2	Providing the airport with charging stations.	3.61	1.107	**0.595**			
IR3	Providing the airport with Emergency procedures for electric aircraft.	3.25	1.040	**0.718**			
IR4	Staff training and ground service crews on handling electric aircraft.	3.34	.939	**0.827**			
IR5	Developing a plan to mitigate any environmental impacts associated with electric aircraft operations.	2.95	.985	**0.720**			
	Environmental sustainability (ENV)				**0.760**	**0.862**	**0.676**
ENV1	Air quality	2.89	1.077	**0.813**			
ENV2	Noise reduction	2.58	1.055	**0.828**			
ENV3	Environmental awareness	3.04	1.106	**0.825**			
	Social sustainability (SOC)				**0.786**	**0.862**	**0.610**
SOC1	Quality of life	2.74	1.053	**0.739**			
SOC2	Cultural diversity	3.08	1.051	**0.778**			
SOC3	Social commitments	2.91	1.028	**0.799**			
SOC4	Social awareness	3.09	1.032	**0.806**			
	Economic sustainability (ECO)				**0.590**	**0.785**	**0.552**
ECO1	Cost of energy reduction	3.29	1.634	**0.646**			
ECO2	Using sustainable and renewable energy.	2.79	1.021	**0.783**			
ECO3	Economic growth.	2.97	1.068	**0.790**			

Table (3) Discriminant validity results

	ICO	IR	ENV	SOC	ECO
ICO	**0.704**				
IR	0.780	**0.722**			
ENV	0.618	0.660	**0.822**		
SOC	0.719	0.772	0.647	**0.781**	
ECO	0.705	0.648	0.589	0.618	**0.743**

Table (4) Model fit and quality indices

	Assessment	Criterion	Supported/rejected
Average path coefficient (APC)	0.717, P< 0.001	P < 0.05	supported
Average R-squared (ARS)	0.518, P< 0.001	P < 0.05	supported
Average adjusted R-squared (AARS)	0.515, P< 0.001	P < 0.05	supported
Average full collinearity VIF (AFVIF)	2.791	Acceptable if < = 5	supported
Tenenhaus GoF (GoF)	0.544	Small > = 0.1, medium > = 0.25, large > = 0.36	supported
Sympson's paradox ratio (SPR)	1.000	Acceptable if > 0.7, ideally =1	supported
R-squared contribution ratio (RSCR)	1.000	Acceptable if > 0.9, ideally =1	supported
Statistical suppression ratio (SSR)	1.000	Acceptable if > 0.7	supported
Nonlinear bivariate causality direction ratio (NLBCDR)	1.000	Acceptable if > 0.7	supported

Structure model assessment

Results from the hypothesis testing (Figure 2, Table 5) showed that there is positive relationship between all latent variables, which ICO and IR ($\beta = 0.78$, $p < 0.01$), IR and ENV ($\beta = 0.66$, $p < 0.0$), IR and ECO ($\beta = 0.65$, $p < 0.01$), and IR and SOC ($\beta = 0.77$, $p < 0.01$). Therefore H1, H2, H3, and H4 are supported. These findings demonstrate that the operation of electric aviation at Sharm El Sheikh airport adopts with the Egyptian government’s initiatives for Sharm El Sheikh city and also contributes effectively the achievement of tourism sustainability goals (environmental, social, and economic) for Sharm El sheikh city.

Figure(2) The Model of the study

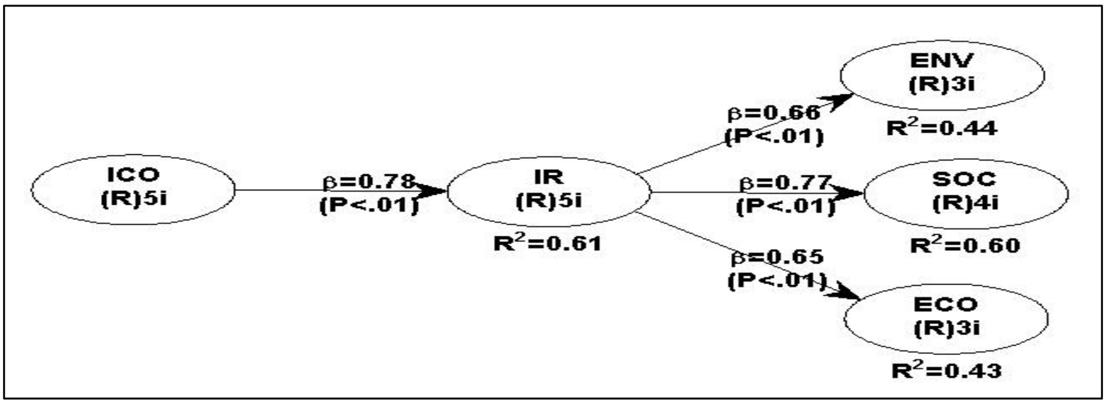


Table (5) direct effect

	B	Sig	Decision
H1. ICO - IR	0,78	P< 0.01	Supported
H2. IR - ENV	0.66	P< 0.01	Supported
H3. IR - ECO	0.65	P< 0.01	Supported
H4. IR - SOC	0.77	P< 0.01	Supported

As per the data presented in Table 6, the examination of the indirect effect within the model was conducted using bootstrapping techniques as recommended by Preacher and Hayes (2008). The results revealed that the impact of (ICO) on (ENV) through Institutional Reputation (IR) (β= 0.516, P < 0.001) demonstrated a moderate effect size of 0.32. Similarly, the connection between ICO and (ECO) through IR (β= 0.507, P < 0.001) exhibited a medium effect size of 0.34. Moreover, the relationship of ICO on (SOC) via IR (β= 0.600, P < 0.001) was established with a substantial effect size of 0.36. Regarding IR's role as a mediator between ICO and ENV, the findings indicated a significant indirect influence with a standardized β of 0.516 (0.78 x 0.66), showing a t-value of 11.05. This indirect effect of 0.516, with a 95% Bootstrapped Confidence Interval: (LL = .543, UL = .777), supported the presence of mediation. Therefore, the mediating effect of IR in the ICO-ENV relationship is statistically significant, hence confirming H5. Analysis of IR as a mediator in the context of the association between ICO and ECO demonstrated a significant indirect effect with a standardized β of 0.507 (0.78 x .65), displaying a t-value of 13.97. Additionally, the indirect effect of 0.507, with a 95% Bootstrapped Confidence Interval: (LL = 0.658, UL = 0.887), suggested mediation. Thus, the mediation effect of IR in the ICO-ECO relationship is considered statistically significant, thereby supporting H6. When examining IR as a mediator in the relationship between ICO and SOC, the results indicated a significant indirect effect with a standardized β of 0.600 (0.78 x .77), along with a t-value of 13.97. Furthermore, the indirect effect of 0.600, coupled with a 95% Bootstrapped Confidence Interval: (LL = 0.658, UL = 0.887), denoted mediation. Therefore, the mediation effect of IR in the ICO-SOC relationship is statistically significant, thus supporting H7. Additionally, the positive impact of IR on the association between ICO and the dimensions of the Triple Bottom Line (TBL) model suggests that H5, H6, and H7 are supported.

Table (6) Indirect Effect

	Path a	Path b	Indirect Effect	Effect size	t-value	Bootstrapped Confidence interval 95% LL	95% UL	Decision
H5. ICO – IR – ENV	0.78	0.66	0.516	0.319	11.051	.543	.777	Partial mediation
H6. ICO – IR – ECO	0.78	0.65	0.507	0.343	13.97	.658	.887	Partial mediation
H7. ICO – IR – SOC	0.78	0.77	0.600	0.360	10.926	.536	.771	Partial mediation

Discussion

The investigation seeks to assess the connection between ICO and IR, IR and TBL, and explore the mediating role of IR in the relationship between ICO and TBL. A quantitative methodology is employed in this research to accomplish its objectives, utilizing a survey to collect data from employees working at Sharm El-Sheikh airport.

The results emphasize the favorable association between ICO and IR. This outcome aligns with Abdul Raouf et al., (2019), who observed that Sharm El Sheikh International Airport is transitioning to environmentally friendly practices as it aligns with the Initiatives of the Egyptian State. Furthermore, Genina et al. (2023) concurred with this finding, indicating that Sharm el-Sheikh airport has embraced the Egyptian guidelines and infrastructural criteria for clean solar energy implementation.

Additionally, the results suggest a positive correlation between IR and TBL. This finding is in accordance with Virginie et al,. (2013), who highlighted the positive correlation between IR and TBL and recognized electric aviation as a promising avenue for sustainable air travel. Gupta et al. (2020) expounded on the positive relationship between IR and ENV, demonstrating the substantial environmental impacts of the aviation sector, including noise, pollutants, and contamination, which affect individuals and the environment. Similarly, the findings of the present study reveal a positive association between IR and ECO. This outcome is supported by the WSDOT (2020) study, illustrating how electric aviation can foster economic development by serving underserved regions, revitalizing stagnant markets, converting general aviation airports to reduce costs, and enhancing pilot training programs in collaboration with vocational institutions. Electric propulsion technologies in aviation present a viable approach to reducing expenses related to fuel consumption. Furthermore, Julio (2022) highlighted the positive correlation between IR and SOC, asserting that electric aviation provides significant social advantages for local communities. By mitigating emissions and noise pollution, electric aircraft contribute to a more sustainable and community-friendly air transport system. The study by Datey et al. (2023) determined that the noise reduction potential of electric aviation could decrease the number of highly annoyed individuals and areas with elevated noise levels, benefiting neighborhoods surrounding regional airports.

Theoretical implications

Examining the mediating role of (IR) in the correlation between (ICO) and sustainability within the tourism and hospitality sectors carries significant implications for the (TBL) framework. This research contributes to the advancement of TBL framework by introducing innovative operational strategies for electric aviation to promote sustainable tourism in Egypt. Specifically, it highlights the positive influence of ICO on the adoption of electric aviation at Sharm El-Sheikh Airport, leading to the transformation of Sharm El-Sheikh into a green city and the promotion of renewable energy utilization at the airport. Furthermore, the study assesses the Institutional Resilience required for the operation of electric aviation at Sharm El-Sheikh Airport, underscoring the necessity of devising strategies to mitigate any environmental impacts associated with electric aircraft operations. By considering ICO as an independent variable and IR as a mediator, the research aligns with the fundamental tenets of TBL framework. The findings emphasise the importance of demonstrating the implementation of electric aeroplanes, which are recognised for their environmentally friendly and effective features and closely correspond with the three pillars of sustainability in the Triple Bottom Line framework. This offers a promising approach to reducing the ecological footprint of conventional aviation while advancing economic viability and societal accountability.

Practical implications

The study's findings emphasise the significance of implementing electric aviation operations at Sharm El Sheikh International Airport to decrease carbon emissions within the region. This is particularly crucial as the Egyptian government has initiated efforts to convert Sharm El Sheikh into a green city. Through the field research, it was validated that the governmental endeavors in Egypt are conducive to fulfilling the necessary infrastructure criteria at Sharm El-Sheikh International Airport to facilitate the accommodation of electric aircraft. The outcomes of the analysis further verified that the utilisation of electric aviation at Sharm El-Sheikh International Airport will have a beneficial influence on advancing the sustainable tourism objectives in Sharm El-Sheikh, encompassing economic, social, and environmental dimensions. Consequently, the study advocates the initiation of efforts to equip Sharm El-Sheikh Airport with the essential infrastructure components for operating electric aviation, in addition to providing workforce training in ground services management, quality assurance, and operational procedures related to maintenance and emergencies that are essential for this innovative aircraft category. Moreover, the strategic agenda of the Egyptian government should encompass initiatives aimed at encouraging private investors to conduct domestic flights amidst Egyptian airports and to destinations in neighbouring countries using electric aircraft, given the cost-effectiveness associated with their operation in contrast to conventional aviation methods.

Limitations and directions for future research

Even though this study contributes to the existing reservoir of knowledge in multiple respects, there remain avenues for further research. First, it would be advantageous to investigate additional variables within the global and local economic context that could influence the study's recommendations for concerned authorities involved in implementing operational procedures for electric aircraft at Sharm El-Sheikh Airport. Furthermore, examining prospective opportunities for the integration of tourism in the region exemplifies the NEOM project, which was initiated to attain sustainability objectives and establish connections among Jordan, Egypt, and the Kingdom of Saudi Arabia. (Essam et al., 2023) Second, while the researchers highlighted various sustainability benefits of electric aviation, they also identified existing primary challenges hindering its widespread adoption. These challenges include the limitation of electric aviation on non-scheduled flights, which is primarily due to its limited range compared to conventional aviation. This limitation primarily stems from the current constraints of battery technology, which could be improved through the utilization of next-generation battery technology, like Cuberg's batteries, offering enhanced energy density and safety compared to current lithium-ion batteries globally.(ICAO, 2023) By employing this technology, electric aeroplanes have the potential to enhance their range in the upcoming years, consequently fueling the growth of tourism and attracting a higher volume of travelers. Third, during the pilot study conducted by the researchers, Former president of the Egyptian civil aviation authority, presented a proposal to expand the use of electric aviation to include tourist tours in the city of Luxor as an alternative to hot air balloon tours. He explained that "*despite the popularity of hot air balloon tours, concerns have been raised. It is related to safety in operations and the lack of control over flight paths, and it also has harmful effects on environmental sustainability, unlike electric aviation."* Therefore, researchers suggest conducting a comprehensive examination of this subject in forthcoming research.

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التحقيق في الدور الوسيط لمتطلبات البنية التحتية للطيران الكهربائي بين مبادرات الحكومة المصرية واستدامة السياحة في مصر

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الملخص العربى

تهدف هذه الدراسة إلى التحقيق في كيفية مساهمة المبادرات الحكومية المصرية في دمج الطيران الكهربائي داخل مطار شرم الشيخ الدولي، بما يساهم في جعله نموذجًا للسياحة الحضرية المستدامة من خلال التركيز على المتطلبات الأساسية للبنية التحتية للطيران الكهربائي، تستكشف هذه الدراسة الدور الوسيط لهذه المتطلبات في تحقيق أهداف الاستدامة الثلاثية (TBL) والتي تشمل الأبعاد البيئية والاقتصادية والاجتماعية. تعتمد الدراسة على إطار عمل الاستدامة الثلاثي لتقييم جدوى وفوائد التكنولوجيا الخاصة بالطيران الكهربائي في تعزيز الاستدامة. تم تنفيذ منهجية كمية لتحقيق أهداف البحث، حيث تم جمع البيانات من موظفي مطار شرم الشيخ الدولي. استخدمت الدراسة أسلوب نمذجة المعادلات الهيكلية الجزئية (PLS-SEM) لتحليل البيانات التي تم الحصول عليها من ٢٢٠ موظفًا بالمطار. أشارت النتائج إلى أن البنية التحتية الداعمة للطيران الكهربائي تؤثر بشكل إيجابي على مستقبل المدينة نحو تحقيق الاستدامة، مما يقدم نهجًا مبتكرًا لتطوير السياحة الحضرية في مصر. تُثري هذه الدراسة النقاش حول السياحة الحضرية من خلال توضيح أهمية الطيران المستدام في دفع مبادرات المدن الخضراء، مما يجعلها ذات صلة خاصة بالممارسات في السياحة الحضرية. كما توفر النتائج رؤى عملية لواضعي السياسات والمخططين الحضريين الساعين إلى مواءمة استراتيجيات الطيران مع تطوير السياحة المستدامة في الوجهات السياحية البارزة.

الكلمات الدالة: الطيران الكهربائي، النموذج الثلاثي للاستدامة (TBL) ، الطاقة المتجددة، الطيران الخالي من الانبعاثات ، مطار شرم الشيخ الدولي.