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Identifying the effective taxonomies of airline green operations strategy

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Abstract

Purpose – The purpose of this paper is to explore the effective taxonomies of airline green operations strategy.
Design/methodology/approach – To this end, a sample of 23 airlines from five regions (North America, South America, Europe, Asia and the Middle East) was surveyed. The annual sustainability reports of the surveyed airlines for the period 2013–2016 were retrieved from the Global Reporting Initiatives website. K-means clustering analysis was used to generate taxonomic clusters of airline green operations strategy. A special data analysis technique, called rank analysis, was also adopted to identify the significant green actions and develop indicative models.
Findings – This study revealed that three effective taxonomies were adopted by airlines: a low-effect strategic pattern, a low-to-moderate effect strategic pattern and a high-effect strategic pattern. A different combination of green operation actions characterized each strategic pattern.
Originality/value – The research contribution of taxonomies of green operations strategy has so far been limited, country focused and concentrated on the manufacturing sector. This study reported the taxonomies and performed an in-depth analysis of the categories of effective actions taken to promote green performance. Moreover, this study developed indicative models for the relationship between categories of action and green performance for each strategic pattern, an action that has seldom been reported by previous studies of green operations strategies for airlines.

Keywords Global, Airlines, Green, Operations strategy, Taxonomies, K-means clustering
Paper type Research paper

1. Introduction

At a historic UN summit in September 2015, world leaders adopted the 17 Sustainability Development Goals (SDGs) as part of the 2030 Agenda for Sustainability Development. These new goals encouraged ways of tackling climate change. Tackling climate change and fostering sustainable development are two sides of the same coin, according to the 2030 Agenda; many SDGs address the central causes of climate change (UN, 2018).

Governments have been compelled to adopt the SDGs, and firms of different sizes from different industries, feeling more accountable with regard to ecology and the environment (Singh and Trivedi, 2016), have developed more competitive green strategies (Bhardwaj, 2016; Kirchoff *et al.*, 2016). The aviation industry, like other industries, started to adopt green practices and ecologically friendly strategies. Aircraft engines have a negative environmental impact; they emit greenhouse gases in the form of carbon dioxide, water vapor and hydrocarbons, and they cause heat and noise pollution (Lee *et al.*, 2010; Brasseur *et al.*, 2016). Approximately 2 percent of the world's emissions of carbon dioxide are produced by aviation (IPCC, 2015).

The environmental impact of this sector has increased over the past 25 years as a result of increased demand (Lee *et al.*, 2009; Macintosh and Wallace, 2009). For example, CO_2 emissions increased by 80 percent between 1990 and 2014 and the emissions of NO_X

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doubled; moreover, between 2014 and 2035, these emissions are expected to grow by a further 43 percent (EASA, 2016). The literature of green air transport strategy reveals that no single strategic pattern can fully alleviate ecological damage. However, a range of green strategies for aviation, embracing technological, operational and infrastructural improvements, could moderate the industry's environmental impact (Teoh and Khoo, 2016). Previous studies have demonstrated the need to learn about effective practices and the key success factors of green airline performance (Abdullah *et al.*, 2016).

Studies of green airline practices have focused on reporting the impact of particular operational practices on the indicators of greenness (e.g. Smith, 2016; Teoh and Khoo, 2016; Will *et al.*, 2016; Yan *et al.*, 2016), but firms' concern to report green strategy (e.g. Lin, 2017; Teoh and Khoo, 2016; Lee *et al.*, 2017) or effective practices (e.g. Abdullah *et al.*, 2016, Migdadi, 2018) is rarely shown. Furthermore, most studies have reported practices in the context of a single country (e.g. Lynes and Dredge, 2006; Harvey *et al.*, 2013; Chapman, 2016; Horio *et al.*, 2016; Liu *et al.*, 2017) or a single region (e.g. Yan *et al.*, 2016), and very few studies (e.g. Migdadi, 2018, 2020) have reported the green strategies across regions. In addition, previous studies have not described the taxonomies of green strategic patterns by airlines. Accordingly, this study sought to bridge the gap in the literature by outlining the effective taxonomies of green operating strategies. The practices of airlines from different regions are reported below. This study also identified the actions implemented by each taxon. It applied the strategy configuration theory to report the taxonomies of airline green operations strategies, and it also reported the taxonomies and performed an in-depth analysis of the categories of effective actions taken to achieve green performance. Moreover, this study developed indicative models of the relationship between categories of action and green performance for each strategic pattern, which were seldom reported by previous studies of the subject.

The future target of airlines is to halve their 2005 total CO_2 emissions by 2050 (Brooks *et al.*, 2016), and they are doing their best to manage the environmental impact of their operations. This raises the following question: "What are the effective green operational strategies adopted by airlines to reduce their negative environmental impact?" To answer this question, the present paper sets the following objectives:

(1) defining the content (actions and green indicators) of airlines' green operations strategy;

(2) reporting the environmental performance of airlines;

(3) reporting the operational environmental actions taken by airlines;

(4) developing the taxonomies of airlines' green operations strategy;

(5) identifying the effective operational actions by each effective strategic pattern; and

(6) developing indicative models for the relationship between green actions and green performance indicators for each strategic pattern.

This paper is structured in seven sections: Section 1 describes the introduction and Section 2 describes the background of study. Section 3 describes the research methodology and data analysis techniques used in the study. Section 4 contains the results of study. Section 5 discusses these results. Section 6 discusses the applications and limitations and some suggestions for future research, and the last section presents the conclusions of the paper.

2. Background of study

The studying of taxonomies of green operations strategy is a part of the strategic configuration research stream. Strategy management scholars such as Miles *et al.* (1978), Porter (1980) and Mintzberg and Waters (1985) developed various configurations. "Strategic configurations" is the term that refers to groups of organizations based on the logical subset of their variables (Meyer *et al.*, 1993). It is used to describe a type of organizational strategy or process according to a multi-dimensional profile (Bozarth and McDermott, 1998). The taxonomic and the typological approaches are two types of configuration of strategic operation (Miller, 1996).

In the literature in this field, typology and taxonomy have sometimes been used interchangeably, but the two terms are in fact different. In typology, organizations are classified into ideal types, each type representing a unique combination of organizational attributes, which leads to a particular outcome (Doty and Glick, 1994). On the one hand, the typological approach is that of testing whether the greater alignment between an organization and a defined ideal type leads to better performance; the typology approach tends to provide ground theory and middle range theories to be tested empirically (Bozarth and McDermott, 1998; Migdadi, 2013). On the other hand, the taxonomic approach is based on an empirical classification of organizations using methods of numerical taxonomy and technique that involves an assortment of clustering algorithms and the testing of hypotheses to identify the membership of the clusters in the data (Miller, 1996). Taxonomies are, thus, based on facts and quantitative data (Bozarth and McDermott, 1998).

The taxonomy of manufacturing strategies has been a research issue since the mid-1990s (e.g. Miller and Roth, 1994), and many studies have been conducted so far (Kathuria, 2000; Frohlich and Dixon, 2001; Menor *et al.*, 2001; Sum *et al.*, 2004; Zhao *et al.*, 2006; Luz Martin-Pena and Diaz-Garrido, 2008).

The narrow research stream of taxonomies of green operating strategies is still in its infancy, with only a few studies published, for example Migdadi, 2015, 2016; Migdadi and Elzzqaibeh, 2018. These studies investigated the taxonomies of green strategies in manufacturing. The study by Migdadi (2016) investigated the leading practices of a small number of cases featuring mobile phone manufacturers, and another by Migdadi and Elzzqaibeh (2018) investigated the practices in a single country (Jordan). The taxonomies of airlines operations strategy have been reported very infrequently (e.g. Alkhatib and Migdadi, 2018, 2019). The above studies reported and analyzed the taxonomies of airlines' capacity and scheduling strategies at the global level, so their central concern was remote from the green practices of airlines. Hitherto, then, the taxonomies of the green operating strategies of the service sector, in general, and airlines, in particular, have never been investigated. Furthermore, the taxonomies of airlines' green operations strategy at the global level have not been investigated so far.

2.1 The variables used to develop the taxonomies of green operations strategy

The taxonomies of a strategy are developed by using various attributes (variables) as strategic decisions or competitive priorities were adopted by the previous studies. The widely adopted variables derive from the operations competitive priorities and capabilities (e.g. Miller and Roth, 1994; Kathuria, 2000; Frohlich and Dixon, 2001; Menor *et al.*, 2001; Sum *et al.*, 2004; Zhao *et al.*, 2006; Migdadi, 2017). Various perspectives have been used to evaluate firms' competitive capabilities. From one perspective, it was decided to identify performance in comparison with a firm's major competitors (e.g. Menor *et al.*, 2001; Sum *et al.*, 2004; Migdadi, 2017), but from another, it seemed better to identify the relative importance of each capacity in a single organization (e.g. Miller and Roth, 1994; Kathuria, 2000; Frohlich and Dixon, 2001; Zhao *et al.*, 2006). The approach should be determined by the research objective: if the objective is to identify the adopted strategy, then the first approach will be appropriate, but if the objective is to identify the effective taxonomies, then the second approach will suit it better (Miller and Roth, 1994).

Studies of green strategy taxonomies, such as Migdadi (2016), adopted the green operating indicators of mobile phone producers as variables in developing taxonomies. These indicators include firm's CO_2 emissions, tons of solid waste generated, tons of recycled wastes, tons of hazard material generated and kilowatts of electricity generated per hour. The approach taken by Migdadi (2016) to develop taxonomies was to assess performance in comparison with a firm's major competitor. The study by Migdadi and Elzzqaibeh (2018) adopted a combination of several indicators in three categories – environmental, operational and economic. To develop taxonomies, the approach taken by Migdadi and Elzzqaibeh (2018) was to compare the value to the same organization of several indicators.

The study of Migdadi and Omari (2019) adopted several green indicators to report the best practices of hospitals' green operating strategies, namely materials (paper consumption), water consumption, energy consumption, electrical power consumption, direct GHG emissions, indirect GHG emissions, fuel consumption and hazard and non-hazard wastes. The approach adopted for developing the taxonomies was to compare the performance of a firm with that of its major competitors. The clear and comprehensive definition of airlines' green indicators was discussed by Migdadi (2018); these indicators could be classified as presented by Table I. This study adopted all the indicators except noise and GHG3 because data on these two indicators are in many cases not published.

2.2 *The taxonomies of green operations strategy*

According to Migdadi (2016), the taxonomies of effective green operating strategies are as follows: hazard material management, solid waste management and hybrid of both solid waste and hazard material management. However, the study by Migdadi and Elzzqaibeh (2018) developed three taxonomies in green manufacturing strategy: green strategy for a caretaker environment, an agile environment and a lean environment. A caretaker strategy scored in all the key performance indicators (environmental, operational and economic or financial) at a moderate to low level. The agile strategy group scored in all the performance indicators (environmental, operational and economic or financial) at a high level. The lean strategic group scored moderately well in the financial and environmental indicators, and at a lower level in the key performance indicators of operational level. Migdadi and Omari (2019) developed five taxonomies for hospitals: resource management, electrical power management, non-hazard waste, emission-resources management and low emphasizer. Most of the previous studies developed different clustering trials and chose the clustering trial that had the maximum number of significant indicators. In this study, the same approach was adopted to identify the best clustering trials. However, the titles assigned for the clusters reflected that mainly the significant indicators were adopted by the clusters; the same approach was adopted by this study. Moreover, the previous studies such as Migdadi and Omari (2019) developed indicative models for the best strategic patterns; also, the same approach was adopted by this study.

Table I. Airlines green indicators

Green indicator	Operational definition
GHG 1 emissions	Metric tons of direct CO_2 emissions from jet fuel and ground support
GHG 2 emissions	Metric tons of indirect CO_2 emissions of electricity, power and heat from direct billing of owned or leased facilities
Energy consumption	Kilowatt per hour of electricity, power and heat
Fuel consumption	Gallons of fuel
Water consumption	m^3 of consumed water
Wastes generated	Tons of generated waste
Recycling	Tons of recycled waste

Source: Migdadi (2018, 2020)

2.3 The content of airlines' green operations strategy

The theoretical stance of green operations strategy is rooted in sustainability theories, as theories of sustainability issues and a "triple bottom line" framework. According to scholars of sustainability issues, successful sustainability practices are affected by critical success factors such as top management commitment, management leadership, strategic alignment, organizational culture, communication (de Sousa Jabbour *et al.*, 2018), etc. However, according to the triple bottom line framework, the sustainability rests on social, economic and operational pillars (Elkington, 1997). For developing green theory, two approaches are used (Nunes, 2011): the first, strategic, approach is to make decisions related to process design and product design (Gupta and Sharma, 1996), whereas the second spreads the scope of the operating actions to include green management of the supply chain, the design for environment, the reverse logistics and the best possible management of the whole environment (Sarkis, 2001). This study due to its focus on green performance is based in some ways on the "triple bottom line" and on green strategic decisions as it's reporting process design and product design actions.

According to the literature and theories on operational strategy, the components of this strategy are the operational actions and operational competitive criteria or competitive capabilities. The latter are the actual strengths of the service provider in comparison with its main competitors, whereas the former are the such operational decisions as those involved in process design, location planning, designing the layout of the facilities, capacity planning (Menor *et al.*, 2001; Migdadi, 2012), etc. The present study, from the perspective of operational strategy theories, examined the impact of green operational actions on the green strength of airlines compared with that of their main competitors. In the next section, there is an in-depth discussion of the components of a green operational strategy.

2.3.1 Airlines' green indicators. The study by Migdadi (2018, 2020) developed a comprehensive list of airlines' green indicators. According to this study, airlines' green indicators are their GHG1 emissions, GHG2 emissions, GHG3 emissions, energy consumption, fuel consumption, water consumption, wastes generated, recycling, NOx emissions, SOx emissions and noise. Table I shows the airlines' green indicators.

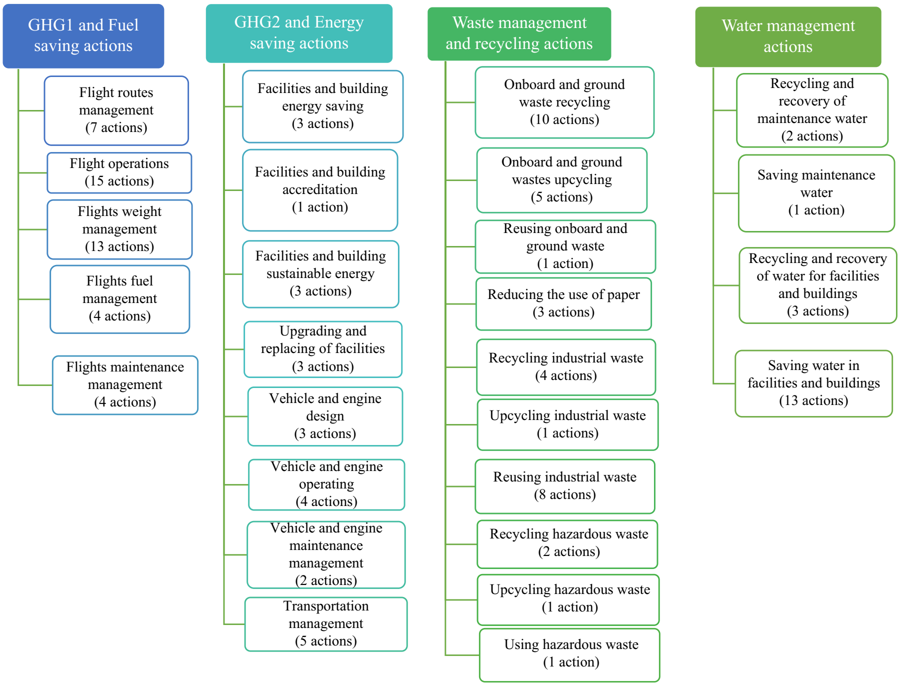
2.3.2 Airlines' green operational actions. According to Migdadi (2018, 2020), such actions may be divided into categories on the basis of their green indicators. Figure 1 summarizes the categories of green actions taken by airlines. It can be seen that the actions that they took to reduce GHG1 emissions and fuel management are related to flight operations. The flight operations actions may have related to aircraft design, the management of routes, the operation of the aircraft, weight management, fuel management or maintenance management. The GHG2 emissions and energy-saving actions relate to operating of ground facilities, buildings, vehicles and engines. The actions related to facilities and building may involve energy saving, facilities and buildings accreditation, the use of sustainable energy or the upgrading and replacement of facilities. The actions taken for vehicles and engines may be designing, operating, maintaining and the management of transportation.

The waste and recycling management actions are classified into onboard and ground waste management, industrial waste management and hazard waste management. The actions in each category are classified as recycling, upcycling or using and reusing. The water management actions taken by airlines are related either to maintenance operations or facilities and buildings. The actions are divided into recycling and recovery actions, and water saving actions.

3. Methodology and methods

3.1 The sample of study

The sample of the present study was a convenient stratified sample determined by the availability of secondary published data (Migdadi, 2018); the sample reported airlines' green



Sources: Adopted from Migdadi (2018, 2020)

Figure 1.
Categories of airlines' green actions

actions and green indicators as published in its sustainability reports and social responsibility reports over the period 2013–2016. The airlines from five regions, North America, Europe, Asia, the Middle East and South America, were surveyed in this study. The study sample consisted of 23 cases: six airlines from North America, six from Europe, seven from Asia, three from the Middle East and one from South America.

3.2 Identifying the study time frame

This study was a time series, to allow the changes in green indicators and actions to be tracked. In this study, two sustainability reports of the selected cases (namely, the initial report and the most recent) were retrieved. Most of cases began to report their level of sustainability (social responsibility) in 2013 and the most recent reports were published in 2016 (Migdadi, 2018). Thus, the study period is 2013–2016.

3.3 The sources of data and data collection

The sources of data were the Global Reporting Initiatives (GRI) database and the reports published on the corporations' websites (Migdadi, 2018). Most of these reports were retrieved from the GRI. The GRI is an independent international organization that was established in the USA in 1997. It seeks to help organizations to report their impact on sustainability. It develops standards of reporting sustainability and publishes reports via its website (GRI, 2017). Data of 17 airlines were retrieved from GRI and six from corporations' websites (Migdadi, 2018). To trace the changes, each airline needed to make two reports available, the first in 2013 and the second in 2016. Once retrieved, these reports were classified according to region and then the facts reported about each airline for the period 2013–2016 were summarized. The summary included the green indicators and the actions taken by each airline.

3.4 Checking the reliability of the data

To check the reliability of the data, the facts were in some cases randomly collected for a second time. In all such cases, the initial and subsequent collections of facts were compared. When the data came from two sources – websites and the GRI – the data from these two were compared, to check their reliability. The facts related to green indicators and actions were compared for case by case; two lists were developed on the Excel sheet, the first one included the green indicators or actions were documented by the websites, and the second column included the green indicators or actions were documented by the sustainability reports. Next, the facts of two columns were compared one by one, if the fact was very close, "Yes" would be written in the third column. After completing the comparison, if the percentage of "Yes" was 90 percent or more, the data would be reliable.

3.5 Data preparation and analytical tools and techniques

3.5.1 Before the analysis phase

(1) The relative changes in the green indices over the study period were computed; the following formula was used for this purpose:

$$\mathrm{RCGI} = (\mathrm{P}_{2016} – \mathrm{P}_{2013})/\mathrm{P}2013,$$

where RCGI is the relative change in green indicator; P2013 the realized performance 2013; and P2016 the realized performance 2016.

(2) The action index for each case was computed. The index reflected the degree to which each category of action had been adopted. Below is the detailed procedure for computing the index:

- Count the number of categories of action adopted by the case.
- Divide the above number by the total number of adopted actions. The result is the adoption index. Table II shows the example of computing action index.

(3) Then the green action score was multiplied on a scale of five points. Figure 2 shows the scale.

3.5.2 Data analysis phase

- Step 1: the airlines were clustered according to their green indicators by a K-means clustering analysis. Several trials were generated; the trial that generated the maximum significant indicators was confirmed. In this study, the best trial was the four clusters trial.

Action category	Actions list	NA1
Aircraft design	Fleet modernization	1
	Split scimitar winglets	
	Sharklet wingtips	
	Engine modification	
	Total number of actions adopted by NA1	1
	Index = 1/4	0.25

Table II.
Example on how to compute green action index

- Step 2: then the level of green performance was identified by dividing the realized score of each cluster by the best score. The best score of this study was −0.21. The result was multiplied by a five-point scale:

$$\text{LGP} = \left(\text{RS}/-0.21\right) \times 5,$$

where LGP is the level of green performance and *RS* the realized score.

- Step 3: the categories of effective green actions made by each effective taxon were identified. An effective action is one which is better realized by the high effectiveness of its pattern in comparison with all other effective patterns. A better realized action means a better level of relative performance.
- Step 4: the indicative models for the relationship between actions and performance indicators were developed, using the approach adopted by Migdadi (2019). The detailed procedure for this was as follows:
  - Step 4-1: identifying all the significant actions affecting the green indicator for each cluster.
  - Step 4-2: summing together all the indices of the significant actions for each cluster:

$$\text{TAI} = \sum \text{AI}_i,$$

where TAI is the total actions index and AI_i the index for each action $_i$.

  - Step 4-3: dividing the index of each action by all the indices of the actions computed in the previous step. The result was the relative impact of each action:

$$\text{RIA} = \text{AI}_i/\text{TAI},$$

where RIA is the relative index for each action; AI_i the index for each action $_i$ and TAI the total actions index.

  - Step 4-4: computing the average improvement in green performance by deducting the relative change in the green performance of the lower ranked clusters from that in the higher ranked cluster:

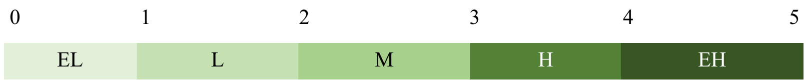
$$\text{AIGP} = \text{RCGP}_{\text{HRC}} - \text{ARCGR}_{\text{LRC}},$$

where AIGP is the average improvement in green performance; RCGP_{HRC} the relative change in green performance of higher ranked cluster and $\text{ARCGR}_{\text{LRC}}$ the average relative change in green performance of lower ranked clusters.

  - Step 4-5: multiplying the relative impact of the action by the improved performance of the cluster. The result indicated the impact of the action taken to improve the green indicator:

$$\text{IA} = \text{RIA} \times \text{AIGP},$$

where IA is the impact of action; RIA the relative index for each action and AIGP the average improvement in green performance.



Source: Migdadi (2019)

Figure 2.
Rating scale of green performance

4. Results

4.1 Taxonomies of airlines' green operations strategy

Table III shows the result of the K-means clustering analysis. It can be seen that each indicator has two ratio values, one negative and one positive. The negative value indicates a reduction, whereas the positive value indicates an increase. So a negative value for all green indicators, except recycling, indicates that something should be improved. The rate number under the ratio value of each indicator is the relative rating number in comparison with the best. The airlines were divided into four clusters: three effective clusters (C1, C3 and C4) and one ineffective cluster (C2). The effective clusters were classified as low emphasizer (C4), low-to-moderate emphasizer (C1) and high emphasizer (C3). The degree of effectiveness was identified according to the relative rating number under the ratio value.

All the indicators showed significant differences across clusters, except recycling and water consumption. The significant differences were identified by using the *F*-value; GHG1 (*F*-value = 10.288, sig. = 0.001), GHG2 (*F*-value = 4.910, sig. = 0.013), fuel consumption (*F*-value = 4.625, sig = 0.016), energy consumption (*F*-value = 4.736, sig. = 0.014) and waste reduction (*F*-value = 12.177, sig. = 0.000). With respect to GHG1, two clusters (C3 and C4) showed improvement in comparison with other clusters; C3 realized −0.21 (5: H), whereas C4 realized −0.04 (1: EL). With respect to GHG2, two clusters (C1 and C4) showed significant differences in comparison with other clusters; C1 realized −0.13 (3.1: M) and C4 realized −0.05 (1.19: EL). With respect to fuel, two clusters (C1 and C3) showed significant differences in comparison with other clusters; C3 realized −0.18 (4.29: H), whereas C1 realized −0.01 (0.23: EL). With respect to energy consumption, two clusters (C1 and C4) showed significant differences in comparison with other clusters; C1 realized −0.07 (1.7: L), whereas C4 realized −0.10 (2.4: L). With respect to waste generated, one cluster (C1) showed significant differences in comparison with other clusters; C1 realized −0.12 (2.86: M).

Table IV shows the taxonomies of green operations strategy across regions. It can be seen that a misleading strategic pattern was adopted by all regions, the low emphasizer strategic pattern was adopted by two airlines, one in Asia and the other in Europe. The low-to-moderate emphasizer strategic pattern was adopted by six airlines, two in Asia, two

	Green strategy patterns					
Green indicators	C1 Low to moderate emphasizer GHG2-Fuel-Energy-Waste strategy $n = 6$	C2 Misleading strategy $n = 13$	C3 High emphasizer GHG1-Fuel strategy $n = 2$	C4 Low emphasizer GHG1-GHG2-Energy strategy $n = 2$	*F*-value	Sig.
GHG1 emissions	+0.01	+0.07	−0.21 5: EH	−0.04 1: EL	10.228**	0.001
GHG2 emissions	−0.13 3.1: M	+0.04	+0.13	−0.05** 1.19:EL	4.910*	0.013
Fuel consumption	−0.01 0.23:EL	+0.08	−0.18 4.29:H	+0.05	4.625*	0.016
Energy consumption	−0.07 1.7:L	+0.01	+0.15	−0.10 2.4:L	4.736*	0.014
Waste generated	−0.12 2.86:M	0.00	0.00	+0.49	12.177**	0.000
Recycling	+0.04	+0.03	0.00	+0.09	0.228	0.876
Water consumption	−0.01	+0.02	−0.10	−0.04	0.969	0.432

Notes: C1, Cluster 1; C2, Cluster 2; C3, Cluster3; C4, Cluster4; EL, extremely low effective; L, low effective; M, moderately effective; H, highly effective; EH, extremely highly effective; grey value shows the improved performance indicator. $^{*}p \leqslant 0.05$; $^{**}p \leqslant 0.01$

Table III.
K-means clustering analysis result

in Europe and two in North America. Also, one airline in Europe and another in the Middle East adopted the high emphasizer strategic pattern.

Asian region airlines adopted three strategic patterns: the low-to-moderate emphasizer (two airlines), the misleading strategic pattern (four airlines) and the low emphasizer (one airline). European airlines adopted all the strategic patterns: low-to-moderate emphasizer (two airlines), misleading strategic pattern (two airlines), high emphasizer (one airline) and low emphasizer (one airline). The Middle Eastern airlines adopted two strategic patterns: the misleading strategic pattern (two airlines) and the high emphasizer (one airline). The North American airlines adopted two strategic patterns: the low-to-moderate emphasizer pattern (two airlines) and the misleading pattern (four airlines). The South American airlines adopted the misleading strategic pattern (one airline).

The European and Asian Airlines were the most diverse in the effective strategic pattern that they adopted in comparison with the remaining regions. The European airlines adopted three effective patterns, the Asian airlines adopted two patterns and the Middle Eastern and North American airlines adopted one effective strategic pattern. However, the South American airlines did not adopt any effective strategic patterns at all.

4.2 The significant operational actions taken by the effective green strategic patterns

Table V shows the significant operational actions taken by the effective green strategic patterns. It can be seen that the significant actions to reduce GHG1 emissions and fuel consumptions were taken using all the green strategic patterns. The airlines that engaged low-to-moderate emphasizers (C1) were significantly better in their fuel management than the airlines that used a misleading pattern. (C2) However, the airlines that deployed high emphasizers (C3) were better than all the users of green strategic patterns in their aircraft design and their fuel management. The airlines that used low emphasizers (C4) were better than those that used a misleading strategic pattern (C2) in route management, flight operations and maintenance management. Fuel management action was the only significant action shared between green strategic patterns.

The significant actions to reduce GHG2 emissions and energy consumptions were taken by two strategic patterns: the low-to-moderate emphasizing strategic pattern (C1) and the low emphasizing strategic pattern (C4). The airlines following the low-to-moderate emphasizer strategic pattern (C1) were significantly better than all the airlines that followed other strategic patterns at adopting Leadership in Energy and Environmental Design (LEED) standards, engine design and engine operations. However, the airlines following the low emphasizer strategic pattern (C4) were better at energy-saving actions, using sustainable energy and upgrading facilities actions, than either those using misleading patterns (C2) or the high emphasizers' strategic group (C3). Significant actions to reduce wastes were taken by those who followed the low-to-moderate emphasizers' strategic pattern (C1); this strategic group was better at onboard and ground recycling, upcycling and reusing than all those using strategic patterns.

	Green strategy patterns			
Regions	C1 Low-to-moderate emphasizer GHG2-Fuel-Energy-Waste strategy $n=6$	C2 Misleading strategy $n=13$	C3 High emphasizer GHG1-Fuel strategy $n=2$	C4 Low emphasizer GHG1-GHG2-Energy strategy $n=2$
Asia	2	4	0	1
Europe	2	2	1	1
Middle East	0	2	1	0
North America	2	4	0	0
South America	0	1	0	0

Table IV. The taxonomies of green operations strategy across regions

Table V.
The green operational actions taken by the effective green strategic patterns

Effective cluster	Better than	GHG1 emissions and fuel consumption actions	
C1	C2	Fuel management	1.67 (L)
C3	C1, C2, C4	Aircraft design	3.75 (H)
		Fuel management	5.0 (EH)
C4	C2	Route management	4.19 (H)
		Operations of flights	3.94 (H)
		Maintenance management	2.5 (M)
Effective cluster	Better than	GHG2 emissions and energy-saving action	
C1	C2, C3, C4	LEED	1.67 (L)
		Engine design	1.67 (L)
		Operations of Engine	2.73 (M)
C4	C2, C3	Energy-saving facilities	2.5 (M)
		Using sustainable energy	2.5 (M)
		Upgrading facilities	2.5 (M)
Effective cluster	Better than	Waste management actions	
C1	C2, C3, C4	Onboard and ground recycling	2.67 (M)
		Onboard and ground upcycling	1.25 (L)
		Onboard and ground reusing	1.24 (L)

Notes: L, low effective; M, moderately effective; H, highly effective. Sig. actions are the actions best taken (higher ranked according to five-point scale) by the effective cluster in comparison with lower performance clusters. For better insight into the indices and ranks of the actions, please see Tables AI–AIV

Out of five, three actions related to GHG1 emissions and fuel consumption actions were highly realized, one action was extremely highly realized, one action was moderately realized and one was low realized. The extremely highly realized action was the fuel management by high emphasizer strategic pattern (C3), whereas the highly realized actions were aircraft design by low-to-moderate emphasizer strategic pattern (C1), route management and operations of flight by low emphasizer strategic pattern (C4). The moderately realized action was maintenance management by low emphasizer strategic group (C4), and the low realized one was fuel management by low-to-moderate emphasizer strategic group (C1). Hence, it appears that a combination of design and operating actions was chosen.

Most of the GHG2 emissions and energy consumption actions were moderately realized. The moderately realized actions were engine operations, energy-saving facilities, the use of sustainable energy and the upgrading of facilities. The low realized actions were the adoption of LEED standards and engine design. Most of the waste management actions were low realized. The low realized actions were upcycling and reusing both onboard and on the ground, whereas the moderately realized action was onboard and ground recycling.

4.3 The indicative models for the relationship between green actions and green indicators

Figure 3 shows the indicative model for the relationship between airlines' actions and the green indicators of a low emphasizer strategic pattern. It can be seen that three actions reduced GHG 1 emissions, namely route management (−3.2 percent), operating flight management (−3 percent) and maintenance management (−1.9 percent). Also, three actions, namely energy saving, using sustainable energy and upgrading facilities, saved energy by −4.3 percent and reduced GHG 2 emissions directly by −4.3 percent; they also reduced GHG 2 emissions indirectly through saving energy by −0.6 percent.

Figure 4 shows the indicative model for the relationship between actions and the green indicators of a low-to-moderate emphasizer strategic pattern. It can be seen that the impact of fuel management on reducing GHG 1 emissions was −10 percent. Energy was saved by three actions, namely good engine design (−4.1 percent), engine operation (−6.7 percent) and adopting LEED standards (−4.1 percent). The impact of these actions in reducing GHG 2 emissions

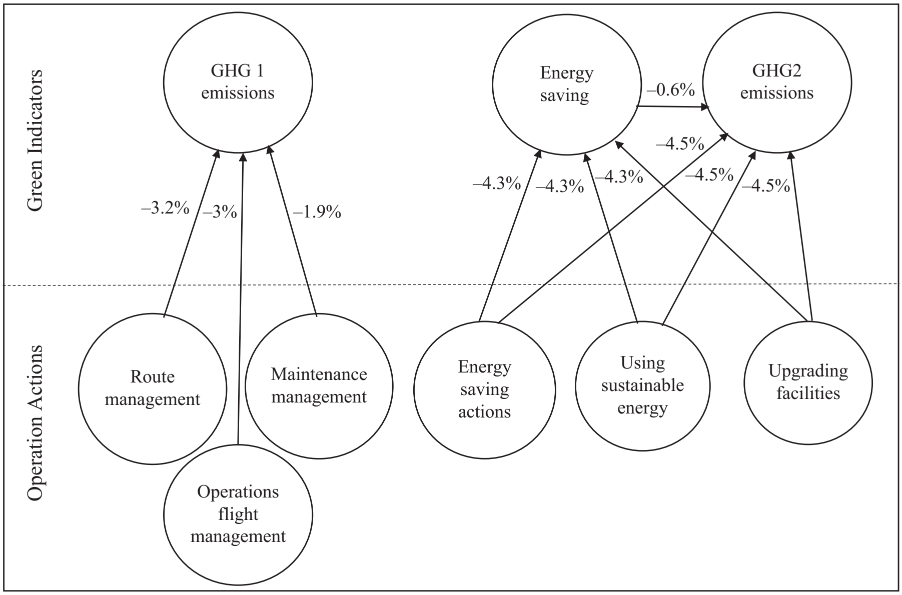


Figure 3. Indicative models of the low emphasizer strategic pattern

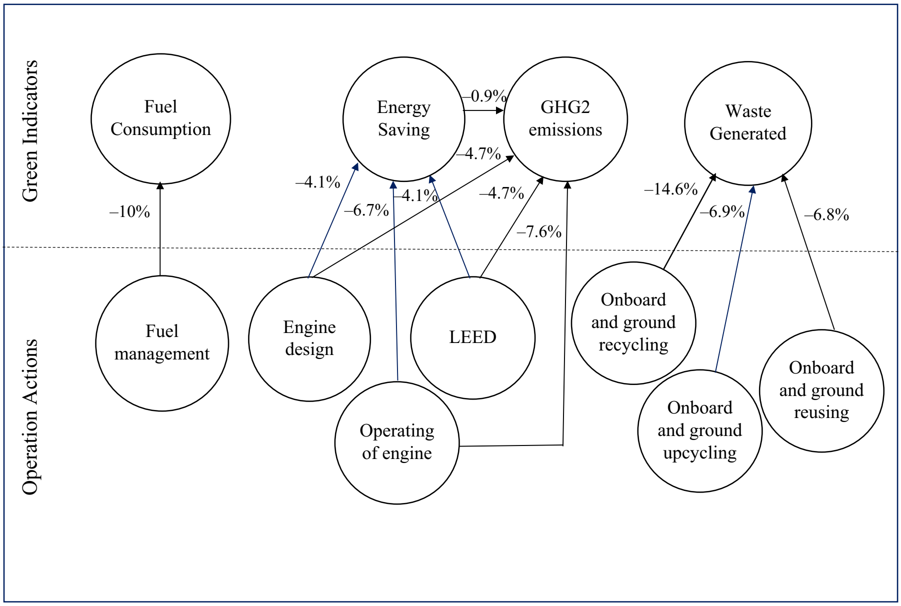


Figure 4. Indicative model of the low-to-moderate emphasizer strategic pattern

was –4.7 percent for engine design, –7.6 percent for engine operation and –4.7 percent for adopting LEED standards. However, the indirect impact of these three actions in reducing GHG 2 emissions through saving energy was –0.9 percent. Wastes were reduced by three actions, namely onboard and ground wastes recycling (–14.6 percent), onboard and ground wastes upcycling (–6.9 percent) and onboard and ground wastes reusing (–6.8 percent).

Figure 5 shows the indicative model for the relationship between actions and the green indicators of a high emphasizer strategic pattern. It can be seen that two actions reduced fuel consumption, namely good aircraft design (−17.9 percent) and fuel management actions (−13.4 percent). The impact of the two actions on reducing GHG 1 emissions was −9.6 percent for aircraft design and −12.8 percent for fuel management actions. However, the indirect impact of these two actions in reducing GHG 1 emissions through fuel energy was −3.6 percent.

5. Discussion

The number of clusters developed by this study was four, the number of clusters reported by previous studies, such as Migdadi (2016) and Migdadi and Elzzqaibeh (2018), was three and the number of clusters reported by Migdadi and Omari (2019) was five. In this study, three clusters reported were effective and one was ineffective; this is consistent with the findings of Migdadi and Elzzqaibeh (2018). The largest group of airlines adopted an ineffective strategic pattern (13 out of 23, about 57 percent of the airlines investigated). This may be justified in the context of the increasing demand to travel by air, suggesting that the environmental impact will also increase over time (Lee *et al.*, 2009). Nevertheless, the misleading green operations strategies of airlines could be affected by other non-technical aspects of green human resources systems, such as eco-focused training, eco-aware performance assessment and rewards, or by green human resources organizational enablers, such as ecological organizational culture, green teams and eco-focused employee empowerment (Jabbour *et al.*, 2019). The willingness of employees to participate in environmental initiatives is encouraged by assessing their green performance, providing environmental feedback, embedding environmental goals and responsibilities and providing environmental training (Pham *et al.*, 2019).

The sustainable performance of organizations can be affected by the internal organizational commitment to green practices and the commitment of external partners (Singh and El-Kassar, 2019). Moreover, organizations nowadays face the challenge of huge amounts of data related to organizational practices such as sustainable green practices. As a result, they adopt more advanced technologies, which help managers to analyze a large

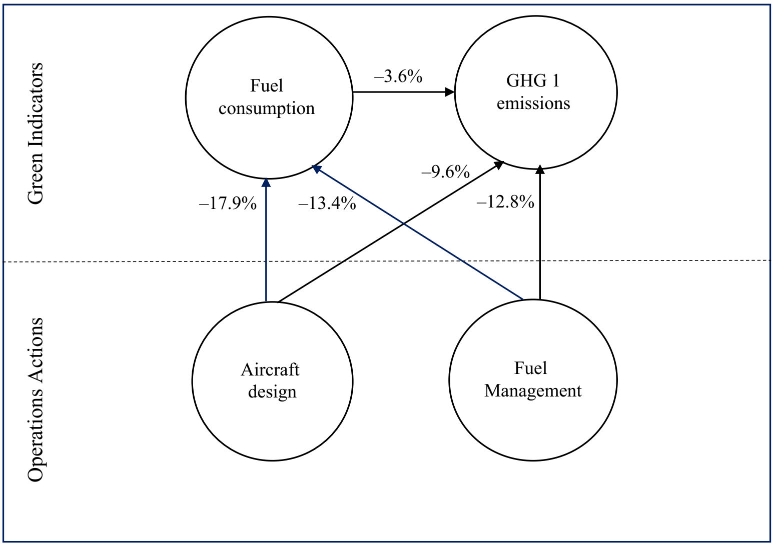


Figure 5.
Indicative model of the high emphasizer strategic pattern

amount of data so as to learn more about green factors and take more effective green actions (El-Kassar and Singh, 2018; Singh and El-Kassar, 2019).

The reported effective green strategic patterns adopted by airlines were low emphasizers, low-to-moderate emphasizers and high emphasizers. This indicates that no single strategy or approach to alleviate ecological damage can be implemented by all (Teoh and Khoo, 2016). Despite the various combinations of effective indicators adopted by each taxon, GHG1 and GHG2 emissions are the most widely shared indicators. The highly effective pattern indicates concern about GHG1 emissions and fuel saving; this could be affected by the target set for airlines by 2050, to halve their 2005 total CO_2 emissions (Brooks *et al.*, 2016). The low-to-moderate performance pattern was more often adopted by airlines than other effective patterns. This reflects the normality of adopting effective patterns; since the low and high are extremes, it is logical that only limited numbers of airlines are in these two categories.

The effective clusters that were very often adopted were clusters of GHG1 and fuel consumption actions. However, other categories of action, such as GHG2 and energy saving, were moderately often adopted, whereas waste management actions were rarely adopted. This indicates that staff members are more concerned to reduce GHG emissions at the global level because of the 2050 target for airlines mentioned above. Nevertheless, according to Blanca-Alcubilla *et al.* (2018), as a result of inappropriate facilities and restrictive regulations, a number of factors have discouraged airlines and other actors from proactively looking for solutions such as low landfill disposal rates (particularly for inorganic wastes) (Blanca-Alcubilla *et al.*, 2018).

Aircraft design action is very often adopted to reduce GHG1 emissions and fuel consumption; previous studies confirm that the use of newer generations of long-haul wide body jets, such as the A380, A350XWB and Boeing 787 and 747-8, helps achieving lower CO_2 emissions (Szodruch *et al.*, 2011). Moreover, adopting the technological innovation of open rotor technology for aircraft engines has the potential to cut carbon dioxide emissions from commercial airlines by 100m tons per year (Smith, 2016). The route management action is very often adopted, since this action is one of the most important factors in reducing carbon emissions (Liu *et al.*, 2017). Flight operational action to reduce GHG1 emissions is often adopted by the effective clusters, since such operating actions as altitude restriction on commercial aircraft may also be an effective way to reduce the environmental impact in the form of CO_2 emissions (Williams *et al.*, 2002). Movements (the number of takeoffs and landings) and the rate of use of each aircraft (productive flight time per aircraft per airline) also have a significant impact on reducing CO_2 emissions (Liu *et al.*, 2017).

The effective waste management actions taken were more often related to onboard and ground waste management. The amount of onboard and ground wastes is excessive; passengers generated 5.2m tons of wastes in 2016, and the figure is set to double over the next 15 years (IATA, 2016). Accordingly, airlines should take more actions to reduce onboard and ground wastes.

European airlines more often adopted their effective patterns in respect of the number of airlines and the diversity of the patterns that they adopted. Out of six, five airlines in Europe adopted three effective patterns in all. In Asia, two patterns were adopted and three airlines out of seven adopted effective patterns. In North America, one pattern was adopted and two out of six airlines adopted an effective pattern. This indicates the European airlines' concern about environmental issues, since they are affected by the European Commission's commitment to reduce environmental damage, and the European commission has published green indicators and reports on compliance. Other regions such as North America share Europe's concern, but this region faces more demand and more traffic in other regions, which could result in a greater environmental impact.

Adopting combinations of facilities and engine actions had more impact on GHG2 emissions. The sources of GHG2 emissions are both facilities/buildings and engines/vehicles, so greater adoption of diverse actions by facilities and engines will result in greater reductions in GHG2 emissions. Fuel saving and reducing GHG1 emissions were more affected by the technology-oriented actions adopted by the high performance strategic pattern. This result is inconsistent with the results of previous studies, which show more impact from process-oriented actions (e.g. Yan *et al.*, 2016; Migdadi, 2018). Technology-oriented actions related to the renewal of aircraft fleets or changes in the design of wings, etc., are more affected since the major source of GHG1 emissions is flight operations.

6. Implications, limitations and future research

This study recommends certain combinations of effective actions that managers could take to ensure better green performance by airlines. It recommends focusing on aircraft design, fuel management and the management of flight routes, maintenance and operational flights in order to reduce GHG1 emissions and fuel consumption effectively. It is also recommended to focus on engine design, the operation of engines, the adoption of LEED standards, the upgrading of facilities, the use of sustainable energy and the adoption of energy-saving actions in order to effectively reduce of GHG2 emissions and energy consumption. Moreover, this study recommended focusing on waste management, the recycling, upcycling and reuse of onboard and ground wastes to effectively reduce the amount of wastes.

This study developed pictorial representations of effective strategic patterns, which could be used as conceptual frameworks to be tested in future studies, while the results of this study could be a source of propositions for future studies. Moreover, it is a further source of academic data about effective green operational strategies, which could be used for training staff in green operational practices. The management of airlines in each region could use its insight into the position of each region in comparison with others and into the effective patterns adopted, which they could use in their own work. However, it should be acknowledged that the sample of this study is limited (23 cases), so it would be useful if future researchers could investigate a more extended sample with a view to more generalized results. The reasons behind the misleading pattern of green strategies adopted by airlines require more in-depth analysis by future researchers. Future studies could also examine the impact of the practice of green human resources on effective green operations strategy.

7. Conclusions

The research on green taxonomies of operational strategy is still in its infancy – the contributions available deal with the taxonomies of green manufacturing strategies, while the studies of airlines' green practices have investigated particular practices in the context of a single country. Hence, this study has helped to fill the gap by investigating the taxonomies of green operations strategies by airlines in several regions. The study revealed that most airlines have adopted misleading strategic patterns and that the effective strategic patterns are divided into three categories: low emphasizer, low-to-moderate emphasizer and high emphasizer patterns. The adoption of these patterns differs across regions, European airlines adopted more categories of patterns. The more an airline adopts diverse GHG2 and energy-saving actions, the more GHG2 emissions are reduced; and the more an airline adopts technology-oriented actions, the more GHG1 emissions are reduced and the more fuel is saved.

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Appendix 1

Table AI. GHG1 and fuel consumption actions' rating scores for each cluster Energy saving

	Aircraft design	Route management	Operations	Weight management	Fuel management	Maintenance
C1	2.5 (M)	0.54	1.7	0.59	1.7 (L)	0.83
C2	2.25	2.5	1.28	1.23	1	1.25
C3	3.75 (H) better than all clusters	0.81	1.76	1	5 (EH) better than all clusters	0
C4	2.5	4.19 (H) better than C2	3.94 (H) better than C2	0.77 (L)	0	2.5 (M) better than C2

Note: Grey highlighted significant action (the cluster realized better actions rating score than lower performed clusters)

Appendix 2

Table AII. GHG2 and energy consumption actions' rating scores for each cluster

	Energy saving facilities	LEED	Using sustainable energy	Upgrading facilities	Engine and vehicle design	Operations of engines and vehicles	Engine and vehicle maintenance	Transportation management
C1	1.654229	1.666667 better than all clusters	1.666667	0.555556	1.666667 better than all clusters	2.727273 better than all clusters	0	0
C2	0.5	0.5	0.5	0.5	1	0	0	0.5
C3	0	0	0	0	0	0	0	0
C4	2.5 better than 2 and 3	0	2.5 better than 2 and 3	2.5 better than 2 and 3	0	0	0	0

Note: Grey highlighted significant action (the cluster realized better actions rating score than lower performed clusters)

Appendix 3

Table AIII. Waste and recycling management actions' rating scores for each cluster

	Onboard and ground wastes recycling	Onboard and ground wastes upcycling	Onboard and ground wastes reusing	Industrial wastes recycling	Industrial wastes upcycling	Industrial wastes reusing	Hazard wastes recycling	Hazard wasted upcycling	Hazard wasted reusing
C1	2.666667 better than all clusters	1.25 better than all clusters	1.243781 better than all clusters	0.833333	0.833333	0.429293	0	0	0
C2	1.571429	0.75	0	0.5	0.5	0.757576	0.5	0.5	0.5
C3	1.428571	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0	0	0

Note: Grey highlighted significant action (the cluster realized better actions rating score than lower performed clusters)

Appendix 4

Table AIV. Water management actions' rating scores for each cluster

	Maintenance water recycling	Maintenance water saving	Facilities water saving
C1	0.416667	0.833333	0
C2	0	0	0
C3	0	0	0
C4	2.5	0	2.5

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