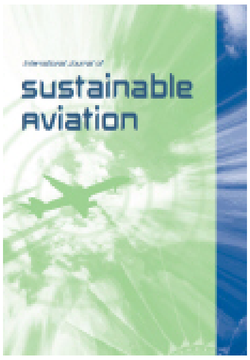

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International Aviation Smart City Alliance as a global strategy for carbon emissions reduction

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Abstract: Climate concerns have been on the global agenda for many years now. With the impact of the aviation sector receiving higher visibility, carbon offsetting and reduction in the international civil aviation sector was introduced by the International Civil Aviation Organization. Their proposed scheme was received with mixed reactions. In this study, we identify issues for carbon emissions reduction in the international aviation sector via a critical analysis of the literature. Results show that meeting carbon emission reduction obligations require some form of social innovation whereby existing structures can be leveraged to meet climate goals. We, therefore, introduce the Carbon Neutral Cities Alliance and adapt it to the international aviation context to illustrate how smart cities have the potential to help and support the international aviation industry meet their carbon emissions reduction obligations.

Keywords: airlines; carbon emissions; smart cities; climate change; carbon offsetting scheme; sustainable aviation; greenhouse gases; GHG.

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1 Introduction

Ever since the eighties, climate change initiatives including the 1987 Montreal Protocol, the 1992 United Nations (UN) framework convention – United Nations Framework on Climate Change (UNFCC), the 2005 Kyoto Protocol, the 2015 Paris Agreement, and the 2015 United Nations Sustainable Development Goals, have considered the various greenhouse gases (GHG) emissions (Carpanelli, 2018) to increase awareness and action towards climate change. As a result, dialogue on climate change has seen an exponential increase in all media outlets around the world, becoming the cause of significant global climate-related activities that many have found to be controversial. Dissatisfaction with the climate action initiatives continues to be echoed by environmental groups as they blame governments for real action and climate change agreement's limitations, leading to the current global environmental crises of ever-increasing heat waves, droughts, hurricanes, floods, sea-level rise, and loss of species (Gössling et al., 2007; Jaśkowski, 2021; Mai, 2021; Sharma et al., 2021; Liao et al., 2022).

As a result, the International Civil Aviation Organization (ICAO), after the 1997 Kyoto protocol, and due to its responsibility regarding international civil aviation, began working on the development of civil aviation carbon emission reduction policy measures, to reduce the sector's contribution to GHG emissions into the atmosphere. Eventually, in 2016 at the A39-3 ICAO assembly, a scheme to mitigate the emissions of carbon was proposed, accepted, and adopted. Meanwhile in 2012, as part of its initiative to mitigate emissions from air transportation, the European Union (EU) launched its emissions trading scheme (ETS) (Scheelhaase et al., 2018).

Briefly, an implementation of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) was set up in three phases with the goal of gradually leading member states' participation (Lyle, 2018; Carpanelli, 2018; Maertens et al., 2020). Some states may be given exemption namely: countries whose land is closed, least developed states, developing island states that are considered small, and countries whose share of global air traffic is less than 0.5%. In general, laws and regulations of a state are applied to an aircraft (from any origin) without distinction as to its nationality. The need for ICAO's involvement is primarily due to international aviation flying through airspace which does not belong to any state and regulatory framework, and therefore, only ICAO has the mandate to establish relevant regulations in those high seas areas (Lyle, 2018).

Prior to CORSIA, the EU developed and implemented a market-based approach to mitigate CO_2 emissions associated with aviation activity. In line with the 2015 Paris Agreement regarding the 2°C target, Lyle (2018) elaborated on the expected effect of EU-ETS and CORSIA on aviation carbon emissions reductions until 2030. What primarily CORSIA means for these offsetting market schemes, is that airlines would buy emission reductions that have been realised in other projects to offset their own exceeded emission levels.

With the recent introduction of CORSIA, it is expected that over the next few years it would evolve to integrate with existing systems, while at the same time other similar initiatives and the aviation sector as a whole would change to adapt to its requirements. For example, CORSIA is launched at a time when every country has some form of emission reduction policy that could conceivably extend to international aviation. Moreover, there are concerns about how COVID-19 will affect CORSIA's implementation (Liao et al., 2022; Peeters and Eijgelaar, 2022). As such, today, the existing national emission reduction schemes for aviation is not clear on how it will (and if it can) continue with CORSIA in place. Literature contains many conflicting analyses and raises many questions and challenges that member states are faced with regarding CORSIA's implementation. There are few scientific studies that address those issues (Lyle, 2018; Maertens et al., 2020; Scheelhaase et al., 2018; Prussi et al., 2021; Sharma et al., 2021; Zhang et al., 2021; Mai, 2021; Pérez-Morón and Marrugo-Salas, 2021; Jaśkowski, 2021; Khalifa et al., 2022; Ren, 2022), and a number of grey literatures that discuss those challenges and knowledge gaps. However, no analysis has been found to critically assess CORSIA's scheme (most are descriptive or highly focused legal issues, while few are dispersed and specific on relevant areas such as alternative fuels or air passenger behaviour), and provide innovative solutions to help facilitate and support CORSIA's implementation.

An overview of the body of literature published in scientific journals, in relation to carbon emissions reduction in the aviation sector, reveal that research studies, in general, are few and dispersed across a limited scope of subject matters. Relevant to the current article we found five CORSIA-related studies focusing on legal issues, and another five following a descriptive approach. The rest of the subjects, such as innovation in technology, sustainable alternative fuels (SAF), carbon offsetting, market-based measures, GHGs, operational efficiencies, air passengers' willingness to contribute to carbon offsetting, and carbon neutral growth, entailed one or two publications in each area and were dispersed over a range of journals. Moreover, from a timeline perspective for CORSIA-related publications, one was found from 2015, three from 2018, one in 2019, six in 2021 and two in 2022. Considering the significance of international aviation carbon emissions on climate change and the importance and impact of CORSIA, the body of literature is small and research gaps are evident. Yet, there is no direction or indications for research in international aviation carbon emissions reduction, and since CORSIA is the driving force in this initiative impacting (and disrupting) all stakeholders in the aviation sector, it is essential to draw insights from its design and aggregate the analyses findings from the research community.

The literature review process revealed an important aspect of research that has not been addressed or linked to CORSIA, and entails studies related to carbon emissions reduction (Şöhret et al., 2019; Balli et al., 2021a, 2021b), but have not been put into a regulatory perspective. In the same vein, related research on tourism (Florido-Benítez, 2021, 2022a) that studies the influence of COVID-19 on air transport is not put into perspective with CORSIA's impacts on low-cost carriers. These research opportunities have the potential to provide innovative solutions to meeting carbon neutral goals, the UN sustainability development goals (SDG), and the successful implementation of CORSIA's scheme. Another important research aspect that has not been addressed by CORSIA related research entails its impact on passengers (who may arguably be considered as a very important stakeholder to the regulatory process). Such impact extends to destination marketing and management (Domínguez-CC et al., 2021; Debbage and Debbage, 2019; Florido-Benítez, 2022b; Sorokina et al., 2022) who are affected by regulations, and in turn highly influence CORSIA's successful implementation.

In general, the major research gap entails studies that link policies and regulations such as CORSIA, to other areas of study such as GHG emissions, landing and take-off cycle, organisational behaviour and change management, climate change, and technological drivers and direction. More specifically the study of sustainable development problem faced by the air transport industry is not addressed.

Although, publications that provide solutions are scarce, Ekici et al. (2022) offer potential solutions for effective policy responses by identifying positive and negative production/consumption and similar externalities. Central to the theme herein, and potential solution proposed as a response to support CORSIA implementation, our view that vital economic and social benefits of aviation environmental issues should be harmonised and distributed fairly, is shared.

Based on the above, our study is motivated by the absence of scientific studies in the following areas: direction in relation to the impacts of aviation carbon emissions reduction regulations, missing linkages between technological, social, environmental, and operational innovations and regulatory framework, and issues specific to the design of CORSIA. To that effect, the purpose of this study entails two objectives:

1 assess ICAO's carbon emissions reduction scheme by identifying critical factors for its successful implementation, as extracted from published studies

2 elaborate on a solution leveraging the Carbon Neutral Cities Alliance (CNCA), to illustrate its facilitation potential in supporting CORSIA's implementation.

In order to meet these two objectives, our goals are to critically analyse the body of literature and identify and elaborate on the factors for Carbon Emissions Reduction in international aviation by consolidating all reported issues (in scientific journals) related to ICAO's nature and strategy, carbon offsetting scheme, GHGs, and the environment, alternative fuels, and economic influences, into three categories, namely regulatory, climate action, and economic influences, and consequently, illustrate how these issues can be undertaken by a smart city alliance initiative to help in the realisation of CORSIA's implementation goals.

2 Background

We review the literature in this section to provide a contextual background to our study, and therefore summarise the state of the body of knowledge regarding aviation climate impact and review CORSIA.

2.1 Aviation climate impact

The state-of-the-art in relation to research works on the negative effects of the transport sector on the environment is abundant. Gössling et al. (2007) addressed the issues of mobility trends and sustainability in the transport sector, showing that not only the existence of a gap between them but that this gap persists. Moreover, he demonstrated that the aviation sector is relatively the largest contributor to GHG's emissions growth in the transportation sector.

They estimated that aviation accounts for an average of 5.1% of all emissions of GHG and acknowledge that this estimate is debatable. Gössling and Peeters (2007) estimated that total aviation emissions of CO_2 attributed to tourism are in the order of 3.4%. The significance of air travel to transport emissions is made more critical for climate change by the following:

1 As per WTO (2005) estimation, less than 2% of the world population, at that time, travelled internationally. Gössling et al. (2007) estimated this value by considering WTO reporting for the year 2000, 291.2 million international tourist arrivals, and a 6.135 billion global population. Based on the latter, it was estimated that every tourist made 2.5% 'international journeys'.

   Following that same logic using WTO's (2020) report, they calculated that there were 1.5 billion international tourist arrivals in 2019. With a world population of 7.594 billion (for 2018), we calculate 7.9% of the world population had travelled internationally. This is a 3-times fold increase from 2005 to 2018, with *an annual average growth of 21% in international travel*.

2 Aircraft engine emissions have a more significant impact on the environment since they are released in the lower stratosphere and the upper troposphere. These emissions from aircraft engines influence GHG which include carbon dioxide (CO_2), aerosols (sulphates and soot), nitrogen oxides (NO_x), sulphur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO), heat, soot, and other atmospheric particulate matter (APM – incompletely burned hydrocarbons, sulphur oxides, and black carbon) (WTO, 2020), which have global warming effects on the formation of the ozone layer and clouds (radiative forcing), and the depletion of methane. Emissions of water vapour and aerosols are responsible for the formation of contrails, emitted during the aircraft cruising stage.

   Gössling et al. (2007) discussed *how emissions from air travel can be up to 5 times more harmful than ground transport*, and the UASA (2005) report, shows that CO_2 contributes the most of harmful gases. (Cokorilo and Tomic, 2019) illustrate in detail the emissions from a typical two-engine jet aircraft during a one-hour flight with 150 passengers on board.

3 Efficiencies gained from innovations and improvements in the burning of fuel have been advancing at a relatively slow pace, and their impacts are small relative to the rate of growth in the air transport industry. In other words, progress in aviation innovation is relatively slow when compared to advances the sector. Peeters et al. (2005) estimated that in 2040, the most efficient aircraft, in the best-case scenario, may consume 35% less fuel. This implies an average of 1.75% fewer emissions per year, which compared to the expected 5% (on average) of increase in travel demand, leaves a gap of 3.25%. In other words, the aviation sector must do much better to be carbon neutral. With the significant increase in air travel, up to 2019, it has been estimated that the demand for aircraft fuel will surpass 1.9% each year and without mitigation innovations, the global carbon emission from aviation can be anywhere from 3 to 7 times more by 2050 (WEF, 2019).

4 The climate crisis has been finally accepted by the world, as we can observe from the United Nations Climate Change Conference in UK 2021 (COP26). It seems that for the first time there is a sense of urgency to establish even more ambitious goals for carbon emissions. Never more so today, the need for aviation innovation to not only reduces carbon emissions but to eliminate its GHG emissions, is existential. The aviation industry heavily relies on fossil fuels, and as we shall see later in this article, achieving half of 2005 carbon emissions by 2050 is not only a challenge larger than has been planned for (Baumeister et al., 2020) but may as well be too little, too late. In their article, Baumeister et al. (2020) provide an interesting study on emissions reduction potentials of first-generation electric aircrafts. Total commitment and increased investments is such innovations which even impact aircraft engine designs are necessary, if the aviation sector is to make a meaningful contribution to climate change. Electric aircrafts have the potential to reduce GHG emissions to zero in the long run (Baumeister et al., 2020).

There are many ways that aviation carbon emissions can be mitigated through innovations (including technological advancements). Currently, the aviation sector has built strong technological momentum for continuously increasing fuel efficiency, via better engines, aerodynamics, and advances in materials. For illustrative purposes, we briefly mention the top five advances that increase fuel efficiencies (Koppula, 2018):

- winglets to improve wing aerodynamics by 15%, and cut emissions by 6%
- flexible real-time navigation system to avoid weather conditions that can save up to 1.4 tons of CO_2 per flight (Enge et al., 2015)
- pilots following the continuous climb and descent as a strategy capitalising on decrease fuel burn, lower gas and noise emissions, and less fuel cost (Toratani, 2016)
- NASA's double-bubble D8 new aircraft design that promises 37% less fuel consumption, 50% reduced noise and 87%, and 87% less NO_x during landing and take-off
- blended wing body with a hybrid wing shape reducing fuel consumption, weight and thrust required, by 27%, 15%, and 27%, respectively.

Despite agreement on the 2.5% contribution of total CO_2 emission by the aviation industry, its impact is more significant compared to ground-level emissions because the emissions are at high altitude (Brueckner and Abreu, 2017). In 2016, ICAO proposed an explicit fuel efficiency standard for new aircrafts taking effect in 2028 (Mouawad and Davenport, 2016) and followed it with a carbon-offset initiative – CORSIA. Due to the very important role that CORSIA plays in climate change as impacted by the international civil aviation sector, we provide an analysis of CORSIA and its challenges in the following sections.

2.2 CORSIA's framework

CORSIA's framework provides support and guidance to the stakeholders of the international civil aviation sector, in order for them to align with global carbon-neutral growth initiatives. CORSIA's regulations took effect starting in 2020. Based on the carbon offsetting scheme, members of CORSIA (such as airlines), will have to adopt mechanisms to offset the growth in their CO_2 emissions. These mechanisms include the following:

1 airlines can obtain tradable CO_2 compliance certificates via the purchase of carbon credits

2 invest in the environmental type of projects, occurring anywhere in the world, which demonstrates a reduction of carbon in the environment, and then translate the reduced carbon into a certificate that they can trade for compliance of CO_2 emissions.

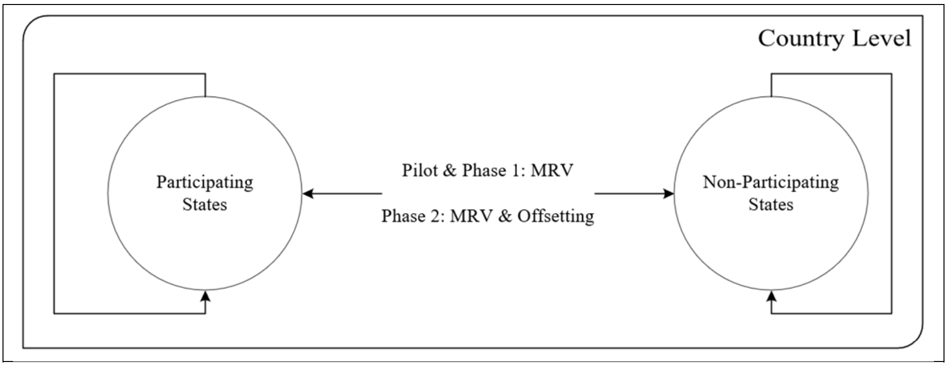
The latter carbon offsetting scheme requires the services of a third party (namely the project occurring anywhere in the world) instead of targeting carbon emissions reduction at the source.

As a result of the air transportation conditions caused by COVID-19, the CORSIA market-based measures (MBM) whose baseline was established on 2020 emissions, were modified to reflect the 2019 emissions levels. A time-varying formula to calculate the amount of offset that each airline would have to purchase is provided by CORSIA. Based on the newly established carbon emissions baseline of 2019, 21.6% of carbon offsetting is expected, for the CORSIA-identified phases between 2021–2035.

Furthermore, in 2020, ICAO approved eligible emissions unit programs that air carriers can use for their offsetting obligations. Fourteen applicants met CORSIA's Emission Unit Criteria (EUC) as approved by the Technical Advisory Board (TAB). Figure 1 presents the schema of how CORSIA works, showing its scope. Offsetting implementation is established across three time periods namely 2021-2023, 2024-2026, and 2027–2035, identified as the pilot phase, phase 1, and phase 2, respectively. The year 2027 makes the point at which all states' participation is mandatory. However, CORSIA did establish criteria for exemptions. In 2021, around 80% of member states declared their voluntary participation. The largest countries that have not volunteered to participate include the BRIC states: Brazil, Russia, India, and China.

Challenges related to the implementation of CORSIA have been reported in both scientific journal articles and grey literature. For example, CORSIA's design does not address issues such as 'double counting' (Schneider et al., 2015), where emission reductions are used by both the country and the airlines. Moreover, emissions unit criteria (EUC) are a good start to assess offset programs, yet it is not clear how it is done, nor has it been assessed for its effectiveness and robustness, especially when all council meetings that make those decisions are closed. From an economic perspective, offsetting requirements will depend only on the served routes and not on the carrier's place of registration. This may lead to competitive distortion between routes and destinations as CORSIA and non-CORSIA-routes can be in competition (Carpanelli, 2018).

Figure 1 CORSIA design and scope, at the country level (see online version for colours)



3 Methodology

The research methodology in this study consists of two primary components:

1. via a critical examination of relevant literature, identify the factors related to the challenges facing the implementation of carbon emission reduction in the international aviation sector
2. illustrate how the smart city alliance concept can address those factors and help support the international aviation sector meet its carbon emission reduction obligations.

The approach applied in our literature review to critically analyse and determine the issues and challenges in international aviation carbon emissions, can be viewed as a qualitative descriptive exploratory study. This approach builds on the interpretive philosophy which views the researcher as a knowledge processor of multiple and relative realities focused on the development of new knowledge (Yin, 2009). A qualitative study is appropriate to investigate issues in depth and in details, to describe, analyse, and understand the problem area of interest, thereby sufficiently addressing, unravelling and interpreting information extracted from social, cultural, and institutional contexts as they relate to stakeholders (Herselman and Botha, 2020; Saunders et al., 2009).

Our research methodology entailed activities in line with the design science methodology (DSM), which has received significant attention and has been widely applied to various areas, in the past decade. DSR focuses on the identification of problem domain and the production of a creative solution (in the present context, that would be the adaptation of the CNCA initiative) with innovative new artefacts such as models, frameworks, methods, and architectures (Herselman and Botha, 2020). DSRM emphasises initially on a problem occurring in a single organisation, industry, or sector (In this case (ICAO – CORSIA), and then expanding the outputs (which can be considered as the CORSIA design elements of its regulatory framework), to others (which can be considered as the international aviation stakeholders) for impact analysis (Denyer et al., 2008). DSM originally consists of three cycles: design, rigor, and relevance (Hevner et al., 2004; Drechsler et al., 2016). In the DSM, design is the starting point which entails the identification of requirements and artefacts needed to device a solution. In the rigor cycle, activities surrounding the development of the design elements are established and executed. Linking the context to the design elements and the body of knowledge (including scientific knowledge, experience, and expertise) is done in the relevance cycle.

In our context and study, we followed a DSR similar to that found in Holopainen et al. (2020), where we started by identifying the problem domain, namely carbon emissions reduction in international aviation. As this task was undertaken by CORSIA, we focused on the influences of its regulatory design framework thereby cross-examining design elements to context/relevance. Based on previous literature, solution objectives were represented in terms of challenges and impacts of the elements of this framework on stakeholders. A solution (i.e., IASCA) was then proposed whose design elements (or features) were crossed examined against those solution objectives. Therefore, from a DSR perspective, our approach consisted of four phases namely, identifying problem domain, extracting critical factors (challenges) from relevant studies, proposing a solution domain that can potentially mitigate those factors, and cross-examining solution design elements against the identified critical factors.

4 Results and analysis

Through our literature review, we were able to identify the factors representing the challenges that the international aviation sector faces in order to meet its carbon emission reduction obligations. We identify and discuss those challenges that fall under three factors, namely regulatory considerations, climate actions, and economic influences.

4.1 Factor 1: regulatory considerations

It is agreed that ICAO, as a UN specialised agency, develops standards and recommended practices (SARPS) for the international aviation industry, as part of international regulatory frameworks. These frameworks, which represent decisions by ICAO, are not binding, such that member states can file a reservation and opt out of participating. Mendes de Leone et al. (2015) elaborated on the issue that ICAO does not have the means nor the mandate to enforce compliance. Compared to INFCC's mandate to reduce GHG emissions, ICAO's mandate is 'to protect and promote international aviation safety and security'.

Moreover, CORSIA has important differences with PARIS Agreement presenting important challenges on how to reconcile obligations to both. Whereas the Paris Agreement considers the member state's carbon emissions contributions based on capabilities, ICAO's activities are centred around auditing the implementation of SARPS, regardless of the country's capabilities (Lyle, 2018).

Under CORSIA, member states' national circumstances and context have not been recognised as part of its scope, with the exception of criteria related to participation. International aviation is viewed as independent of a country's economic and social development. Consequently, it follows that national commitment for international aviation carbon emissions could be weak, lacking emphasis in their national climate plans, and with diluted potential to act and align itself with CORSIA.

Considering the complexity of international aviation, non-compliance, and ineffective offsets or alternative fuels, are expected to occur. Contrary to other UN agencies, ICAO does not help in this matter as it continues to not share information such as the positions submitted by states and in its process.

4.2 Factor 2: climate action

Climate action – carbon offsetting scheme

An important part of the ICAOs carbon offsetting scheme is a TAB that it created to deal with the development of emissions criteria and offsetting challenges. The way it works is as follows: a member state utilises the TAB emissions criteria guidelines to propose an offsetting program; the TAB would then assess this proposal and give recommendations for improvement to be accepted under CORSIA. However, the TAB approach was challenged in terms of the robustness, and transparency of its process.

Moreover, double counting and countries without climate targets represent further challenges to carbon offsetting. Double counting is the mechanism where purchased carbon offsets are possibly allowed to be used at both country and CORSIA levels, which was less relevant prior to the Paris Agreement because developed countries purchased offsets from countries without a target. However, today, double counting has the potential to establish weak targets, especially since all countries have climate goals, and purchasing offsets from them becomes more difficult.

Furthermore, international aviation and complex logistically, and therefore the processing of data that it generates along its entire lifecycle, from data capture to data interpretation ready for decision making and carbon emissions reduction computations, is intensive and requires a large amount of technical and human resources. Airlines today are already struggling to keep up with their data management requirements, which is especially true with the COVID-19 information communication that has imposed an extra load to integrate into their information systems. With the addition of CORSIA's requirements to meet their obligations for reporting, airlines and member states are faced with a significant increase in cost associated with the challenges of how their systems will handle the amount of data management. IATA has provided some tools for airlines to support their data management, yet they are basic and only put a band-aid to the problem. CORSIA and IATA should aim to build capacity and strategic transformation instead.

Climate action – GHG and the environment

When climate action is considered, all GHGs should be taken into account. This is not true for CORSIA since it only addresses CO_2 and CO_2 equivalent. Consequently, other challenges and difficulties arise for CORSIA to meet emissions reduction for all GHGs. Non-CO_2 effects as a result of international aviation may be more important than CO_2 effects alone (Peeters et al., 2005). Moreover, as mentioned earlier, with the option of purchasing carbon credits from projects anywhere in the world, carbon emissions reduction may not occur at the source. Keeping track of relevant information and data presents yet another set of uncertainties to the effectiveness of CORSIA mechanisms.

From a climate goals perspective, the CORSIA baseline as compared to other emission programs is not ambitious. CORSIA's offsetting mechanism is not novel and is the same as existing ones. This implies that CORSIA's effectiveness will experience the same challenges that exist today with current mechanisms including, but not limited to, the difficulty is demonstrating that mitigation efforts by environmental projects have indeed successfully reduced carbon emissions. The difficulty arises from proving accurate emissions computations, permanent emissions reduction, and that the emissions reduced were not actually displaced somewhere else.

A fourth of the projects registered under the 'UN Clean Development Mechanism' delivered the emission reductions they claimed (Oko-Institute, 2021). One study found that in the seven-year period between 2013–2020, the potential that carbon emission reduction resulting from carbon offsetting projects, are in fact additional, and was found to be 75% less likely to occur. Only 7% were found to have a high likelihood (Cames et al., 2016) of meeting their offsetting goals.

Climate action – alternative fuels

SAF have received much attention from CORSIA. To encourage carriers to switch to SAF, CORSIA provided detailed explanations and approaches for use to meet their offsetting obligation. It is generally accepted that SAF has the potential to produce lower GHG emissions. However, research is lacking on alternative fuel GHG emissions, innovations have not matured enough, and their calculation is based on empirical estimates. Moreover, Transport Environment (2019) reported that SAFs can have a greater emissions profile than fossil fuels if production effects are considered (Transport Environment, 2019).

Crediting of 'lower-carbon aviation fuel – low carbon aviation fuel (LCAF)' is also accepted. However, the production of LCAF is the same as that of kerosene. As such, it is considered a fossil fuel and therefore is not 'alternative'. The acceptability of LCAF will draw attention away from absolute GHG's emissions reduction and misleadingly give the impression that 'cleaner' kerosene is better than 'dirtier' ones and from CORSIA's perspective, that this would be acceptable. Moreover, the scope of CORSIA framework lacks the proper treatment of sustainability criteria, where the risk of crediting alternative fuels possessing poor environmental performance may occur.

4.3 Factor 3: economic influences

Considering the aviation industry, there are over one thousand operators that would have to meet the obligations to CORSIA. A significant number of those operators are small, trying to survive in the challenging environment plagued by climate change, geopolitical turmoil, and the pandemic. These small operators have few resources (as is usually the case with start-ups), dedicated to keeping the organisation in the air. Meeting CORSIA's obligation adds another layer of costs to their existing infrastructures, as discussed above in the case of data management.

Economically speaking, the voluntary offsetting market is not stable, and transaction prices are volatile with wide-ranging fluctuations in transaction prices. A globally standardised platform for voluntary offsets is not available, and CORSIA depending on the current state simply introduces more uncertainty to it achieving its goals. This would result in project developers feeling forced to establish their own offsetting environments including marketing teams and intermediaries who have access to clients, further increasing the complexity of the carbon offsetting system, that CORSIA should be actually simplifying it.

It is expected that in the pilot and first phases of CORSIA, it is unlikely that compliance would be achieved due to possible challenges in the cost structures and market competition, especially that larger airlines would have stronger price power to purchasing their offsets in large volumes. Yet, airlines would find ways to collaborate towards forming carbon offsetting cartels (Transport Environment, 2019).

With the continuous endeavours towards profitability, global airline alliances can help its members buy carbon offsetting certificates. SkyTeam, for example, can sell emission allowances within their members, develop common strategies for compliance, and leverage each other's excess CO_2 certificates prior to selling them on the open market. The design of CORSIA as a framework does not include mechanisms to mitigate the airline alliances strategies. If this behaviour should occur, the resulting voluntary carbon market will increase the risk of the successful implementation of CORSIA by increasing the volatility of offsetting prices and veer the airline industry (if not the entire aviation sector) towards undesirable, unhealthy, and unsustainable market behaviour (Cames et al., 2016).

Mitigating those challenges and risks should include mechanisms to encourage operators to budget for building capacity and resources that would serve CORSIA's obligation. This would, for example, push airlines to innovate in line with CORSIA's interests and build such initiatives as financial reserves, as a resource backup for those that may have trouble paying their liabilities resulting from meeting their CORSIA obligation. However, this may still not be sufficient for emerging post-2020 aircraft operators, as their exemptions for the pilot and phase one of CORSIA will be missed.

5 Case study – IASCA

As we have seen earlier, relatively very few scientific studies were performed on carbon emissions reduction in international civil aviation. None of these studies were found to propose or endorse any methodology, but rather, they all identify many challenges facing the industry. In this section, we illustrate how the IASCA can be leveraged to support the industry's carbon emissions reduction obligations, through the lens of the factors identified, keeping in mind that such support is necessary because CORSIA does not have the resources necessary to cooperate in the implementation of its framework, and its involvement in that is outside of its mandate and beyond its scope of facilitation.

The IASCA adapts the CNCA framework that already exists, and piggy-back on the smart city's physical, informational, and experience infrastructures (Alhefdi et al., 2019). The regulatory, climate action and economic factors benefit from the following advantages of the CNCA approach, as follows:

- is already established and has many years of experience on climate action in transportation areas other than international civil aviation
- has shown to be successful in cooperating with not-for-profit organisations supporting the alliance

- cities are becoming increasingly smarter due to digital innovations and are more adept for transformation
- smart cities already have functional carbon emissions reduction framework with proper processes and required resources
- smart cities already have climate change initiatives, plans and policies in-line with national and international considerations
- smart cities' carbon neutral plan is much more aggressive than CORSIA
- deals with GHG and not only CO_2 emissions
- smart cities have the data capture and analysis mechanisms in place.

Cities can be very advantageous with regards to their worldwide 'low carbon future' role. This is true due to their population density and centralised economy which allows them to capitalise on efficiencies, and social advantages. Moreover, they present unique opportunities for financial planning especially in, mobilising, taking advantage of, and achieving large-scale carbon reduction. Inherently, large density cities would have lower carbon emissions when calculated on a per-capita basis.

The CORSIA framework is clearly yet another set of policies that governments, aviation authorities, airlines, and airports must contend with. These organisations today are operating under increasingly less resources, and are already overwhelmed in keeping up with their national climate change regulatory frameworks. Therefore, CORSIA's implementation requirements are not an independent additional set of activities that these organisations must perform, but they are high level instructions for its integration into the organisation's functions and fabric. Being international, this integration involves significant efforts, and overhead costs, to align it with existing policies whereby conflicts will arise and their resolution (and harmonisation) with national policies, inter-governmental regulatory frameworks, UN, commercial activities for compliance, and sustainability, will need to completed.

Alignment of the stakeholder's obligations for international aviation with the CNCA can occur at all levels, and enhance the chances of success for CORSIA's requirements. Moreover, the components that CORSIA needs for its implementation are already in place in the IASCA, as shown in Figure 2, which illustrates the logical infrastructure and frameworks of carbon neutral smart cities. For example, the international aviation sector's obligations would be added to the 'transportation' framework, which already has aggressive targets and includes GHG.

Figure 3 is an updated reconstruction of the expected aviation emissions and climate mitigations initiatives (Macintosh and Wallace, 2009). Figure 3 shows that the International Aviation Smart City Alliance – IASCA, would achieve better 2050 targets for the climate. While the aim of only CO_2 reduction by the year 2050 is –50% that of the 2005 level, we see, in comparison, in Table 1 that all listed cities in the alliance have targets for 2050 of 80% or more of GHG reduction, and not only CO_2 (CNCA, 2014). Aligning CORSIA with IASCA via an independent third party would achieve greater climate effectiveness and benefits, and responds directly to environmentalists' critical claims that CORSIA is not aggressive in its targets.

Figure 2 Logical infrastructure and frameworks of carbon neutral smart cities (see online version for colours)

Figure 3 Projected aviation emissions, carbon neutral growth and targets timeline (see online version for colours)

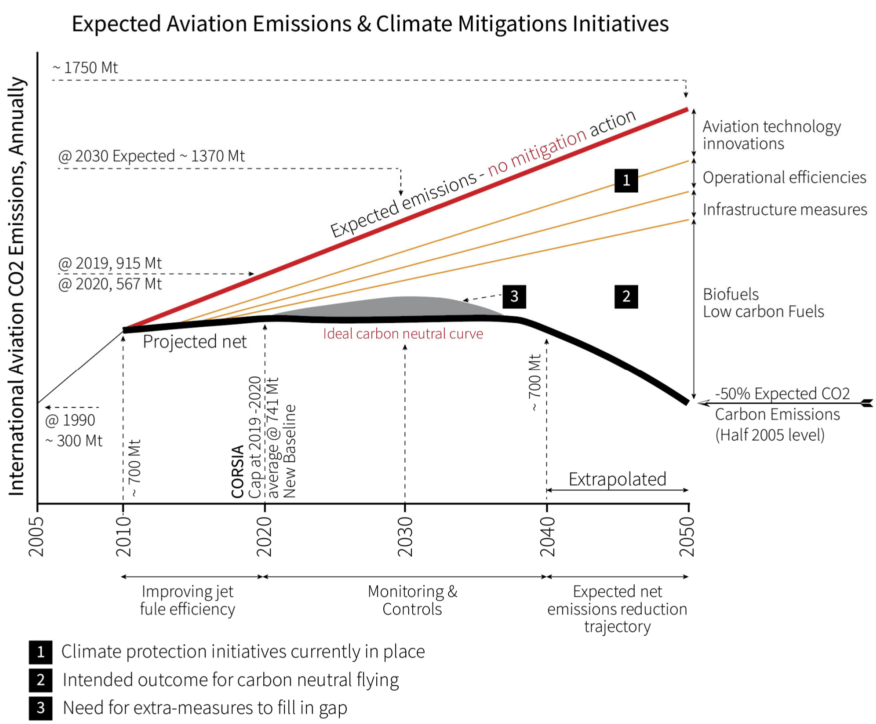


Table 1 CNAC cities' short- and long-term GHG reduction targets

City	*GHG reduction*	*Since*	*MT GHG reduction*	*LT GHG reduction, by 2050*
Berlin	29%	1990	40%	85%
Copenhagen	31%	2005	Carbon neutral by 2025	
London	14%	2008	60%	80%
Minneapolis	9.4%	2006–2013	30%	80%
Oslo	22%	2013	50%	100% fossil fuel free
Portland	14%	1990	40%	80%
San Frans.	23%	1990	40%	80%
Stockholm	9%	2011–2013	100% fossil fuel free 2040	
Sydney	12%	2006–2012		70% by 2030
Vancouver*	30%	1990–2007	33%	100% fossil fuel free
	13%			
Washington*	24%	2006–2013	50%	80%
CORSIA**	–200%	1990	50% of CO_2 from 2005	

Notes: *On a per-person basis; MT: mid-term; LT: long-term.
The GHG (greenhouse gases) reductions occurred while cities were growing in population (1% in Berlin, to 31% in Portland), local economy (from 18% in Copenhagen to 49% in San Francisco), and GDP.

Subsequently, we cross-examine IASCA against the three factors resulting from our analysis of the literature and CORSIA.

5.1 Regulatory considerations

With IASCA, CORSIA can continue to enjoy its role as an international regulatory and standards body without enforcement implications or legal considerations to ensure full compliance with obligation, and remain within its prescribed mandate of climate change. Smart cities (endorsed and advised by ICAO) would facilitate, encourage, and establish mechanisms for enforcement.

As part of the smart city's infrastructure, provisions would apply equally to all stakeholders regardless of differences between contexts. This is because city-to-city alliance agreements would be established with such considerations. National perception of contribution of international aviation emissions critical for climate impact planning would be absorbed and executed in the climate plan of the city. As such, international aviation would benefit from all awareness and educational initiatives committed by the city's public plan.

IASCA would have the mandate, experience, and engage in multilateral international city-to-city aviation agreements on economic issues. Failure of international aviation stakeholders to comply with GHG reduction mechanisms are already in place and the process is clear, as it has been practiced and refined for many years. Moreover, smart cities under IASCA would already have the capacity towards international cooperation and operate in an international context, as well as in an independent and inter-disciplinary fashion that includes a well-represented International Environmental Committee (IEC) for decision-making.

5.2 Climate action

Total GHG would be considered under the IASCA. This includes the assessment of the relative impact of the different GHG. Already established as part of the smart city infrastructure are: Incentives for offsetting entailing proper oversight in-line with targets and following fair practices; Appropriate big data management mechanisms; Monitoring, reporting and verification of outputs, outcomes, and impacts; Robust carbon offsetting scheme with established offset quality criteria.

Moreover, as part of a smart city, it is more feasible for international aviation carbon emissions reduction as well as carbon offsetting projects to occur at the source (ideally the city). International aviation carbon offsetting could be easily comparable to other emission programs as they would be managed by the same city and using same procedure, policies, and resources. Alternative fuels for international aviation sector would also be handled in the same fashion as it has been done in other sectors.

5.3 Economic influences

Economic impacts of carbon offsetting would be fair across organisations and sectors and would be more effectively addressed, as the city institutes the same policies and exceptions for all. The dynamics between compliance and effectiveness of implementation while considering market competition would be better understood and accounted for in an IASCA setup, as smart cities have experience and cases from other sectors, increasing the chances of successful implementation in the international aviation sector.

Voluntary carbon markets mechanisms and their potential economic risks would be mitigated as they evolve similarly and together in all sectors, including international aviation. Consideration of the impact of other emission policies would be considered via integration, and not competition schemes, since the CNCA has experience in the area, aggregated and consolidated all other emissions.

5.4 The carbon emission reduction imperative of IASCA

Since IASCA will be integrated into smart cities, we can report on some findings concerning the commitment and successes of leading cities regarding carbon emission reduction.

Cities as major source of GHG emissions

Cities are the most critical place for carbon emission reduction, and provide the most impact for any initiative, even though carbon emissions are a global phenomenon. The same challenge occurs in international civil aviation where GHG are emitted into the environment at high altitudes, in international space, and includes other climate disruptions. Cities occupy 2% of the earths total land mass, yet they consume 80% of global energy and population. This phenomenon is also true with international civil aviation where most international travel occurs between smart leading cities. Therefore, to effectively mitigate climate change and reduce carbon emissions, major cities must be put at the forefront of associated efforts.

Reducing vulnerability

Due to the large density of people in cities and its continued increase in population, cities are the most vulnerable to climate change. As a result, it is the cities that must take responsibility and be serious in undertaking efforts to mitigate climate disruptions before they become unmanageable.

Smart cities are key to international carbon emissions reduction

Collectively, cities constitute most carbon emissions, worldwide. Consequently, they also provide the most opportunity to achieve large-scale carbon reduction, including the entire supply chain of international travel.

Mutual benefits among sister cities

A cities alliance would enjoy mutual benefits beyond purely carbon reduction. Seen today in COVID-19 travel bubbles such as the recent one between Australia and New Zealand bring many advantages that can be extended into a city-to-city climate change COVID-19 bubbles. Not only cities will support each other, share resources, collectively find solutions to challenges, and exchange knowledge, they will also engage travellers as they become part of that bubble and share responsibility to climate efforts. Cities can be paired as mature-to-developing sister-cities, thereby providing global climate impact more effectively via knowledge transfer, capacity building, and coaching.

5.5 Opportunities within IASCA – smart destinations

IASCA is a foundational framework that can be utilised for creative development across many dimensions such as social innovation, passenger behaviour, route management, and tourism management. One very promising concept that can be enabled by IASCA is ‘smart destinations (SD)’. SD capitalises on the integration of physical and technological infrastructures found in smart cities to optimise people’s experiences including passengers and city residents. One the one hand, passengers would like to experience seamless processes, enjoy the city, and immerse in what it has to offer. On the other hand, residents welcome tourists as they contribute to the economy and overall welfare of the city. The goal is to minimise disruptions from environmental concerns, to resident’s lifestyles. Operationalising the SD concept is not well studies and presents destination marketing organisations (DMOs) with a whole set of challenges (Sorokina et al., 2022).

The integration of the eight dimensions of IASCA shown in Figure 2, into every aspect of city life creates new opportunities to achieve higher level of efficiency and sustainability to enhance competitiveness of the destination. A case study published by Lohmann et al. (2009) demonstrates how two cities, namely Singapore and Dubai can establish an alliance to become major international tourism destinations. Imagine with the advances since 2009, what can be achieved today, in terms of tourist’s seamless experience and resident’s quality of life.

With IASCA focusing on the inclusion of the international aviation sector in smart city alliances, tourist’s destinations and airline alliance have the potential to harmonise strategic behaviour of airlines, cooperation on top tourist routes, and scarce resources (Domínguez-CC et al., 2021). In a study by Florido-Benítez (2022b), issues related to exploration and were identified for practitioners and researchers alike, DMOs, airports and airlines, to enhance their process of future decision-making on tourism promotion and tourism destinations.

DMOs have an important role in SD and would need to be an integral part of the IASCA since DMOs would need to consider not only visitors but residents as well. As part of the IASCA family, DMOs would also need to consider aspects such as sustainable development of tourist's areas and enhanced experiences of visitors. According to Sorokina et al. (2022), the 4 pillars that form the foundations of SD are IT infrastructure, sustainability, e-governance, and livability. These four pillars are core to IASCA and it would be natural for DMO's engaged in SD to collaborate with IASCA. The alliance established between smart cities (includes airports and aviation service providers), DMOs, and airlines would substantially help airlines, tourists, and residents meet their sustainability and organisational goals by improving competitiveness, livability and governance, while accounting for smart cities ambitions and member states' national goals.

6 Discussion

The 80s marked the start of increasing pressures to address climate change through conventions, agreements, and protocols. With the most recent initiatives of the Paris Agreement, ICAO-CORSIA, and COP27, there finally seems to be a successful increase in global awareness and intended significant actions towards climate change. It was made clear in the United Nation's Change Conference (UNFCC COP27), held in Sharm el-Sheikh, Egypt, from 6–18 November, 2022, that "science has established beyond doubt that the window for climate action is closing rapidly", validating the persistent dissatisfaction of environmental groups across the globe, where they blame governments for real action and agreement's limitations.

In 2016 at the A39-3 ICAO assembly, a scheme, CORSIA, was proposed and adopted to reduce carbon emissions from international aviation, while four years prior, the EU launched its own initiative to mitigate emissions from their air transportation. The CORSIA was set up in three phases to allow member states to gradually participate. There were provisions for exemption when a state meets certain pre-defined criteria. What CORSIA means for offsetting market schemes, is that airlines would buy emission reductions that have been realised in other projects to offset their own exceeded emission levels.

The body of research in the area of carbon emissions reduction in the aviation sector is at times contradictory and raises many questions and challenges that member states are faced with regarding CORSIA's implementation. Grey literatures, on the other hand, is rich with content that discusses CORSIA's challenges and knowledge gaps. However, no analysis has been found to critically assess CORSIA's scheme and none was found to provide innovative possible solutions to help facilitate and support CORSIA's implementation.

The literature review performed herein highlights the lack of studies that attempt to connect aviation challenges to regulatory frameworks, such as research on tourism or impacts on low-cost carriers. As such, our research is motivated by the absence of scientific studies in the following areas: direction in relation to the impacts of aviation carbon emissions reduction regulations, missing linkages between technological, social, environmental, and operational innovations and regulatory framework, and issues specific to the design of CORSIA. To address our goals, we assess ICAO's carbon emissions reduction scheme by identifying critical factors for its successful implementation, as extracted from published studies, and elaborate on a solution leveraging the CNCA, to illustrate its facilitation potential in supporting CORSIA's implementation.

We adopt the notion of CNCA to our IASCA framework that we proposed herein. It seems to us that by piggy-backing on the smart city's physical, informational, and experience infrastructures, benefits for enhancing the CORSIA implementation chances and the challenges highlighted can be capitalised. These benefits are extracted from established and operational mechanisms for climate action in transportation, successful cooperation with governments, institutions and organisations, increasing digital infrastructure and intelligence, sustainable human resources and talent, experience in GHGs emissions and management, and data infrastructure and analytical frameworks.

Cities have a great advantage worldwide in the 'low carbon future' role due to their population density and centralised economy which allows them to capitalise on efficiencies, and social buy-in. The CORSIA being another framework that governments, aviation authorities, airlines, and airports must contend with is small compared to the existing regulations in other sectors and makes only a small addition to the smart city. Moreover, organisations today are faced with increasingly less resources and geopolitical challenges and are already overwhelmed in keeping up with their national climate change regulatory frameworks. Smart cities can play in integral role in helping the sustainability of organisations by integrating a social resources-based-view to their operations with common shared resources, talent, and values.

Smart cities such as those identified in Table 1, have already achieved significant reduction in GHGs of up to 31% and are on their way towards 85% by 2050. With climate change pressures today as seen at the COP27, these levels of GHG reduction in smart cities may be reached well before 2050. By example, it is only logical to assume that the aviation sector and especially the international aviation and CORSIA have much to learn from the smart cities' methodology.

As an example of the proactive city in the context herein, IASCA would be operationalised via multilateral international city-to-city aviation agreements, with an open dynamic agenda of shared value creation. This would be feasible to achieve since smart cities under IASCA would already have the capacity towards international cooperation and operate in an international context, as well as in an independent and inter-disciplinary fashion that includes a well-represented International Environmental Committee (IEC) for decision-making.

As part of a smart city, IASCA will focus of facilitating international aviation carbon emissions reduction and carbon offsetting projects to occur at the city (or nearby region). International aviation carbon offsetting could then be easily aligned/integrated with other emission programs as they would be managed by the same city and using same procedure, policies, and resources. Alternative fuels for international aviation sector would also be handled in the same fashion as it has been done in other sectors.

Economic impacts of carbon offsetting would be fair and equitable across different sectors, as the IASCA would enjoy the same policies and exceptions for all under the same smart city alliance. Voluntary carbon markets mechanisms and their potential economic risks would be mitigated as they evolve similarly and together in all sectors, including international aviation. Consideration of the impact of other emission policies would be considered via integration and not competition schemes.

7 Conclusions

In this paper, we set out to investigate the factors representing the critical issues that the international aviation sector is facing today to meet their carbon emissions reduction obligations. Those issues indicate the need for innovative solutions to help the industry implement regulatory frameworks while sustaining their operations and profitability. We therefore, introduce the concept of IASCA which is based on CNCA, and discuss how that model has the potential to meet those challenges.

We found that establishing an International Aviation Smart City Alliance based on the existing CNCA shows good promise to meet the factors for successful carbon emissions reduction. Through IASCA, we find that ICAO's legal mandate for CORSIA's implementation effectiveness can be enhanced. The economic environment for international aviation commerce sector would be leveraged by the city's infrastructure, and appropriate methods and policies would be easy to put in place so the sector can meet their carbon emission obligations. Moreover, the offsetting methods for international civil aviation would be utilised and adapted, if necessary, to already existing ones that the city is implementing in other sectors. Consequently, international aviation would take part in the already existing mechanisms for SAF, ensuring equitability across all sectors, and all GHG would be evaluated as per existing initiatives, thereby considering all climate impacts, putting environmentalist's concerns to rest.

7.1 Theoretical and practical implications

This research identifies critical research directions essential for the successful implementation of international aviation carbon emissions reduction regulations. These directions are represented by the factors identified in Section 4. Whether it is sustainable aviation fuels (offsetting computations, performance, or switching management); compliance with obligations; voluntary market's schemes and behaviour; data capturing, management, and reporting; issues related to transparency; management of double counting of emissions; economic influences leading to collusive behaviour; or technological advances of aircraft engines and their impact on regulatory frameworks, essentially all have theoretical and practical implications.

From a *theoretical* perspective, our alignment to the design science research approach has implications on its suitability and advantages to our type of studies and area of inquiry, and opens the door to other design science research methodologies elaborated in Herselman and Botha (2020), and which can be customised to better suit different areas of study. In fact, since its introduction in 2007 in Information Systems, the DSR methodology has become widely used as an approach in areas such as innovation development, application development, pedagogics, and architecture (Holopainen et al., 2020), but they are not applied in the aviation or regulatory sectors. Moreover, applying DSR in the aviation sector may present opportunities to bridge the above-mentioned gap in linkages between the technical areas of aviation carbon emissions reduction and the social, economic, and regulatory issues.

From a *practical* perspective, our findings provide guidance to all practitioners including regulators, and organisations. For regulators, our focus is towards CORSIA and their evolution towards successful implementation of their role. We identify and recommend a few critical areas of strategic implementation changes within the perspective of IASCA, transforming CORSIA's design into a more sustainable framework, encouraging its extension for building partnerships, such as IASCA:

1 In relation to its mandate, it is important that ICAO, through partnerships, find ways for compliance, on aspects such as data reporting, processing, and approvals for alternative fuels, and carbon offsetting.

2 Establish a comprehensive cloud-based global data warehouse by leveraging the smart cities Internet of Things infrastructure. Create partnerships around the world which already have technology infrastructure, building an international civil aviation network to house relevant data, and offer that data to researchers and practitioners as a platform for analytics with CORSIA identified goals to help stakeholders in the implementation of their obligations. In the same vein and utilising that same infrastructure, establish targeted incentives to researchers to publish in scientific journals their results.

3 Move towards evidence-based transparent policies. Facilitate the scientific studies on all aspects and impacts of alternative fuels (economic considerations, business impact, readiness, feasibility, industry transformation, finance, readiness, and budgets to comply, etc.), open a 24/7 communication channel with the scientific community via facilitation of studies, funding for their relevant publications in open scientific journals, and build on the results to establish a data supported policy and plan.

4 Commission a project that critically analyses 'CORSIA impact assessment on international aviation commerce'. This project should contain a team of specialists from the aviation industry, researchers from academia, and experts from regulatory bodies. The goals would be to primarily engage in discussions for feasible and equitable solutions for CORSIA implementation, and devise adaptive mechanisms to reduce the risks of negative reactions to the overall consumer and supplier's (airlines) wellbeing, and ways to foster growth as a result of the implementation of CORSIA.

5 Engage in the carbon offsetting sector including highly regulated as well as open markets, with the intention to facilitate and harmonise carbon offsetting schemas. We recommend that ICAO establish a think tank dedicated to that purpose.

For organisations, awareness of the critical issues and pitfall as identified and analysed in this study would be the first step towards their planning to meet their climate change obligations. The set of issues under the three categories of organisational, environment and economic influences would help organisations use our findings as part of a self-appraisal framework to evaluate their readiness to implement CORSIA's scheme. With that appraisal, they can identify their corresponding operational and strategic gaps, assess required resources and capabilities, and plan for establishing a comprehensive resource and change management strategy. At the same time, organisations would be aware of the risks due to such issues of engaging in collusive behaviour, double counting, and investing in emissions reduction initiatives that could be obsolete due to new technologies. For example, hydrogen powered aircraft engines versus the use of alternative fuels. More specifically, organisations should consider the following three major issues (in order of highest to lowest impact):

1 Impact of not joining CORSIA scheme. This has national considerations and challenges since filing of differences is done by the member state.

2 Cost of data processing and management necessary to compute carbon emissions.

3 Strategic identification of areas for carbon emissions and comprehensive analysis. For example, whether the focus would be on adoption of new technologies, alternative fuels, aircraft operational considerations, route optimisation management, carbon credits, etc.

Overall, primary research gaps entail the linking of fundamental research in environment, organisational behaviour and change management, climate change, and technology, to CORSIA issues and challenges identified above. For example, some major research areas include primarily the linking of a large body of studies related to GHGs, carbon neutral goals, carbon offsetting, alternative fuels, economic developments at state and organisational levels, social innovation, and engineering, to CORSIA design elements. Detailed analysis of these research gaps is outside the scope of this study; however, we provide some examples to demonstrate and highlight specific areas for essential research areas. For example, a lot of research is being done on alternative fuels where the use of hydrogen compared with kerosene is explored to fuel aircraft engines (Balli et al., 2021a). Linking aircraft engines energy research (Şöhret et al., 2019; Balli et al., 2021b) to carbon emissions reduction schemes in the aviation sector would provide great potential for solutions to meeting carbon neutral goals and the UN SDG. Another important research gap entails SD marketing and management (Domínguez-CC et al., 2021; Debbage and Debbage, 2019; Florido-Benítez, 2022a, 2022b; Sorokina et al., 2022) which includes the tourism sector where the persistence of COVID-19 and the heightened sense of urgency for climate change mitigation alters passenger's behaviour. Finally, case studies across all elements of CORSIA's design would benefit in the sharing critical success factors for its implementation (Cui et al., 2022; Han et al., 2022).

7.2 Future research

We have identified throughout the paper different areas for further research, as the opportunity during the discussions occurred. We primarily identified lack of linkages between fundamental researches in areas of concern to the design elements of regulatory schemas. In this section, in addition to the above, we recommend future research studies based on the three factors from our analysis in Section 4.

Factor 1: regulatory considerations

- Compliance with CORSIA obligations and reconciling them with national obligations.
- Management of ineffective offsets or alternative fuels.
- In the context of IASCA, airport carbon emissions reduction inventory takes centre stage, since in the local context, it directly effects the cities local air quality and those around it. Therefore it is essential that GHG emissions from aircrafts during the landing and take-off (LTO) cycle be assessed. ICAO has specified 'time-in-mode' (TIM) estimates for its member states, however, in many situations such as those

found in Sri Lankan context, TIM is inconsistent with local conditions. This is a specific example where ICAO standards impact on member states' contexts needs further research.

Factor 2: climate action

Climate action

- Studies on double counting which entail policies on how purchased offsets are treated independently for either country or CORSIA regulations. How can this be mitigated and what role can ICAO play in this matter?
- How would the international aviation sector cover the non-CO_2-effects which may even be more significant than CO_2 effects alone. The effects of GHGs injected into the upper atmosphere by aircraft engines need to be studied. What mitigation initiatives including regulations need to be established?
- Emissions reduction offsetting projects need to occur at the source and not elsewhere. Comparative studies and much needed in this area to demonstrate the effects of offsetting projects on climate change at the national level and how would CORSIA manage the regulation process?
- Certain SAF, identified by CORSIA, have been argued to have a lower GHG emissions carbon footprint, but research is lacking in alternative fuel GHG emissions and innovations in this area have not matured enough, and their calculation is based on empirical estimates.
- As part of the alternative fuels, few studies are found on liquid hydrogen fuels in commercial aviation, and investigating how it compares to kerosene is essential to the regulatory process as well as to investments in biofuels (Azami et al., 2017; Rondinelli et al., 2017; Balli et al., 2021a).

Factor 3: economic influences

- Consideration and analysis of CORSIA's obligations on small airline operators with little resources.
- Studies on how global airline alliances can engage in collusive behaviour and manipulate voluntary carbon markets and undesirable market behaviour.
- Studies on post-COVID-19 tourism as affected by CORSIA's obligations especially on the bottom-line organisations and low-cost carriers are timely and necessary and timely. CORSIA was launched at a time where COVID-19 dramatically disrupted the tourism and air transport industry with bankrupt airlines and major disruption to the tourism industry (Florido-Benítez, 2022a).

Other research opportunities:

- Studies on DMOs role after COVID-19 as well as their strategies to play their part in climate change such as influencing destinations (Mirjafari et al., 2022).
- Case studies on the early implementation of CORSIA by different member states.

- Technology innovation is the aviation sector (such as electric propulsion) and how it will impact the sector as well as the CORSIA regulatory framework (Lentini and Tacca, 2020).
- Aircraft operation inside the airport (Zaporozhets and Synylo, 2017).

7.3 Limitations

This study has limitations, as is the case in every study, in that some information sources come from news articles, which although cross-examined with scientific publications, still remain to be verified by further studies. Moreover, reports from credible organisations such as the European Aviation, Environmental Report (2019), Air Bus, Bombardier, and World Economic Forum provide estimates without scientific explanations on their methods. This stresses the case we are making for collaboration. Finally, IASCA in this article is just a proposal that needs to be further studied, especially with regards to its operationalisation and investigating how it can be realised. It requires more analysis on its current state of global affairs, its practices, lessons learned, feasibility of including international civil aviation, impacts and impact chains and finally design and plan for carbon emissions reduction integration.

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Abbreviations

CNCA	Carbon Neutral Cities Alliance
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CO_2	carbon dioxide
CO	carbon monoxide
COP	conference of the parties (to the UNFCC)
DMO	destination marketing organisations

EU	European Union
EUC	emissions unit criteria
ETS	emissions trading scheme
GHG	greenhouse gases
HC	hydrocarbons
IASCA	International Aviation Smart City Alliance
ICAO	International Civil Aviation Organization
LCAF	low carbon aviation fuel
NO_x	nitrogen oxides
SAF	sustainable alternative fuels
SARPS	standards and recommended practices
SD	smart destinations
SDG	sustainability development goals
SO_x	sulphur oxides
SLR	systematic literature review
TAB	Technical Advisory Board
UN	United Nations
UNFCCC	United Nations Framework on Climate Change
WEF	World Economic Forum
WTO	World Tourism Organization.