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Analysis of Carbon Emission Reduction in International Civil Aviation through the Lens of Shared Triple Bottom Line Value Creation

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Abstract: Overall, climate concerns have been on the global agenda for many years now. However, the aviation sector's impact on climate change has been receiving increased attention recently. This is primarily due to the adoption of the 2016 carbon offsetting and reduction scheme for international civil aviation (CORSIA) which was introduced by the international civil aviation organization (ICAO). The aims of our study are to analyze ICAO's carbon offsetting reduction scheme through the lens of the triple bottom line (TBL) value creation dimensions and to explore implementation issues relevant to its success and alignment between regulatory and commercial capabilities. Findings from our analysis were presented to a pilot focus group to further our understanding of the area. After cross-examination of the carbon emission reduction implementation issues against the TBL dimensions, we show the gap between regulatory schemes and the realities of the sustainable commercial aviation sector to meet climate goals. By highlighting the regulatory versus commercial social capabilities, our study illuminates the dimensions which need to be considered in regulatory practice, emphasizing the necessity for commercial sustainability. We finally provide recommendations to be considered for the successful implementation of CORSIA.

Keywords: international aviation; climate change; CORSIA; carbon emissions; sustainability; triple bottom line; ICAO; shared value creation

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1. Introduction

Ever since the eighties with the 1987 Montreal Protocol, climate change initiatives have been undertaken to address greenhouse gas (GHG) emissions. It is evident today that climate change has become a major challenge for all, and the debate has been the source of significant global activities, with increased rhetoric from opposing sides on how to manage it. In general, it seems that dissatisfaction with climate action initiatives persists.

The aviation sector has been recorded to be a significant carbon dioxide (CO_2) emitter, contributing just under 900 million metric tons annually [1], and is forecasted by the International Air Transport Association (IATA) to nearly double by 2035. It is, therefore, expected for a sustainable future that the aviation sector, including regulatory bodies, transform into a more climate-friendly industry, operate in a more socially responsible manner, and align itself with carbon-neutral plans.

From a regulatory perspective, the 1997 Kyoto Protocol, which was adopted at COP3, treats emissions from international aviation separately as per Article 2.2: "Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation . . . working through the International Civil Aviation Organization . . . ". Since then, the International Civil Aviation Organization (ICAO) assumed responsibility to address the civil aviation carbon emission contribution and prepare policy measures to reduce aviation Green House Gases (GHG) emissions.

Eventually, in 2016 at the A39-3 ICAO assembly, a carbon emissions reduction scheme was produced.

The ICAO's need for its involvement in climate change is due to the fact that there is no indication and guidance on airspace over high seas, where no state can exercise sovereignty except for those established by the ICAO [2]. The Paris Agreement, for example, did not elaborate on specifics regarding international aviation and by default has continued to work through the ICAO. Therefore, mitigating carbon emissions in the international aviation industry fell under the responsibility of the ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [3]. CORSIA's task is quite unique as it represents the first carbon emission reduction initiative targeting a global single industry.

With the COVID-19 pandemic, international aviation has been one of the most affected industries due to severe travel constraints, where businesses switched to online and travel restrictions discouraged any movement across borders. Many airlines have seized their operations and large portions of fleets were grounded. Eventually, the international aviation industry lost up to one million jobs. This unexpected and uncertain situation has caused a significant negative impact on the CORSIA implementation, where the ICAO acknowledged it disrespecting its originally agreed objectives [4].

Yet, despite these critical challenges, there seems to be a global common understanding that the situation may present opportunities for climate change where businesses invest in innovations including cleaner transportation technologies, business process re-engineering, sustainable tourism, and green infrastructures. Environmental pressures from regulatory bodies, COVID-19, geo-politics, carbon credit schemes, and carbon emissions reduction initiatives ultimately influence the post-pandemic world where awareness of climate change has become central, opportunities for green growth are stimulated, and global aviation recovery grows into a more sustainable form.

In view of the above, the literature in peer-reviewed scientific outlets on the subject of carbon emissions in international aviation, in general, and more specifically in relation to CORSIA, was examined. We also assessed any of the literature relating to aviation in general so as not to miss any studies that might be related to the international aviation arena and CORSIA. The few publications we found included scarce and dispersed studies on air passengers, market-based mechanisms in the transportation sector, alternative fuels, legal issues in relation to aviation regulations, and the impact of airline alliances [5–7]. A search (for example in google scholar) for the literature would return many records, but a close examination of the records reveals that most are grey literature. This lack in international aviation emission studies creates a knowledge gap otherwise necessary for the ever-increasing complexity of regulators' jobs with regard to evaluating carbon offsetting schemes and preventing possible antitrust behavior [8]. The other literature has discussed and raised important questions and challenges related to CORSIA's implementation [2,9–12].

Most importantly, we aim in this study to improve our understanding of CORSIA's impact on the international aviation sector by revealing critical issues/challenges in its design and implementation, and as identified by the scientific community. The body of literature entails many publications on aspects that CORSIA addresses (i.e., alternative fuels, and carbon offsetting), but no connections are made. Overall, CORSIA-related publications include one or two studies in such areas as COVID-19, legal implication, governance, sustainable fuels, carbon offsetting, market mechanisms, and life cycle GHG emissions. Studies comparing the European Union Emissions Trading System (EU-ETS) with CORSIA included most publications with five published articles. Only one case study on the impact of CORSIA on US full-service carriers was published. The papers published on CORSIA are few, and although informative, they do not provide a complete view of its implementation issues and challenges nor discuss its impact on its stakeholders.

From a total of twenty-one relevant articles, only twelve discussed specific CORSIA critical issues and their impact on stakeholders. A recent study by [13] reported the same results as our study herein, using a systematic literature review approach. Despite that the studies they were interested in included a broader perspective (aviation in general,

with keywords 'CORSIA', 'Sustainable Aviation', and 'Aviation Gas Emissions'), they found only a small number of articles (20 in journals) that discussed CORSIA. In our current study, articles whose focus is on CORSIA (and not including CORSIA as part of the discussion) were retained for analysis, and include the most recent articles from 2021 and 2022 (eight). Consistent with [13]'s structured literature review findings, and considering the lack of research that studies management perspectives on carbon emission reduction in international aviation, to the best of our knowledge, this is one of the first studies that identifies and addresses a complete set of issues related to CORSIA's impact on its stakeholders and its potential to contribute to the carbon-neutral goals.

More specifically, and considering the above, the purpose of this study is to further our understanding of CORSIA's implementation challenges from a management perspective and is composed of two parts: (1) to examine CORSIA through the lens of the triple bottom line value creation theory for sustainable aviation, followed by (2) an exploratory study to obtain feedback on the results of the analysis, from a focus group of professionals. It is important to note that in part 1, the TBL was utilized as a framework to organize CORSIA's issues and challenges reported in the literature, thereby providing guidance for the present study analysis as well as for future research. Subsequently, the questionnaire used in the exploratory study was devised based on the findings from the previous part and was formulated, as much as possible, to remain within the TBL theme while at the same time being consistent and accurate with the findings.

We conclude our study by providing recommendations for consideration that we assess to be necessary for the successful implementation of CORSIA. Our contribution entails the critical analysis of carbon emission reduction in international aviation, identifying issues and challenges for the implementation of regulations, primarily those of CORSIA, connecting with stakeholders and collecting their feedback on the issues and challenges identified, and synthesizing the literature to provide recommendations essential for the success of member states in meeting their obligations.

With more research in the area of international aviation carbon emissions reduction, we advocate herein that CORSIA can be brought to its full potential by the scientific community as a key and effective driver in identifying the scope of industry-wide climate-change-critical policy-related factors, creating value and opportunities for innovative, context-aware, socially responsible and sustainable solutions to international travel.

2. Carbon Emissions Reduction and CORSIA

There is a large body of the literature that has studied the negative effects of the transport sector on the environment. Yet, [14]'s findings show a significant gap between mobility trends and sustainable transport that is still true today, and that air travel contributes the largest portion of the growth in greenhouse gas emissions in the transport sector, despite the demand setback caused by COVID-19. Research indicates that the annual growth rate of aviation is estimated at just below 5% [15,16], and considering this growth relative to the average growth of aviation greenhouse gases emissions of 5.1% and the annual fuel efficiency improvement rate of 1–2% [17], the environmental impact of aviation will continue to increase over time. Assuming that this increase in greenhouse gases emissions is directly proportional to the demand for air travel, then we can roughly estimate that growth in demand will continue to cause greenhouse gases emissions at an approximate rate of 5%, while efficiencies will be increasing at an average of 1.5%, which is clearly not sufficient to meet any climate targets.

CORSIA aims at supporting international aviation Carbon Neutral Growth (CNG) from 2020 onwards. As members of CORSIA, airlines will have to offset the growth of their CO_2 emissions coming from post-2020 international routes by one or more of the following ways: purchasing carbon credits, or investing in environmental projects that aim at reducing carbon in the environment. Naturally, as in other sectors, airlines are expected to obtain certificates that they will be able to trade as part of compliance with CO_2 emission regulations. In the CORSIA Market Based Measures (MBM), and due to COVID-19, the

ICAO passed a resolution to make the net CO_2 emissions baseline equal to 2019 levels, instead of the originally planned in 2020. This carbon offsetting scheme involves paying another actor (e.g., an environmental project happening somewhere in the world) instead of reducing one's own carbon emissions, at the source. The amount of offset that each airline would have to purchase is determined by a formula that evolves over time. It is expected, that under CORSIA's scheme, the aviation sector would offset 21.6% of its cumulative emissions for the period of 2021–2035.

ICAO Standards and Recommended Practices (SARPS) are established to govern the type of allowed offsets. Furthermore, simplified monitoring, reporting and verification (MRV) procedures are created. Member states are required to set up their own MRV system that supports the reporting of annual emissions from international aviation activities by air carriers and reported to the ICAO's consolidated registry that has been available since 2020. On a triennium basis, air carriers reconcile their offsetting requirement. For compliance purposes, air carriers must purchase emission units (one unit equals 1 ton of CO_2) offsets/credits through a carbon market such as the EU-ETS. Only international flights between participating member states will have to meet their offsetting requirements while the others will only need to monitor, report and verify their emissions.

Offsetting implementation in CORSIA occurs in three phases at the country level: pilot (2021–2023), phase 1 (2024–2026) and phase 2 (2027–2035). Participation is voluntary for the pilot and first phases. Participation is mandatory starting in 2027 for all states—with some exemptions. Starting in 2021, actual offsetting under CORSIA started and air carriers are required to compensate for the emissions more than the average of 2019. At the same time, all member states are obliged to report on their emissions [10]. Overall, issues of concern related to CORSIA have been reported [4,12]. In this study, we aim to classify and discuss those concerns by using the TBL value creation theory, for the purpose of better understanding the issues surrounding carbon emissions reduction in international aviation and identifying methods for its successful implementation.

3. The Triple Bottom Line Value Creation

To better understand the interplay between regulatory obligations (CORSIA) and industry practices (commercial stakeholders), we direct our attention to the TBL which has the potential to help us better understand relevant issues and bridge the gap between profit-oriented industry and not-for-profit organizations, and the present context in the international aviation sector, towards improved global sustainability management, and shared social responsibility.

Ref. [18] emphasizes that organizations, and in this case the aviation industry, should link their strategic goals and corporate performance to meet their economic (from a classical resource-based view economic performance perspective), environmental (aligned with climate change), and social (primarily responsibility) objectives. These three dimensions are considered to be the triple bottom line (TBL) indicators that can bridge the gap between the commercial-driven private sector and regulatory climate obligations, and operationalize and engage social responsibility outcomes. As such, the TBL should be managed as a set of shared community (private, public and international) values focused on collective wealth [19].

Shared value has been defined as " ... which involves creating economic value in a way that also creates value for society by addressing its needs and challenges. Businesses must reconnect company success with social progress. Shared value is not social responsibility, philanthropy, or even sustainability, but a new way to achieve economic success. It is not on the margin of what companies do, but at the center ... " [20]. In this definition, the emphasis given to shared value is on the continuous creation of value over time to all stakeholders and goes beyond simply being socially responsible, philanthropic or sustainable, but does not necessarily exclude them. The aim is not to redistribute value but to connect the continuous generation of value to the three TBL dimensions [21] to a broad base of stakeholders.

The notion of shared value is still in its infancy [22,23]. However, the aviation industry and CORSIA still need to be reconciled by engaging in social innovation and keep in mind that one possible way forward is through a harmonized interpretation of an aviation sector's shared value and support guidance on how to implement it, across the TBL dimensions.

4. Research Methodology

The research methodology entails two parts: (1) to critically examine research on CORSIA against the triple bottom line value creation theory and elaborate on reported challenges and issues for its implementation, and (2) to utilize the identified challenges from step 1, to conduct an exploratory pilot study by questioning a small group of senior professionals from various industrially relevant backgrounds, to further enhance our understanding of how these challenges are perceived, as well as to help better understand possible venues for the successful facilitation and implementation of carbon emission reduction regulations.

More specifically, the purpose of the pilot study is to better understand the perceptions of a small group of professionals on the concerns found in the critical analysis of CORSIA's body of research. It is an exploratory study to obtain insights into the level of agreement of different aviation stakeholders from the public and private sectors.

It is important for carbon emissions reduction to include the participation of a broad scope of aviation stakeholders to manage the implementation of CORSIA. This implies that all these stakeholders have to be on board regarding the issues and challenges towards domestic and global climate goals. With the guidance of the TBL dimensions and results of the CORSIA literature analysis, we extracted 10 representative statements of concern, listed in Table 1, identifying the critical issues and challenges that the international aviation sector is facing today.

Table 1. Statements used in a small pilot to measure perceptions.

Q	Statement
	Environmental
1	Regulatory bodies, in general, such as the ICAO, and as part of their mandate, do not have the legal capacity to ensure full compliance with CER measure's obligation. Multilateral aviation agreements on economic issues are outside their scope.
2	One of the international CER regulation's shortcomings is that it does not cover the non-CO_2 effects of aviation (that is all Green House Gases). As such, the impact of such regulations on overall climate change is not sufficient and would be negligible.
3	Offsetting has proven difficult to make work because it is inherently challenging to prove that the mitigation project only occurred because of the offset revenues it generated and calculating carbon emissions is complex and costly.
4	The effects of production of some alternative fuels are such that they have an emissions profile greater than the fossil fuel they replace.
5	The method proposed by CORSIA for calculating the emissions is based on overly optimistic assumptions.
	Economic
6	How airline systems will handle the significant amount of data that will be needed to be collected and reported for CER regulations, is very challenging and includes many data management-related risks, making the carbon emission reduction schemes not feasible.
7	Monitoring, Reporting and Verification, will have to be undertaken not only at the airlines, but also at the mechanism, program, and project levels. This will increase overall transaction management costs.

Table 1. *Cont.*

Q	Statement
8	The primary challenge of CER regulations affects close to a thousand operators worldwide, with many of them being small with limited resources to comply with requirements properly.
	Social
9	Offsetting creates an incentive for parties to set weak targets, and when they overachieve, to sell that overachievement as an offset. Or, to leave part of their economies outside of their target and sell emission reductions from that sector as an offset.
10	A voluntary carbon market holds the risk of leading to significant price variations or collusive behaviors.

NB: Underlined represent keywords that were used to associate each statement to the TBL dimensions.

To understand the perceptions of the broad stakeholders in relation to the issues raised and challenges identified, in the statements in Table 1, we presented those statements in an online survey format for the participants to indicate their level of agreement with these statements based on their knowledge and experience, on a 5-point Likert scale from strongly agree to strongly disagree.

It is noteworthy to elaborate on the categorizing of the statements in Table 1 to the TBL dimensions. In our methodology, we utilized the TBL as guidelines for analysis of literature and organization of issues and challenges. These issues and challenges were then transformed into statements that were then presented to 45 different stakeholders, whose responses were then analyzed. To remain consistent with the TBL throughout the study, we examined the statements against the TBL dimensions to ensure proper mapping. Many of the statements can be easily categorized as environmental or economic, such as Q4 and Q7, respectively. However, based on our literature review the direct link between CORSIA and the social dimension of the TBL has not been studied. To resolve this conundrum, an analysis of the mapping of statements to the TBL dimensions was conducted. Due to the lack of literature on the direct impact of CORSIA on social responsibility and common value creation, indirect impacts on social aspects can be made allowing us to define statements that can be associated with the social dimension of the TBL.

Consequently, we underline the keywords that qualify the association of each statement to the TBL dimensions. As mentioned earlier, the environmental dimension includes organizational strategy and role as well as climate impact. Therefore, questions 1 to 5 are associated with the environmental dimension due to 'ensure full compliance', 'does not cover the non-CO_2-effects', 'calculating carbon emissions', 'emissions profile' for alternative fuels, and assumptions to 'calculating the emissions', respectively. Similarly, questions 6, 7, and 8 are associated because of 'significant amount of data', 'monitoring, reporting, and verification', and 'limited resources', respectively, all of which have resources management implications impacting associated direct and indirect costs.

Questions 9 and 10 were associated with the social dimension because of their link to behavior which may occur at all stakeholders' levels including the individual, organization, sector, city, regulatory, government or intergovernmental. Behavior in the current context of the TBL pertains to social progress, and as per the definition of TBL above, " . . . involves creating economic value in a way that also creates value for society by addressing its needs and challenges." In other words, we can contextualize our understanding through a perspective that organizations, as a result of CORSIA, would need to find ways to realign the way they do business to redistribute and connect the continuous generation of value across the three TBL dimensions. Therefore, questions 9 and 10 were associated with the social dimension due to the keywords, incentive and collusive behavior, respectively. Offsetting incentives, have resources and capacity implications, that may influence a change in organizational behavior to potentially manipulate (manage) targets such that they would

be contrary to the continuous generation of shared values and common social progress. In a similar vein, question 10 addresses the notion of collusive behavior.

5. Analysis of the Literature

Our analysis consisted of reviewing the literature published in peer-refereed journals, and reports from the ICAO and IATA. Only English publications were evaluated. In brief, we initially observed that concerns were related primarily to the sustainability of the organization, issues related to carbon offsetting, GHG, challenges and opportunities with alternative fuels, economic influences due to regulatory obligations, and social responsibility and engagement. The least addressed is social responsibility, while the most discussed is GHG and the environment. These concerns fall within the scope of the three TBL dimensions, namely environmental, economic and social. The concerns or issues within the TBL value creation backdrop can be utilized to explore opportunities and present the parameters for current management and future growth in the aviation sector's stakeholders to recognize areas for environmental action, harmonization, cooperation, collaboration, and alignment, as well as future research agenda and direction. We raise concerns based on the TBL dimensions below.

5.1. Environmental

5.1.1. Organizational

Whether voluntary offsetting or not, the ICAO's decisions are non-binding as it was not mandated to establish mechanisms to enforce its measures. A member state can refuse to volunteer for participation and file a reservation, yet the ICAO is not able to enforce any compliance because it does not have the legal capacity nor mandate to do so [24]. The ICAO's mandate is "to protect and promote international aviation safety and security". This is outside the scope of climate change, in comparison to the UNFCC's mandate for GHG reduction.

Moreover, the ICAO has neither the experience on issues that deal with multilateral agreements nor on national economics (necessary in negotiating climate action initiatives). The ICAO's genome excludes any implementation role of its standard and recommended practices (SARPs). The ICAO formulates SARPS and it is up to the member states to implement it successfully. Any participating state can opt out from the system with 6 months' notice. Even after 2027, when all member states are required to enforce offsetting on their airlines, it is not clear how failing to meet requirements will be met with penalties, if any at all.

Considering conflict with other national climate regulations and initiatives, the ICAO CORSIA has important differences from the Paris Agreement (as an example), which presets important challenges for organizations to meet conflicting obligations and align their corresponding strategies, and that needs to be addressed [25,26]. The Paris Agreement accounts for member states' contributions based on their individual capabilities, while the ICAO, in general, is focused on auditing global safety and security standards, regardless of countries' capabilities. A 'bottom-up' process in the current context is more pragmatic economically because it accounts for the major differences between the states' contexts [2].

Moreover, international aviation is data-intensive, and airlines already struggle to manage their current data-related challenges. One should not take for granted that all airlines have the technology infrastructure to handle their data management requirements. With CORSIA, airlines and member states are faced with a costly challenge to how their systems will handle the significant increase in the amount of data that will need to be collected, processed and reported for the purpose of carbon offsetting. Tools such as the one created by IATA to support data management only put a band-aid on the problem. Efforts would be better served if aimed to build capacity and strategic transformation for data management.

5.1.2. Carbon Offsetting Scheme

Double counting entails the scenario where purchased offsets are used for both the country and airline. Before the Paris Agreement, double-counting was less relevant because offsets were purchased by developed countries from countries without targets. This might become a limitation to establish weak targets. Environmental groups have been vocal in expressing their opinion about the need for international aviation to adopt more ambitious targets and to include a broad base of economic stakeholders.

The effectiveness of the offsetting mechanism introduced by CORSIA will determine the impact on its climate change mitigation. In general, and in other areas, offsetting mechanisms have not demonstrated that they work because of its inherent difficulty to prove that the mitigation project was successful due to (1) the offset revenues it generated, (2) accurate estimation of emissions, (3) a permanent reduction of the emissions, or (4) emission reductions not being displaced elsewhere. It is worthwhile to note that only one-quarter of the projects registered under the "UN Clean Development Mechanism" delivered the emission reductions they claimed [27].

There is a strong possibility that offsetting from projects under the CORSIA scheme would be achieved from other projects. It is therefore reasonable to assume that the impact on carbon emissions reduction from CORSIA may be small. The potential for additional and not over-estimated carbon emission reductions (i.e., offsetting projects) between 2013 and 2020 was found to be 75% less likely to occur. In the same study, only 7% were found to have a high likelihood of success [28].

5.1.3. Green-House Gases

CORSIA only considers CO_2 and CO2e in its scheme and, as such, it would seem that it will face important difficulties to achieve absolute emissions reductions. It does not cover the non-CO_2 effects of aviation which may even be more significant than CO_2 effects alone [29]. Regarding investment in greenhouse gas reduction projects for offsetting, one would expect that emission reduction occurs at the source. However, this is not the case with CORSIA, as carbon offsetting can occur on projects occurring in different regions around the world, which introduces yet another set of uncertainties.

Moreover, aircraft engine emissions are released in the lower stratosphere and the upper troposphere, with greenhouse gases that include CO_2, aerosols (sulfates and soot), nitrogen oxides (NOx), sulfur oxides (SOx), hydrocarbons (HC), carbon monoxide (CO), heat, soot, and other atmospheric particulate matter (APM—incompletely burned hydrocarbons, sulfur oxides, and black carbon) [17], contributing to global warming, formation of clouds, and depletion of methane. These gases are not considered independently by CORSIA, which treats them as CO2e, whose calculations are not well researched and validated and include many uncertainties.

5.1.4. Alternative Fuels

The subject of alternative fuels, in general, continues to be contentious. This may possibly be due to the economics of their engineering, challenges for integration, demand, and carbon footprint that may replace one type of emission with another. Under the CORSIA scheme, carriers can use CORSIA-eligible fuels (CEF) to reduce their offsetting obligation. Alternative fuels are expected to produce lower GHG emissions; however, there are still a lot of potential areas of research to enhance the body of knowledge, especially in the area of commercial scaling that is missing, possibly due to a combined lack of economic viability and political stimuli. This is true, however, in all areas of the transportation industry, including automotive. Alternative fuels can actually have a greater emissions profile than fossil fuels if production effects are considered [30]. Nevertheless, CORSIA has addressed this problem recently via a supporting document on the technical information describing the processes to manage and maintain the default life cycle emissions values for eligible fuels (Referenced in Annex 16).

CORSIA includes rules that aim to ensure the inclusion of alternative fuels that compared to kerosene could possibly have a 10% or more emission reduction [31]. The shortcoming of such rules is that there exist uncertainties in the calculations and may result in possible alternative fuels with actual total emissions that fail to meet the established rules. In a study by [32], they found that introducing synthetic paraffin kerosene alternative fuels to fully replace kerosene would bring only a marginal reduction of the cumulative direct emissions of CO_2 and as such, it would not contribute to achieving the globally agreed targets on GHG emissions reduction. However, they did find that another alternative fuel was found to be acceptable in helping to achieve agreed targets.

Sustainability criteria are established for CEF. GHG emissions savings from specific alternative fuels are quantitatively assessed using a life cycle assessment (LCA) tool. Ref. [11] elaborate on the LCA and report on their study of CEF. Based on unique data and assumptions such as conversion efficiency and yield, and which reflect source differences such as agriculture, electricity, or transportation purposes, they established default values suitable for the application to the CEF scheme. In their article, they demonstrated the potential major role of sustainable aviation fuels (SAFs) in reducing aviation's carbon footprint.

Crediting of 'lower-carbon aviation fuel—LCAF' is also accepted. This LCAF is produced in the same way as kerosene. As such, it remains a fossil fuel and cannot be viewed as an 'alternative'. With that notion in place, "cleaner" kerosene is acceptable, while "dirtier" ones are not, but can still be used outside the CORSIA scheme. This approach will distract the attention from the spirit of the overall reduction of emissions. There is an absence of sustainability criteria where there is a risk of crediting alternative fuels with poor environmental performance.

5.2. Economic

From an aviation business perspective, CORSIA's efforts are well-founded, but important challenges remain. CORSIA's global reach extends to around 1000 operators with a significant percentage that is small and with challenging resources.

Voluntary offsetting transaction prices vary widely, as a common platform for voluntary offsets does not exist. The process ends up being complex where project developers find themselves having to form their own marketing teams or engage with broker intermediaries connected to end-buyers. Expectations for a compliance market in the first two phases seem unlikely due to possible distortion in cost structure and market competition. This is especially true when factoring the COVID-19 pandemic into the equation. Considering that purchasing offsets in large volumes has cost advantages, naturally, airlines would find effective ways to cooperate and form cartels [28].

Global airline alliances, such as those that exist today, can help their members buy CO_2 permits. Consider, for example, the case of SkyTeam selling emission allowances to one another, sharing procurement and compliance strategies, and agreeing to offer excess CO_2 permits internally first before selling them on the open market. These strategies can also occur with CORSIA's design. As a result, a voluntary carbon market holds the risk of increasing offsetting price volatility and undesirable market behavior [27].

Moreover, CORSIA may have a significant economic impact, especially since only close to 88 countries out of the 193 (~46%) have joined. The non-participating countries represent a very important portion to meet climate goals and would introduce major risks that will undermine the implementation of the scheme and foster competitive distortions. However, European Union (EU) member states have shown strong commitments since they have acknowledged that it is the only market-based measures scheme for the management of international aviation emissions [25].

An ongoing issue entails the scenario exemplified by intra-BRIC and intra-EU flights. How will CORSIA and BRIC flight agreements be reconciled? Exceptions for such flights have not been considered and consequences include less effective emission policies. For example, in the case of Europe, airlines should not have to pay for CORSIA carbon cred-

its, which may have been already accounted for in the EU Emissions Trading System (ETS) scheme [33].

CORSIA seems to be a positive step towards the reduction of CO_2, yet it may be difficult for this to occur efficiently, as the costs of each airline's emissions are already partially borne by other airlines. This scenario will provide fewer incentives for airlines to adapt and adopt other cost-effective options as compared to the price of offsets until 2030 and even after.

5.3. Social

The social dimension in this context entails organizational behavior within sectors and communities, as well as the dynamics established between a broad scope of stakeholders, which lends itself to organizational issues and themes of sustainability that may lead to social impact.

Today, aside from alternative fuels, CORSIA is silent on sustainability criteria; however, it is currently engaged in other sustainability themes such as human, labor and land use rights, conservation, and local and social development. Experts, over the years, have developed several sustainability criteria that include water rights, biodiversity and food security, and have only addressed those linked to CO_2 reduction. By contrast, through its Renewable Energy Directive, the EU has already established sustainability criteria for alternative fuels.

Moreover, operator's costs include those that organizations need to budget for building capacity and resources to process CORSIA's requirements. This forces airlines to make financial reserves and many may have trouble paying their liabilities (financial involvement in offset programs), increasing the risk of successfully participating in CORSIA offset programs. For post-2020 operators, they are not required to pay for emissions for the first three years. Thus, emerging aircraft operators will have a disadvantage over the already existing ones.

To overcome offset challenges, the ICAO developed Emissions Criteria, and established a Technical Advisory Body (TAB). The TAB's purpose is to assess offset programmes that are proposed by member states, using the developed emissions criteria, and then provide recommendations for their approval under the CORSIA scheme. There are important questions regarding the robustness of the TAB mechanism (approach) as well as with regard to its process as documentation made to the public is limited.

From another perspective, international aviation is treated as an independent sector without consideration of the different contexts and national circumstances of member states. To that effect, one cannot observe any national commitment to just international aviation, and as such, there is no emphasis on national carbon emissions reduction contribution. Consequently, the potential to act in this respect is diluted.

CORSIA seems to give much more attention to sustainable alternative fuels than to other areas. Nevertheless, the social aspect of its impact should not be downplayed in order to meet the carbon-neutral growth goals that both airlines and airports have, which play an important role in curbing emission levels. In addition to the expected adoption of alternative biofuels (at least in the near-term until technological advancements such as highly efficient aircraft bodies and engines, and electric aircrafts), airlines should engage in social initiatives such as promoting voluntary carbon offsetting, creating awareness campaigns for their employees and partners, and encouraging their clients/passengers to take part in the carbon emissions reduction process. At least at the onset, major airlines should take leadership in increasing their scope for social innovation such as Qantas and, recently, Air Canada, and support others to be part of relevant initiatives. In the same vein, airports should participate in the greening of their infrastructures and operations such as those necessary for biofuel storage and distribution, recycling, benefits for green airlines, suppliers and partners, and incentives for passengers.

Based on the examined literature, we did not find any studies that make a direct connection between CORSIA and its impact on the social dimension of the TBL, such as

organizational social responsibility or shared value creation by the international aviation community. Our analysis of the literature, however, indicates that the social impact due to CORSIA is indirect and connections may be made through its regulatory implications to the different areas such as economic, alternative fuels and offsetting schemas. As mentioned in the methodology section, these influences on social progress and commonly shared value creation have been reflected in statements 9 and 10 which address social issues related to offsetting incentives, and collusive behavior in voluntary carbon markets.

Based on the above, we consider the social dimension in this study as consisting of stakeholder's behavior particularly as they react to CORSIA's scheme and as they relate to incentives and collusive behavior. In other words, an organization's contribution to shared common value creation and social responsibility as they adapt to CORSIA may result in social behavior contrary to what the TBL is advocating. Therefore, questions 9 and 10 in Table 1 are considered with that perspective in mind, where: (1) carbon reduction performance and offsetting plans, as a result of CORSIA, may influence the behavior of organizations in how they manage and manipulate their offsets and carbon credits, such that one sector will be disadvantaged for the sake of another, possibly resulting in the compromise of socially acceptable commonly shared values, perceptions of, and willingness to, participate in climate action by all stakeholders including passengers; and (2) new external and internal organizational forces as a consequence of adapting to the their international aviation carbon emissions obligations and playing a significant role in their sustainability, contributing further to the destabilization of the price fluctuations of the voluntary carbon market, opening the door wider for collusive organizational behavior, leading to further distrust in carbon emissions reduction initiatives, and resulting in similar outcomes of negative perceptions and image of climate change initiatives.

6. Exploratory Pilot Study

The statements in Table 1 were presented to 74 professionals, 9 of which were in a graduate classroom setup and the others were remote, where a link to the questions was sent to them by email. Out of the 74 participants, 45 responses (roughly 60%) were usable and retained for analysis. In order to identify a comparative perspective to the respondent's perceptions of the criticality of the issues, we investigated the results by examining the responses (Table 2) followed by descriptive statistics (performed using Microsoft Excel data analysis module), skewness analysis, and inclination of respondents towards every issue in question (Table 3).

Fifty-two percent of the respondents were female, and eighty percent had completed a graduate degree. Nine participants worked in a university, 5 came from a legal background, 3 were in aviation, 6 were from aviation authorities, and 15 worked in different areas of industry. Since the question was not mandatory, 7 participants did not answer the question. Around 21% of the participants have a very good knowledge of environmental pollution issues, and close to 63% reported having little to moderate level of knowledge on the same issues. These issues included a range of subjects such as the impact of aviation on climate, carbon emission reduction, carbon offsetting and taxes, climate change mitigation, sustainability, compliance markets, different protocols and climate agreements, the ICAO and its mandate, greenhouse gases, and economic influences of carbon emission reduction schemes. Around 70% of participants knew about the ICAO, 27% of them were familiar with CORSIA, 44% were aware of environmental policies in the aviation sector in general, and 51% were aware of international aviation in specific environmental policies.

Table 2 presents the results (in percent) of the participant's answers to the 10 statements (also referred to interchangeably as questions) (numbered in the Q | TBL column) as an average, and categorized based on TBL dimensions. The question asked was "To what extent you agree with the following statements". We report the results in Table 2 in terms of agreement, neutral, and disagreement.

Table 2. Responses to participant's perceptions (n = 45).

Q | TBL	Agreement (%)	Neutral (%)	Disagreement (%)
1 | Environmental (Org.)	*57.8*	24.4	17.8
2 | Environmental (GHGs)	48.9	35.6	15.6
3 | Environmental (C. Offsetting)	53.3	33.3	13.3
4 | Environmental (Alt. Fuel)	48.9	40.0	11.1
5 | Environmental (CER)	35.6	*53.3*	11.1
Environmental Average	**48.9**	**37.3**	**13.8**
6 | Economic	53.3	28.9	17.8
7 | Economic	*71.1*	26.7	2.2
8 | Economic	*57.8*	31.1	11.1
Economic Average	**60.7**	**28.9**	**10.4**
9 | Social	48.9	*46.7*	4.4
10 | Social	*60.0*	33.3	6.7
Social Average	**54.4**	**40.0**	***5.6***

Bold, italicised and underlined numbers are highlighted for reference in the text.

Table 3. Descriptive statistics and respondents' general inclination.

Q	Median	SD	Min.	Max.	Skewness	Deg. Skewness	Inclination
1	24.4	21.4	17.8	57.8	1.5	High	A
2	35.6	16.8	15.6	48.9	−0.6	Moderate	D
3	33.3	20	13.3	53.3	0	None	N
4	40	19.8	11.1	48.9	−1.3	High	D
5	35.6	21.2	11.1	53.3	−0.5	Moderate	D
6	28.9	18.2	17.8	53.3	1	High	A
7	26.7	34.9	2.2	71.1	0.8	Moderate-High	A
8	31.1	23.4	11.1	57.8	0.4	Low	A
9	46.7	25	4.4	48.9	−1.7	High	D
10	33.3	26.7	6.7	60	0	None	N

Note: All numbers are in percent; Mean for all questions is 33.3%. SD = Standard Deviation; Deg. Skewness = Degree of Skewness [>1 and <−1 = Highly Skewed (High); −1 to −0.5 and +1 to +0.5 = Moderately Skewed (Moderate); and −0.5 to +0.5 = Fairly Symmetrical and no skewness (Low or None)].

Overall, looking at the TBL environmental-related challenges (Q 1–5), close to 50% of the participants agree to Q2, Q3 and Q4, with the exception of Q1 which has the highest value in the category of 58%, and Q5 being the least agreed upon with 36%. Close to 60% of the participants reported agreeing or strongly agreeing with the challenge that the ICAO "does not have the mandate nor legal capacity to ensure full compliance . . . " (Q1); however, around 18% disagree or strongly disagree, with 25% not sure (neutral). Over one third of the participants agreed to the challenge that "the method proposed by CORSIA of calculating emissions is based on overly optimistic assumptions" (Q5), while over one half were neutral on the same question. Fifty-three percent agreed that "offsetting has proven difficult to make work . . . " and that " . . . carbon emissions is complex and costly . . . ", while one third of the responses were neutral (Q3).

In relation to economic challenges described by Q6 (pertaining to airline's methods to handle the amount of data required for CER regulations), Q7 (about monitoring, reporting, and verification), and Q8 (effect of regulations on small operators), 53%, 71% and 58% of the respondent agreed with the statements, respectively. At least close to half of the respondents

agreed with the statements in the TBL social category, represented by Q9 and Q10. Forty-nine and sixty percent of participants agree that "offsetting creates an incentive for parties to set weak targets . . . " (Q9), thereby potentially creating scenarios to manipulate the sales of emissions reduction as offsets, and that a voluntary carbon market has a significant risk for price variation and collusive behaviors (Q10), respectively.

Several further observations can be made from Table 2. We notice that in all three TBL categories, around one-third of the responses, on average, were neutral. Close to half agreed with the environmental challenges, slightly over fifty percent agreed with economic issues, and close to 55% agreed that manipulating offsets (the subject of Q9) and collusive behavior (the subject of Q10) may be a significant outcome of carbon emissions reduction policies (as represented by the statements). Consequently, for all intents and purposes, and compared to those who disagreed with the statements, most participants seem to acknowledge that the identified challenges exist. Moreover, the 40% of combined neutral and disagreement responses, on average, provide an indication that a better understanding of the issues is required.

Table 3 presents the descriptive statistics of the responses to the 10 questions, and the respondent's inclination towards agreement or disagreement. We note that questions 7, 9, and 10 have the relatively highest SDs (evaluated as 25 and over) of all ten questions, and questions 1, 7, 8, and 10 have maximum values of around 60% or higher. Question 7, which is related to monitoring, reporting, and verification impacting transaction management costs, seems to have the largest SD, least disagreement, and highest agreement. Most importantly, we consider the skewness of the data for insight into inclination towards agreement.

Skewness is an indicator of lack of symmetry from a typical bell-shaped curve distribution, and in the present context may provide insight into the inclination of respondents towards agreement or not. Skewness can be positive, negative and zero. A positive skewness has a longer and flatter tail to the right of the bell-shaped curve while the opposite is true for negative skewness. Skewness also provides information about where to expect outliers on the curve (+ skewness means outliers are on the right side of the curve). Table 3 presents the skewness found in each question along with its interpretation in terms of the degree of skewness and inclination. We draw attention to questions 1, 4, 6, and 9 which have high degrees of skewness; question 4 is negatively skewed, implying that outliers may be found on the agreement side and that there is an inclination for the participants to disagree with the issue at hand. This is also evident from Table 2, question 4, where 40% of responses were neutral and close to 49% agreed. Perceptions about issues 3, 8 and 10 are relatively well distributed among respondents.

Overall, on the one hand, inclination to disagreement seems to be found in issues 2, 4, 5, and 9. It seems that respondents are not completely convinced that CER regulations are not sufficient and would be negligible, that alternative fuels may have emissions greater than fossil fuels, that CORSIA calculations are overly optimistic, and that the offsetting scheme impacts negatively social behavior. On the other hand, there is a positive degree of skewness and inclination to agreement regarding the role and mandate of regulatory bodies such as the ICAO, data management risks, transaction management costs, and effects of CER regulations on operators, as shown by questions 1, 6, 7, and 8, respectively. Interestingly, the skewness of zero for issues related to offsetting from an environmental impact perspective (question 3), and voluntary carbon markets behaviour (question 10), may imply that the group of respondents are split on those issues.

This exploratory pilot provides important insights into the challenges for carbon emission reduction regulations, as assessed by a small group of professionals and researchers. Table 2 indicates that the economic dimension of the TBL is the most agreed upon (average 61%) as an important challenge, further stressing the need for more economic impact studies in the international aviation carbon emission reduction initiatives and regulations. Moreover, Table 2 shows (in italics and undesigned) that the first issue from the environment TBL dimension, the 7th and 8th issues from the economic dimension, and the 10th issue from the social dimension had the most agreement of close to and above 60%, thereby

indicating that the majority of respondents agree the issues related to the ICAO's mandate, economic challenges (where the 6th issue is not far from the 60% selected for a majority agreement), and collusive behavior. Yet, it is important to look into the neutral scale; Table 2 shows (in italics and underlined) that close to half of the respondents were not certain of issues such as questions 5 and 9, namely related to CORSIA's method of calculation of emissions and offsetting behavior.

In terms of the respondent's inclination or tendency to agree or disagree with the issues in question, Table 3 suggests that there is a strong inclination that the majority agree on economic-related issues (issues 6, 7, and 8), and the ICAO's mandate (issue 1). However, they are not so confident about the social dimension (which may be due to the lack of understanding of what it pertains to, and how it would relate to the present context). With respect to the environmental dimension (with the exception of issue 1), respondents seem to be leaning more to disagreement than to agreement, indicating that, statistically (degree of skewness being negative), the outliers are on the agreement side of the curve, and contextually, that issues related to GHGs (issue 2), alternative fuels (issue 4) and carbon emissions reduction (issue 5), in general, may be sufficiently addressed. Overall, Table 3 shows an inclination to agree on 4 issues, to disagree on 4 issues, and neutral (no skewness) on 2 issues.

7. Discussion

The ICAO, under CORSIA, has produced a plan which has been met with mixed reactions, some of which were in support of the initiative, while others were critically negative. The relatively very few scientific studies performed on carbon emissions reduction and management in international civil aviation, to date, do not endorse any methodology, but rather identify critical challenges, and pose important questions that are yet to be answered.

International aviation stakeholders including organizations, hubs of operations, governments, and passengers impacted by the international aviation carbon emissions reduction initiatives should play a more effective role in building support from the international aviation community to help with CORSIA's implementation. This can be facilitated by looking through the lens of the TBL value creation proposition, to help researchers, practitioners, governments, regulatory bodies, commercial organizations, and travelers better understand key success factors to reach CORSIA's climate goals, and beyond.

Based on the analysis above, carbon emission reduction for international aviation, under CORSIA, is yet an additional responsibility and effort to the already overtaxed stakeholders including governments, aviation authorities, airlines, airports, and human resources. It is understandable that any new regulations, especially of international nature, entail major overhead in terms of alignment with existing ones and resolving conflicts with national policies already in place, inter-governmental (political in many cases) regulatory frameworks, and United Nations Organizations that intersect with same missions, and commercial activities for compliance (with increasing complexity) and sustainability [25]. The task to adapt to new additional international regulations for carbon emission reduction and climate change in the international aviation arena is daunting and costly, to say the least.

This perspective implies that the social international aviation enterprise should entail cross-sector partnerships which traditionally entail a broad spectrum of stakeholder bases, which focus on challenging settings such as the bottom of the pyramid organizations, and the improvement of the situation of the community [34]. Consequently, social capabilities need to be addressed as enablers of CORSIA.

Table 4 presents a mapping of CORSIA against the TBL dimensions and their outcomes. The outcomes were extracted from the critical analysis above and the social resources-based view of the organization [23]. We also identified in Table 4 the statements that map to the outcomes. Out of the 20 TBL value creation outcomes, CORSIA meets 5 completely, and 3 partially. Twelve of those outcomes are not considered in CORSIA (see outcomes italicized). In that respect, a TBL approach to CORSIA and considering the TBL value creation

approach would present an important set of opportunities for its successful implementation, since all significant outcomes would be considered.

Table 4. CORSIA's needs and opportunities via the lens of shared TBL value creation objectives.

TBL Factor	Outcomes	CORSIA
Environmental	Carbon emissions reduction (Q5)	✓
	Management of non-compliance (Q1)	
	Use of renewable resources (Q4)	✓
	Carbon offsetting (Q3)	✓
	Carbon offsetting experience (Q9)	
	Governance mechanisms (Q1)	
	International cooperation capacity (Q1)	
	Management of non-renewable resources (Q4)	
	GHGs (Q2)	✓ Limited to CO_2/CO2e
Economic	*Innovation*	
	Increased efficiencies (Q6, Q7, Q8)	
	Enhanced processes (Q6, Q7, Q8)	
	Bottom of Pyramid	✓ Partially
	Incentives	
Social	*Community target (Q9)*	
	Access to education	✓
	Access to resources such as financial services	
	Stakeholder management	
	Collaboration and partnerships	✓
	Transparency of information	Mostly

Social capabilities as a concept (and a source for the TBL outcomes), are core to the alignment of socially responsible organizations and CORSIA and can be viewed as the ability to manage and utilize the broad spectrum of stakeholders for fair and equal exchange with respect to all tangible and intangible assets such as information, money, products, human resources, technologies, education, compassion, and care. In effect, tradeoffs need to be solved by combining these capabilities efficiently and effectively, and conflicts in motivation between private, public and non-profit stakeholders need to be resolved.

8. Conclusions

This paper primarily aims to analyze carbon emission reduction in the international aviation sector based on the body of scientific studies published in research journals. We utilized the TBL as a theoretical framework for the analysis and conducted an exploratory survey-based pilot study to better understand stakeholder perceptions of our findings from the literature analysis. This study was motivated by the lack of published research on the critical assessment of international aviation carbon emission reduction, which was also reported by many in the scientific community.

Since the task of CER regulations for international aviation was undertaken by the ICAO, we reviewed its most recent scheme, CORSIA (a significant effort in the right direction) and identified all published studies related to it, as well. However, concerns regarding its implementation and adoption were reported in the literature. Consequently, we provided an analysis of the literature on CORSIA through the lens of the TBL theory

and obtained feedback on our findings of critical reported issues via an exploratory pilot study conducted with 45 stakeholders.

We highlight some of the most significant findings. Sustainable aviation fuels have the potential for important climate impact (despite some major challenges such as that of cropland expansion), yet they are at an early stage of development in terms of application in general, and specifically in the aviation sector. Considering SAF for cleaner aviation, CORSIA is the first approach devised for the calculation of life cycle GHG emissions. It is also worth noting that the ICAO is engaged in ongoing work in relation to other sustainability themes including waste and chemicals, rights (human, labor, land use), local and social development, food security, water, soil, and air.

While CORSIA is being implemented, other carbon reduction initiatives are already in place in other countries and regions such as the European Green Deal, the European Renewable Energy Directive for SAFs, the SAF act in the United States, and the European Emission Trading Scheme. These initiatives are linked to CORSIA's sustainable alternative goals and may influence its implementation. Moreover, fuel producers would need to invest in re-engineering their distillation process and technology to obtain SAFs, and we echo the caution by [32] that organizations, governments, and other stakeholders still face significant cost barriers to realizing large-scale deployment of SAFs and corresponding GHG gains.

The TBL provides guidance on how international aviation carbon emissions reduction challenges can be managed within the three dimensions of environment, economic and social. Such is the case herein (in the pilot experiment results), where most stakeholders primarily are inclined to agree with the TBL economic dimension and its implications on the international aviation sector. Responses to the statements in the social dimension indicate that over 50% of stakeholders agree with challenges related to the managing of offsets and collusive behavior due to voluntary markets. When it comes to the environmental dimension of the TBL, there is a clear indication that stakeholders see ICAO's mandate as a challenge to CORSIA's implementation, and are less inclined to disagree with the way it aims to regulate GHGs, SAFs, and CER in general.

In general, results from the exploratory pilot study also revealed that approximately 50%, 60%, and 55% of the participants agree on the environmental, economic, and social challenges to the implementation of carbon emissions reduction in international aviation. Skewness analysis of the results indicates that economic challenges seem to be more on stakeholder's concerns, followed by social issues and then environmental challenges. Due to the large percentage of neutral responses and very low disagreement, it seems that social challenges to the implementation of CER regulations are not well understood which may suggest that only half believe it to be an important factor for success. In the same vein, respondents were more confident about economic issues, in terms of agreeing or not, as shown by less neutral responses of around 25% compared to that of social challenges.

Our research shows that it is important for CORSIA to re-align its design and implementation scheme with the community's concerns as highlighted by the TBL. The TBL value creation can be used as guidance for this re-alignment. We provide the following recommendations we feel are important areas of strategic implementation changes that CORSIA and other regulatory bodies (such as civil aviation authorities) may consider:

1. Central to its mandate, the ICAO can play a more significant role by enhancing its transparency related to SAF pathways and the approval process, more specifically for the submission of lifecycle assessment data, including: data collection necessary for calculations, monitoring, quality (to ensure credibility of information sources such as from peer-reviewed scientific studies), computational support, technical support, technology infrastructure support, transparency, accessibility, data submission, and knowledge management via case studies. In other words, stakeholders would benefit significantly if CORSIA would engage in facilitating access to a global network of specialists, support structures, and mechanisms.

2. Seek to establish an open-source international aviation data center (or data laboratory) that offers researchers and practitioners around the world an open platform to perform relevant international aviation data analytics and with the aim to increase scientific peer-reviewed publications in scientific journals and conferences, addressing CORSIA's objectives and evolution as it progresses through its implementation plan.
3. Revisit the CO_2 emissions reduction plan and align the plan strategically with other existing greenhouse gas climate action plans considering two components, the first being fixed for all states and the second being flexible to allow integration with existing national plans to limit their disruption due to CORSIA implementation.
4. Perform a more in-depth study/studies (in collaboration with) on the state-of-the-art of alternative fuels, seek feedback from the scientific community via publications in scientific journals, and build on the results to establish a data-supported policy and plan. As mentioned earlier, CORSIA has provided a detailed SAF document; however, a framework is needed on how the use of SAF is to be managed across the SAF stakeholders, and the readiness of the international aviation sector for switch-over. This is especially true since the SAF supply chain is a cross-cutting theme across multiple sectors and as such, is much more complex than simply following the scheme presented for allowable SAFs. We suggest establishing a section or unit where technical cooperation can occur to facilitate and support this initiative along the lines mentioned herein.
5. It is clear from the stakeholder's analysis of the TBL dimensions that economic considerations are the most important of the three dimensions, and the inclination of the responses strongly agree with the indicated challenges. Very few studies discuss the economic impact of regulations on commercial aviation stakeholders. This is especially true due to the nature of the aviation sector where many 'bottom of pyramid' (see Table 4) airlines exists and whose resources and capabilities are limited to dealing with such risk related to operational innovations (such as increasing efficiencies, and optimizing aircraft operations) which are not clear and established, COVID-19, which looks like it is here to stay, weather patterns caused by climate change, and geopolitical risks. We feel that it is important that CORSIA facilitates an "impact assessment on international aviation commerce" study involving, in the process, the global commercial sector in discussing feasible and equitable solutions for its implementation, and devising flexible mechanisms that mitigate the negative reactions of the commercial sector, and promote their growth through its implementation stages– Although the ICAO may be mandated for safety and security of international civil aviation, it should, as part of its social responsibility role, take serious consideration of its impact on healthy sector growth.
6. Regarding carbon offsetting schemes (issues indicated in questions 3 and 9), this subject matter, as has been discussed earlier in the introduction, is dubious with controversial history and outcomes. Several carbon offsetting schemes exist and can be viewed as being on a spectrum from highly regulated to the open market, making it very complex to implement and enforce. More importantly, the intended effects of carbon offsetting are still not agreed upon and are not clear. Whether carbon offsetting works or not is still being discussed, and when it comes to climate justice, it seems that the devil is in the details. Carbon offsetting has generated a lot of discussion and controversy and continues to do so today. Carbon offset credits may not represent acceptable GHG mitigation and can be misleading and cause adverse effects to communities. Since ICAO CORSIA includes carbon offsetting regulations, we feel it is its responsibility to provide a comprehensive understanding of what carbon offsetting entails, its challenges, and its acceptable use by all stakeholders. Essentially, we recommend that the ICAO encourages and facilitates the aggregation and dissemination of information related to carbon offsetting via such activities as the construction of relevant think tanks. Moreover, CORSIA could establish a carbon offsetting mechanism specific to the international aviation sector which takes into

account a balanced approach to the three TBL dimension. CORSIA is the only initiative that may steer the discussion away from offsetting and influence the minimization of using it as public relations while maximizing the focus on taking out emissions from the environment instead. Furthermore, since offsetting plans is unavoidable, CORSIA can consider being involved in technology innovations such as blockchain-based offsetting mechanisms to improve the quality of verification, monitoring and controls.

We presented in Table 4 how CORSIA's needs and opportunities are mapped against expected TBL outcomes, showing that there are yet a number of areas that CORSIA should consider playing a leadership role in to enhance its chances for its successful implementation, and more importantly, to engage the community at large in its mission. The TBL outcomes are derived from the study by [23] on the social resources-based view of the organization and the TBL. This table highlights the expanded role of regulatory bodies in general, and CORSIA specifically, by being more holistic in their implementation of standards and recommended practices. Impacts of expected outcomes across the TBL dimensions, such as management of non-compliance and stakeholders management, should be considered during the regulatory development process. Table 4 identifies 11 outcomes that can be considered as part of the regulatory implementation process.

Few articles relevant to this study have been published (also supported by [13]'s findings) related to carbon emissions reduction in the international aviation sector, seventeen of which focus on CORSIA. Considering the impact that CORSIA has in relation to the TBL (environment, economic, and social), it is only logical that this research body is relatively small. Every challenge/question (statement) identified in this paper (see Table 1) is an area that needs further in-depth research and lends itself to theoretical, applied, critical, review, and empirical types of studies. Due to the nature of international aviation, it is necessary to forge close relationships between industry, governments, regulatory bodies, and researchers, and operate as a harmonized and integral unit rather than the silos within which they exist today.

The implications of our work in this critical study stress the need for more cooperation and joint integrated research and development. To be more specific, we list our assessment of the most critical areas for research:

1. Evaluation of all GHG emissions and how to replace them with the CO2e part of CORSIA's scheme calculations.
2. Independent carbon credit market and offsetting mechanisms targeting international aviation carbon emissions reduction, whereby issues such as CER occur at the source rather than elsewhere in the world.
3. Managing the supply chain of SAF, its economic feasibility, and plan for the least disruptive integration.
4. Examining SAF vis à vis technological innovations, such as electric aircraft engines, and their feasibility in the long term.
5. All types of analysis in relation to the impact of different parts of CORSIA's scheme on the economic sustainability of stakeholders.
6. The effects of CORSIA's standards and recommended practices on changes in stakeholders' behavior.
7. The interactions between CORSIA's scheme with other environmental and national regulations.
8. CORSIA's role in supporting or disrupting the climate goals of other states.
9. Understanding stakeholders' perceptions and knowledge of CORSIA's elements, carbon emissions reduction initiatives, and climate goals.
10. Organizational, and countries' preparedness for CORSIA's implementation.

Our study has some limitations that we acknowledge and primarily entail the statements used in the exploratory study. Our methodology utilized the results of our critical analysis of published research to create those statements and to remain true to the research we did not process those statements into other terms. The resulting statements include complex notions and entail multiple areas. This is why some statements can be associated with more than one dimension of the TBL. The treatment of the questions has been elaborated in

the methodology section. However, this leaves us with the social dimension, which was challenging in associating it with the questions. This was treated herein by setting the scope of TBL to examine questions that are most illustrative of change of undesirable behavior that does not contribute (or even become detrimental) to the creation of commonly shared values and social progress (including environmental impact and passenger's behavior such as willingness to participate in carbon emissions reduction programs). As such, although questions 9 and 10 may have economic influences, they are viewed herein to have a closer association to behavior change (not necessarily obvious as direct impact, but as elaborated, at least indirect), and as such included in the social dimension. This limitation brings into light the perspective of the statements' complexity (as also evident in the number of neutral responses) and their direct and indirect effects on the TBL dimensions. In that perspective, more research is necessary and the statements in this study provide a starting point for future research where the issues are simplified and used to measure the TBL dimensions more accurately.

Moreover, in addition to how we scoped the social dimension in the study, there are other potential social issues that were not included in our pilot study nor found in other research works, that include developing countries (for example, their use of sustainable aviation fuels, impact on indigenous people, passenger's behavior, destination marketing in the tourism industry, or incentives related to greenwashing).

Furthermore, limitations can be found in the exploratory study. Acknowledging the difficulty associated with this kind of social sciences type of study and in relation to recruiting professionals in specific, the sample size can only allow us to perform descriptive statistics. A suitable larger sample would benefit is performing exploratory and confirmatory factor analyses to statistically support the questions and TBL dimensions as factors, and explain their relationships. This study provides a strong stepping stone toward this direction.

Considering that (1) in the short term, total CO_2 emissions for the CORSIA pilot stage will most likely be much lower than the established 2019 levels, and (2) in the longer term, the Paris Agreement targets are more stringent than CORSIA and would require much deeper cuts in aviation emissions, pressures by the international aviation stakeholders to take a proactive approach to the management of CORSIA seem to be marginalized. The CORSIA scheme needs to be revisited and aligned with the TBL and issues raised herein in order to harmonize its requirements with all stakeholders.

Moreover, there is a risk that CORSIA would not end up targeting aviation emissions but rather be considered as a maintenance scheme. Offsetting versus capping emissions that the EU ETS aims to achieve is a scenario that needs to be studied as it may render CORSIA less environmentally efficient in both the short and long terms [11,29]. Furthermore, technological innovation progress such as electricity and hydrogen, and operational improvements such as aircraft body designs, seat occupancy, taxiing behavior, takeoff and landings, etc., should be considered [35,36].

Ref. [4] estimate that international aviation emissions for the CORSIA pilot stage will be far below the 2019 levels. Consequently, they suggest that there will be very little motivation by the airline industry to manage their obligation proactively. As such, and in the post-COVID-19 pandemic, the focus of the international aviation carbon emissions paradigm would benefit by shifting to aligning the three dimensions of TBL, namely industry recovery (economic), GHGs (and not only CO2e) and climate change mitigation, and a socially oriented approach.

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