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# Aircraft cost index and the future of carbon emissions from air travel

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## HIGHLIGHTS

- Cost index determines the $CO_2$ emissions of a flight by controlling aircraft speed.
- Optimal use of cost index could reduce $CO_2$ emissions by 1% per flight on average.
- Carbon pricing has very little effect on the cost index.
- Importance of biofuels and direct routes highlighted using future cost index values.
- Airlines must improve their calculation of cost index to ensure reduced emissions.

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## ABSTRACT

Air travel accounts for 2% of global $CO_2$ emissions and this proportion is set to grow in the future. There are currently no large scale solutions to drastically reduce the industry's dependence on oil. Therefore, airlines are looking to use a basket of measures to reduce fuel consumption. Optimisation of the use of cost index (CI) could be a valuable addition to this. By balancing time-dependent costs with the cost of fuel, it controls the speed of the aircraft to achieve the most economic flight time. This has a direct impact on the $CO_2$ emissions from the aircraft, with higher speeds resulting in higher fuel consumption. The aim of this study is to assess the impact that CI has on $CO_2$ emissions for six different aircraft models on a flight-by-flight basis and to evaluate how the CI could be affected by future impacts on the industry for a representative aircraft. Results show that a range of representative CI values for different aircraft models exist and suggest that the maximum benefit for optimising CI values occurs for long range flights. The average saving in $CO_2$ emissions is 1%. Results show that time-related costs have the greatest effect on the optimum CI values, particularly delay costs. On the fuel side of the equation it is notable that a carbon price resulting from the implementation of a market based mechanism has little impact on the optimum CI and only reduces $CO_2$ emissions by 0.01% in this case. The largest savings in $CO_2$ emissions result from the use of biofuels, with reductions of between 9% and 44% for 10% and 50% blends respectively. This study also highlights the need for further research into crew and maintenance costs, cumulative costs and delay induced by congestion and climate change events, as well as policy considerations to ensure that there is a reduction in $CO_2$ emissions. The study concludes that CI should be seen as a valuable tool in both helping to reduce $CO_2$ emissions, as well to assess the impact of future events on the industry.



## 1. Introduction

Aviation emissions currently account for approximately 2% of global $CO_2$ emissions, but with few large-scale technological solutions and an annual average increase in demand for air travel of 5%, these emissions are set to represent a greater proportion of global emissions in the future. The industry is therefore reliant on a basket of smaller measures to contribute to stabilising emissions. These measures include improvements in aircraft technology such as propulsion efficiencies, reduction of drag and structural weight, operational improvements, such as more efficient flight paths, and market based measures. With the majority of these measures only producing small savings of less than 5% by 2020 [1], this highlights the need for the use of multiple measures to stabilise emissions.

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The International Civil Aviation Organisation (ICAO) aims for a 2% improvement in fuel efficiency per annum in the short term, with the objective of stabilisation of global $CO_2$ emissions at 2020 levels through incremental improvements in efficiency.

The cost index (CI) is a tool, which has been available in most commercial aircraft since the 1970s, has the potential to contribute to the basket of measures. Fuel costs have increasingly become one of the largest burdens to airlines accounting for 32% of global airline operating expenses in 2014, five times higher than in 2003 [2]. Therefore, there would appear to be an impetus to optimise flight operations in favour of lower fuel use. One of the easiest ways to do this is to reduce the speed of a flight. However, fuel is not the only cost that needs to be considered, as slower flights can also increase other costs. These are termed time-dependent costs and refer primarily to crew costs and maintenance, which are paid by the flight hour. In the case of delay, time-dependent costs associated with passenger compensation also become important. Therefore, the purpose of the CI is to find the speed which results in the minimum cost when both fuel costs and time-dependent costs are taken into account.

The CI represents the cost per unit of time divided by the cost per unit of fuel, for a specific flight. The value that results from this calculation is supplied to the pilot in the briefing package, who enters it into the Flight Management Computer (FMC) prior to departure. As CI values are determined in advance, the FMC will automatically calculate the final flight profile by adjusting the figure to incorporate conditions for that particular flight, such as wind speed and altitude. The CI is the tool that ultimately determines the $CO_2$ emissions on a flight-by-flight basis, which are directly proportional to the amount of fuel used, and therefore should not be overlooked as contributing to the basket of measures to reduce emissions.

There has been very limited research on the effect that CI has on fuel use and $CO_2$ emissions, given its importance on a flight-by-flight basis. There are two early studies that relate the CI to fuel use savings, Liden [3] and DeJonge and Syblon [4]. These studies highlighted the importance of optimising CI in terms of its impact on fuel use and in reducing $CO_2$ emissions. More recent studies have also looked at the issue of fuel use and the speed of the aircraft but have principally addressed the problem from the delay recovery point of view rather than optimisation of CI on a flight-by-flight basis [5–7].

Optimisation of CI is still an area that needs a significant amount of research and effort by airlines for implementation. There are reports of a small number of airlines putting significant efforts into this issue. The most notable is Air Canada, who began their efforts in the early 1990s. In 2009 it was reported that the airline had carried out the initial stages of their City Pair CI program, resulting in fuel savings of $4.7 million annually and a greenhouse gas reduction of 20,000 tonnes. The program tailors CI values to specific city pairs and the latter stages alter schedules to accommodate optimum CI values [8].

However, there can be difficulties amongst airlines in optimising CI values. Burrows et al. [9] highlights some of the ways in which CI is misused, such as general miscalculation, the use of average CI values when fuel costs diverge widely on different flight sectors and failing to revise CIs when fuel or other cost elements change substantially enough to vary optimum CI speeds. Artürk et al. [5] adds that the current standard CI does not fully capture the flexibility of controllable flight times and even in the area where there has been the most research, delay management, optimisation decision support tools are still at the early stage of implementation at major airlines. Cook et al. [10] is one of the only recent studies that has included $CO_2$ emissions in its analysis. A Dynamic CI is proposed including an environmental decision support tool, although there is no in-depth analysis of savings in emissions from changing CI values. Another is [11] who examine the use of optimum speeds and altitudes against those currently used. The study finds that higher savings can be made from optimising speed compared to altitude with savings of 2.4% compared to 1.5% respectively. This has a system wide benefit of a saving in 300 billion gallons of fuel and 3.3 billion tonnes of $CO_2$ annually.

From examining the literature it is clear that there are significant gaps in research regarding the value of CI, not just for delay recovery, but also for normal operations to reduce fuel and $CO_2$ emissions. There have been no recent studies which have examined the effect of CI on different aircraft models across different distances in terms of flight time, fuel use and $CO_2$ emissions.

The opportunity to use the CI as a tool to establish the impact of future events on the aviation industry for individual flights has also not been realised. An important addition to the CI equation in the near future could be putting a price on carbon from the introduction of a market-based mechanism by ICAO. There are a number of other factors that will have an impact in the longer term. Time-related costs may increase significantly in the future owing to delay if capacity issues are not resolved and there may be more weather related delay owing to the effects of climate change. Positive developments, such as the introduction of biofuels and more efficient routing can also help to further reduce $CO_2$ emissions whilst maintaining competitive flight times.

The aim of this study is to assess the impact that CI has on aircraft $CO_2$ emissions and how this impact could evolve in the future. The objectives are to examine the CI range for a variety of aircraft models over different flight distances and assess the change in fuel consumption between CI values. The other key objective is to see how future events on the aviation industry may affect CI values and highlight where further research and policy intervention is needed. The value in this research is two-fold, firstly to assess the importance of CI in fuel use and emissions savings, which will aid airlines in understanding the importance of the CI, and secondly to demonstrate how the CI can also be used as a tool for policy makers and aviation organisations in helping to assess the impact of future policy decisions on climate change mitigation on an individual flight basis.

## 2. Methodology

### *2.1. Calculating cost index values for six aircraft models*

The effect of CI on the fuel use and flight time for different aircraft models was determined using Piano-X [12]. This is an aircraft analysis tool based on Piano, which is a widely used tool worldwide by airframe and engine manufacturers and in major environmental studies and by ICAO. Flight profiles can be created by adjusting performance characteristics, drag, fuel consumption and environmental emission indices. The six aircraft models analysed using this software were the A300-600R; A340-600; A380-800; B767-300ER; B777-300ER; and the B787-8. The six aircraft were chosen based on their availability in Piano-X. They have different design ranges to provide insight into the effect that CI has on different types of aircraft.

Fig. 1 shows the process involved with producing a range of CI values for each aircraft model. Distances between 1000NM and 6000NM were used, along with the design ranges of each aircraft. Standard Piano-X settings for thrust, drag and fuel reserves were used, along with passenger numbers for the different aircraft types. These were obtained from the aircraft manufacturer, with seating configurations for two classes for the A300-600R and three classes for the other aircraft models. The economy speed setting is used in the first instance to find the speed that corresponds to the maximum range cruise (MRC). This is the speed at which CI = 0 i.e.