A New Model for Aircraft Cost Index Calculation

Holly Edwards*, Doctoral Training Centre in Low Carbon Technologies, University of Leeds, Leeds, LS2 9JT, UK, Tel: +447875531114, E: pmhae@leeds.ac.uk

Darron Dixon-Hardy, Energy Research Institute, University of Leeds, Leeds, LS2 9JT, UK, Tel: +44113 3432800, E: D.W.Dixon-Hardy@leeds.ac.uk

Zia Wadud, Centre for Integrated Energy Research and Institute of Transport Studies, University of Leeds, Leeds, LS2 9JT, UK, Tel: +44113 34 37733, E: Z.Wadud@leeds.ac.uk

*Corresponding Author

1 August 2015
ABSTRACT

The cost index (CI) is a tool that is growing in importance for airlines. It works by balancing the costs of time with the cost of fuel to determine the speed of a flight. Slower speeds result in fuel cost savings but higher time-dependent costs and faster flights vice versa. With the cost of fuel rising and climate change issues surrounding air travel increasing the need for efficiency, the CI needs to be optimised. However, in general airlines find the calculation of CI challenging, particularly regarding extra costs owing to delay and cumulative maintenance and crew costs. The aim of this paper is to present a new way of calculating CI values on a flight-to-flight basis through the optimised cost index (OCI) model. Instead of constraining all costs to the traditional CI equation, the OCI model uses additional alternative calculations to take all costs into account fully. The OCI model provides an accessible and transparent way of calculating optimum CI values for airlines through a simple interface. In the future the model can also be used to assess the impact of future policies on a flight-to-flight basis, adding extra value to the OCI model.
1 INTRODUCTION

The cost index (CI) has been available in most commercial aircraft since the 1970s, with the purpose of controlling the speed of aircraft in order to minimise operational costs. Fuel costs have increasingly become one of the largest costs to airlines, accounting for 32% of global airline operating expenses in 2014, which is five times higher than in 2003 [1], suggesting 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 needing to be considered, as slower flights can also increase other costs. Time-dependent costs include crew costs and maintenance, which are paid by the flight hour and increase with slower aircraft speeds. In the case of delay, time-dependent costs associated with passenger compensation also become important.

The CI represents the cost per unit of time divided by the cost per unit of fuel, for a specific flight. The resulting value 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. CI values range from zero at Maximum Range Cruise (MRC) where fuel costs are minimised, to a value corresponding to the highest possible aircraft speed, where time-dependent costs are minimised.

As well as flight time and fuel use, the CI ultimately determines the CO$_2$ emissions on a flight-by-flight basis, which are directly proportional to the amount of fuel used. Aviation emissions currently account for 3% of global CO$_2$ emissions, but with an annual average increase in demand for air travel of 5%, these emissions are set to represent a much greater proportion of global emissions in the future. With limited large-scale technological solutions, the industry is reliant on a basket of smaller measures to combat increases in emissions. The CI could be a valuable contributor to these measures if its use can be optimised.

Limited research exists on the optimisation of CI for normal operations, especially in terms of its effect on fuel use and CO$_2$ emissions. Two early studies relating the CI to fuel use savings are Liden [2] and Dejonge and Syblon [3]. More recent studies have 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 [4, 5].

Cook et al. [6] have undertaken the most comprehensive work regarding the CI and have produced one of the few studies to include environmental impacts in their analysis. The study focuses on creating a dynamic CI tool to help with delay recovery. The inclusion of an environmental decision tool and an environmental signature acknowledges that the “political position relating to emission charges is uncertain therefore a flexible framework” is needed to ensure that the dynamic CI stays relevant in the decision making process in response to delay.

A previous study by the authors [7] shows the importance of CI in determining emissions on a flight-by-flight basis by comparing fuel burn and flight time of six different aircraft models over six different distances (Figure 1). When aircraft are flown at their design range the difference between the maximum CI and MRC, an average of 1% emissions saving can be made, with as much as a 3.9% change in CO$_2$ emissions for the A380-800. This may seem small but if 1% of the global CO$_2$ emissions from aviation of 705,000,000 tonnes were reduced, this would be equivalent to the CO$_2$ emissions of around 1000 long-haul flights. This also represents a saving of in the global aviation fuel bill of around $2 billion a year. As aircraft are already equipped with the cost index tool, there are only small monetary and time costs involved in implementing changes.

Although it is generally accepted that aircraft fly at their Long Range Cruise (LRC) speed – one in which a 1% penalty in fuel consumption is sacrificed for a faster flight time – research by Lovegren and Hansman [8] shows that this is not always the case and in fact a large number of aircraft fly above these speeds and a 1.6% saving could be achieved by moving to flying at LRC, with a 2.4% for optimisation to MRC speed.

But there are significant gaps in the research regarding the value and optimisation of CI. Most studies focus on delay recovery, but CI is also important for normal operations in determining the optimal speed of the aircraft. Although there is consensus that CI is a useful tool there has been little work on how to optimise it in a practical way for airline use and address issues with its calculation.
The aim of this paper is to demonstrate how CI can be optimised using a newly created optimised cost index (OCI) model taking into account the current difficulties in CI calculation by airlines. Section 2 evaluates the issues that exist with the current use of CI, justifying the need for a new model and Section 3 outlines the setup of the OCI model created by the authors. Section 4 discusses the results of a sensitivity analysis using the model and Section 5 discusses its practical use within the airline industry, as well as areas for future research.

2 ISSUES WITH EXISTING COST INDEX

Two issues can arise with the use of CI; incorrect use and/or miscalculating the costs associated with the CI equation. Airlines have been reported to use CI to approximate the Long Range Cruise (LRC) - this where a 1% penalty in fuel consumption is taken in exchange for a faster flight time; adjustment to higher CI values if necessary for schedule regardless of the associated fuel costs; calculating a speed just below LRC; meeting schedule requirements; adoption of CI values from other aircraft models; and adapting speed requirements only [9].

Airlines are often hindered by the complication of apportioning costs for the CI equation. Fuel costs are the most volatile aspect of the calculation and CI values need readjustment regularly to take changes into account. However, the difficulties associated with time costs are more fundamental. Evidence suggests that many airlines make elementary errors in this area or make questionable assumptions, such as assuming that maintenance costs owing to flight hours are 50% of total maintenance costs [10].

Crew labour costs cause problems in determining the optimum CI as they can vary significantly depending on the country of operation, the type of operation and the size of the aircraft [11]. There are also issues with estimating costs for relief pilots, overtime payments and rest hours required between flights [10, 12]. These latter issues are complicated by the need to determine them over a period of time e.g. a month or a year, not just one flight. Faster flight times can reduce the amount of rest times need and may avoid the need for reinforced crews, but conversely slower speeds eventually lead to block hour increases to the extent that additional crew need to be recruited [10].

The other key component of time cost is maintenance. The principle time-dependent costs arising include engine components and the labour intensive nature of checks required at certain flight time intervals. As these checks take place over a number of years marginal costs needs to be based on a total five year maintenance program [10]. Difficulties differentiating from flight cycle costs from flight hour costs creates a significant barrier to accurate costing [10, 13]. In addition, maturity of the aircraft also needs to be taken into account, as this has a significant impact on the cost of aircraft maintenance at a given time [14].

Once time-dependent costs are correctly calculated, they should not significantly change over time as they are under the control of the airline, unlike fuel costs, which can change rapidly. A caveat to this is the occasional change to these costs from external sources. For example, in 2013 the European Parliament implemented new aircrew fatigue legislation. Maximum flight duty time was decreased by 45 minutes for pilots on night flights, as well as the maximum number of flight hours in a 12 month period [15]. This results in increased pressure on scheduling crews and may require either more overtime payments or the addition of extra relief crews, adding to the issue of cumulative costs.

In the case of delay, resulting passenger costs also need to be accounted for in the CI calculation, which are divided into hard and soft costs. Hard costs include actual bottom line costs to the airline from rebooking passengers onto other flights if connections are missed and providing compensation. Soft costs mainly concern a loss of market share owing to passenger dissatisfaction. In theory hard costs should be easier for airlines to calculate, but this is generally not the case as the data involved can be very complex. Soft costs are understandably difficult to calculate as they rely on a number of assumptions and on market conditions [6].
Figure 1: The relationship between fuel burn and flight time for six aircraft models over six distances with data points representing individual CI values. Note: A300-600 unable to fly at distances over 3000nm [7].
Aktürk et al. [4] 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.

Encouraging airlines to optimise their use of CI may be a considerable challenge. Airbus [9, pp.8] states that “the mere fact that fuel costs can significantly vary from one sector to another throughout the year should prompt airlines to consider adopting different cost indices for their various routes”. However, this appears not to be the case and it is added that operations departments struggle to persuade airline financial analysts to assess marginal operating costs, probably as they have not understood the importance of the CI, which is still a largely unknown concept to their decision makers.

Burrows et al. [10, pp.282] backs up these assertions stating that the CI is “an accounting innovation which has been developed by largely non-accountants”, resulting in airlines failing to exploit the full economic potential of CI. Simulations of CI calculations by Burrows et al. [10] indicate that there is sufficient sensitivity of ECON speed to change in input variables and the mis-specifying of variables produces sub-optimal speeds.

Given the issues that have been discussed it is evident that there are two key areas that need to be addressed in terms of providing a new model for calculation of CI values. Firstly it needs to be shown that improved CI values can be calculated in a simple and cost effective way and secondly that the problems with calculation of costs can be overcome.

3 CREATING THE OCI MODEL

The OCI model is created with the aim of providing an easy to use interface to calculate CI values initially using the CI calculation and then adjusting for addition costs and schedule restrictions. Figure 2 presents the processes involved in the OCI model. Produced using Excel, the basic premise of the model is to avoid constraining all costs to the traditional CI equation, but to instead use additional calculations to determine the optimum CI value. The model is set up in such a way that the CI is calculated on a flight-by-flight basis, taking into account the specific aircraft, flight characteristics for that day and up-to-date costing information.

From the airlines perspective the model should be easy to use on a day-to-day basis. The interface page requires simple inputs about the flight that should be known to the airline’s operation department and the only page of the model they should have to use on a regular basis. These inputs are:

1. Flight No. – linked by a dropdown list to the flight database page.
2. Aircraft Code – a dropdown list is used to pinpoint the specific aircraft in the maintenance database. Even for the same model, different aircraft will have varying maintenance costs depending on age and number of hours already flown for the month is question.
3. Average Wind Speed – represents the average wind speed in knots excepted for the flight in question.
4. Crew Members – a drop down list of crew members linked to the crew database.
5. Cargo Weight – weight of cargo being carried on the flight that is linked to the Flight Data.
6. Number of Passengers – total number which is linked to the Flight Data.
7. Expected Delay – this can include the number the minutes of expected delay for an aircraft by either regular holding time at the destination airport or unexpected delay owing to factors, such as weather and maintenance problems.
8. Connecting Passengers – this requires the number of passengers for each class that are connecting for each onward flight to be entered. This will be linked to delay costs.

Once all of these inputs have been entered the user can then press the calculate button. The optimal CI is displayed from the calculation page in both kg/min and 100lb/hour as different flight management systems use different units. The corresponding Mach number, flight time, fuel use and emissions of CO₂, NOₓ, hydrocarbon and carbon monoxide emissions are also displayed.

Figure 2: Cost Index Model Processes

Inputs are linked to eight other worksheets representing the individual aspects of the cost calculation. These should only need to be sporadically updated by the airline. The first worksheet compiles the crew costs for all flight and cabin crew of the airline. As well as basic salary information, the number
of hours already flown for the month and number of hours remaining are presented. In order to take account of cumulative crew costs the time available for the flight in question is calculated by the flights already flown and the scheduled time for the flights remaining (Equation 1).

\[ T_F = (T_M - T_F) - T_R \]  \hspace{1cm} [1]

Where:
- \( T_F \) = Time available for the flight in question
- \( T_M \) = Maximum time available per month for crew member before overtime
- \( T_F \) = Time already flown this month by crew member
- \( T_R \) = Time needed for other flights remaining to be flown this month

The maintenance costs worksheet works in a similar way with each aircraft in the fleet being available for the user to choose from a dropdown list on the interface page. Information is held on each aircraft for time-dependent maintenance costs and hours flown in the given month. Also if the aircraft is under a maintenance contract then the contracted hours and the hours remaining on that contract are also included.

The fuel worksheet contains the spot price of jet fuel taken from the interface page along with the percentage of fuel that is hedged and the hedging price. It is anticipated that the latter two will need occasional adjustments by the airline but not as regularly as the spot price of fuel, therefore are not included on the interface page. The other fuel related cost included here is the carbon price, if applicable, which is proportional to the amount of fuel used. The total fuel costs are calculated from Equation 2.

\[ F_C = (%F_H \times F_{HP}) + (%F_S \times F_{SP}) + CP \]  \hspace{1cm} [2]

Where:
- \( F_C \) = Fuel Cost ($/kg)
- \%F_H = % of jet fuel that is hedged
- \( F_{HP} \) = Jet fuel hedge price ($/kg)
- \%F_S = % of jet fuel that is not hedged and subject to the spot price
- \( F_{SP} \) = Jet fuel spot price ($/kg)
- CP = Carbon price ($/kg)

There are three types of passenger delay costs that need to be taken into account (Figure 3). The simplest calculation is for those passengers not connecting to other flights. These passengers will be owed compensation (depending on the country in which the flight arrives) if the flight is later than a defined period e.g. 3 hours. Connecting passengers will need to be rebooked onto other flights if they miss them owing to delay of the original flight, as well as any compensation if their final flight arrives after the defined period. The third does not concern passengers of the original flight, but the passengers on the succeeding flight by the same aircraft. In this case help and care costs i.e. meal vouchers, phone cards etc. are required to be paid if the aircraft is late departing. These are again only payable after a certain period of time and depend in part on the minimum time that the aircraft can be turned around in.

Compensation costs are calculated by multiplying the number of passengers by the amount of compensation if the delay exceeds a certain period of time. For example in the EU there are different categories of compensation for short-, medium- and long-haul flights with the minimum delay period being three hours before passengers are entitled to this compensation.
For care costs the minimum turnaround time for the aircraft is taken from the actual time between the two flights (if there is a difference) and this is taken from the overall delay time. The new departure time is calculated from this delay and compared with the original delay time. If a delay time threshold is crossed, the care costs are multiplied by the number of passengers on that next flight. Accommodation is also included in the care cost if a night-time threshold is reached. Equations 3 and 4 demonstrate the process in the model to determine if care and help costs need to be paid and if so by how much, using IF functions.

\[
A = \text{IF}((D_{PS} + (D_{PS} - (I_S - I_{MIN})) > NT, "Yes", "No")}
\]

\[
TC_H = \text{IF}(A = "Yes", (C_A + C_H) \times P, \text{IF}(D_R > D_T, C_H \times P, 0))
\]

Where:
- \(A\) = Overnight accommodation required
- \(D_{PS}\) = New departure time
- \(I_S\) = Scheduled interval between flights
- \(I_{MIN}\) = Minimum interval between flights i.e. fastest turnaround of the aircraft
- \(NT\) = Night time threshold time
- \(TC_{AH}\) = Total cost of help, care and accommodation
- \(C_A\) = Cost of overnight accommodation
- \(C_H\) = Cost of care and help
- \(P\) = Number of passengers
- \(D_R\) = Remaining delay after turnaround of aircraft
- \(D_T\) = Care and help delay time threshold
- \(C_H\) = Cost of care and help
Rebooking passengers is slightly more complicated. Firstly it is calculated as to whether passengers will miss their connecting flights given the information inputted on the interface page by the airline. The departure time for the connecting flight is taken from the flight information page and compared to the expected arrival time of the original aircraft given the expected delay. This gives the available transfer time, which is compared against the minimum transfer time required by the passengers. Whether the flight will be missed or not can then be determined (Equation 5).

\[ \text{MF} = \text{IF} ((\text{DP}_C - \text{AR}_O) - I_S) > 0, \text{No}, \text{Yes}) \]  

Where:

MF = Missed Flight
DP\_C = Scheduled departure time for connecting flight
AR\_O = Arrival time of original flight
I\_S = Scheduled interval between two flights

If the output is no, then no costs are incurred, if the output is yes then the same process is undertaken for the next available flight and so on. If a flight has to be rebooked it is first determined whether the flight is operated by the same airline as the original airline by searching for the identifier for that airline in the flight code. If it is a flight operated by another airline then rebooking costs depending on the class of passenger are multiplied by the number of passengers in that class.

The remaining parts of the model focus on the calculation of the optimum CI. A database of flight Mach speeds is necessary to find the optimum speed. This data is taken from Piano-X [16]. This is an aircraft analysis tool based on Piano, which is a widely used tool worldwide by airframe and engine manufacturers, in major environmental studies and by the International Civil Aviation Organisation (ICAO). Flight profiles can be created by adjusting performance characteristics, drag, fuel consumption and environmental emission indices.

Using the number of passengers, cargo weight and the distance of the flight, a range of speeds for the flight in question can be calculated. Firstly the MRC of the flight is calculated from the economy speed setting in Piano-X. This gives an output displaying flight time, fuel use and emissions of the flight. Mach numbers at 0.001 increments are then inputted into Piano-X starting from the MRC up to the maximum speed the aircraft is able to fly, with every flight time, fuel use and emissions value taken for the individual speeds. The initial CI calculation takes the form of the traditional CI calculation using data previously calculated in the preceding databases (Equation 6).

\[ CI = \frac{L_C + M_C}{F_C} \]  

Where:

CI = Cost Index (kg/min)
L\_C = Labour Costs ($/min)
M\_C = Maintenance Costs ($/min)
F\_C = Fuel Costs ($/kg)

Once the CI is found it is used to find the Cost Function (CF) for each Mach number calculated by using Equation 7. The Mach number for which the lowest CF is found i.e. where direct operating costs are minimised is the desired flight profile that results from the calculated CI, giving the flight time needed for further calculations.

\[ CF = \frac{ff + CI}{V_g} \]  

Where:
ff = fuel flow in kg/min  
CI = in kg/min  
Vg = Ground Speed which is the Mach (including addition of wind speed) multiplied by the speed of sound at altitude.

The final part of the model is the optimisation of the CI. In total four different CI values are calculated and the one that results in the lowest cost within the flight schedule is the one chosen as the optimum CI value to use for the flight. The four CI values are as follows:

CI-1 The initial CI value calculated from the per-minute time-dependent costs and the fuel costs per kilogram for that flight.

CI-2 A new CI is calculated if the flight time from CI-1 does not fit the schedule representing the closest flight parameters that does meet schedule time.

CI-3 A recalculated CI taking into account delay, if present. This calculates any passenger costs and overtime for crew or maintenance.

CI-4 If delay is present this recalculates the CI to make up as much of the delay as possible, regardless of the total cost.

For the original CI-1 flight the cost of labour, maintenance and fuel are combined with the additional costs of delay. Crew overtime costs are calculated by taking the hours available and comparing them to the actual time of the flight with delay. If this number comes out positive i.e. more time than the crew have available then the amount of overtime for the month is calculated for each crew member. There are three categories for this: 84-90 hours at 1.5 times salary, 90-100 hours at 2.5 times salary and over 100 hours at 3.5 times salary.

For maintenance, the contracted hours or extra hours affecting flight maintenance schedules are also calculated in a similar way. An exceedance of hours resulting in any penalty payments will also be added to the cost. Passenger delay costs will also need to be added as described previously i.e. compensation, help and care and the rebooking of passengers.

For the newly recalculated CI-3 and CI-4 values flight the costs are calculated in a similar way but with smaller delay costs. For CI-4 this may mean no delay costs if all delay time can be made up in-flight but when the delay is so significant that it cannot be accounted for in the schedule, even with the fastest possible flight time, delay costs are applied to remaining delay time. This basically assesses whether a faster flight to avoid delay is worth it when additional fuel costs are considered.

Once these total costs for the different CI values have been calculated the smallest total cost is found and this is the CI that is displayed to the user on the interface page, along with the flight characteristics e.g. fuel use, emissions, flight time etc.

4 RESULTS OF MODEL USE

Using current fuel prices and costs provided by a major international airline, a 10% increase in inputs to the OCI model on the key outputs was undertaken to test the use of the model. It is evident that fuel price and time-dependent costs have a very similar impact on all the outputs. The only slight variation is in flight time where time costs have a slightly higher impact in decreasing flight time, although all results are fairly negligible. As the CI balances extra delay, increasing it by 10% has no or very little impact.

As CI is not linear the sensitivity of results depends on the base CI that is used. As seen in Figure 1 the higher the CI the greater effect changing it can have on outputs. The same analysis as previously undertaken at a CI of 40 was performed with a base CI of 100. In this case, the impacts on fuel use, flight time and emissions are still small, although higher than for CI=40. However, this time the impact on total costs is more noticeable with fuel price having the greatest impact, followed by time costs.
In the sensitivity analysis the 10% increase in delay time was conducted from a low base of 15 minutes, therefore a 10% increase had very little impact. However, delay costs associated with passenger compensation and care/help costs are unique in that specific delay time thresholds trigger them. In the case of long haul flights this is at three and five hours. It is evident from Error! Reference source not found. that the impact of these thresholds being passed is significant. When there is any delay the alternate optimum CI is always favoured, although the difference between this and the normal CI is marginal. However it is clear that once the three-hour threshold is passed, costs are kept to a minimum by taking account of this extra delay, opposed to using the normal CI that would cause total costs to spike dramatically.

However, it is very important to note that accounting for extra passenger delay costs does not mean trying to recover all the delay time. This is also represented in Figure 4, showing that the total costs are still higher than optimum CI and are still subject to the same thresholds as the normal CI value. This is because this strategy of recovering delay does not include the additional costs of fuel that result from such a substantial increase in speed caused by the significant increase in CI.

![Figure 4: Impact of delay time on total costs and change in CO\textsubscript{2} emissions](image)

However, there is also another complicating factor: the impact on CO\textsubscript{2} emissions. In contrast to total costs, the best scenario would be the one where the normal CI value is used. The optimum CI still performs well compared to the normal CI until delay reaches around 120 minutes when the CO\textsubscript{2} emissions start to increase. By far the worst scenario for CO\textsubscript{2} is the one where all delay time is recovered. This is partly to do with the fact that at present the emission of CO\textsubscript{2} is not priced and therefore in the CI equation it currently has no value. If a carbon price was to be added then this could change the situation. However the highest carbon price projected by DECC [17] in 2050 is $124/kg. Even with only a 15-minute delay a price double this would be needed to stop the CI from increasing. As delay gets higher this number increases dramatically. At only 45 minutes the price needed would be $11/kg, at 180 minutes $35/kg and at 300 minutes $100/kg. These latter prices for carbon are very unrealistic; therefore this highlights the need to reduce delay in order to reduce carbon emissions as well.

5 APPLICATION OF THE OCI MODEL

The aim of creating the OCI model is to make an accessible and transparent model for the calculation of optimal CI for airlines. Excel is deliberately used for this purpose as it creates a more accessible model with the steps involved in calculation easy to follow. By seeing that these kinds of calculations
can be done in this way may help to convince airlines that optimising the CI is something that can easily incorporate into their flight planning systems. The use of Excel also makes the model easily adaptable by airlines. The setup of the model means that on a day-to-day basis airline operations would only need to use the interface page. However, adjustments to other parts of the model would need to be made occasionally, such as the amount of fuel hedged and at what price, additional connecting services, additional crew etc., although this is relatively easy to do.

Whilst the model effectively addresses the problems that exist with cumulative crew costs, there are some costs that the airline may still find it hard to account for. For example, maintenance costs are particularly problematic. Although the model does address the issue of maintenance contracts, the initial maintenance costs may still not be known as discussed in section 3. It is suggested that if maintenance costs cannot be determined by the airline, a good estimation to use would be the costs for A and C checks as suggested by the University of Westminster Transport Studies Group [14].

Delay costs represent one of the trickiest parts of the model, as it is so changeable even throughout the flight. Delay management is already a part of some airline’s decision process. The OCI model is flexible enough to accommodate an airlines own system of accounting for delay if necessary. The only caveat with this is ensuring that airlines delay models actually take the balance of costs into account, with extra fuel costs being considered as well as time dependent costs.

There is also the option of airlines using a basic version of the OCI model, which has the same features of the OCI model, but with a slimmer down delay cost calculation. These delay costs are taken from the University of Westminster Transport Studies Group [18] who have done extensive work in this area and include pre-set values for different delay categories (e.g. 1-15 minutes, 16-30 minutes etc.). This means that airlines do not need to include the connecting flights of passengers, which may be more time consuming. However, this method should be used with caution as these costs are not airline specific and therefore are only a rough estimate compared to the advanced OCI model.

Whilst this model does provide a significant improvement on the current system of CI calculation, there are still areas that could be improved upon. Firstly the Piano-X calculations are time consuming as each Mach number has to be generated individually. Using average passenger numbers and cargo loads for the flight in question could solve this. However, it should be noted that Piano-X is free software whereas most airlines have more sophisticated flight analysis software at their disposal. Therefore, this could be integrated into the system to optimise calculations.

Another issue is the amount of data potentially needing to be held in the worksheet for flights, crew members and aircraft. Multiple copies of the model can be created for different flights, which may overcome the problem. However, more powerful computing software may be needed in the future to accommodate data demands. This will ultimately depend on the individual airline using the model.

Even though these issues need to be addressed, it should be noted that if the assertion by Burrows et al. [10] that “relatively crude approaches are likely to be cost effective” is correct then the model still has significant value even when inputs may not be 100% accurately known by the airline e.g. good estimation of maintenance costs would be sufficient.

Going forward the model will also be used as part of on-going research into the effects of policy on flights costs and emissions. This adds additional value to the OCI model, making it not just of use to airlines but also to policy makers and airline authorities.

6 CONCLUSION

With rising fuel costs and climate change concerns, the optimisation of the CI calculation is vital. To date there has been a general issue amongst airlines with the misuse or miscalculation of CI values which has led to the practice of sub-optimal CI values being used.

Many airlines have expressed an interest in correcting this as they begin to appreciate the value of CI in optimising costs. Therefore the aim of this research was to create a new model for the calculation of the optimum CI. The OCI model looks to break out of the assertion that the calculation must take place within the constraints of traditional CI equation and instead proposes that complex cost factors should be dealt with in an alternative way. The OCI does use the CI equation as a basis
for the initial CI calculation, but then relies on an assessment of whether the flight can be achieved in a scheduled time, including delay. If not then further calculations can be made that take into account any additional costs to achieve this flight with the current CI, such as cumulative crew costs, extra maintenance costs and the cost of passenger delay and compare those with the cost of flying at a CI which will result in a faster flight, within schedule.

The OCI model which has been created has shown that these calculations can be conducted in this way with a simple to use interface for airline operations departments. Further adaptation of the model could take place with, for example, airlines integrated their own flight analysis software to increase its functionality. But the basic premise of the model provides evidence that optimisation of CI can take place in an efficient manner that is neither costly nor time consuming.

In addition to developing this model as a tool for airlines, the model will also be used in future research to assess the impact of changing costs and policy on a flight-by-flight basis. This will particularly focus on the potential introduction of a carbon price, as well as an increase in fuel prices in the future. This adds value to the OCI model as it can not only be of benefit to airlines, but also to policy makers and aviation authorities.

ACKNOWLEDGEMENT

This work was financially supported by the Engineering and Physical Sciences Research Council through the University of Leeds Doctoral Training Centre in Low Carbon Technologies.

REFERENCES

8. Lovegren, J.A. and R.J. Hansman, Estimation of potential aircraft fuel burn reduction in cruise via speed and altitude optimization strategies, in International Center for Air Transportation. 2011, Massachusetts Institute of Technology: Cambridge MA.
9. Airbus, Getting to grips with the cost index 1998, Flight Operations Support & Line Assistance Blagnac Cedex, France


16. Lissys Ltd. *Piano-X* 2010 14/08/2013]; Available from: [http://www.lissys.demon.co.uk/PianoX.html](http://www.lissys.demon.co.uk/PianoX.html).
