

Cost Effective Measures to Reduce CO₂ Emissions in the Air Freight Sector

Magnus Blinge (Ph.D.)

TFK – Transport Research Institute,
Vera Sandbergs Allé 8, 412 96 Göteborg,
SWEDEN

Tel.: +46 31 772 51 65, Fax: +46 31 772 51 64,
magnus.blinge@tfk.se

Abstract

This paper presents cost effective measures to reduce CO₂ emissions in the air freight sector. One door-to-door transport chain is studied in detail from a Scandinavian city to a city in southern Europe. The transport chain was selected by a group of representatives from the air freight sector in order to encompass general characteristics within the sector.

Three different ways of shipping air cargo are studied, i.e., by air freighter, as belly freight (in passenger aircrafts) and trucking. CO₂ emissions are calculated for each part of the transport chain and its relative importance towards the total amount CO₂ emitted during the whole transport chain is shown. It is confirmed that the most CO₂ emitting part of the transport chain is the actual flight and that it is in the take-off and climbing phases that most fuel are burned. It is also known that the technical development of aircraft implies a reduction in fuel consumption for each new generation of aircraft. Thus, the aircraft manufacturers have an important role in this development

Having confirmed these observations, this paper focuses on other factors that significantly affects the fuel consumption. Analysed factors are, e.g., optimisation of speed and altitude, traffic management, congestion on and around the airfields, tankering, "latest acceptance time" for goods and improving the load factor. The different factors relative contribution to the total emission levels for the transport chain has been estimated.

Keywords: CO₂, Air freight, Transport chain, Fuel consumption, Environment, Greenhouse effect

Introduction

Global warming is perhaps the most challenging task for our society to solve. In the Kyoto Protocol, under the United Nations Framework Convention on Climate Change (UNFCCC), has most of the industrial countries agreed to reduce their emissions of six greenhouse gases by 5 % from 1990 levels by 2008-2012. If this target shall be realised, it is likely that governments will put economic or legal pressure on the polluters. The aviation's share of the global CO₂ emissions are still only 2-3 percent but it contributes to about 12 % of the worlds annual transport related CO₂ emissions. Compared to the other means of transport is the air freight sector more exposed to fuel price fluctuations. If there will be economic means of control in order to reduce the CO₂ emissions from the transportation sector it will influence the competitiveness of the air freight sector in a negative way.

Fuel efficiency has traditionally been one of the most important issues for the aviation industry and impressive achievements has been made. Large resources are invested by aircraft manufacturers and research organisations to increase the fuel efficiency even more in the future. Due to the market forces is this development in full progress. There are, however, other parts in the transportation chain that can be improved. Many of these measures can be realised with better planning and improved information tools. Another barrier is the resistance against behavioural changes. The cost of these measures are often impossible to measure as the price for the transportation companies will be in terms of, e.g., lowered customer service levels. However, compared to the resources invested in technological improvements of the aircrafts fuel efficiency these behavioural and logistical measures are estimated to be low

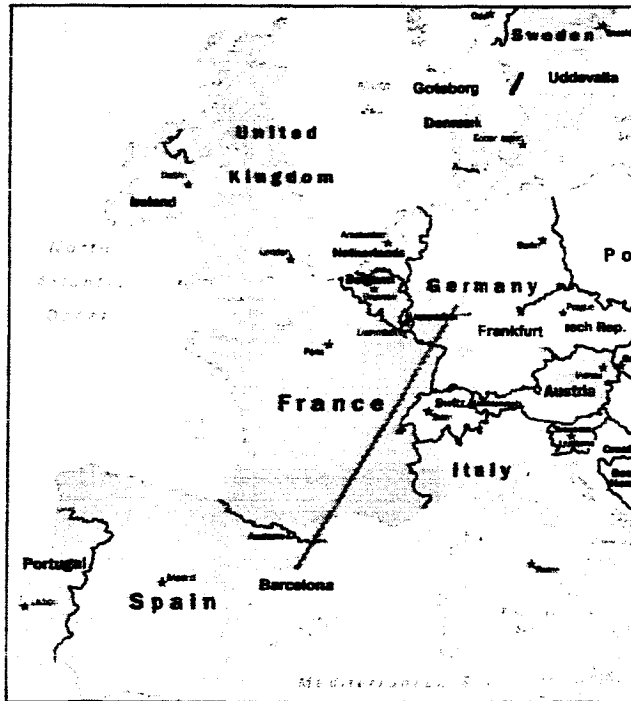
This paper aims at identifying cost effective measures to reduce CO₂ emissions in the air freight sector. One door-to-door transport chain is studied in detail from a Scandinavian city to a city in southern Europe. With this method can the environmental "hot-spots" in the transport chain be identified.

In spite of the fact that other factors, e.g., NO_x, vapour and particulates are more aggressive greenhouse gases than CO₂ is CO₂ used as measurement for the global warming potential in this study. This is done as the primary scope of this paper is not to calculate the exact GWP for the transport chain, but to identify possible reduction possibilities. In most cases are the emissions of CO₂ in the transportation chain proportional to the emissions of NO_x and the other greenhouse gases. In the cases where there might be a counter effect, e.g., decreased fuel consumption implies higher levels of NO_x it will be discussed.

Emission calculations are made in the PIANO-Harp model in cooperation with the Department of Aviation Environmental Research, FOI – The Swedish Defence Research Agency. Information about the logistic and terminal related issues was obtained by interviews of airport and air transport company personnel.

Description of the transport chain

One door-to-door transport chain is studied in detail from the city of Uddevalla in Sweden to Barcelona in Spain. The transport chain was selected by a group of representatives from the air freight sector in order to encompass general characteristics within the sector. The same group defined the cargo characteristics for this study to 1000 kg and 9.6 m³. The transport chain represent transportation by truck, by freighter and by belly-hold in passenger aircrafts.



The first segment of the transport chain is a truck transport in Sweden from Uddevalla to Göteborg. The truck has a maximum load weight of 26 ton and consumes 35 litres of diesel oil / 100 km (2.86 km / l). The load factor is assumed to be 70 %

The second segment is an air freight transport from Göteborg to Frankfurt, Germany in a MD-11, freighter version.

The third segment of the transport chain is from Frankfurt to Barcelona, Spain. There are no flights with freighters on this route; there are only passengers' flights that take the cargo by belly-hold. One of the most common aircraft operating this route is the Airbus 310.

Table 1: Summary of CO₂ emissions from the studied transport chain

Route	Transport mode	Vehicle/aircraft	Load factor	Distance (km)	Dur. time (min)	CO ₂ /ton (kg)	CO ₂ /tkm (gram)	CO ₂ total trip (kg)
Uddevalla-Göteborg	Truck	26 ton	80 %	81	60	3	0.04	69
			60 %	81	60	4	0.05	64
Göteborg - Frankfurt	Air freighter	MD 11	80%	981	83	431	0.44	32 100
			60%	981	83	531	0.54	29 600
Frankfurt Barcelona	Passenger aircraft	A310	80%	1 193	99	706	0.59	19 300
			60%	1 193	99	908	0.76	18 600
Uddevalla - Barcelona	Truck	Max. load 26 ton	80%	2 492	2 340	102	0.04	2 100
			60%	2 492	2 340	127	0.05	2 000

The calculations show that the fuel consumption increases if more cargo is loaded on the aircraft. However the environmental efficiency increases in terms of lowered CO₂ emissions per transported ton cargo if the load rate increases and more cargo is transported in the same aircraft.

It is also clear that a freighter is more efficient than belly cargo. This is however dependent on which allocation method that is used for the calculations. It can be argued that cargo transported in a passenger aircraft should only be allocated the emissions from burning the extra amount of fuel consumed due to the extra weight of the cargo. This allocation model is called the marginal method. To highlight the methodological dilemma on how to allocate the total emissions from an aircraft transporting both passengers and cargo are the calculations above complemented with calculations on what the outcome would be when three different allocation methods are used; by weight, by volume and by the marginal method.

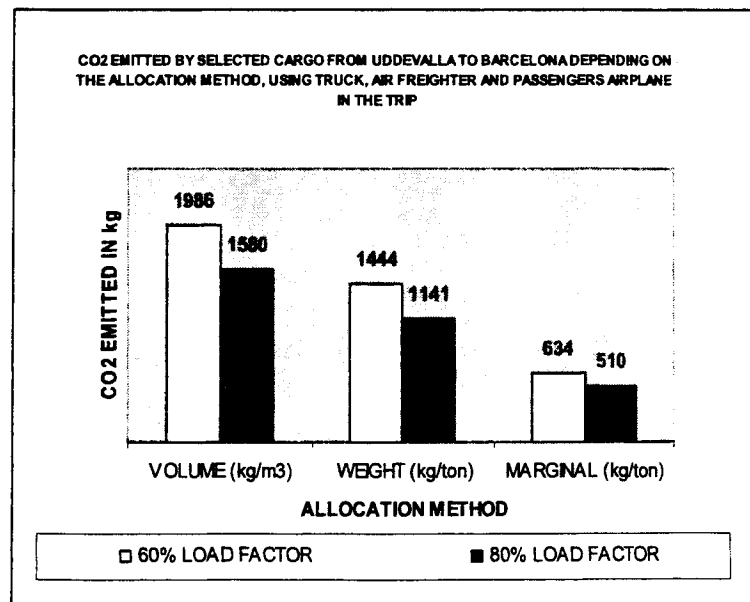


Figure 1: CO₂ from the studied transport chain, with the three allocation methods and 2 different load factors.

The difference in results are significant and it stresses the importance of transparency when showing results from an emission analysis of a transport chain. It must be clearly defined what allocation method that is used and for what purpose the study is performed.

If the emissions of CO₂ from air freight is compared to trucking it is clear that the truck shows the lowest figures. However, if a comparison is made in only the section Frankfurt – Barcelona for the selected cargo with the marginal allocation method, some interesting figures come out to light. It can be noted that in this segment with an 80% load factor with the marginal method there are 75 kg of CO₂ produced per extra transported ton of cargo on an A310 passengers' aircraft on this route. On the other hand for the same segment using a truck with 80% load factor there are 55 kg of CO₂ emitted. There is a difference of only 20 kg of CO₂. With 60 % load factor on the truck is the corresponding figure 69 kg. What method to use in different analyses is a classical issue in LCA (Life Cycle Assessment) methodology and is not discussed in this paper.

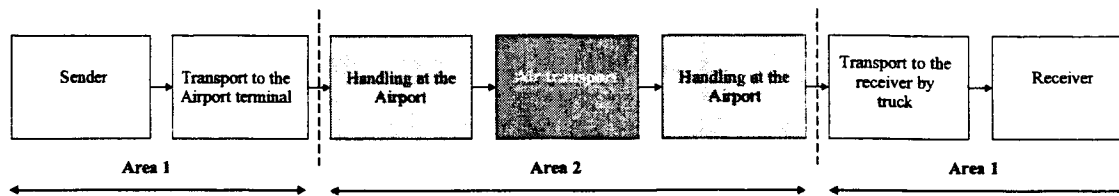
Some of the points that can be highlighted from the calculations are:

- In the phases taxi out, take off, climb out and climb 2 are about 50% of the total CO₂ produced for the shorter route (981 km) and about 35 % for the longer (1193 km).
- The phase of cruise produces about 40% respective 55 % of the CO₂.
- The rest of the trip which is descent 2, approach, landing and taxi in, produces about 10% of the CO₂.
- The 8 minutes of taxi for the MD-11 produces about 800 kg of CO₂. Depending on air traffic, congestions on the airports, bad weather, and any kind of delays, the taxi times generally raise. According to some average taxi times (LFV, 2001) there is an average of 26 minutes for the phases of taxi out and taxi in, which implies about 2 500 kg of CO₂.

Measures to reduce CO₂ emissions

There are two main areas of processes in this logistic chain, there are activities outside and within the airports. The first one, includes the delivery of goods from the sender to the trucking company if there is one, the transportation of the goods, and after this the delivery to the airport terminal. The same would be on the other end of the transport chain, the pick up of goods from the airport terminal, is done directly by the receiver or by a trucking company, which later will deliver these goods to the receiver.

The second area is the one in which all the activities are held inside the airport. Flights between origin and destiny airports, including loading and unloading of goods, handling and manoeuvring of the cargo, all the technical inspections and activities related to the maintenance of the aircrafts, flight operations, all the operations included in the turnaround, etc.



This paper is structured on what can be done in the different segments.

Area 1

Beside the obvious measures of ensuring a high load factor on the distribution vehicles can the transport company and their customers affect the emissions of CO₂ by supplying the air freight transporters with accurate information and time to plan the loading of the aircraft. This will reduce the risk of unbalanced and delayed freighters.

Latest acceptance time

The Latest Acceptance Time is the deadline that air transporters have to receive cargo from the customer. In modern logistics, where the forwarders offer their customers a high service level, there has been a trend towards short lead times and late acceptance time. It has become an important competition factor. Together with an increased security level on air traffic after September 11th this has put more stress on the terminal personnel. Nowadays some air transportation companies have 1 hour of Latest Acceptance Time for cargo but the ideal time needed in order to do an efficient balance and distribution is of 2 to 4 hours before departure. The shorter the Latest Acceptance Time, the less time to organize and distribute the cargo in an optimal way in the aircraft. The only way to correct this unbalance in the air is to compensate it by increased power on the engines. For the MD-11 studied in this paper there can be savings of up to 4 - 5 % of the total fuel consumption. These figures varies from aircraft to aircraft but the principle is the same.

Other reasons for unbalances are, e.g., the shape of the cargo or the container, special quality demands on the cargo, inaccurate information from the customer about the volume or weight of the cargo.

Delays

The delays of air transportation causes extra emissions due to fuel burned unnecessarily. The delays can occur due to e.g., weather conditions, mechanical problems, late delivery of cargo. To give an idea of the impact of these delays in the amount of emissions produced, it is estimated that German airports in 1999 burned 50,770 tons of fuel due to delays which corresponds to about two percent of the fuel burn of the entire Lufthansa Group fleet..

To get passengers and cargo to their destinations as punctually as possible and to avoid further delays, pilots often fly faster than the optimised cruise speed (see section Aircraft Cruise speed), which result in significantly higher fuel consumption. Data on exact quantities has not been obtained.

Area 2

Handling at the airport

Airport operations in Sweden adds an extra 1.2 kg CO₂ per passenger (LFV, 2001). This represents about 1-3 % of the total emitted CO₂ depending on the flight routes. No data was available for the air freight sector separately but considering the facilities needed to supply service for passengers compared to handling the cargo it can be assumed that the additional CO₂ emissions for cargo handling at the airport is less than 1 %.

Auxiliary power units (APUs) are engine-driven generators contained in the aircraft (usually in the tail) that provide the aircraft with necessary energy during the time the aircraft is at the gate. Part of the generated energy is used for air conditioning. As an alternative at airports, the required energy can be supplied by ground-based equipment that gains significant net saving of carbon emissions. Fuel used by APUs is only a relatively small part of the total fuel use of an aircraft. British Airways estimates that the amount of fuel used by an APU is less than 1 % of the total fuel used by an aircraft.

Taxi times

The minimization of taxi times reduces the CO₂ emissions. The taxi phases in most of the cases can be optimised by reducing its times and distances. It's been noticed that the normal taxi time can vary between 8 and 26 minutes, which means that there is a big area of opportunities to reduce the CO₂ emissions. In the case of the freighter MD-11, for a load factor of 80%, the difference between making a taxi time of 8 and 26 minutes means 1,850 kg or about 5 % of CO₂ produced. This amount could be eliminated by having the appropriate systems for planning a shorter taxiing, by encouraging the control tower and the logistics personnel to make the shortest taxi routes for every operation. This taxi plan can be done in a more efficient way by designing appropriately from the beginning the airport, runways and the location of the gates and cargo terminals.

Tankering

Tankering is the extra quantity of fuel loaded into the airplane before the departure obeying to unexpected flight circumstances. The obvious reason for this is safety. The pilot decides this amount basing this decision on his experience, load of the aircraft, weather conditions, destination, etc. Other factors that can affect fuel costs and decisions on tankering include the following:

- Genuine high fuel costs because of expensive distribution infrastructure and local taxes
- Fuel availability at some remote airports
- Government-imposed fuel pricing
- Monopoly distribution of fuel, which can involve cross-subsidies from large to small airports and expensive manpower practices
- Concern over fuel quality (e.g., water content) at particular locations
- When limited aircraft turnaround time allows insufficient time for refuelling, an aircraft may have to tanker to minimize the risk of losing slots. Problems in this area are enhanced at congested airports, where there may be limitations in runway and/or terminal capacity.

This extra fuel implies extra weight for the aircraft, which requires more fuel. Estimates from British Airways suggest that additional fuel burn as a result of tankering is on the order of 0.5 percent of total aircraft fuel consumption.

Aircraft

One obvious factor that dramatically influence the CO₂ emission is the technical standard of the aircraft. The oldest models in use consumes about twice as much fuel per passenger km as the most modern once. This development is ongoing and the aviation industry is continuously working on increasing the fuel efficiency. The forecasts is that fuel efficiency will improve about 40-50% more by the year 2050 (IPCC, 1999).

Flight altitude

Even though the fuel consumption increases a couple of percent (4 % for a 1500 km flight in a Boeing 737-800) when changing altitude from 37000 ft to 31000 ft, the total global warming potential (GWP) is likely to decrease due to less influence of NO_x in ozone perturbations. Klug et al. (1996) claims an 80 % increase in GWP for flying on this altitude due to larger influence by NO_x and vapour.

Aircraft Cruise Speed

A number of fuel-conscious airlines developed the concept of a long-range cruise (LRC) speed schedule. LRC was introduced as a compromise between maximum speed and the speed that provides the highest mileage in terms of km per kg of fuel burned in cruise (maximum range cruise, or MRC speed), taking some account of costs associated with flight time. LRC is defined as the fastest speed at which cruise fuel mileage is 99 percent of fuel mileage at MRC. At the time LRC was introduced, it was not possible to fly at lower speeds, closer to MRC, because of the stability needs of the auto throttle and/or the autopilot. At speeds close to MRC, the auto throttle would continuously “hunt” which could give rise to an increase in fuel burn.

Figure 7.6 shows the relationship between the difference in block time and the difference in fuel consumption for various cruise speed schedules such as constant Mach number, LRC, MRC, or ECON for the Boeing 747-400. Block time is the time between engine start at the airport of origin and engine stop at the airport of destination and thus block fuel is the fuel burned in this time. The data presented suggest that reduction of fuel use by further speed optimisation is likely to be small.

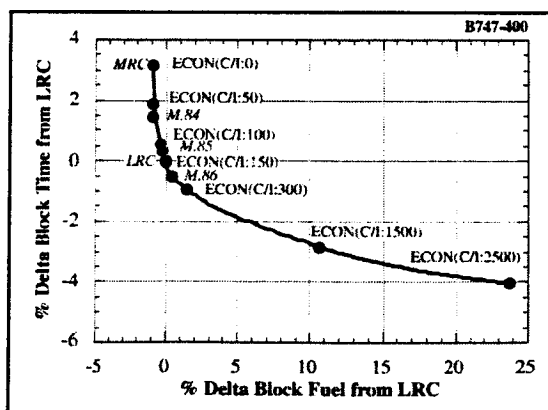


Figure 2: The effect of cruise speed dependent on block fuel and block time. (ICAO, 1999).

Improved Air Traffic Management

There are congestion problems in some air routes. This occurs mainly because the distribution of the routes crossing the air spaces is not updated and some of them are "great-circle routes". It often happens that the aircrafts do not fly in the shortest way to the destination, because they are obliged to follow the assigned route. Previous studies have calculated that inefficiencies in European Air Traffic Control, resulting in circuitous routings and sub-optimal flight levels, cause an increase in fuel burn and hence impact on the environment of between 6-12 percent (AEA, 2001). The solution for an improved global air navigation infrastructure is often known as the concept of integrating communications, navigation, and surveillance/air traffic management (CNS/ATM) systems. ATM systems will therefore be developed and organized to overcome shortcomings previously discussed and to accommodate future growth.

Table 2: Projected fuel efficiency improvement in 2010 from accelerated implementation of CNS/ATM systems. (ICAO Journal, 2001).

<i>Region</i>	<i>Fuel</i>	<i>NO_x</i>	<i>CO and HC</i>
Africa	6	6	8-9
Asia/Pacific	6	6	17-19
Europe	10	10	14
Latin America/Caribbean	8	8	8
Middle East	4	4	4-5
North America	10	9	16
Global	9	8	15-16

The inefficiencies that exist in aircraft operations around the airport terminal mean that aircraft spend significantly longer on the ground with their engines running than is necessary. It is estimated that at Heathrow alone there could be a saving in fuel burn of 90,000 tonnes per annum through the introduction of advanced surface movement guidance and control system (A-SMGCS) and related ground management systems, such as improved surface management. This saving is roughly equivalent to one day of fuel burn across the whole ECAC area (Arthur D Little, 2000).

The projected fuel efficiency improvement in 2010 from accelerated implementation of CNS/ATM worldwide is predicted to be about 9 percent.

Discussion

This paper aims at identifying cost effective measures to reduce the emissions of CO₂ in the air freight sector. It shows the results of an analysis of CO₂ emissions for a transport chain based on air freight. The calculations confirms that the most CO₂ emitting part of the transport chain is the actual flight and that it is in the take-off and climbing phases that most fuel are burned. It is also known that the technical development of aircraft implies a reduction in fuel consumption for each new generation of aircraft. The forecasts is that fuel efficiency will improve about 40-50% more by the year 2050. Thus, the aircraft manufacturers have an important role in this development.

There are also other strategies for mitigating the environmental impact of emissions from aviation that could achieve environmental benefits through reduced fuel burn. These strategies include: optimising aircraft speed, reducing additional weight, increasing the load factor, reducing

nonessential fuel on board, limiting the use of auxiliary power units, and reducing taxiing. Airlines are already under strong pressure to optimise these parameters, largely because of economic considerations and requirement within the industry to minimise operational costs. The potential reduction in fuel burn by further optimisation of these operational measures is in the range of 2–6 percent. Improvements in air traffic management could help to improve overall fuel efficiency by 6-12 percent. Other important factors identified are tankering and latest acceptance time which reduction potential are estimated to be about 5 % of the fuel consumption for a trip.

Most of the measures suggested are estimated to be comparably cost effective compared to the investments that are made to reduce the fuel efficiency of the aircraft and should be regarded as a complement. Reliable data on costs for introducing these measures are lacking due to e.g., confidentiality, and vague connections between the direct costs and reduced market attractiveness due to lowered customer service level. , these measures can be realised with better planning and improved information tools. Another barrier is the resistance against behavioural changes. These issues are suggested to be addressed in future research.

The analysis of the transport chain also shows the importance of choosing allocation method when emissions from a passenger aircraft with belly-freight shall be split between the passengers and the cargo. The result of a the study differs with a factor 3 between the different allocation methods.

Acknowledgements

I would like to thank the Master students Christian Larsson, Ernesto Vidaurri Gutiérrez and Mauricio Pérez Pena at Chalmers University of Technology, Göteborg, Sweden who highly contributed to the empirical data collection for this paper.

References

AEA, 2001; *Association of European Airlines Yearbook 2001*, Brussels, Belgium, 2001.

Arthur D Little, 2000; *Study into the Potential Impact of Changes in Technology on the Air Transport in the UK*, Cambridge, UK.

ICAO Journal, 1999; volume 54, number 7:1999. Demonstrated commitment to environmental protection is increasingly important for airlines, Montreal, Quebec, Canada, p 18,19,29.

ICAO Journal, 2001; volume 56, number 4:2001. Operational measures for minimizing aircraft fuel consumption is of great importance to the world's airlines, Montreal, Quebec, Canada, p 24,25,31.

IPCC, 1999; *IPCC Special report: Aviation and the Global Atmosphere*, Report of IPCC Working Groups I and II.

Klug H. G. et al, 1996; *CRYOPLANE – Quantitative Comparison of Contribution to Anthropogenic Greenhouse Effect of Liquid Hydrogen Aircraft versus Conventional Kerosene Aircraft*, European Geophysical Society, XXI General Assembly, The Hague, The Netherlands, May 1996.

LFV, 2001 – Luftfartsverket, Swedish Civil Aviation Administration, Norrköping, Sweden
www.lfv.se