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Evaluation of intermediate stop operations in long-haul flights

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Abstract

Recent crises - both economic and geopolitical - and the rise of new competitors in the form of low-cost carriers and Middle East carriers have put a heavy strain on the profitability of traditional legacy airlines worldwide. Many airlines are struggling to survive and are looking for ways to cut their operational costs.

Continuously increasing fuel prices further contribute to the financial difficulties, and although airlines (and aircraft manufacturers alike) have put a significant effort on reducing the operational fuel consumption, fuel still accounts for approximately 35% of airlines' operating expenses. Therefore many airlines seek new ways to further reduce the operational costs through improved fuel efficiency.

One of the less self-evident methods to potentially significantly reduce the total operational fuel consumption is the introduction of intermediate refueling stops. Previous studies have already shown that operating existing aircraft on a long-haul flight with one or two intermediate stops can lead to potential fuel savings varying from 5% to 25% by reducing the additional fuel burn on long-haul flights referred to as transport loss. On the other hand, the concept of intermediate stop operations will also affect the operational costs through higher landing fees, an increased required maintenance effort, a longer total flight time and different crew costs. As previous studies have not addressed the additional costs or benefits of intermediate stop operations, this study aims to identify the total potential of the concept.

For this purpose, a software tool was developed to analyze individual long-haul origin-destination pairs to identify the optimal operation: either direct or including an intermediate stop. Within the tool crew cost, maintenance cost and local fuel prices are determined for simulated flights according to typical operating procedures. A Dijkstra's algorithm then selects the most suitable and cost-efficient airport from a large database if an intermediate stop proves a viable option for the city-pair.

A number of case studies has shown that although in all cases intermediate stops proved beneficial to reduce the total fuel burn, reducing the total operating cost depended highly on city-pair specific conditions, mainly the local fuel prices, changed crew-composition and wind direction. Still, the case studies do indicate that the concept of intermediate stop operations may offer significant cost reductions for many typical long-haul flights across the world, and could prove a viable concept to gain a competitive advantage for specific airlines and routes.

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Keywords: Airline operations; intermediate stop operations; fuel efficiency

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1. Introduction

The economic and geopolitical crises of the last decades in combination with growing competition from Middle-East carriers and low-cost carriers on the domestic and (since recently) long-haul markets have put a heavy strain on the profitability of traditional legacy airlines. This is further exacerbated by the increasing jet fuel prices. Although in recent months the jet fuel price showed a temporary but significant decrease, in general the fuel prices have nearly quadrupled in the last two decades, and fuel accounts for up to 35% of airlines' Direct Operating Cost (DOC). Consequently, airlines are looking into new strategies to reduce their total expenses, amongst others by reducing the total fuel burn.

One of the more straightforward ways to reduce the total fuel burn is by renewing the fleet, and hence to obtain more fuel efficient aircraft. However, clearly fleet planning is a long term strategic process and requires large capital investments, essentially prohibiting frequent fleet renewal. Also in the process of flight planning efficiency gains can be achieved. By accurately planning flight routes on the day of operations using accurate take-off weight and en-route weather predictions the optimal flight route and altitude profile may be selected to further reduce the fuel burn. However, although efficiency gains can be significant in this area, most legacy airlines have already optimized their flight planning process leaving little room for further improvement.

This paper focuses on a third strategy that has been shown to potentially lead to significant fuel savings. Planning one or multiple intermediate refueling stops on long-haul flights significantly reduces the fuel weight to be carried, and as such reduces the cost of transportation, i.e. the additional cost of transporting fuel that is required at a later stage. Langhans (2010) states that although flights longer than 4,000 nautical miles only account for 3% of the total number of scheduled flights, these flights account for around 25% of the yearly total fuel consumption in commercial aviation.

Previous research into *Intermediate Stop Operations* (ISO) has already shown significant potential fuel savings when refueling stops are included in long-haul flights. Creemers and Slingerland (2007) show that the design range of an aircraft plays an essential role in the effectiveness of ISO. The work shows that the total fuel consumption of a 7,200 NM flight can be reduced by up to 15% by making an intermediate stop half way, while using conventional existing long-haul aircraft. When the aircraft is specifically designed for medium-range operations (such as e.g. the Airbus A300), the total fuel savings could increase to 27%. Although the potential fuel savings differ significantly, the work of Green (2002), Hahn (2007) and Kenway et al. (2010) all confirm that ISO can lead to 15-29% fuel savings using one or multiple stops and existing long-haul aircraft.

Although previous research has shown the potential to save fuel through intermediate stop operations, in the work mentioned above only the effect on fuel burn is taken into account, or only part of the Direct Operating Cost. In reality, though, ISO also significantly impacts other flight-related costs such as flight and cabin crew cost, maintenance cost, landing fees, etc. Furthermore, the efficiency improvement resulting from ISO depends heavily on the local fuel prices at the departure and intermediate stop airports. Therefore this study aims to analyze the total potential reduction of the Direct Operating Cost of an Origin-Destination (OD) pair, taking into account all time- and cycle-related costs and local fuel prices. It should be noted, though, that the effect of ISO on demand is not modeled in this study, and that the number of passengers traveling is assumed equal to that of direct flights. To analyze the effect of ISO, a database of relevant airports has been created which includes the local fuel prices and the geographic location of the airports. These airports, including the airport of origin and destination for a selected long-haul flight, then serve as the nodes in a network for which all viable connections are simulated using an aircraft model. This yields the total cost of operating each of the flight legs in the network, and allows to identify the optimal combination of flight legs between the airport of origin and destination in terms of total operating cost using a modified Dijkstra's algorithm.

The structure of this paper is as follows. In Section 2 the method to simulate the individual flight legs will be explained in more detail, followed by an elaboration on the cost modeling for each of the flight legs in Section 3. Section 4 describes in more detail the definition of the network of relevant airports and the algorithm used to identify the optimal combination of flight legs. Then, Section 5 will introduce some relevant case studies, followed by the conclusions and recommendations in Section 6.