Tesi

Andrea Gasparin

Introduction

Motivations

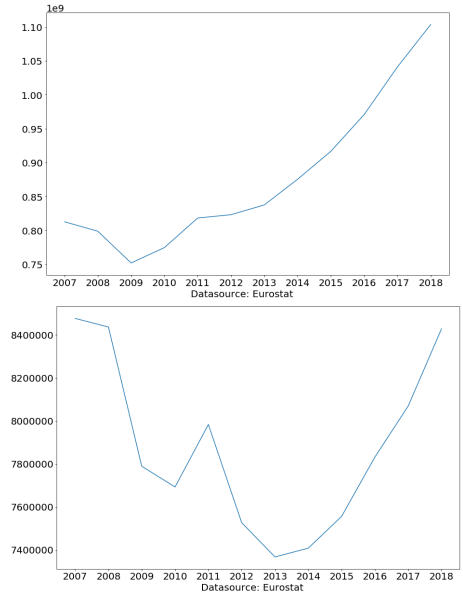
In modern days Air traffic network became a consistent part of our lives. An exponentially increasing number of people use every day air transport for their business or holiday travels. As a side effect, this consistent growth of air space demand, led unfortunately to a more difficult management of the network and consequently to a significant increase of delayed flights, which represents a major economical issue for both companies and passengers.
Since the early 2000s the American FAA (Federeal Aviation Administration) and SESAR (Single European Sky ATM Research), have made a huge effort to find new mechanisms and algorithms in order to reduce delays and costs. This problem has been largely studied for decades also in academic literature and many solutions have been proposed, but a practical application of the existing results still struggle do be deployed. The main reason behind this fact lies in the intrinsic complexity of the task they are trying to address. In fact, any framework designed to tackle this problem should, on one hand consider the reduction of total network delay and on the other, take into account the necessity to guarantee an equitable delay distribution among the different airlines and their need to be more involved in the delay allocation process. These requirements can sometimes be conflicting. Moreover, a rigorous definition of the concept of equity, still represents a strong limitation to all the attempts of a mathematical approach as well as the estimations of the additional costs caused by delays.
Currently, delay allocation is determined using the First Planed First Served (FPFS) policy, an algorithm that minimises the total delay preserving the original scheduling order of the flights involved. This last characteristic makes this framework widely accepted by the companies as it is considered fair. In addition, FPFS guaranties optimality in terms of delay reduction. On the other hand, different flights may have different economical value and it has been shown that in terms of cost reduction this algorithm is not guarantee to provide an optimal solution. Indeed, in FPFS airlines can play just a passive role and even with the introduction of Compression mechanism, a feature that encourages companies to notify flight cancellation to further reduce delays, the involvement of the airlines in the allocation process still results quite limited. In order to improve flexibility, SESAR developed UDPP (User-driven prioritisation process), and af-

ter several years of testing, some of its features have been recently implemented at Paris Charles de Gaulle and Frankfurt airports, and it is planned to soon extend the implementation also in Austria and Poland. This framework, alongside FPFS, directly involves airlines into a collaborative decision process aimed to a cost reduction through a prioritization and credits assignment mechanism. UDPP has been developed mainly to optimise intra-airline delay allocation, in the sense that it tries to improve the scheduling order within flights of the same airline to which a delay has been assigned. Despite this mechanism may have a positive effect of other airlines, has been shown that there is still a considerable room for improvement in terms of costs reduction, if a more general inter-airlines scheduling reorder is permitted.

*** (Abbozzo)
The main aim of this work is to study and develop a new mechanism which alongside FPFS tries to reduce the impact of delay taking into account companies priority and allowing inter airlines slots swaps***.

Increasing network congestion

As mentioned in the introduction, the air traffic volume is increasing exponentially. According to the data retrieved by Eurostas the number of passengers per year in the EU went from 1.002.292.978 (with 11.033.305 flights) in 2005 up to 1.658.325.861 (wit 13.731.237 flights) in 2018.



Such growth implies some potential issue in air traffic management (ATM), especially during periods of high congestion, which are typically between July

and September.

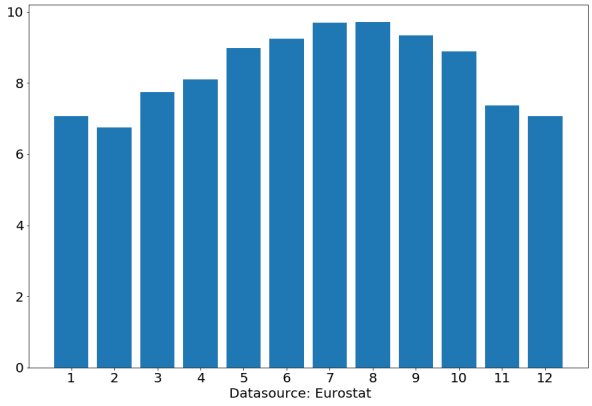


Figure 1: Average percentage of year traffic from 2005 to 2018

To further understand the reason of delay occurrences a basic introduction of the ATM mechanism is needed.

Airspace operations

The main actors in air traffic control (ATC) are airports and flight sectors. Airports are in charge of managing all flight operations concerning aircraft on the ground, taking off and landing, for all the time they remain inside the surrounding control zone. Once a departing aircraft has left the airport control zone, it starts to follow its planned route until it enters into the destination airport control zone. To increase guaranteed sky safety during the en-route period of a flight, the entire airspace outside airport control zones, is partitioned into several flight sectors, each one managed by its own area control centre (ACC). Their task is to keep constant radio contact with all the aircraft crossing their control area, in order to assist their navigation and guarantee that safety regulations be respected, from the moment they enter into the flight sector until the moment they leave.

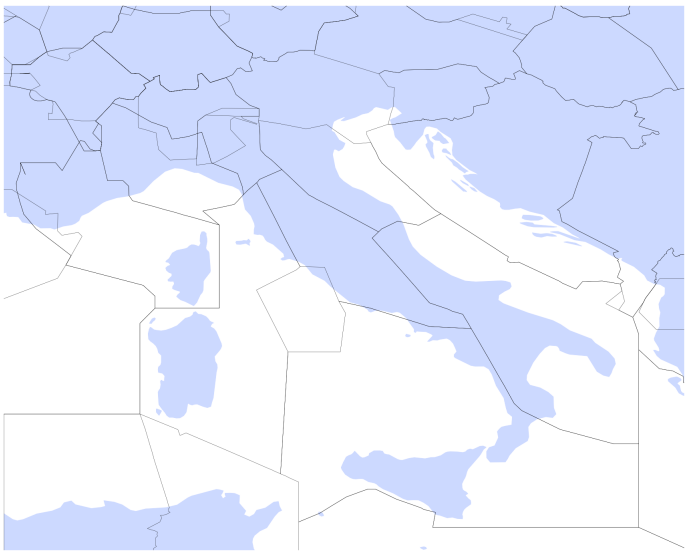


Figure 2: Sector configuration over Italy at 0.30 AM

Different sectors may also be located into the same geographical area, but referring to different altitude levels (flight levels). In order to maintain safety during congestion periods, flight sectors' configuration may also variate over time. Once the number of aircraft flying simultaneously through the same area overtakes a certain threshold a single sector can be split into different sub-sectors, so many different flight sectors' configurations are possible during a single day.
Naturally, there is a limit to the number of flights that an airport or a flight sector can host. This limit depends on several factors, such as: equipment at disposal of the ATC and human resources deployed, number of runways in the case of airports and size of the ACC in the case of sectors etc.... All of these considerations lead to the following:

Definition 1 *Capacity: The maximum number of aircraft that can be accommodated in a given time period by the system or one of its components (Eurocontrol ATM Lexicon)*

Delay occurrence

Fights schedules and routes are designed to never exceed air traffic controllers capacity. They are generally defined far in advance but they can often be planed also a few weeks before the departure. Still,close to the operations day, many unexpected circumstances might occur: adverse weather conditions, visibility reduction, runway closures, instrumental issues, strikes, military operations and other unpredictable disservices. When any of these events take place an ATC involved may decide, in order to guarantee safety, to decrease the original number

of flights it can host, for a certain period of time.

Definition 2 *Capacity constrained situation (CSS): a capacity reduction of some of the operating ATCs for a certain time period.*

Especially during air traffic congested periods, when a CSS occurs, it might occur that the demand for a certain ATC resource exceeds its reduced capacity. As long as no resource can operate beyond its declared capacity, some of the flights originally scheduled are no longer allowed to use such resource during that period. An aircraft is only allowed to take off when all ATC resources encountered on its route (airports and flight sectors) are available.
If a CSS occurs to a destination airport and the demand exceeds its reduced capacity, a possible solution is to apply a holding procedure to some of the flights, which consists in keeping an airborne aircraft in some dedicated airspace zones located in the approaching area of the airport, until it receives the permission to land. However, this operation is performed under certain circumstances, and tends to be avoided as holding procedures cause additional fuel costs and in particular it is considered unsafe to unnecessarily increase the number of airborne flights. If the exceeding capacity concerns a flight sector, another possibility is to reroute some of the flights scheduled to cross the sector during the critical period. Indeed, especially when the entire air traffic network is congested, rerouting results sometimes unfeasible as a great number of sectors are working near full capacity and it could be that no other routes are available.
In practice, the most common procedure when a capacity constrained situation occurs to an ATC (either airport or flight sector) is to keep some of the involved flights on the ground. This, may lead to flight cancellations or to postponed departures until all necessary resources are available. The latter circumstance is one of the main causes of flight delays.

Delay stats

Costs

Hotspots

Slots and regulations

Delay reduction alg intro

Delay reduction-fairness trade-off

FPFS

UDPP