**Scheduling Aircraft Landings – The Static Case**

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**Abstract:** This paper presents the problem of Scheduling Aircraft Landings, an important practical problem in today's world, as the industry suffered an overall tremendous growth in the past decades, and in many countries, effective use must be made of the available runway capacity. The problem consists of determining how to land aircraft approaching an airport and involves assigning each aircraft to an appropriate runaway, by computing a landing sequence for each runaway and scheduling the landing time for each aircraft. The main objective is to achieve effective runway use. For this purpose, the Aircraft Landing problem is considered. Two techniques will be presented: Mixed Integer Programming and Constraint programming. Computational results are then presented comparing the two techniques used and for tests using …**FINISH/COMPLETE/CHANGE**

**Keywords:** Aircraft landing scheduling, Delay minimization, sequence-dependent scheduling, Runway operation, Mixed integer programming, Constraint programming.

# Introduction

Over the past few decades, air traffic has experienced tremendous growth, as air transport become one of the fundamental modes of transport for personal and business travel, and commercial delivery. However, in 2020 due to the worldwide COVID pandemic (that started that same year), the industry observed a setback in their numbers, with less traffic for passengers and freight traffic their growth has dropped tremendously [1]. In the next year (2021) the numbers rose to show an improvement from 2020, but they are still very far away from the pre-pandemic numbers [2].

As air traffic developed, the limitation of resources, like manpower but special the limitation of runways become a bottleneck during airport operations. Located in Europe, London Heathrow airport is one of the busiest airports in the world and has only two runaways. When the number of approaching flights overpasses the airport capacity, some of these aircraft can’t be landed on their “target” landing time. Resulting in an extra cost mainly on a waste of fuel for each plane flying faster than its most economical speed. Airlines will have to deal also with costs for delays of their fights and unsatisfied customers. Transfer customers can miss their connecting flights. The crew operating the current flight can be needed on another flight, which has now to be rescheduled resulting in another extra cost. Flights that are on land (departing flights) can also be affected by this, as they can also be delayed and not authorized to depart due to the lack of available runaways, this will also have an impact on the operations of the destination airport of these flights. Other possible costs are crew overtime payments, crew rescheduling, etc. Back in 2017, it was reported that congestion cost to airlines and passengers around 25 billion euros, according to FAA/Nextor estimated [3].

Therefore, even now that the air industry is not growing or even having the same results as in past years it's important to solve the problem of Scheduling Aircraft Landings which is referred as Aircraft Landing Problem (ALP) in the literature. APL consists of the problem of assigning each aircraft an optimal landing time and runaway in a way that the cost is minimized. This can be achieved by reaching the maximum efficiency of resources and overcoming the problems observed in the past decades when the increase in air traffic causes a drastic increase in the number of aircraft take-offs and landings within a given period at a certain airport or runaway, that results in an overload issue in terms of airport capacity and delay issue in terms of aircraft scheduling.

Air traffic control (ATC) aims to control air traffic, to prevent collisions and delays. ATC is usually operated by humans and therefore human error can happen. An important part of their responsibility is the planning of airport operations, such as the arrival and departure of aircraft, which is the focus of this paper. Automating this solution, will not only save time but overcome human error.

Aircraft landing scheduling can be understood as giving priority to different aircraft, that need to land at a certain time. This problem becomes more complex, as previously explained, in busy airports with limited runaways and with several aircraft trying to land at the same period.

But there are different ways of formulating this problem, depending on the perspective used. For instance, from a point of view of an airline, their main objective would be to minimize the deviation from the “target” landing time, while from an airport management perspective is to maximize the airport capacity usage and therefore minimize their cost in losses. Both objectives are directly related to cost and the final objective is to minimize direct and indirect costs associated with aircraft landing for both airliners and airport managers.

In resume, air transportation has established itself as one of the most important means of transport, which directly implies the increase in air traffic, and therefore the efficient management and scheduling of aircraft take-offs and landings (given the limited resources such as time, budget, etc..) have become a very challenging and complex problem for air traffic controllers.

Therefore, this paper, it will be considered the problem of scheduling aircraft landings at a given airport. The problem is considering a landing time on a runaway for each plane for a given set of planes such that:

* each plane lands on the predefined window.
* separation criteria between the landing of a plane, and the landing of all successive planes, is respected.

Mixed Integer Programming and Constraint programming will be used to address the problem, formulating this from the point of view of airport management. The main goal is to find an optimal landing sequence based on the available runaways, number of flights, and expected delays and therefore minimize their cost.

The organization of the paper is as follows. In section 2, an overview of the problem context is given. In section 3, … In section 6, the results obtained in sections 4 and 5 are discussed.

In section 7, the paper is concluded. **FINISH/COMPLETE/CHANGE**

The aircraft scheduling problem has been widely studied in the operation research community, and therefore this research will have as a foundation the paper “Scheduling Aircraft Landings—The Static Case” by J.E. Beasley, M. Krishnamoorthy, Y.M. Sharaiha and D. Abramson [4].

As in their study, is important to refer that through our paper we will typically refer to planes landing, but the models presented can be applied to problems involving just takeoffs or to problems involving a mix of landing and takeoffs on the same runaway. Also, we are dealing only with the static case, where we have all the knowledge about the set of planes that are going to land and no information (i.e. planes land, new planes appear, etc) changes.

# Problem Context

Air traffic control will give instructions to each aircraft entering within the range of an airport radar. A landing time and a runaway will be assigned to each plane. The landing time must be comprehended between the earliest landing time and the latest landing time.

The earliest landing time corresponds to the time at which the aircraft can land if it flies at its fastest speed, and the latest time corresponds to the maximum landing time achievable considering delaying mechanisms, such as decreasing the speed of the plane, or the flight plan can be lengthened by circling. Comprehended in this time window there is the target time that corresponds to the time at which the aircraft can land if it flies at its cruise speed. This is considered the preferred landing time.

To ensure safety is necessary to ensure that separation distances are respected. Separation distances are converted into separation times using a fixed landing speed that will be different according to the type of aircraft that is landing. After this, a minimal lapse of time between the landing of a plane and the landing of any successive plane needs to be ensured. Separation time holds between a pair of planes landing on the same runway or on different runways.

In resume, the Aircraft Landing Problem (ALP), concerns the scheduling of planes at an airport by assigning to each plane a runaway and a landing time that falls within the specific time window (target landing time) and does not violate the safety constraint (separation time) in a way that the cost is minimized. When it’s not possible to land the plane at the target landing time, the plane can be landed at any time that falls between the early and the late landing time, but this will incur a cost.

The objective function, considered in this study is the minimization of the total cost associated with landing planes at times that differ from the target landing time, for the static case.

# Problem Formulation

In this section (for conciseness) we will formulate the adopted from [4]:

# The MIP Model

# The CP Model

# Computational Results

An analysis of the tests and results (including some KPIs on the difficulty of the instances and resolution time)

# Conclusions

Future Works

# References

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| [1] | International Civil Aviation Organization, "Presentation of 2020 Air Transport Statistical Results," [Online]. Available: https://www.icao.int/annual-report-2020/Documents/ARC\_2020\_Air%20Transport%20Statistics\_final\_sched.pdf. [Accessed 01 2023]. |
| [2] | International Civil Aviation Organization, "2021 global air passenger totals show improvement from 2020, but still only half pre-pandemic levels," [Online]. Available: https://www.icao.int/Newsroom/Pages/2021-global-air-passenger-totals-show-improvement.aspx. [Accessed 01 2023]. |
| [3] | Leeham News and Analysis, "Congestion costs billions, but airlines show little concern," [Online]. Available: https://leehamnews.com/2019/03/21/congestion-costs-billions-but-airlines-show-little-concern/. [Accessed 01 2023]. |
| [4] | J.E. Beasley, M. Krishnamoorthy, Y.M. Sharaiha and D. Abramson, "Scheduling Aircraft Landings—The Static Case," *Transportation Science,* 2000. |