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Managing Airline Crew Scheduling in an Era of Operational Complexity and Real Time Decision Making

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Abstract: ***The airline crew scheduling problem has received extensive attention, particularly in the last 60 years. This problem is frequently divided into crew pairing and crew assignments because of its large size and the complex safety agreements and contractual rules. Several solution methodologies have been developed, but many objectives and constraints are treated approximately and research is ongoing. The process integrates crew qualifications, duty and rest limitations, aircraft types, base assignments, and seniority rules to construct legal and cost-effective schedules. Modern crew scheduling systems must also support dynamic re-optimization in response to disruptions such as weather events, aircraft maintenance issues, and crew unavailability. Advanced algorithms, including integer programming, heuristics, and real-time decision support, are increasingly used to balance operational reliability, crew satisfaction, and cost efficiency. As airlines scale operations and regulatory complexity grows, robust crew scheduling solutions play a critical role in maintaining safety, compliance, and on-time performance.***

Keywords: airline crew scheduling, crew pairing and assignment, operational disruptions, optimization algorithms, regulatory compliance

1.Introduction

Airline crew scheduling terminology

- Air leg-A nonstop flight segment. Each air leg is characterized by five features: the flight number, the origin airport, the destination airport, the departure time, and the arrival time.
- Deadhead-An air leg in which a crew member flies as a passenger for relocation purposes.
- Duty-A sequence of consecutive air legs (and/or deadheads) comprising a working day for a single crew member. Two consecutive duties should begin and end at the same airport. Duties are separated by layovers.
- Layover-A rest period (an overnight stop) between duties that typically lasts for at least 10 h.
- Pairing-A sequence of duties and layovers for an unspecified crew member that starts and ends at a base. In short-and medium-haul problems, pairings typically last 1-5 days; in long-haul problems, longer pairings are allowed.

- Base-A large airport. Each crew member is associated with a base, which means that all his/her associated pairings must begin and end at that airport.
- Elapsed time-A period in which a crew member is away from the base, referred to as Time Away from Base (TAFB).
- Credited flying time in a duty The active flying time plus a specific percentage of deadhead flying time (typically 50 %).
- Monthly schedule (schedule) A sequence of pairings separated by time off that covers a given time horizon (usually a standardized planning month). In this paper, the term schedule refers to a monthly schedule.
- Briefing time, A period before the start of each duty is spent on instructions and crew discussions with the goal of transforming a group of individuals into an effective team.
- Debriefing time A period at the end of each duty that gives the crew members an understanding of the events that occurred and their implications.
- Crew members Generally divided into two groups based on their role: the cockpit crew members are the pilot (captain), copilot (first officer), and flight engineer, all of whom are qualified to fly one or more aircraft types. The cabin crew members are the cabin captain and the flight attendants.
- Post-pairing rest A rest period between two consecutive pairings that respects a minimum and a maximum duration.
- Post-pairing A rest period between two consecutive pairings that contains a complete day off (from midnight to midnight).
- Aircraft route A sequence of air legs flown by a specific aircraft.

Crew scheduling methods:

There are three general approaches to solving this complex crewing challenge: Assigned Lines, Bid lines and PBS (Preferential bidding system)

Assigned Lines:

In the Assigned Lines approach, the properties of the line, and days off are simply managed via the use of constraints to build "legal" lines. The optimizer finds the most efficient use of the pairings and reserve assignments. A crew member will have no bidding or preferences.

Bid lines:

In the bid lines approach, pairings are placed within pre-built lines by line optimizer, a computer program that puts the pairings into "legal" lines, and does not consider the individual crew members' preferences, nor the constraints imposed by crew members. The generic set of lines are then published for bidding. A crew member is free to choose any

line and it will be awarded as long as no other senior crew member who also wants this same line. Unless the most senior in the bid package, crew members need to submit multiple preferred lines to guarantee a preferred line; otherwise, a leftover line will be awarded. By the bidding process, the preferred line may not be awarded completely, because the line was created without reference to specific crew member constraints, it may conflict with crew members Predetermined activities. The conflicting pairings must then be reassigned to other crew members resulting in a wide range of inefficiencies. Clearly this post-award reallocation is costly to the airlines. These inefficiencies also force airlines to hire more crew members. However, bid line does offer a transparent and easy process to bid and to award, and in many cases the conflict itself benefits the crew members that being paid without the work according to the contracts. Though management is eager to streamline operations, crew members may still prefer the bid lines.

Preferential bidding system (PBS):

In the PBS approach, the lines have not been created at the bidding, and the crew members can designate what kind of pairings, the properties of the line, and days off they prefer, thereby building a line themselves. PBS also allows crew members to bid reserve duties mixed with the pairing's biddings. PBS provides a one-step process from the pairings to the lines that each crew member prefers and can legally cover.

Conventional PBS:

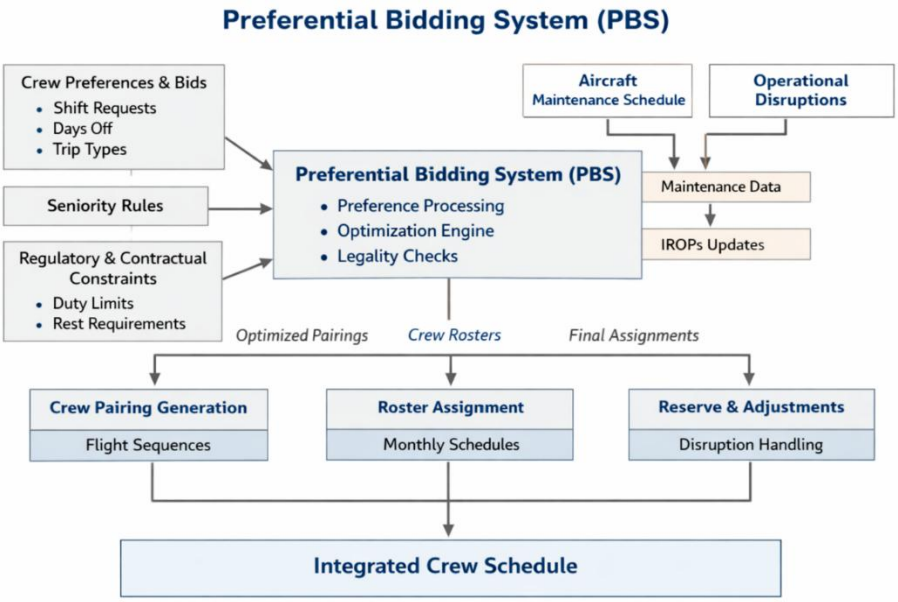
In a conventional PBS, crew members make their bids and choose their preferences based upon their own best interests. Once all the bids are made and the bid period ends, the program attempts to create the solution by an "optimization" process. Each crew member will be awarded the best line of his own definitions from available pairings at his seniority. For each crew member, when there are many best lines, the one with the least interest conflict with the junior crew members will be awarded, which is an advantage that interactive PBS cannot achieve. The optimization system finds a way to satisfy both senior and junior crew members while still honoring seniority and operation coverage requirements. The optimization process itself is complicated and may take many hours and multiple runs to achieve the optimal solution. A preference is rejected due to a pairing being awarded to someone senior, overall coverage issues, or legality violations. The reason for rejection will be provided.

Interactive PBS:

Computerized Bidding was first introduced in 1986 by SBS. The application was developed by SBS founder Christian Boegner who later founded Crewing Solutions and was in use on powerful internal computers at TWA among other airlines. By 1992 using such services as CompuServe and the newly introduced home PCs, SBS allowed Pilots to Bid using the internet to connect to the SBS bidding and scheduling programs running within the airlines networks.

With the advent of increasingly more powerful airline and home computers as well as high speed internet connectivity having become ubiquitous and mainstream, those original computerized programs have evolved into today's web-based, with crew members using laptop computers or even mobile devices to bid. The conventional PBS process can now be fully interactive, affording the possibility that more crew members get a schedule that fulfills their wishes. In this scheme, bidding can be a continuous process lasting several days or weeks, and can offer interactivity, where crew members can see the status of other crew member bids reflected as they bid. A crew member can change preferences during the process after seeing how others are bidding.

Below picture shows how a PBS system integrates with other Aviation systems to get a crew schedule for proper crew allocation.



2.Conclusion

Aviation crew scheduling is a critical and highly constrained function that directly affects airline safety, compliance, and operational efficiency. The complexity of regulatory requirements, crew qualifications, labor rules, and operational disruptions necessitate advanced optimization and real-time decision-support systems.

Modern crew scheduling solutions must balance efficiency with flexibility, enabling rapid recovery during irregular operations while maintaining strict regulatory compliance. Continued advancements in optimization techniques, data integration, and intelligent automation will be essential to improving schedule robustness, reducing costs, and supporting the reliable operation of airline networks.

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