Solving the Problem of Irregular Airline Operations

Michael Clarke
MIT Flight Transportation Laboratory 33-409
77 Massachusetts Avenue, Cambridge MA 02139

Presented at the
INFORMS New Orleans Fall 1995 Meeting
Airline Operations Planning and Control
Section on Aviation Applications
October 30, 1995

Abstract

Airlines are constantly faced with operational problems that develop from severe weather patterns and unexpected aircraft failures. A summary of research related to irregular operations will be given with a primary emphasis on aircraft rescheduling and rerouting. Issues such as tactical operations decisions, impact of yield management, maintenance and crew scheduling will also be considered.

Introduction

Airlines are constantly faced with operational problems which develop from severe weather patterns and unexpected aircraft or personnel failures. A significant amount of computational time and effort is invested in developing an airline's operational schedule which is impacted by these irregular events. Over the last decade, airlines have become more concerned with developing an optimal flight schedule, with very little slack left in the system to accommodate for any form of variation from the optimal solution. Substantial research has been conducted on the problem of fleet assignment and aircraft routing. However, very little research has been done on the problem of addressing the impact of irregular operations, and developing potential decision systems which could aid in aircraft re-scheduling.

The primary goal of this research program is to develop and validate algorithms, procedures and new methodologies to be used in the event of irregular operations in large scale scheduled transportation systems. Recommendations for these real-time decision support systems (DSS) will incorporate several aspects of the tactical operations of the transport system, including yield management, vehicle routing, maintenance scheduling, and crew scheduling. The DSS will enable the carrier to recover from an irregular operation and maintain an efficient schedule for the remainder of a given rotation period. Having been exposed to issues relevant to the problem of irregular operations, the author is confident that these procedures when developed, will have a substantial impact on future transportation system operations.

In the first stage of the program, the overall structure of the problem will be defined. Network flow theory will form the basis of the solution methodology for the problem. A heuristic approach will to taken to the solution process in order to achieve a real-time solution. The overall framework of the problem has to be established, as well as the operational capabilities of the decision support system. A series of heuristic algorithms will be developed for use in the system. In phase two, the decision support system will be initially developed, incorporating the algorithms created in phase one of the program. After initial testing and product validation, the final prototype version of the decision support system will be ready final testing. In phase three, historical data from a major US domestic carrier will be used to compare the benefit of using the system to what actually occurred at the Airline Operation Control Centre of the carrier.

Background

Overview of the Airline Operations Control Centre (AOCC)

Airline operations are generally handled in two phases, strategic and tactical. Strategic operations are concerned with schedule planning. Given the desired schedule of services to be offered to passengers (called the Schedule of Services) established by the Commercial / Marketing department, the Operations group generates the Nominal Operational Schedule (NOS) for the airline's resources such aircraft rotations and crew rotations, and then assigns tail numbers, and individual crew members to a given flight. These activities constitute the schedule generation and resource allocation phases of the scheduling process. They are carried out by various groups which support the development of the planned schedule for all airline resources.

Given these resource schedules, the tactical side of the Operations group is responsible for the final stage of the scheduling process: Execution Scheduling. Execution scheduling is the process of executing the system resource schedules on a daily basis. This involves three main activities: executing the pre-planned schedules, updating the schedules for minor operational deviations, and rerouting for irregular operations. The tactical operations of a regular scheduled air carrier is usually under the 24 hour / day control of a central organization often referred to as the Airline Operational Control Center AOCC.

This section presents a summary of a typical AOCC, outlining its organization, primary activities within the airline, and operational facilities. The facilities and personnel of a particular AOCC will vary considerably depending on the type and size of the airline. AOCC centers can range from a single controller / dispatcher on duty to several dispatchers and hundreds of other personnel handling flights throughout the carrier's entire global network. During the process of operation control, the AOCC is supported by the Maintenance Operations Control Center (MOCC) which controls aircraft maintenance activities, and various Station Operations Control Centers (SOCC) which control station resources (gates, refuelers, catering, ramp handling, and passenger handling facilities).

Operations Control Centers are usually linked to the Aeronautical Radio Inc. (ARINC) and the Societe International Telecommunications Aeronautiques (SITA) networks to send and receive teletype / telex messages. Communications with maintenance and engineering, customer service, and airport services are maintained to facilitate prompt contact with the appropriate personnel. Teletype, telex, facsimile, telephone, leased lines, and public data networks combine to provide an effective medium of collecting information and communicating revised operational plans developed by the AOCC center. In some cases, the AOCC has communications systems connected to VHF, HF and Satcom radio links, air traffic control centers, and other relevant locations, allowing them to effectively gather and disseminate information instantaneously.

Functional Groups Within AOCC

The AOCC is organized into three functional groups, each with a distinct responsibility within the schedule execution process. The airline Operations Controllers are responsible for maintaining the operational version of all the system resource schedules (crew, aircraft and flight) and the management of irregular operations. The final operational decisions are made by one (or more) Operation Controller(s) who are assisted by a variety of operating personnel. The Flight Dispatch group is responsible for flight planning, flight dispatch and enroute flight following. Crew Operations group is responsible for tracking individual crew members as they move through the airline's route network, for maintaining up to date status for all crew members, and for calling in reserve crews as required. These three groups are usually located together in the AOCC Center.

The AOCC at larger airlines may have a dedicated airline Air Traffic Control ATC coordinator, as well as specific supporting personnel for functions such as dispatch, crew scheduling, aircraft scheduling, and meteorology services within the AOCC center. Ancillary off-line services such as the maintenance of the navigation database, operations engineering (or flight technical services) are usually located nearby and serve to provide supporting resources for AOCC personnel. In addition, the crisis center to manage activities after an accident or incident is often an integrated part of the Airline's Operational Control Center.

Operations Controllers

The airline Operation Controllers are the center of the airline operation control process. They are the sole operational group within the AOCC with the authority and responsibility to resolve problems that develop during the course of both regular and irregular operations. Airline Operation Controllers receive information from every facet of the airline during operations (see Figure One). From these inputs, the Controllers maintain an updated version of the airline system resource schedules which includes delays, irregular routings for aircraft and crews, and additional flights. These can be called the "Current Operational Schedules " (COS). Other personnel in the AOCC are normally grouped by the geographic areas of the flights they manage and monitor. As the focal point in the AOCC for flight and schedule management, controllers interact with the following key personnel and organizations:

- Flight Dispatchers
- Crew Operations (scheduling, tracking, and rescheduling)
- Station managers and gate coordinators
- Passenger service managers

- Ramp service managers (fuelers, baggage handling, aircraft loading, catering)
- Maintenance and engineering
- Meteorology
- Operations engineering / route planning
- Air traffic control coordinator

During normal operations, Dispatchers are responsible for the successful release of a flight, depending on maintenance issues (deferred maintenance equipment list (MEL) or configuration deviation list (CDL) items), aircraft restrictions (such as noise), the availability of required operational support (fuel, gates, ground power, airport facilities) at the departure, destination and alternate airports. During irregular operations and emergencies, the Dispatcher will inform the Operations Controller of the problem, and their role is to handle the additional coordination that such situations demand. If the airline is experiencing irregularities, the Operation Controllers have to devise modified operational schedules on a very short notice. The Current Operational Schedule is the plan that the airline with follow to order to return to Nominal Schedule of Services. These modified schedules are disseminated to the relevant airline divisions, and airports of the system.

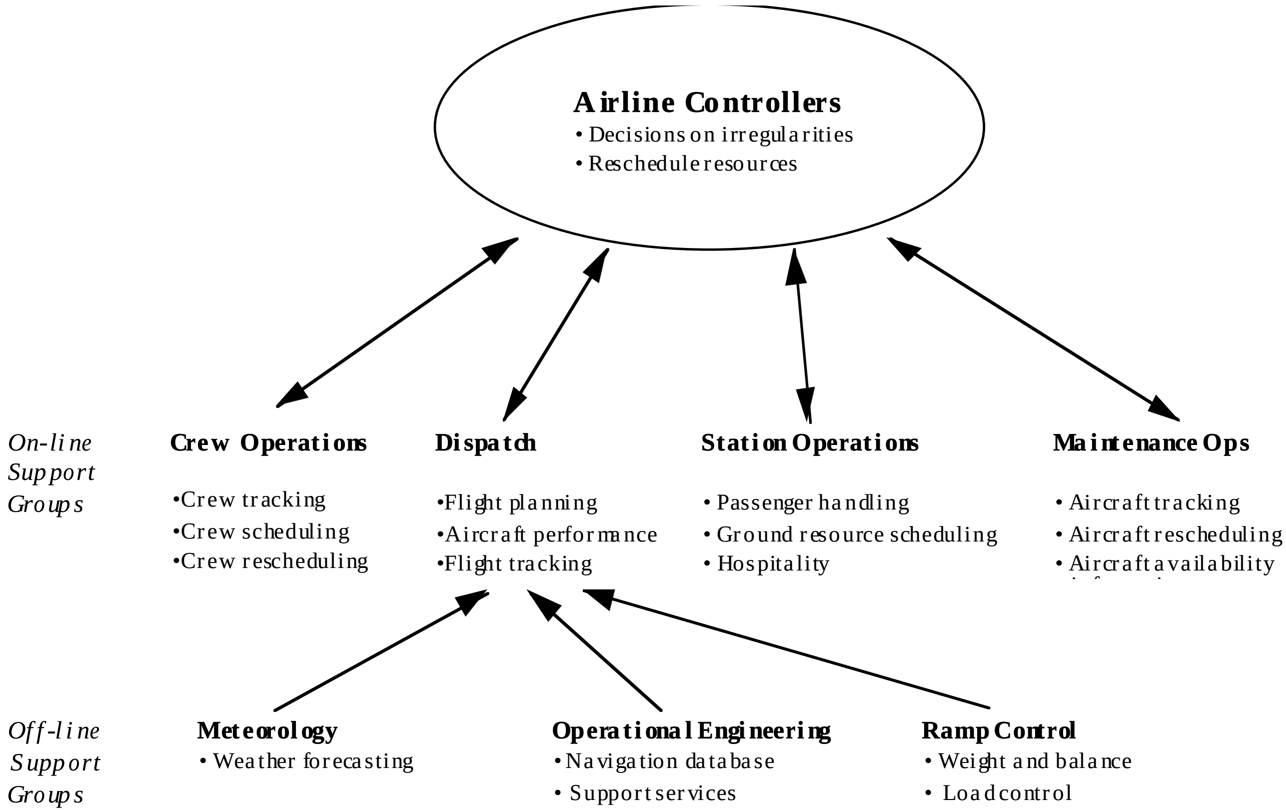

Figure 1 Information Flow Diagram for the Airline Operations Control Center (AOCC)

Statement of the Problem

Throughout the course of daily operations, an airline is faced with the potential of deviations in the planned flight schedule as a result of various unexpected events. The impact of these deviations on the three primary airline system schedules (Passenger, Crew Rotations, and Aircraft Rotations) will vary, depending on the flexibility and robustness of the original schedules. Any changes which may occur to the airline system schedules are often defined as operational deviations. It is necessary to distinguish between deviations that do not cause problems in the airline network, and deviations that do cause problems and require rescheduling.

Deviations that do not cause significant problems are defined as time deviations, and deviations that lead to flight rescheduling are referred to as irregular operations. Time deviations are defined as any variation from the original scheduled times in any of the system schedules. They do not have a negative impact on the airline's operations, but simply reflect small changes in the arrival and departures times during normal daily operations. Time deviations are distinguished from irregular operations are they do not require any rescheduling of airline resources.

An irregular airline operation is defined as the aftermath of unexpected variations in operations which have a significant impact on the carrier's schedule. This often results from severe weather patterns and the resulting delays in the air traffic control system, airport closures, aircraft breakdowns, lack of adequate flight personnel (cockpit and cabin crew), problems in ground handling and support services, and equipment failures. Irregular operations generally result in aircraft rescheduling and rerouting, with the added impact of flight delays and cancellations. In addition, the aircraft rescheduling will have an impact on maintenance scheduling for the carrier.

Many airlines suffer from irregular operations which have a significant impact on their profitability and ability to compete effectively. In fact, many carriers now see the need to address the problem of irregular operations as one of the main issues necessary to improve their poor financial state. However, the existence of decision support systems for the purpose of aircraft operational re-scheduling is not known, and very little research has be done on the topic. At the majority of the airline operation centers throughout the world, irregular operations are dealt with manually, with a heavier reliance on the human operator and his past experience, and knowledge of available spare aircraft, regulations and maintenance schedules. The need for real-time decision making tools to assist in the event of irregular airline operations is therefore apparent.

There are several questions that have to be considered when trying to the solve the problem of irregular airline operations. These include:

- How can aircraft rotations be adjusted in order to minimize passenger delay throughout the airline network?
- What flights can be cancelled to minimize profit loss, based on available resources and the actual number of passenger "on-board" a given flight?
- Is it possible to carry-out the proposed flight schedule with the available number of flight crews?

- How easy is it to develop new crew rotations in the aftermath of irregular operations?
- How will the revised airline schedule affect the scheduled maintenance program of the airline?

The availability of high-performance workstations, which are already in use in the strategic stage of airline planning could play a significant role in tactical airline planning, with the ability to improve communication between the two groups. The use of these computers would give the flight operator the ability to incorporate demand data from yield management systems, to interact with maintenance scheduling, crew scheduling, and other aspects of airline planning. In the majority of airlines, little interaction exists during the tactical phase of operations between the various operational groups (maintenance, fleet assignment, yield management, etc.), and the presence of irregular operations only adds to the problem.

It is possible however, to develop a support system whose primary goal would be to regain the strategic schedule of the airline within a given time period, minimizing the overall impact of cancellations and delays on profitability, and overall changes in operational conditions. The most severely impacted aspects of the planning process are fleet assignment and subsequent routing. Although these aspects are generally developed independently in the strategic stage, the need to reschedule aircraft real-time causes both fleet assignment and routing to be done concurrently. The utilization of a decision support system will cause significant benefit to the airline, and potentially to the traveller (through significantly reduced flight delays, and/or cancellations).

Summary of Previous Work

The creation of a decision support system primarily for the aftermath of irregular airline operations has been limited in published work to only one such system, which is being developed by United Airlines. In addition, research has been done by Dusan Teodorovic, developing a sequential approach based dynamic programming algorithm to assist dispatchers in the aftermath of irregularities. There is knowledge of unpublished work for Northwest Airlines at the Georgia Institute of Technology on topics related to irregular airline operations and the crew recovery problem.

An article on the United decision support system was published in Transportation Science Vol. 27, Number 3, August 1993, which covered the conceptual design of the problem solution methodology. In the proposed DSS system, the issue of flight cancellation and delay are addressed independently. The problem is modelled as a network flow problem, in which the solution provides either the flight delays or the necessary cancellations required to regain the intended schedule of operations in a given time. However, the underlying structure of the decision support system does not allow for the necessary trade-off between a flight cancellation and delay.

Although very little work has been done on the problem of dynamic rescheduling in the aftermath of irregular operations, there has been significant research in the area of fleet assignment and aircraft routing. In addition, topics such as airline exception scheduling, schedule discontinuities, and schedule transition have been studied in great detail in previous research projects. These topics have been given a lot of attention, since airlines often find themselves faced with aircraft breakdowns, the need to carry-out unexpected maintenance checks, and the need to vary the overall flight schedule to compensate for the variation in passenger demand in a given origin-destination market. However, the majority of work in these areas have not addressed the issue of irregular operations as a result of severe weather conditions.

Flight cancellations and delays which result from irregular operations often create a large pool of irate travellers, as well as a substantial pool of aircraft for swapping. Within the US domestic market, over 90% of all flights pass through a hub-airport. This situation is somewhat unique as it allows for easy aircraft swapping, and replacement, which could potentially reduce the impact of delays or cancellations of incoming flights on future flight departures. The key point here is that aircraft swapping generally occurs within a given fleet. As aircraft manufacturers develop families of aircraft (same cockpit crew rating, similar maintenance requirements, etc.), airlines could conceivably use varying capacity aircraft for a given flight.

In a market where the airline has numerous flights, as an example, the cancellations of four flights of an aircraft with a capacity of 100 seats, could be easily replaced by two flights using a larger aircraft. Moreover, the potential may exist to conduct aircraft swapping with multiple aircraft types (different crew rating). Some of the concepts used in Boeing's Demand Driven Dispatch methodology could be used as a foundation for incorporating the issue of dynamic aircraft assignment in the resolution of flight schedules in the aftermath of irregular operations.

Proposed Research Program

The ability to resolve irregular airline operations is a very complex, as it may require the knowledge and involvement of all the operational divisions of an airline. As outlined in the statement of the problem, irregularities result from a variety of operational deviations and their impact on scheduled operations can be very significant. As such, the primary motivation of this doctoral program is to attempt to address a subsection of irregular airline operations, and to present heuristic algorithms which could be implemented at an airline's operations control center in the event of irregularities.

In general, the majority of airline irregular operations result from aircraft breakdowns and severe weather patterns and their resulting impact of the air traffic control system. The decision methodologies that will be developed in this research program would address these two main "problem" areas, and would incorporate all aspects of the airline's various operational divisions, as it pertains to aircraft scheduling and routing. The decision process would take into account the benefit of the rescheduling, delay or cancellation of a given flight, and its overall impact of the airline's operating profit.

In order to develop real-time decision support tools for use in airline irregularities, it is imperative to establish a thorough understanding of the activities at the operations center of several major US domestic carriers, in addition to those of international carriers. Only then, can a comprehensive system be developed that can make a significant impact of the airline's operations in the event of irregularities. Based on this knowledge, and appropriate coursework, efficient heuristic solution procedures can be developed and tested. The need for real-time solutions dictates the use of heuristic algorithms which will result in near optimal resolutions of previously "optimal" aircraft schedules. The primary interest in this dynamic rescheduling process is that of the scheduling of aircraft, and its impact of the airline's operating profit.

References

Clarke, Michael et. al. The Airline Operation Control Centre: An Overview of Garuda's Operation Control (EM) at Cengkereng Jakarta, Indonesia (Final Report to PT Garuda Indonesia) FTL Report 95-9, Cambridge MA.

Jarrah, Ahmad et. al. A Decision Support Framework for Airline Flight Cancellations and Delays. Transportation Science, Vol. 27, No. 3, August 1993.

Teodrovic, Dusan et. al. Model to Reduce Airline Schedule Disturbances. Journal of Transportation Engineering, Volume 121, Number 4, July-August 1995.