A Quantitative Assessment of the Impact of Flight Delays on the Scheduling of Airport Ground Service Staff

Dr Yi Gao*
Faculty of En. & Ind. Sc.
Swinburne University of Technology
PO Box 218 (Mail H38), Hawthorn,
Victoria, 3122, Australia
Phone: +61-3-9214 8865
Fax: +61-3-9214 8264
Email: ygao@swin.edu.au

Dr Dongxuan Wei
School of Highway,
Chang’An University,
Nan Er Huan Zhong Duan, Xi’an,
Shanxi, 710064, China
Phone: +86-18710351680
Fax: +86-29-82334453
Email: dxwei@chd.edu.cn

Scheduling of airport ground service staff is critical to airline ground operations. When scheduling ground service staff, as well as flight crew, airlines use published flight schedules as primary inputs to determine the manpower demand at different times of a day. Flight delays, which are part of actual flight operations and cannot be fully avoided by airlines, are usually not considered during the scheduling stage. In actual flight operations, however, the presence of flight delays will create disruptions to flight operations, thus affecting the scheduling of ground service staff. Using Integer Programming (IP), this study compared the manpower plan made during the planning stage and the actual manpower plan as required on the day of operations to quantitatively assess discrepancies between the two plans. The comparison will enable airlines to understand the impact of flight delays on ground operations more accurately. Results of the present study will also be used as a basis to build a robust manpower scheduling plan for airport ground service staff, which will mitigate the impact of flight delays on ground operations.

KEYWORDS: Operations Research, Manpower Scheduling, Integer Programming, Airport Ground Operations;

CLASSIFICATION: Operations Research in Air Transport: Modeling and Applications;
Introduction

Today, a typical major airline operates tens, or even hundreds, of airplanes around the clock domestically and internationally. All of these flights require the collaboration and coordination of many different positions, such as pilots, cabin crew, mechanics, and ground service staff, whose total number can be added up to at least several thousand in a major airline. Airlines, on one hand, need to ensure adequate manpower supply to satisfy the varying demands of different positions at different times of a day. On the other hand, they need to cut the cost of manpower to save the increasing cost of airline operations. Therefore, how to schedule these positions efficiently and effectively becomes a challenge for modern airlines.

As of the scheduling of airport ground service staff, many earlier studies used deterministic manpower demand coverage optimization methods to satisfy manpower demands and to improve the scheduling efficiency (Brusco, Jacobs, Bongiorno, Lyons, & Tang, 1995; Holloran & Byrn, 1986). Numbers of employees needed at different times of day, which was used as manpower demands in such studies, were usually calculated based on long-term operations statistics, company resource budget and published flight schedules. For an airline that provides scheduled commercial service, flight schedules are usually made months before the actual operation for planning purposes. Flight delays, which are very common in today’s busy operating environment, are not being considered by many studies addressing scheduling problems (Dowling, Krishnamoorthy, Macketizie, & Sier, 1997; Yan, Chen, & Chen, 2008). Therefore in practice, theoretically optimal scheduling solutions made under the assumption of on-time arrival and departure of flights will no longer be optimal due to the discrepancies between the planned time and the actual time.

In order to create a robust manpower scheduling plan that can remain effective and efficient under the impact of flight delays in practice, the very first step is to assess the impact of flight delays on the scheduling plan that is currently used by commercial airlines. An accurate estimate of the extra cost caused by flight delays can be used to justify whether any fund to financially support the research of robust scheduling is necessary. In addition, the estimate can be used as a benchmark to quantitatively evaluative other scheduling plans.
Method

This study analyzes a major commercial airline from a mature market that operates multiple gates in one of its hub airports. Ground service staff employed by this airline provides services such as marshaling, parking, baggage unloading and loading to flights during aircraft turnaround. The airline has provided flight schedules and other relevant operational data of a particular month at this hub airport for research. These documents were also used by the airline in their resource planning. In addition, the actual flight arrival and departure time during that month is also available so that an evaluation of the impact of flight delays becomes possible.

In this study, numbers of ground service staff needed at different time of a day have already been calculated by the airline based on published flight schedules and other internal scheduling policies (See Figure 1 for manpower demand at different times of a typical day in the month selected for this study). Researchers need to produce a scheduling plan that can satisfy demands for ground service staff of all times as well as comply with all the practical scheduling constraints such as the ratio between part-time employees and full-time employees. In order to simulate the scheduling practice of many airlines, flight delays are not considered during the planning stage. After the scheduling plan is generated through the scheduling model, it will be assessed with the actual arrival and departure information for its “robustness” under real scenarios.

Figure 1. Daily Demand for Ground Service Staff
A simplified integer programming scheduling model can be written as (Gao, 2010):

\[
\min C_x \sum_{i=1}^{81} x_i + C_y \sum_{j=1}^{71} y_j + C_z \sum_{k=1}^{63} z_k + C_e \left( \sum_{i=1}^{81} a_i + \sum_{j=1}^{71} b_j + \sum_{k=1}^{63} c_k \right)
\]

Subject to:

\[
\sum_{i \in A_i} x_i + \sum_{j \in S_j} y_j + \sum_{k \in T_k} z_k \geq d_n \quad (n = 1, 2, ..., 96)
\]

\[
x_i - M \cdot a_i \leq 0 \quad (i = 1, 2, ..., 81)
\]

\[
y_j - M \cdot b_j \leq 0 \quad (j = 1, 2, ..., 71)
\]

\[
z_k - M \cdot c_k \leq 0 \quad (k = 1, 2, ..., 63)
\]

\[
\sum_{i=1}^{81} a_i + \sum_{j=1}^{71} b_j \leq F_p
\]

\[
\sum_{k=1}^{63} z_k \leq F_f
\]

\[
\sum_{i=1}^{81} x_i + \sum_{j=1}^{71} y_j - \lambda \sum_{k=1}^{63} z_k \leq 0
\]

\[x_i, y_j, z_k\] are all non-negative integers. \((i = 1, 2, ..., 81; j = 1, 2, ..., 71; k = 1, ..., 63)\)

\[a_i, b_j, c_k\] are binary. \((i = 1, 2, ..., 81; j = 1, 2, ..., 71; k = 1, ..., 63)\)

In this scheduling model, three different shift types are currently being used by the subject airline, denoted by decision variables \(x_i, y_j,\) and \(z_k\) respective. There is a 30-minute meal break built into the 6.5-hour part-time shift and the 8.5-hour full time shift, but no meal break for the 4-hour part-time shift, as regulated by the company policy. The scheduling of meal breaks is not considered by the current study. Staff leaders at airport gates will make ad-hoc decisions about when staff should take their meal break based on the actual workload of that day.

For the purpose of planning, every hour in a 24-hour working day is divided into four 15-minute periods. Since most domestic flight activities will stop in two hours past mid-night, for the purpose of planning, the first time period in a day starts from 3:00 am. For the 4-hour part-time shift, there are 81 different time periods to start a new shift in a day. Similarly, there are 71 and 63 time periods in a day to start a 6.5-hour
part-time shift and a 8.5-hour full-time shift, respectively. Binary variables $a_i$, $b_j$, $c_k$ indicate if the $i^{th}$ 4-hour part-time shift, the $j^{th}$ 6.5-hour part-time shift, and the $k^{th}$ 8.5-hour full-time shifts are actually used by the optimal scheduling plan or not. For instance, if $b_{32} = 0$ in the optimal solution of the scheduling model, then the 32nd 6.5-hour part-time shift, which starts at 10:45 am, in not used by the solution and no employee will be assigned to that shift.

The objective (1) of this model is to minimize the total cost of manpower, which consists of salary cost and scheduling overhead. Daily cost coefficients for three different shift types are denoted by $C_x$, $C_y$ and $C_z$ respectively. There is also cost associated with starting a new shift, as currently used by the airline in the planning. The purpose of introducing shift-starting costs in the scheduling is to discourage the scheduling model from creating too many shifts, which may create management difficulties.

The constraint (2) ensures that the number of available staff will always meet the demand. $R_n$ is the set of all the 4-hour part-time shifts that include $n^{th}$ time period. Similarly, $S_n$ and $T_n$ are the sets of 6.5-hour part-time shifts and 8.5-hour full-time shifts including the $n^{th}$ time period respectively. The left side of the inequality is the sum of employees working on three different shift types in the $n^{th}$ period, and $d_n$ is the manpower demand for ground service staff in that time period.

Constraints (3) – (5) guarantee that no more than $M$ employees will be assigned to any single shift. The purpose of this restriction is mainly due to practical management considerations. Total number of part-time shifts and full-time shifts in a day also have their upper limits, which are $F_p$ and $F_f$ in constraint (6) and (7) respectively. The maximum ratio between part-time employees and full-time employees is $\lambda$, as used in constraint (8), due to the agreement with the union mainly to protect the interest of full-time employees.

The optimal solution to the above scheduling model solved by CPLEX identifies which part-time shifts and full-time shifts are used and how many employees are assigned to these shifts. The results will be later used by the airline to make decisions
regarding budgeting and hiring, and to generate weekly or monthly staff scheduling rosters.

In order to assess the scheduling plan generated by the scheduling model, operational data of the same period of time were used. With the actual arrival and departure information, the actual demand for ground service staff at different times of a day in that selected month could be calculated, using the same method that was previously used by airlines to determine manpower demand. Then the scheduling plan was compared with the actual demand for ground service staff to determine if there was a surplus or shortage of manpower.

A penalty cost is associated with manpower shortage, representing the actual cost in practice to call in staff who are not on duty or pay over-time to cover the shortage. The following formula was used by the airline to calculate manpower shortage penalty cost for every 15-minute period. $x$ is the number of shortages, and $p$ is the unit cost for one staff shortage for 15 minutes. The value of $p$ can vary at different airports indicating the different levels of difficulty in solving temporary manpower shortage.

\[
penalty = \begin{cases} 
  P \cdot x & (0 \leq x \leq 2) \\
  2 \times P + (x - 2) \cdot 2 \times P & (2 < x \leq 4) \\
  2 \times P + (4 - 2) \cdot 2 \times P + (x - 4) \times 4 \times P & (x > 4)
\end{cases}
\]

**Results**

In this study, operational data of a month was used to assess the impact of flight delays on the scheduling of ground service staff. Since flight schedules vary for different days of a day, daily manpower demands will also be different. Therefore, shift types and number of employees assigned to different shifts by the optimal scheduling plan will vary, ensuring the potentially lowest cost of manpower while satisfying manpower demands at different times of all days. See Figure 2 for shift types and number of employees used by the optimal plan for different days in the month selected for this study.
As introduced earlier in this paper, flight schedules used in manpower scheduling are usually made months before the actual operation, and flight delays are not considered by many airlines when making scheduling plans for ground service staff. Discrepancies between estimated time of arrivals/departures and actual time of arrivals/departures will result in staff shortages at different times of a day. See Figure 3 for the number of time periods that actual manpower demands cannot be satisfied and associated penalty cost calculated based on formulas introduced earlier.

Figure 2. Number of Employees Used by the “Optimal” Scheduling Plan

Figure 3. Time Periods that Are Understaffed and Associated Penalty Costs
Discussion

In airlines’ manpower scheduling and resource planning, flight schedules play a central role by providing information such as aircraft type, route, estimated time of arrival (ETA) and estimated time of departure (ETD). Such information is later used to determine the number of staff needed for various positions at different times of a day. However, flight delays, which are very common in civil aviation operations and can seriously affect resource allocation, are not being considered by many airlines in the stage of planning mainly due to the fact that flight delays can be caused by many factors (International Air Transportation Association, 2009) and the fact that delays are almost impossible to forecast accurately months before operations.

It can be seen from the result of this study that flight delays do have a large economic impact on the scheduling of airport ground service staff. The average daily direct cost of manpower, consisting of staff’s salary and shift starting overhead cost, in this study was about $50,257 at the selected hub airport. Meanwhile, the average daily penalty cost to compensate insufficient manpower supply reached $20,243. Simply relying on ad-hoc adjustment at airport gates will not effectively solve manpower shortages caused by unaligned flight schedules. Therefore, in a more robust scheduling approach, flight delays must be considered as an important input during the planning stage.

Very few literatures can suggest an accurate estimate of the impact of flight delays on the scheduling of a particular position, not to mention the impact on airlines’ resource planning as a whole. The quantitative assessment of the impact of flight delays on the scheduling of airport ground service staff by this study is an important step to address this issue, which should be followed by a series of studies focusing on other relevant positions. With a more precise assessment of the economic impact of flight delays, the commercial airlines will be able to more smartly plan its resource, which in turn will improve airlines’ on-time performance and reduce flight delays caused by insufficient resource.
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