Dynamic Staff Rostering at Auckland International Airport using DORIS

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Abstract

Over the last 2 years, a new simulation and optimisation based rostering system has been developed for the Primary Line Customs staff at Auckland International Airport. The initial work in this project built optimised rosters just once every six months. A new system has been developed that is being implemented at the Airport to generate both weekly, daily and hourly changes to the staff rosters. This paper details the development of this Dynamic Online Roster Improvement System (D.O.R.I.S.).

1 Introduction

The last two years has been a period of significant change for the Customs staff and management at Auckland International Airport. The original staffing process of using historical precedents and reacting to passenger and flight changes as they occurred has been replaced by a computer based quantitative optimisation and simulation driven system. This paper discusses the development of this new system.

This report begins by summarising the staffing requirements for both arrivals and departures at the primary lines at Auckland International Airport, and briefly discusses the six-monthly generation of base rosters for these areas. This work has been presented before [1, 2], and the interested reader is referred to these earlier articles for full background details. The main focus of this work is the so called 'repair' of these rosters whereby changes are made to reflect actual work requirements as they become known. This software solution developed for this problem is presented and discussed before conclusions and future directions are given.
2 Passenger Processing Requirements

New Zealand Custom’s responsibilities at the Auckland International Airport include the ‘primary processing’ of both arrival and departure passengers. This processing includes both the profiling of passengers to detect high-risk passengers and also the immigration function of passport entry and clearance. These passengers are processed at 8 departures booths and 16 arrival booths.

The principal factor driving staffing is the need to meet Government specified passenger ‘facilitation targets’. For arrivals, the facilitation agreement specifies that passengers be processed within 1 hour 15 minutes of the flight touching down. For departures, operating practice requires that passengers be processed about 10 minutes before the scheduled departure time.

Information has been collected on average processing rates for the various categories of passenger (e.g. New Zealand passport holder, Australian passport holder etc.). These figures can be used to calculate the total processing associated with a given arrivals or departures flight. However, more critical to the process is the behaviour of the passengers, and in particular the distribution over time by which they become available for processing by Customs. Because arriving passengers collect their baggage before proceeding through Customs, the distribution of arrival passengers presenting themselves at Customs depends on the time at which the baggage handlers make the luggage available at the luggage carousels. The baggage collection process is further complicated by the need for each passenger to collect up to three or four bags, and the practice of family groups to delay their entry to the Customs queue until all bags have been collected for all family members. Considering the distribution of departures passengers, it is known that this distribution depends on the scheduled flight time, the time of day, and the rate of check-in by the airline concerned.

A detailed study of the behaviour of arriving passengers has recently been completed at the airport, and up to date parameter estimates have been determined for the various underlying distributions. While some data is available on departures passenger behaviour, a new study is planned to improve modeling of the departure process.

An additional requirement specified by Customs is that arrivals staff are not removed from booths during a busy period. This prevents passengers becoming annoyed when an arrivals booth is closed while a large queue is standing in front of that booth. A staffing plan is deemed infeasible if the average queue per booth exceeds a given limit whenever a staffing reduction occurs.

3 Customs Staffing

The primary lines at the airport are staffed by a mix of full and part time staff. The full time staff work an 8 hour, six days on, three days off roster, while the part timers are available for periods of between 3 and 5 hours as needed. In practice, it is difficult to alter the roster for the full time staff, and so these staff typically work the same roster pattern for a six month cycle. New full time rosters are developed twice a year to follow the six monthly seasonal flight schedules operated by most
airlines. Initial part time staffing levels are estimated for the same six month period, and then altered by management on a week by week basis.

4 A Simulation and Optimisation Approach

The generation of the six monthly roster begins with the identification of a ‘typical week’ with corresponding flight movements and predicted passenger levels. This typical week is used both to determine the full time roster and give an approximate base roster for the part time staff. This is a 2 step process, with work requirements being calculated first and then an appropriate staffing plan being determined that meets these requirements.

Given flight and passenger data, and assuming known flight arrival and departure times for each day, a simulation system has been developed that allows any staffing arrangement to be tested for feasibility, where a plan is feasible if all flights are processed within their facilitation targets, and no arrivals staff are removed during busy periods.

The simulation process uses three separate simulation programs. The first two packages determine the distribution by which arriving and departing passengers present themselves to Customs, giving a minute by minute breakdown for each flight of passenger numbers joining the Custom’s arrivals or departure queues. The arrivals version of this passenger simulation has been developed by Dr David Whitaker from Waikato University, and models the behaviour of arrivals passengers as they disembark from their flight, collect their baggage, and then join the Customs queue. The second passenger simulator developed by the author performs the equivalent function for departures passengers. The third combined simulation takes as input specified staffing levels for both arrivals and departures during each 15 minute interval in the day, and then uses the passenger movement data generated by the previous two simulations to test this staffing plan for feasibility according to the previous criteria.

The actual work requirements are generated by repeated calls to the third combined simulation with successively reduced staffing levels. When no further reductions are possible, this work requirements heuristic returns the last feasible staffing level as a minimum staffing requirement.

Given a work requirement for each day, the final step in the roster build process is to determine a suitable combination of full and part time shifts that covers the work requirement. This problem is solved using an integer programming model that minimises the total paid hours given some predetermined requirement for total full time staff numbers. This entire process is summarised in Figure 1.

5 Development of DORIS

The initial simulation and optimisation systems were developed for use by the authors at the University. However, a long term goal has always been the movement of these technologies out to the airport for use directly by Customs management and supervisors. This process is currently underway via the development of a
Figure 1: The original simulation and optimisation staff rostering solution process.
software package termed DORIS (Dynamic Online Roster Improvement System). We briefly give an overview of DORIS before discussing the new solution approaches it encompasses.

Written in Visual Basic to run on a PC, DORIS is an integrated environment giving access to flights and roster databases, and incorporating the simulation packages discussed above. It will also include an integer programming optimisation engine when this has been successfully ported to the PC environment.

DORIS is used by the supervisors to determine the actual work requirement given the latest estimates of flight arrival/departure times and passenger levels. The flights database is updated weekly using information provided by Air New Zealand, with more recent updates being entered manually as information becomes available from the various airlines concerned. This information is used by the simulation packages to determine the actual work requirements, and show these graphically overlaid by the current staff availability as read from the staff database. At the moment supervisors then manually determine the changes required in their staffing arrangements to meet the changes in work requirements. However, an optimisation based engine has been developed and is currently being ported to run on the PC.

There were a number of developments required to make DORIS feasible. Firstly, the original arrivals and departure passenger simulations had to be replaced by faster versions. These original simulations were written in Simscript, and could require up to 20 minutes to generate the required results. This was clearly not acceptable. A new arrivals passenger simulation has been written by Dr David Whitaker of Waikato University, and gives running times of about 30s per day. A temporary departure simulation has been written by the author; this will be replaced with a more accurate model once further data has been collected on the departure process.

While these changes were an important part of the development process, other changes were required in the work requirements heuristic and the shift generation integer program. These developments are discussed next.

6 Roster Repair

One of the principal uses of DORIS is to determine a net work requirement given updated flight data and a current availability of staff. This ‘roster repair’ can happen at a range of time scales. For example, every week the requirement for part time staff needs to be determined given the predetermined full time staff availability; the full time roster is ‘repaired’ using part time staff. (The full time staff availability is calculated from the underlying six monthly full time roster after adjusting for any planned leave.) During day to day operation, DORIS is required to determine adjustments to both full and part time shifts; the full and part time rosters are repaired using either overtime and/or adjustments to shift start times.

Now, if we consider the heuristic for generating work requirements, we note that the work requirements produced are not necessarily unique, but will be one of perhaps many staffing arrangements that meet the desired targets. For example, a flight can be processed well within target if a large number of staff are available, or processed more slowly if staffing is tight. Therefore, when generating a work...
requirements in a roster repair situation, the new requirements should reflect the
known availability for staff. It is not acceptable to determine a low average staffing
solution that requires additional staff to be brought in when a high staffing solution
using already available staff will be feasible. Therefore, the goal is now to reduce
the extra staff required to become feasible. That is, we now wish to reduce the
net staffing requirement given by the required staff minus the available staff; we
no longer need to focus on the total staff required. This change was incorporated
within the work requirements heuristic as follows.

Firstly, the work requirements heuristic operates by determining the next 15
minute period in which staffing is to be reduced, and then attempting a reduction
in that period. In the original heuristic, the period to reduce was simply that with
the highest total staffing requirement. However, in the new approach, we wish to
reduce first those requirements with the largest net work requirement. While such
an approach is possible, it can be improved by noting that the reduction of short
duration but large net work requirements is likely to give greater benefit than the
reduction of net requirements in intervals of consistently high requirements. This
is because a short isolated net work requirement is likely to be met by bringing on
an extra part time staff member who works for just, say, 30 minutes out of their
minimum 3 hour shift length. However, if the same staff member were brought in
to cover some other 2 hour work requirement, then their time would be used more
efficiently.

To determine isolated peak requirements, a smoothing approach is used to cal­
culate the average net work requirement in an interval, and then determine how
much an individual 15 minute requirement exceeds the surrounding average require­
ment. If \( a_i, i = 1, 2, \ldots, n \) represents the net requirement in period \( i \), then let \( d_i \)
represent the 'left' average work requirement, and \( e_i \) the 'right' work requirement,
where \( d_i \) and \( e_i \) are defined by \( d_1 = a_1, d_{i+1} = a_{i+1} + (1 - \alpha)d_i, \) and \( e_m = a_m, \)
\( d_{i-1} = a_{i-1} + (1 - \alpha)d_i, \) where \( m \) is the number of 15 minute intervals in the day.
We choose \( \alpha \) between 0 and 1, e.g. \( \alpha = 0.1 \). Thus, \( c_i = a_i - ((d_i + e_i)/2) \) indicates
the degree to which the net work requirement \( a_i \) exceeds the neighbouring work
requirements. The modified work requirement heuristic now attempts to make a
staff reduction in that period with the largest \( c_i \).

Once the net work requirements have been established, the final step in the
roster repair process is the generation of minimum cost changes to the shifts to cover
the new work requirement. This problem is solved using an integer programming
model as follows.

The repair problem is formulated as a set covering problem, where the adjusted
work requirement \( r_i, i = 1, 2, \ldots, m \) is to be covered. (Note that \( r_i \) is the new total
work requirement in each 15 minute interval, not just the net requirement discussed
above.) This coverage is achieved by a combination of different options, being: use
of existing full time shifts, extensions of these shifts either past their planned finish
time or before their planned start time through overtime, use of existing part time
shifts, extension of part time shifts either earlier or later than planned, movement
of part time shifts without changes in their length, or the addition of new part
time shifts. We let the matrix \( P = (p_{ij}), i = 1, 2, \ldots, m, j = 1, 2, \ldots, n \) represent
all such legal possible shifts and changes, where \( p_{ij} = 1 \) if (existing/modified/new)
shift \( j \) covers period \( i \). The cost \( c_j \) of column \( j \) in \( P \) is calculated as the number of
additional hours associated with that (existing/modified/new) shift. Furthermore, if \( n_s \) is the total number of distinct pre-existing shifts, then let matrix \( Q = (q_{kj}) \), \( k = 1, 2, \ldots, n_s \), \( k = 1, 2, \ldots, n \) be defined by \( q_{kj} = 1 \) if column \( j \) in \( P \) uses or modifies an existing shift \( k \), and zero otherwise. We require that the total number of times an existing shift \( k \) is used or modified in the solution does not exceed the number of staff \( s_k \) working that shift.

Let \( x_j \) be the number of staff working (existing/modified/new) shift \( j \) in the repaired roster. The following optimisation model will determine an allocation of full-time and part-time personnel satisfying the staffing requirements for each period with the minimum number of additional paid hours.

\[
\text{Minimise} \quad \sum_{j=1}^{n} c_j x_j
\]

\[
\text{subject to} \quad \sum_{j=1}^{m} x_j p_{ij} \geq r_i \quad \forall i = 1, 2, \ldots, m
\]

\[
\sum_{j=1}^{m} x_j q_{kj} \leq s_k \quad \forall k = 1, 2, \ldots, n_s
\]

\[
x_j \geq 0 \text{ integer} \quad \forall j = 1, 2, \ldots, n
\]

This model has been solved successfully in a workstation environment using the Zip software package developed by Professor David Ryan. It is currently being ported to a PC environment for inclusion in DORIS.

7 Conclusions and Future Directions

An integrated software framework has been constructed to solve the Customs staffing problems at Auckland International Airport. This DORIS system is now being used at the airport by Customs supervisors. The design of DORIS allows improved solution engines to be developed and incorporated to further automate management decision making. Engines that are currently being planned and/or implemented include the roster repair integer program discussed above, an engine to automate the allocation of part time shifts to named part time staff (with shift preferences), the improved forecasting of passenger levels and arrival times, and some means by which staffing plans can be tested for robustness given the uncertainty of arrival times.

8 Acknowledgments

The authors would like to acknowledge the work Peter Hoogenboom in developing the initial roster repair engines. Thanks are also due to Dr David Whitaker from Waikato University for developing improved passenger simulation models, and to the management of Auckland International Airport Limited for supporting this development. The coding of DORIS's user interface in Visual Basic was undertaken by David Blake of David Blake Consultants. The design of the underlying staff
and flight databases was developed with substantial input and coding from Peter Maxwell, who has also proved invaluable in his role as technical support, co-designer and programmer for the DORIS system. Finally, this project would not have been possible without the vision and support of Customs management including Fiona Joe, Glenys Hoffman and Kevin Donovan.

References
