Plane and Crew Scheduling

MAST90050: Scheduling and Optimisation

Group H2S

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Abstract

This report addresses the complex challenges associated with flight and crew scheduling (CS) problems, focusing on Virgin Australia, which can also be described as a machine-job scheduling problem. The Bender decomposition approach is employed, dividing the problem into three stages: fleet assignment and routing (MILP), flight scheduling (E/T), and CS ($\sum T$). We proposed two MILP models; one is proven to improve the objective value by 17%, suggesting that the sixth and latest flight must go to the origin city. Additionally, the Earliness-Tardiness approach is used to create flight schedules, with due dates set at 13:00, aiming to align with passenger preferences. This approach results in a promising flight timetable: the majority of the flight is scheduled at midday. Moreover, a modified list scheduling (LS) is used to solve the CS problem, ensuring even distribution of the working hours across the team in each home base, with due dates set to 36, that is, the maximum working hours per week. In solving CS, some cases were observed by changing the maximum number of shifts, which can be analysed to determine which is more profitable between hiring additional crew or paying overtime. However, despite these findings, the model proposed in this report still used several assumptions and simplifications, which still need to be adjusted for practical implementation.

1 Introduction

Virgin Australia, originally known as Virgin Blue, began its aviation journey in August 2000 with a modest fleet of just two aircraft serving one route. Co-founded by British entrepreneur Richard Branson, the visionary behind Virgin Group, along with former CEO Brett Godfrey, the airline is taking its first steps in the Australian aviation market. They did not expect that this business would develop into a major player in the domestic aviation industry (IBISWorld, 2022).

The airline's growth story is a testament to its resilience and adaptability. The aircraft successfully weathered the turbulence following the collapse of Ansett Australia in September 2001, strengthening its position in Australian skies. Currently, Virgin Australia directly serves 32 cities across the continent, operating from strategic hubs in Brisbane, Melbourne and Sydney.

However, the aviation industry is not without its challenges, and Virgin Australia is facing its share of challenges. The complex task of assigning aircraft to various flight paths to minimise operational costs presents a difficult puzzle. To overcome this complexity, the airline planning process is divided into several aspects, including flight scheduling, aircraft allocation, route planning, and crew assignment. Each aspect represents a unique optimisation challenge, which is closely interrelated with the pursuit of operational efficiency (Unal et al., 2021).

The heart of the problem lies in aircraft assignment—a strategic effort to efficiently match aircraft to flight legs while complying with various constraints and objectives. At the same time, aircraft routing problems require careful assignment of tail numbers to predetermined flights or routes, considering factors such as flight range, aircraft maintenance, and utilisation limits (Mancel & Mora-Camino, 2006).

To further improve its commercial viability and target a higher market share, Virgin Australia underwent a transformation under new ownership by Bain Capital. The airline aims to align its fleet expansion with anticipated demand recovery over the next five years (IBISWorld, 2022).

The crux of the problem lies in optimisation. This report begins the journey to optimise fleet assignments —the allocation of available aircraft for scheduled flights—by designing and implementing Mix Integer Linear Programming (MILP) models then continue with the scheduling algorithm. As airlines plan to expand their fleets and expand their presence in the market, the ultimate goal is to minimise the total costs associated with flight assignments and find the best schedule for the aircraft, thereby ultimately increasing the company's profitability.

The evaluation criteria for the Virgin Australia fleet optimisation problem revolve around objective functions, decision variables and constraints. The ultimate goal is cost minimisation, which is achieved by matching the right fleet to the right flight cycle, thereby increasing productivity and customer satisfaction. Decision variables include the frequency of flights for a particular fleet type on a specified flight cycle, as well as the number of aircraft types assigned. Constraints, ranging from aircraft availability and distance to operating hours, seat capacity, and passenger demand, are carefully incorporated into the model to ensure a holistic optimisation approach.

2 Literature Review

Numerous publications regarding plane and crew scheduling address similar problem characteristics and foundational assumptions. Gopalakrishnan and Johnson (2005) addressed five main stages of aircraft scheduling: flight scheduling, fleet assignment, aircraft routing, crew pairing, and rosters. Valouxis et al. (2012) also suggested that crew scheduling becomes one of the top priorities since its cost contributes to the second largest after fuel. Moreover, solving all the stages simultaneously is highly challenging due to its complexity, suggesting that the most effective approach is decomposing the problem into multiple sub-problems. This idea is widely known as Bender decomposition.

Another example by Mercier and Soumis (2005) uses Bender decomposition to reformulate their integrated aircraft routing, crew scheduling and flight retiming model. They separate the problem into the master problem and the sub-problem and solve the sub-problem first before using the result to solve the master problem. Based on this technique, the sub-problem can also be decomposed being a sub-master problem and sub-sub-problem. On the other hand, De-Yi and Zong-Xian (2010) introduced an integrated model aimed to address fleet assignment and routing concerns simultaneously, utilising the Branch and Search algorithm. However, it is essential to acknowledge that this model poses challenges due to its nonlinear programming nature, potentially consuming high computational time for resolution.

As solving the optimisation problem in flight scheduling is challenging, many experts try to construct their own algorithm. Valouxis et al. (2012) presented a model which considered the flight schedule as input, construct the flight graph and then tackle the crew scheduling problem using Genetic Algorithm (GA). While his proposed approach could yield innovative results, it is worth noting that schedules generated over different types of problems would span for different days. Moreover, in Earliness and Tardiness (E/T) problem, Beck and Refalo (2003) suggested an approach involving the initial solution of the linear relaxed version, followed by solving the constrained optimisation problem when dealing with E/T problems.

Hence, we will use the Bender decomposition approach to model the fleet assignment and flight routing, the flight the crew schedules. The first will be solved using Mixed Integer Linear Programming (MILP), addressing them simultaneously, while also relaxing the timetabling. Subsequently, when creating the flight schedule, we view this as an E/T problem.

Earliness-Tardiness (E/T) or also known as just-in-time (JIT), is a useful method for solving the scheduling problems. In an E/T scheduling environment, a job that completes early must be held in inventory until its due date, whereas the jobs that complete after their due dates may disrupt the costumer's operations. Hence, the ideal schedule is one in which all jobs finish exactly on their assigned due dates (Baker & Trietsch, 2013).

Moreover, in the case of crew scheduling problem, we will adopt a similar idea, utilising the flight schedule as an input. However, we will solve it using a Greedy Algorithm, often referred to as List Scheduling. List scheduling serves as a real-time decision-making method for managing tasks. Essentially, it operates by maintaining a list that can be seen as a lineup of pending jobs. As jobs are completed and their respective machines become available, the next job in the queue is assigned to the current free machine (Baker & Trietsch, 2013).

3 Problem Description

3.1 Problem Definition

It is essential for a company to enhance their business stability, which can be done by optimising resources such as fleet assignments and crew scheduling. The fleet assignment is defined as the scheduling and optimisation problem, which optimises the use of available aircraft while scheduling the corresponding aircraft simultaneously. This part of the problem has two objectives: minimising the cost and ensuring that the flight is mostly scheduled at midday. Meanwhile, the crew scheduling is to schedule the crew effectively according to the available flight schedule, ensuring a balanced distribution of working hours for all crew members.

3.2 Problem Scope

Virgin Australia has four types of aircraft, which are Boeing 737-800, Boeing 737-700, Airbus 320, and Boeing 737-700 ER. However, in this report, we only consider one type of aircraft, which is Boeing 737-800, the most widely held aircraft by the company. The Boeing 737-800 has a passenger capacity of 176, and incurs an operating cost of $4,213,000 per 60 minutes and an annual fixed cost of $13,470,000. Since the same aircraft type will be utilised for all available routes, the available seats are the same, so the crew-to-passenger ratio remains consistent. Consequently, we can treat the crew as a crew team consisting of the pilot, co-pilot, and flight attendants.

In this project, there are initially 42 flight routes that will be scheduled from and to 8 destinations. However, because of the demand requirement, all routes cannot be served every day. There are only 36 routes for Monday, as shown in (1). Every edge in the picture represents two routes. For example, an edge between SYD (for Sydney) and MEL (for Melbourne) corresponds to route SYD-MEL and MEL-SYD. For other destinations, the abbreviations will be ADL (Adelaide), BNE (Brisbane), CBR (Canberra), DRW (Darwin), HBA (Hobart), and PER (Perth).

In addition, the daily traveller demand experiences substantial hourly variations. As per Infrastructure Australia (2020) data, Sydney Airport witnesses the highest number of average movements around midday(Figure 2). We utilise this information to schedule the majority of flights around 13:00.

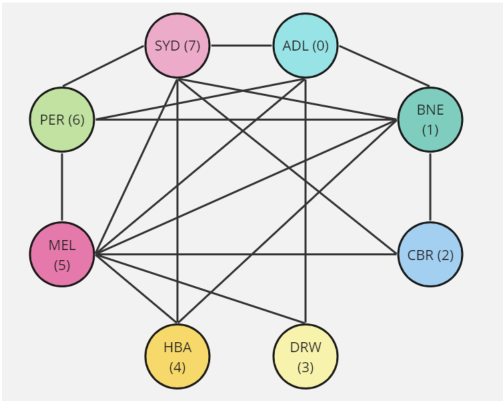


Figure 1: Flight Cycles

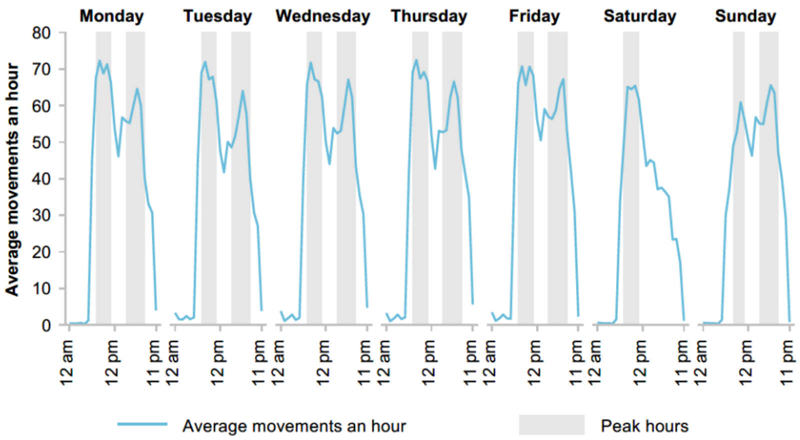


Figure 2: Average hourly movements at Sydney Airport

3.3 Assumptions and Simplifications

To simplify matters, we made several assumptions and streamlined certain aspects as follows:

1. The maximum number of flight per plane is twelve each day.
2. There is only one airport in each city.
3. The departure time of the first flight for each plane cannot be earlier than 5:00 (5 a.m.).
4. The arrival time of the last flight for each plane cannot exceed 21:00 (9 a.m.).
5. The flight duration is found by sampling from the Virgin Australia website without considering the plane type used, added by 30 minutes for turn-round times (Aviation, 2015).
6. The passenger demand is calculated from the real demand data from January 2023 to July 2023 and based on the market share gained by Virgin air, which is 24.9% of the domestic passenger demand in Australia (IBISWorld, 2022).
7. The demand for a one-way route in the same cycle is assumed to be the same; for example, the demand for ADL-BNE is equal to the demand for BNE-ADL
8. The daily demand ratio is calculated by sampling from Virgin Australia route SYD-MEL only in the period 1-28 October 2023.

9. The hourly operating cost is assumed to be linear.
10. The total working hours in a day is assumed to be 16 hours maximum.
11. It is assumed that there are a maximum of two shifts for each plane per day to facilitate crew scheduling.
12. Crews are organised in teams consisting of a pilot, co-pilot, and flight attendants.
13. Each team only has maximum of one shift each day.
14. Each crew member has a maximum working hours of 36 hours/week; any hours worked beyond this are considered overtime.
15. Crew salary is divided into fixed salary and hourly flight salary.
16. Each crew team has their own home base, where they start and end their shift every day to ensure they return to their original location each day.

4 Model Formulation

The objective of the model is:

$$\min f = v + w + z$$

where v is the objective of the crew scheduling problem for minimising the total crew salaries, w is the objective of the flight scheduling for minimising the cost by the effect of earliness/tardiness, and z is the objective of plane routing for minimising the cost of of using the planes. Furthermore, by using the bender decomposition method, the third objective will be solve first as sub-problem 1. This is followed by solving the second objective w as sub-problem 2 using the result from sub-problem 1 (the z value). Lastly, the result of sub-problem 2 is used to solve the first objective v.

4.1 Sub-problem 1: MILP

Sub-problem 1 is defined to find the flight routes for all planes in a weekly schedule. This problem can be solved using two model approaches (Model 1 and Model 2). These approaches will use the demand for Monday/ Thursday/ Friday (demand 0) only.

4.1.1 Model 1

Here, it is assumed that the flights are in cycle (the planes should return to its origin after serving one route).

Constants:

N : Set of planes

F : Set of flights

C : Set of cities

TH : Maximum working hours per day in minutes

S : Number of available seat per plane

FC : Fixed cost of using the plane on that day

VC_{kl}: Operational cost from city k to city l

FD_{akl}: Flight duration from city k to city l on day a

DM_{akl}: Passengers demand from city k to city l on day a

Decision Variables:

x_{nfkl} : The binary variable equal to 1 if plane n flight f travels from city k to city l for even f or from city l to city k for odd f.

Objective Function:

$$\min \quad z = \sum_{n \in N} \sum_{k \in C} \sum_{l \in C} \Big(VC_{kl} \cdot x_{nfkl} + FC \cdot x_{n0kl} \Big) \tag{1}$$

Constraints:

$$\sum_{k \in C} \sum_{l \in C} x_{nfkl} \leq 1 \qquad f \in F; n \in N \tag{2}$$

$$\sum_{f \in F} \sum_{k \in C} \sum_{l \in C} x_{nfkl} \cdot FD_{0kl} \leq TH \qquad n \in N \tag{3}$$

$$\sum_{f \in F} \sum_{n \in N} x_{nfkl} \cdot S \geq DM_{0kl} \qquad k, l \in C \tag{4}$$

$$\sum_{l \in C} x_{nfkl} \geq \sum_{l \in C} x_{n(f+1)kl} \qquad f_{\text{odd}} \in F \backslash \{F_{\max}\}; n \in N; k \in C \tag{5}$$

$$x_{nfkk} = 0 \qquad f \in F; n \in N; k \in C \tag{6}$$

$$x_{nfkl} = x_{n(f+1)kl} \qquad f_{\text{even}} \in F \backslash \{F_{\max}\}; n \in N; k, l \in C \tag{7}$$

Explanation:

(1): The objective function minimises the total costs (the operating cost and the fixed cost). Once the plane is used to travel then the fixed cost is only applied once in that day.

(2): The plane can only serve one route maximum per flight.

(3): The total flight duration for each plane must be less than the total working hours.

(4): Demand satisfaction.

(5): The previous and later flight should be connected.

(6): There is no flight to the same city.

(7): The round trip flight from city k to city l should happen consecutively.

4.1.2 Model 2

Here, it is assumed that the plane should return to its home base after serving maximum 6 routes. Here, we still use the constants, the decision variable x_{nfkl}, the objective function (1), and the constraints (2) and (3). In this model, the dummy flights from and to the same city are allowed to make the problem feasible. Followings are the additional constraints:

Constraints:

$$\sum_{f_{\text{even}} \in F} \sum_{n \in N} x_{nfkl} \cdot S + \sum_{f_{\text{odd}} \in F} \sum_{n \in N} x_{nflk} \cdot S \geq DM_{akl} \qquad k, l \in C \tag{8}$$

$$\sum_{l \in C} x_{nfkl} \geq \sum_{l \in C} x_{n(f+1)kl} \qquad f_{\text{odd}} \in F \backslash \{F_{\max}\}; n \in N; k \in C \tag{9}$$

$$\sum_{k \in C} x_{nfkl} \geq \sum_{k \in C} x_{n(f+1)kl} \qquad f_{\text{even}} \in F \backslash \{F_{\max}\}; n \in N; l \in C \tag{10}$$

$$x_{nfkk} = x_{n(f+1)kk} \qquad f_{\text{odd}} \in F \backslash \{F_{\max}\}; n \in N; k \in C \tag{11}$$

$$x_{n0kk} = 0 \qquad n \in N; k \in C \tag{12}$$

$$\sum_{l \in C} x_{n0kl} = \sum_{l \in C} x_{n5kl} \qquad n \in N; k \in C \tag{13}$$

$$\sum_{l \in C} x_{n0kl} = \sum_{l \in C} x_{n(11)kl} \qquad n \in N; k \in C \tag{14}$$

$$\sum_{n \in N} \sum_{l \in C} x_{n0kl} \leq 10 \qquad k \in C \tag{15}$$

$$\sum_{n \in N} \sum_{l \in C} x_{n0kl} = 0 \qquad k \in \{2, 3, 4\} \tag{16}$$

$$\sum_{n \in N} \sum_{l \in C} x_{n0kl} \geq 2 \qquad k \in C \setminus \{2, 3, 4\} \tag{17}$$

Explanation:

(8): Demand satisfaction, here we need to justify the demand for each route. Model 1 does not need this justification as the flights are in cycles.

(9): Constraint to make sure the flight sequence for flight with odd numbers.

(10): Constraint to make sure the flight sequence for flight with even numbers.

(11): two dummy flights should happen consecutively and start with flight with odd numbers

(12): The first flight is not allowed to be dummy.

(13): The sixth flight should flight to the origin city for shifting purpose.

(14): The last flight should flight to the origin city (home base).

(15): The maximum number of planes for each home base are 10

(16): No plane with home base Canberra (2), Darwin (3), and Hobart (4)

(17): There must be at least 2 planes in each home base except Canberra (2), Darwin (3), and Hobart (4)

4.1.3 Model 2a

Model 2 can be extended with more indices d represent the days. However, it could be computationally expensive. To deal with this problem, we choose to loop the Model 2 for other days with different demands. Therefore, we add a new constant and change constraints 15, 16, and 17 to be:

Constant:

CP_k : The number of planes with home base city $k \in C$ based on the result from Model 2

Constraint:

$$\sum_{n \in N} \sum_{l \in C} x_{n0kl} \leq CP_k \qquad k \in C \tag{15a}$$

Explanation:

(15a): The maximum number of planes for home base k is CP_k

The usage of the Model 2a is truly based on the result of Model 2 which is better than Model 1. Otherwise, the Model 1 should be extended to other days data.

4.2 Sub-problem 2: Flight Scheduling

$1 \mid p_j, d_j = d \mid E/T$

In this project, we approach a complex multi-machine system by solving a number of single machine sub-problems, therefore sub-problem 2 is defined to find the flight schedule for each plane based on the optimal flight routes found in Sub-problem 1 model 2 (4.1.2). Here, we can view the set of planes as the set of machines, and the flight routes per plane are job sequences for the corresponding machine.

The following is the example of the resulting output from Sub-problem 1 model 2 (4.1.2):

'52': [[0, 5, 4, 105], [1, 7, 4, 140], [2, 7, 5, 115], [3, 5, 5, 0], [4, 5, 5, 0], [5, 7, 5, 115], [6, 7, 5, 115], [7, 2, 5, 100], [8, 2, 5, 100]],

This has a formula:

$$\text{Plane code}: \text{[[flight number, city 1, city 2, duration (minutes)]},[\cdots],\cdots]$$

and noting that:

1. The plane code consists of two digits, digit 1: city, digit 2: plane number, and
2. City 1 can be origin city if the flight number is even, otherwise it will be the destination.

Therefore, the output reads: The flight route for Plane 52 with Home Base 5 (City Melbourne):
1. The first flight travels from Melbourne to Hobart with a flight duration equal to 105 minutes
2. The second flight travels from Hobart to Sydney with a flight duration equal to 140 minutes
3. The third flight travels from Sydney to Melbourne with a flight duration equal to 115 minutes
4. The fourth flight is a dummy flight
5. The fifth flight is a dummy flight
6. The sixth flight travels from Sydney to Melbourne with a flight duration equal to 115 minutes
7. The seventh flight travels from Melbourne to Canberra with a flight duration equal to 100 minutes
8. The eighth flight travels from Canberra to Melbourne with a flight duration equal to 100 minutes

Moreover, the input for scheduling sub-problem 2 is as follows:

j	5-4	4-7	7-5	5-7	7-5	5-2	2-5
p_j	105	140	115	115	115	100	100

where j is a list of jobs and p_j is the processing job. Each job j is represented by $a - b$ that reads the flight from city a to city b. Notice that the sequence would be (5-4)-(4-7)-(7-5)-(5-7)-(7-5)-(5-2)-(2-5). Subsequently, we need to determine the departure time of each flight that should be scheduled, such that the maximum Earliness and Tardiness is minimum. We can write the problem in the notation $\alpha \mid \beta \mid \gamma$, where:

$\alpha : 1$. Since there is only one plane (machine)
$\beta : p_j, d_j = d$. Since each flight has different duration, meaning that each job has different p_j. The due dates here are considered to be 13:00, which is the most preferred departure time. All flights are assumed to have the same due dates.
$\gamma : E/T$ denotes that the objective is to minimise the maximum Earliness and Tardiness.

Therefore, sub-problem 2 is: $1 \mid p_j, d_j = d \mid E/T$.

The objective for this model is to minimise the maximum E/T which has unit in minutes. This result could be converted to cost w stated in the main objective problem if the data of the lost revenue for not offering the passengers the flight with a good schedule is available. As we cannot find this data, the result for sub-problem 2 will only show the flight schedule with the least earliness/tardiness.

4.3 Sub-problem 3: Crew Scheduling

$\boldsymbol{P_m \mid p_j, d_j = d, r_j \mid T}$

Sub-problem 3 is defined to find weekly crew scheduling for serving all flights. Here, we use the output from Sub-problem 2 (4.1.2) which is the same with Sub-problem 1 model 2 (4.1.2) but with departure time. In this stage, we can view the set of crew as the set of machines, and flights shift as the set of jobs. Moreover, since there are five home base airports (Adelaide, Brisbane, Melbourne, Perth, and Sydney), we then create a set of teams for each home base. Subsequently, we view each home base has its own parallel machine scheduling problem.

The followings are the example of list of shifts in Home Base 0 for day 0:

0: [[0, '00', 730, [[0, 0, 6, '08:50'], [1, 7, 6, '13:00'], [2, 7, 0, '18:35']]],
[0, '01', 220, [[0, 0, 5, '09:20'], [1, 0, 5, '11:10']]],
[0, '01', 465, [[2, 0, 1, '13:00']]]

This has a formula:

Home Base : [[day, plane code, duration (minutes), lists of flights],[$\cdots$],$\cdots$]

This reads that on Monday, there is one shift for plane 00, but there are two shifts for plane 01.

We can convert this to the following table:

	Shift 0	Shift 1
Plane 00	730	0
Plane 01	220	465

Therefore, the input for scheduling sub-problem 3 will be as follows:

j	0	1	2	...
p_j	730	220	465	...

where j is a set of jobs (shifts) for a whole week in each home base, and p_j is the processing job (flight duration for the corresponding shift). Each job is represented by shift index. Subsequently, we need to determine which job/ shift is assigned to each machine/ crew team for a whole week per home base, such that the total tardiness is minimum. We can also write the problem in the notation $\alpha \mid \beta \mid \gamma$, where:

$\alpha : P_m$. There will be m machines (teams) which share the same characteristics.
$\beta : p_j, d_j = d, r_j$. Since each shift has different total flight duration, meaning that each job has different

p_j. The due dates here is considered to be 36, which is the maximum working hours per team. Each the initial flight on a particular shift has its own departure time, meaning that each job/shift has different release times
$\gamma : T$ denotes that the objective is to minimise the maximum total tardiness.

Therefore, we can denote Sub-problem 3 to be $P_m \mid p_j, d_j = d, r_j \mid T$.

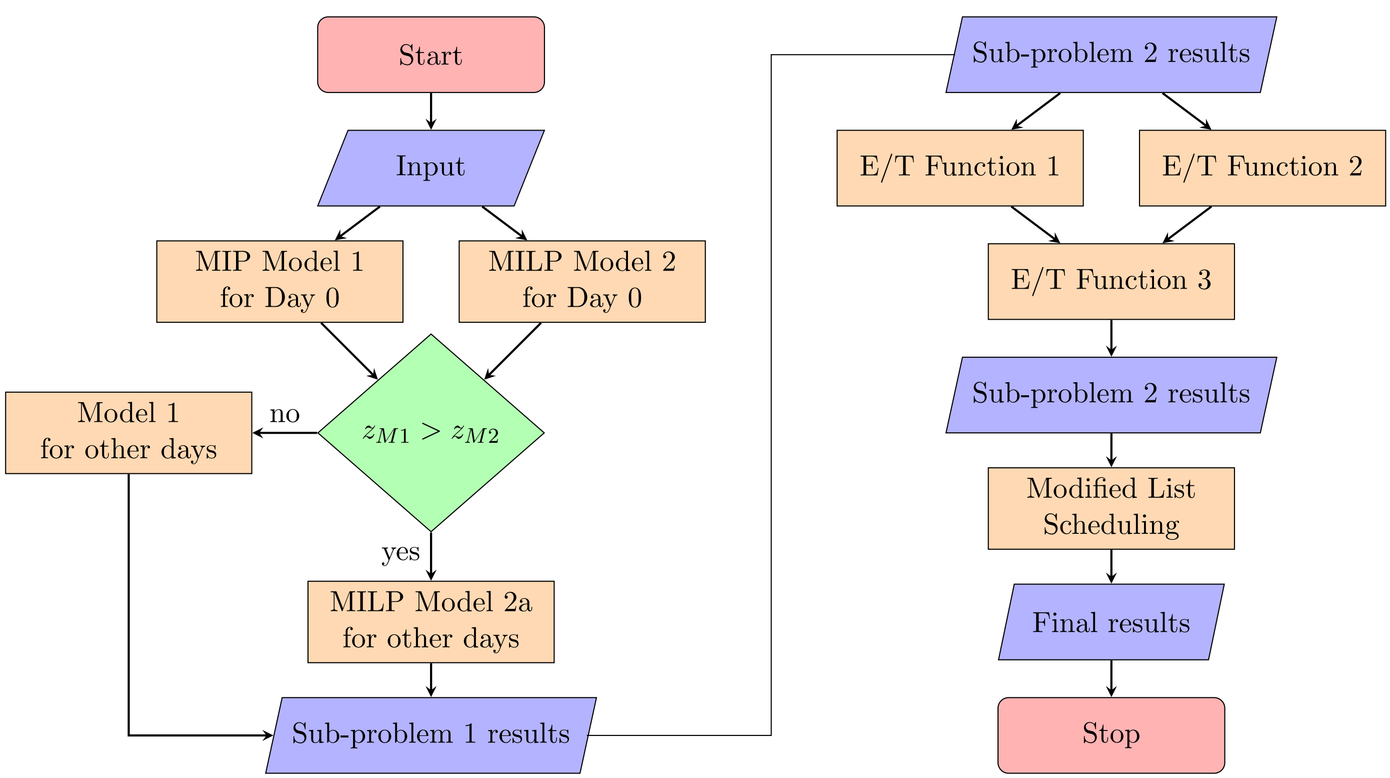
Calling back the main problem, the maximum total tardiness can be converted in terms of v, which represents the total crew salaries, including the overtime payments. However, as we do not know the salaries of the crew, we stop the final result in the crew scheduling, which minimises the maximum total tardiness.

5 Methodology

5.1 Method Proposed

In order to tackle the problem, the Mixed Integer Linear Programming (MILP) approach is employed for efficient fleet assignment. This algorithm would generate which plane serves each route. We then regard the routes as the job and the planes as the machine. We formulate the problem to be an identical parallel machine problem, as all planes share the same characteristics. Using the resulting output from MILP, we apply Earliness/Tardiness Algorithm 6.3 to schedule the routes for the corresponding plane, with a due date set at 13:00. This algorithm would yield a weekly flight schedule for each aircraft.

Furthermore, within a single day, the flight schedule is divided into two distinct block routes or shifts. The first shift encompasses the first through fourth flights, while the second comprises the fifth through eighth flights. These shifts will then be viewed as the job for the second problem, which pertains to crew scheduling. In this scenario, we will apply the modified list scheduling approach. Following is the flow chart of our algorithm design to solve the problem:



5.2 Data Processing

After sampling from Virgin Australia website, we determine that the daily demand ratio of the flight is as follows:

Table 1: Daily Demand Ratios

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1.1	1.05	1.05	1.1	1.1	0.7	0.9

From table (1), we can observe that Monday, Thursday, and Friday exhibit identical ratios, while Tuesday and Wednesday also share the same ratio. Consequently, we can group Monday, Thursday, and Friday as one set of days, and likewise, Tuesday and Wednesday as another set of days. Therefore, the flight schedules for the grouped days will be identical.

Subsequently, we apply the ratio specified in (1) to calculate the daily passenger demand for any given city-to-city route. Leveraging data from (IBISWorld, 2022), we can compute the weekly average number of passengers, allowing us to ascertain the number of flights needed to satisfy the passengers demand over a week. We then use the ratio (1), to distribute those required flights to each day, resulting in the following table:

Table 2: Daily Required Flights

Route	MON	TUE	WED	THU	FRI	SAT	SUN	Total
Adelaide - Brisbane	2	1	1	2	2	2	1	11
Adelaide - Canberra	0	1	1	0	0	1	0	3
Adelaide - Darwin	1	0	0	1	1	0	1	4
Adelaide - Melbourne	6	4	4	6	6	2	3	31
Adelaide - Perth	1	2	2	1	1	1	1	9
Adelaide - Sydney	4	3	3	4	4	2	3	23
Brisbane - Canberra	1	2	2	1	1	1	1	9
Brisbane - Darwin	0	1	1	0	0	1	2	5
Brisbane - Hobart	1	1	1	1	1	0	0	5
Brisbane - Melbourne	7	7	7	7	7	4	5	44
Brisbane - Perth	2	2	2	2	2	2	2	14
Brisbane - Sydney	9	8	8	9	9	6	7	56
Canberra - Melbourne	2	2	2	2	2	2	2	14
Canberra - Sydney	1	1	1	1	1	1	2	8
Darwin - Melbourne	1	0	0	1	1	0	1	4
Darwin - Perth	0	1	1	0	0	1	0	3
Hobart - Melbourne	3	3	3	3	3	1	2	18
Hobart - Sydney	2	1	1	2	2	1	1	10
Melbourne - Perth	4	4	4	4	4	3	3	26
Melbourne - Sydney	15	15	15	15	15	11	15	101
Perth - Sydney	3	3	3	3	3	3	3	21

From table (2), we can see that now the available cycles would be different from figure (1). For example, there is no flight needed for route Adelaide-Canberra on Monday, Thursday, Friday, and Sunday. It means, in the next step, we will use the daily available cycles found in (2). Following this, we can easily determine the daily passengers demand by multiplying the number of daily flights by the weekly passengers demand, and then dividing by the total required flights, as illustrated in (10)

5.3 Benders Decomposition

In this project, we employ the Benders Decomposition approach to solve a complex optimisation problem. This approach is particularly useful when dealing with optimisation problems that exhibit mixed structure components. By dividing the process into three stages: solving the MILP model to determine the efficient fleet assignment, applying the Earliness/Tardiness algorithm to the results of MILP model, and then assigning the crew to achieve the optimal crew schedules.

5.3.1 Mixed Integer Linear Programming (MILP)

The first stage is developing a model based on the problems. The models 4.1.1 and 4.1.2 that we have developed in this project is a concrete example of the Mixed Integer Linear Programming (MILP) model. In 4.1.1 and 4.1.2 we deal with binary variables denoted as x, representing the utilisation of aircraft on various routes. The goal is to optimise the total cost, which encompasses both variable costs (VC) and fixed costs (FC). This objective function is implemented using Gurobi optimisation solver. The model also incorporates a set of constraints governing the use of aircraft, capacity, flight times, and more. These constraints are formulated to ensure that the resulting solution complies with all relevant operational requirements.

During the optimisation process, 4.1.1 and 4.1.2 search for solution that minimises the total cost while adhering to the imposed constraints. The optimal result provides valuable insights into aircraft resource management and efficient operations. The outcomes of this model include the optimal allocation of aircraft to routes, enabling a company to optimise aircraft utilisation and reduce operational costs.

After obtaining the results from Model 1 (4.1.1) and Model 2 (4.1.2), the next step is to compare the outcomes to determine which model to advance for further development. This is because, in the initial phase, both models were executed solely to obtain optimal results for sequencing on a specific day, which is day 0 (Monday). Once the more optimal results have been identified, that model will be further developed to perform the same optimisation process for the remaining days of the week.

The selection of the more optimal model is pivotal since its outcomes will serve as the foundational basis for sequencing on the other days throughout the week. In other words, the chosen model will be used as a reference for conducting similar optimisations across all days of the week, ensuring efficient and well-coordinated scheduling.

5.3.2 Earliness-Tardiness (E/T)

In this project, the concept of Earliness-Tardiness (E/T) is used to achieve optimal scheduling for each aircraft. The input data utilised in this context is the result of optimisation carried out in the previous stage. We can see the data as a complex multi-machine system by solving a number of single machine sub-problems since each aircraft has its own schedule, which is independent of other aircraft. This data is then processed using the E/T approach, where each plane is seen as a machine while the routes are jobs. Then, each job is driven to be completed precisely at the due date. However, although the E/T concept is utilised, there is a slight difference in defining the due date.

In the original E/T or JIT production, due date determination aims to minimise storage costs for early-completed jobs and optimise service for late-completed jobs. While, in this project, the due date is set at 13:00, aligning it with the preferred time for the majority of the customers to embark on their flights. By setting the due date at 13:00, we anticipate that the resulting schedule will encourage many aircraft arrivals and departures exactly at that time.

Since the problem can be seen as a multi-single machine, i.e. single machine scheduling for each aircraft, we solve the E/T problem by using two different approaches. First, by implementing Theorem 6.3 (No straddling jobs) which states that an optimal schedule exists in which some jobs are completed exactly at the due date d = 13:00. This approach is useful for the sequence that is unrestricted which means that the sequence does not start at time zero (in this project, is 05:00) and does not finish at 21:00 (airport closing time). Since there are still gaps/idle time at the beginning and/or ending, we can shift the block of sequence that we have and determine when the first jobs start so that there exists a job that completes exactly at the due date that minimises the E/T. Furthermore, We call this approach as "Function 1" in the code.

In the second approach ("Function 2" in the code), the sequence is forced to start at time zero (05:00) or finish at time 21:00 (when the airport closed). This approach is useful for the sequences that are restricted, i.e. do not have any gaps either at the beginning or the ending since these jobs will be infeasible if using the first approach (the sequence cannot be shifted). Even though this approach is useful for the restricted sequence, we still do this approach to the unrestricted sequence so that we can finalise the process by comparing the result of those two approaches and then take the most optimal schedule to be the final schedule. We find the most optimal schedule by "Function 3" in the code which compare the result from "Function 1" and "Function 2".

These schedules are expected to benefit the company significantly. The more flights occur around mid-day, particularly around 13:00, the greater the satisfaction among customer might be. Additionally, the company stands to gain higher profits as ticket prices during this time are relatively higher. This strategic approach enhances customer satisfaction, improves operational efficiency, and contributes to the company's profitability.

5.3.3 List Scheduling

List scheduling, in this project, is used to address the crew assignment problem. The schedules achieved by the Earliness-Tardiness algorithm in the previous stage serves as the basis of this stage. List scheduling emerges as the most effective method to address the aforementioned constraints.

This is primarily because it allows us to approach the crew assignment problem as minimising the total tardiness at parallel machine scheduling with the release time of each job (r_j) and common due date $d = 36 \times 60 = 2160$ minutes. In this context, each crew team is regarded as a machine, and shifts are treated as jobs while the release time is the start time of each shift on each day. However, as the team can only work in one shift/ day, we modified the list scheduling as shown in the algorithm.

The number of teams (machine) for each home base obtained from:

$$NT = \frac{TS}{NS} + 1$$

NT : Number of teams

TS : Total Shifts

NS : Maximum number of shifts allowed

The maximum shift for each team is set to be 5 or 4 shifts since the maximum working hour for each team is 36 hours. The exception is only for the team whose their home base is at Perth, where there are exist several teams that have maximum three shifts. This is because most of the aircraft that departure and/or arrived at Perth has longer flight hours, so they do not need to work more than three days to fulfil their maximum working hours. Following is the proposed pseudo code:

By adopting this approach, we can efficiently allocate and optimise the scheduling of crew members, ensuring that they adhere to the specified work-hour limits and remain aligned with the aircraft schedule.

Algorithm 1 (Modified) List Scheduling

```
for every home base do
    sort the job (flight shifts) in descending order based on their processing time (shift duration)
    for each job do
        choose the team (machine) with the smallest completion time
        if the number of shift < NS and no shift from the same day then
            assign the job to the chosen machine
        else
            assign the job to next machine with the smallest completion time
            and no shift from the same day
        end if
    end for
end for
```

This strategic use of list scheduling as a parallel machine scheduling problem simplifies the allocation of crew teams to shifts, facilitating a more streamlined and efficient crew assignment process.

6 Numerical Study

6.1 Sub-problem 1

In this section, two Mixed Integer Linear Programming (MILP) models are introduced. The summary of all models' implementation can be seen in table 3.

Table 3: Comparison of different models

Model	Time (s)	Objective (10^6)	Gap (%)	#Planes
Model 4.1.1	1.68	1451789	0.01	32
Model 4.1.2	90.18	1206448	0.01	24
Model 4.1.3$^{(*)}$	584	1176221; 898696; 1061740	0.01	24

$^{(*)}$ similar model to 4.1.2 but for other days

Model 1, as outlined in Equation (4.1.1), forces each aircraft to return to its designated home base after completing a route. For instance, if plane a operates the Melbourne-Sydney route during its initial duty, its subsequent flight should be Sydney-Melbourne. The implementation of Model (4.1.1) can be found in the attached appendix (9.3).

In this case, the Gurobi solver optimisation is utilised, which executes the MILP model in approximately 1.68 seconds with a minimal 0.01% gap. The best achieved objective value is 1451789.0. Furthermore, the total number of aircraft required is determined to be 32, with specific details for each home base outlined in the table 4

The second model, as described in Equation (4.1.2), shares the same variables and objective function as the first model. However, in this model, the requirement for planes is slightly different. Instead of mandating that planes return to their home base after every completed flight, Model (4.1.2) allows planes to return to their home base after serving a maximum 5 routes, subject to additional constraints.

This model is also optimised using the Gurobi solver, which requires approximately 90.18 seconds for execution, maintaining the same 0.01% optimality gap. Despite the longer computational time, this model achieves a 17% (1206448.0) improvement in the best objective value compared to the previous

Table 4: The Number of aircraft needed from model 1

Airport	Number of planes
ADL	3
BNE	5
CBR	1
DRW	2
HBA	2
MEL	7
PER	6
SYD	6

model. Moreover, it determines that only 24 aircraft are needed to meet the demand, which is fewer than the total number found in the previous model. The implementation of the model (4.1.2) can be found in the appendix (9.3)

Detailed information regarding the number of aircraft assigned to each home base is provided below:

Table 5: The number of aircraft needed from model 2

Airport	Number of planes
ADL	3
BNE	4
CBR	0
DRW	0
HBA	0
MEL	8
PER	2
SYD	7

This model suggests that the company should establish Adelaide, Brisbane, Melbourne, Perth, and Sydney as their home bases, while Canberra, Darwin, and Hobart are not included in the list of home bases.

In addition to calculating the minimum cost incurred by the company and determining the necessary number of aircraft at each home base, Model (4.1.2) also generates output in the form of sequences for each aircraft. These sequences outline the precise routes that each aircraft is assigned to cover. Consequently, with a total requirement of 24 aircraft, the model provides 24 distinct aircraft sequences. Below is one of the sequences obtained, representing the sequence for Aircraft 1, with its home base located at Adelaide Airport:

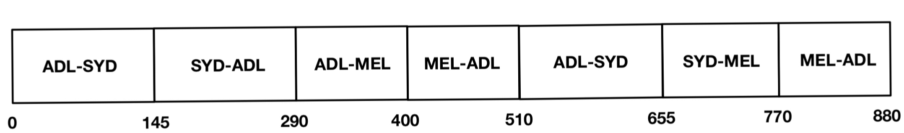


Figure 3: The sequence for Aircraft 1, based in Adelaide

This model was then extended to Model 2a (4.1.3) to accommodate varying levels of demand for each day. There are four distinct passenger demand ratios: one for Monday, Thursday, and Friday; another for Tuesday and Wednesday; one for Saturday, and one for Sunday. These differences impact the number of flights and routes for each day. Model (4.1.3) addresses this challenge by utilising the same objective function as (4.1.2), augmented by an additional constraint.

Gurobi executed this model for approximately 584 seconds, achieving minimal gaps of 0.01%. The best objective values found for each demand ratio are as follows: 1,206,448.0 for the first demand ratio (Monday, Thursday, and Friday), 1,176,221.0 for the second (Tuesday and Wednesday), 898,696.0 for Saturday's demand, and 1,061,740.0 for the Sunday's demand ratio. In conclusion, the total cost from Model 2 and 2a for a weekly schedule is 7,932,222.0.

6.2 Sub-problem 2

In this sub-problem, the Earliness-Tardiness (E/T) approach is employed to the sequences obtained by the model 2a (4.1.2). The purpose is to find the best schedule for each aircraft that minimise the E/T. Two functions are used to find the most optimal schedules. The implementation of this approach can be seen in the appendix (9.3).

The output of this approach provides us with the precise departure times for each plane. While the previous stage only presented sequences with the flight times for each route, and we can now align these sequences with the actual operating hours of the airports (05:00 - 21.00). Now, the sequence (3) for aircraft 1, based in Adelaide, can be seen as:

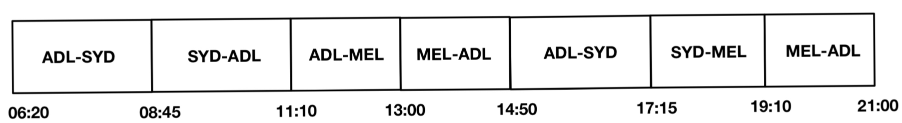


Figure 4: The sequence for Aircraft 1, based in Adelaide with time

However, for the sake of clarity and simplicity, we have organised the schedules into tables for each airport on each day. The table below illustrates the schedule for Adelaide on Monday, Thursday, and Friday:

Table 6: Flight Schedule for Adelaide on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Darwin	02	05:00
Sydney	01	06:20
Sydney	51	07:00
Perth	00	07:45
Brisbane	60	09:10
Sydney	10	10:50
Melbourne	01	11:10
Brisbane	13	12:15
Melbourne	53	12:20
Melbourne	02	13:30
Melbourne	61	14:25
Sydney	01	14:50
Melbourne	52	18:40
Melbourne	54	19:05

Table (6) contains information about the Destination, Plane Code, and Departure Time. The "Destination" column lists the destinations of the aircraft departing from Adelaide. The "Plane Code" clarifies which plane will be used to operate the route. For instance, Plane Code 01 indicates that the aircraft is based in city 0 (Adelaide) and is identified as Plane 1. The complete schedule for each airport per day can be found in the appendix (9.2).

6.3 Sub-problem 3

In the final stage, following the determination of the optimal number of flights and their corresponding aircraft to meet the demand, along with the optimal daily schedules for each aircraft, we employ a modified list scheduling approach to tackle the crew assignment problem. The crew assignment problem is treated as an optimisation problem aimed at minimising the total tardiness ($\sum T$) within the context of parallel machine scheduling, taking into account the release time for each job. In this scenario, the crew teams are considered as the machines, and the shifts represent the jobs, while the release time is the starting time for each shift. By implementing the modified list scheduling (9.3), we first calculate the number of crew teams needed to cover all the possible shifts.

Table 7: The number of Team needed

Airport	Number of Team	Maximum Shift
ADL	5	5
ADL	6	4
BNE	10	5
BNE	12	4
CBR	0	0
DRW	0	0
HBA	0	0
MEL	20	5
MEL	25	4
PER	3	5
PER	4	4
PER	5	3
SYD	17	5
SYD	21	4

Table (7) reveals variations in the maximum number of shifts for teams within a home base. For example, in Adelaide, there are 5 teams with a maximum of five shifts, while another 6 teams have a maximum of 4 shifts. These differences arise due to variations in flight times for each route, which, in turn, impact the duration of shifts on different days. Teams assigned to relatively shorter shifts require more shifts to fulfil their maximum working hours, whereas those assigned to longer shifts require fewer shifts to meet the same requirement.

Once we have determined the required number of teams in each home base, we proceed to allocate shifts to each team to create the optimal schedule for every team. Here in table (8) is an example of the output for the timetable of Team 1, which is based in Adelaide and has a maximum of 5 shifts:

Moreover, as we approach crew assignment with the goal of minimising total tardiness at parallel machine scheduling with a specific release time for each job (r_j) and a common due date of $d = 36 \times 60 = 2160$ minutes, we have now computed the total tardiness. In this context, the total tardiness corresponds to

Table 8: ADL - Team 1 (2910 mins) - 5 Shift (max)

Day	Shift Duration	Plane Code	Flight Routes
Monday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
Tuesday	290	00	ADL-SYD (05:25), SYD-ADL (07:50)
Thursday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
Friday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
Sunday	720	01	ADL-DRW (08:45), DRW-BNE (13:00), BNE-ADL (17:40)

the total overtime for each team. This calculation is derived from an analysis of the summary of each team's duration, as outlined below:

Table 9: Crew Scheduling Summary

City	#Required	Max Shifts	Duration (Avg)	Details
ADL	5	5	2708	2910, 2505, 2445, 2835, 2845
ADL	6	4	2257	2325, 2265, 1980, 2360, 2295, 2315
BNE	10	5	2351	2200, 2440, 2480, 2410, 2175, 2190, 2405, 2440, 2480, 2290
BNE	12	4	1959	1775, 2005, 2045, 1975, 2050, 1965, 1970, 1955, 1925, 1985, 1930, 1930
MEL	20	5	2405	2430, 2480, 2300, 2325, 2420, 2290, 2390, 2445, 2380, 2430, 2465, 2455, 2430, 2480, 2475, 2295, 2455, 2300, 2430, 2420
MEL	25	4	1932	2000, 1945, 1945, 1975, 1935, 1975, 1935, 1935, 1925, 1975, 1985, 1995, 1980, 1940, 1935, 1975, 1850, 1905, 1935, 1820, 1795, 1915, 1960, 1965, 1795
PER	3	5	4285	3680, 4620, 4555
PER	4	4	3214	2820, 3620, 3615, 2800
PER	5	3	2571	2720, 2715, 1900, 2760, 2760
SYD	17	5	2343	2360, 2380, 2510, 2365, 2275, 2365, 2345, 2345, 2360, 2475, 2355, 2150, 2335, 2170, 2330, 2360, 2350
SYD	21	4	1897	1780, 1885, 1895, 1895, 1995, 1945, 1860, 1840, 1940, 1900, 1990, 1855, 1855, 1870, 1870, 1880, 1940, 1880, 1890, 1875, 1990

From table (9), we can calculate the total tardiness of the whole crew team and find that $\sum T = 19635$ minutes or 327.25 hours.

7 Discussion

The task of flight scheduling has long piqued the interest of problem solvers. In practice, industry experts often divide this intricate problem into distinct stages and introduce specific assumptions to simplify the solution. In this project, we present the Bender decomposition approach, which is divided into three stages to address the flight scheduling challenges faced by Virgin Australia.

These methods aim to offer a comprehensive framework for optimising flight schedules, dealing with the airline's multifaceted demands and operational complexities. By breaking down the problem into manageable stages and utilising essential assumptions, we aim to provide efficient solutions that improve the effectiveness of Virgin Australia's flight scheduling operations.

In this project, in the implementation of model (4.1.2) we employ a daily demand ratio, which primarily hinges on the day of the week. The daily demand ratio signifies the variation in passenger demand as it fluctuates between different days of the week. However, it is crucial to acknowledge that, in a more comprehensive approach, this ratio could also vary across distinct routes, considering that passenger demand may not remain consistent across all routes. In our project, we have made the assumption that the daily demand ratio remains the same across all routes, simplifying the complexity of the problem.

This simplification aids in expediting the computational process and achieving more manageable results. However, it is essential to recognise that in practical scenarios, passenger demand may exhibit variations across routes, necessitating a more granular approach to ensure optimal flight scheduling and crew assignment. Future refinements of the methodology may consider incorporating route-specific demand ratios to better reflect the real-world dynamics of airline operations and passenger preferences. This would introduce an added layer of sophistication to the approach, potentially leading to even more precise and context-aware scheduling solutions.

Moreover, in the scheduling process, we employ the Earliness-Tardiness approach, a strategy that compels jobs to conclude precisely on the due date. In the context of our project, we set the due date (d) at 13:00. The utilisation of this approach leads to schedules where the due date is positioned in the middle of the flight sequences. We do this because we aim to create routes that commence at 13:00, a time typically preferred by the majority of travellers. However, in practice, this approach can result in schedules where two different aircraft, departing from the same airport and heading to the same destination, are assigned to fly simultaneously. This scenario, while feasible within the computational model, could be considered impractical or unusual in the real world.

Therefore, instead of using a common due date, implementing unique due dates for each aircraft could potentially address this issue. For instance, Aircraft 1 might have a due date (d) of 12:00, while Aircraft 2 could have a due date of 13:00. This approach would provide greater flexibility and practicality, reducing the occurrence of simultaneous departures from the same location, aligning more closely with real-world operational expectations and passenger preferences. However, it also adds an additional layer of complexity to the scheduling process, requiring careful consideration of how to set these individual due dates effectively to optimise overall scheduling outcomes.

In the context of aircraft scheduling and crew assignment, our chosen method follows a structured pattern. Each day is divided into two distinct shifts, and we have a fundamental rule in place: each crew team works maximum one shift per day. Additionally, we have introduced a policy where each shift is handled by a specific aircraft. For example, if a crew team, like Team A, is assigned to Shift 1 on a given day, they stay with the same aircraft for the entire shift.

These guidelines are carefully crafted to simplify the crew assignment process. This approach provides us with consistent crew assignments, which ultimately boosts our assignment management efficiency. In contrast, if we allowed crew members to switch between aircraft during a single shift, it would require a more individualised approach, significantly increasing the problem's complexity. Hence, we have chosen to maintain consistency in team and aircraft assignments to achieve a more practical and manageable crew assignment solution.

Another interesting point in crew assignment is that a crucial decision point arises regarding the optimisation of crew utilisation. One intriguing aspect that warrants further investigation is whether it is more advantageous to expand the crew size or rely on the existing crew while encouraging overtime work. This decision carries significant financial implications for airline operations.

The dilemma lies in striking a balance between the fixed costs associated with hiring additional crew members and the variable costs linked to overtime payments for the existing crew. Increasing the crew size entails committing to fixed salaries for each new member, irrespective of flight demands. This may result in increased operating costs, particularly when flight schedules experience peaks and troughs. On the other hand, optimising existing crew members' schedules to accommodate overtime allows for a more flexible approach. Overtime payments are made only when necessitated by increased workloads, minimising the financial commitment during periods of lower demand.

While this topic offers an intriguing avenue for exploration, the project's scope may not allow for an in-depth analysis. However, the potential insights gleaned from a detailed study on crew size versus overtime utilisation could hold valuable implications for airline companies seeking to optimise crew scheduling and operational costs. Further research in this area may reveal a nuanced understanding of the trade-offs between fixed and variable labour costs, ultimately contributing to more cost-efficient crew assignment strategies.

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9 Appendices

9.1 Dataset

9.1.1 Daily Passengers Demand per Leg

Table 10: Demand Calculations from the Real Data

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Adelaide - Brisbane	336	168	168	336	336	336	168	1848
Adelaide - Canberra	0	149	149	0	0	149	0	447
Adelaide - Darwin	134	0	0	134	134	0	134	536
Adelaide - Melbourne	1039	692	692	1039	1039	346	519	5366
Adelaide - Perth	167	334	334	167	167	167	167	1503
Adelaide - Sydney	688	516	516	688	688	344	516	3956
Brisbane - Canberra	161	322	322	161	161	161	161	1449
Brisbane - Darwin	0	155	155	0	0	155	310	775
Brisbane - Hobart	143	143	143	143	143	0	0	715
Brisbane - Melbourne	1218	1218	1218	1218	1218	696	870	7656
Brisbane - Perth	335	335	335	335	335	335	335	2345
Brisbane - Sydney	1570	1396	1396	1570	1570	1047	1221	9770
Canberra - Melbourne	328	328	328	328	328	328	328	2296
Canberra - Sydney	173	173	173	173	173	173	345	1383
Darwin - Melbourne	167	0	0	167	167	0	167	668
Darwin - Perth	0	132	132	0	0	132	0	396
Hobart - Melbourne	510	510	510	510	510	170	340	3060
Hobart - Sydney	345	172	172	345	345	172	172	1723
Melbourne - Perth	681	681	681	681	681	511	511	4427
Melbourne - Sydney	2624	2624	2624	2624	2624	1924	2624	17668
Perth - Sydney	521	521	521	521	521	521	521	3647
Total	11140	10569	10569	11140	11140	7667	9409	71634
Ratio	1.09	1.03	1.03	1.09	1.09	0.75	0.92	

- Total weekly demand $= 2 \times 71,634 = 143,268$.
- We assume that for the demand, Adelaide - Brisbane = Brisbane - Adelaide

9.1.2 Flight Duration per Leg

Table 11: Flight Duration for Monday, Thursday, and Friday (in minutes)

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Adelaide	0	185	M	255	M	110	250	145
Brisbane	185	0	140	M	200	170	360	125
Canberra	M	140	0	M	M	100	M	90
Darwin	255	M	M	0	M	290	M	M
Hobart	M	200	M	M	0	105	M	140
Melbourne	110	170	100	290	105	0	285	115
Perth	250	360	M	M	M	285	0	335
Sydney	145	125	90	M	140	115	335	0

- M: Big M number to deny the flight in the route. In the model, we use M = 540.

Table 12: Flight Duration for Tuesday and Wednesday (in minutes)

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Adelaide	0	185	125	M	M	110	250	145
Brisbane	185	0	140	280	200	170	360	125
Canberra	125	140	0	M	M	100	M	90
Darwin	M	280	M	0	M	M	260	M
Hobart	M	200	M	M	0	105	M	140
Melbourne	110	170	100	M	105	0	285	115
Perth	250	360	M	260	M	285	0	335
Sydney	145	125	90	M	140	115	335	0

Table 13: Flight Duration for Saturday (in minutes)

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Adelaide	0	185	125	M	M	110	250	145
Brisbane	185	0	140	280	M	170	360	125
Canberra	125	140	0	M	M	100	M	90
Darwin	M	280	M	0	M	M	260	M
Hobart	M	M	M	M	0	105	M	140
Melbourne	110	170	100	M	105	0	285	115
Perth	250	360	M	260	M	285	0	335
Sydney	145	125	90	M	140	115	335	0

Table 14: Flight Duration for Sunday (in minutes)

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Adelaide	0	185	M	255	M	110	250	145
Brisbane	185	0	140	280	M	170	360	125
Canberra	M	140	0	M	M	100	M	90
Darwin	255	280	M	0	M	290	M	M
Hobart	M	M	M	M	0	105	M	140
Melbourne	110	170	100	290	105	0	285	115
Perth	250	360	M	M	M	285	0	335
Sydney	145	125	90	M	140	115	335	0

9.1.3 Flight Routes

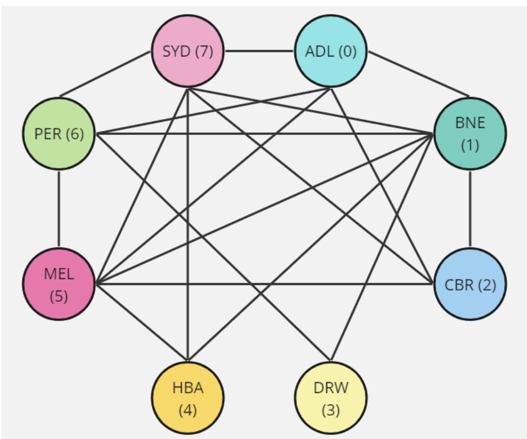

Figure 5: Flight Route for Tuesday and Wednesday

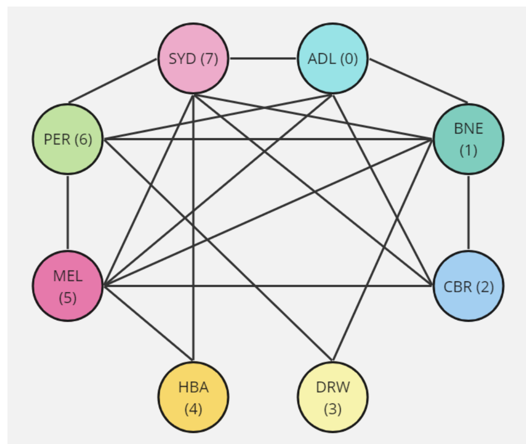

Figure 6: Flight Route for Saturday

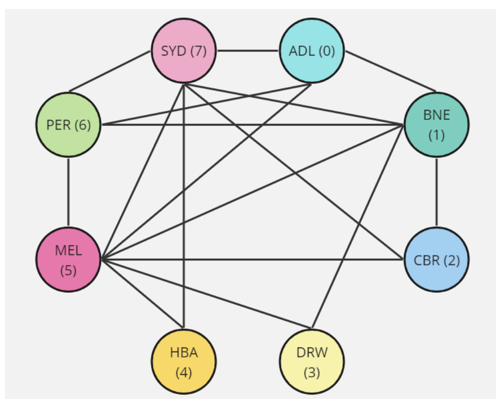

Figure 7: Flight Route for Sunday

9.1.4 Variable Cost per Leg

Table 15: Operational Cost (in AUD)

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Adelaide	0	10883	6670	15798	0	5617	15447	8074
Brisbane	10883	0	7723	17554	11936	9830	23171	6670
Canberra	6670	7723	0	0	0	4915	0	4213
Darwin	15798	17554	0	0	0	18256	16149	0
Hobart	0	11936	0	0	0	5266	0	7723
Melbourne	5617	9830	4915	18256	5266	0	17905	5968
Perth	15447	23171	0	16149	0	17905	0	21416
Sydney	8074	6670	4213	0	7723	5968	21416	0

9.2 Results

9.2.1 Flight Schedule for Adelaide

Table 16: Flight Schedule for Adelaide on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Sydney	00	05:25
Melbourne	01	06:15
Melbourne	57	06:55
Brisbane	60	09:10
Perth	52	09:20
Perth	00	10:15
Sydney	70	14:45
Sydney	76	14:45
Melbourne	01	15:25
Canberra	72	17:25
Melbourne	56	19:10

Table 17: Flight Schedule for Adelaide on Saturday

Destination	Plane Code	Departure Time
Melbourne	51	06:55
Perth	00	08:50
Brisbane	11	09:55
Canberra	50	10:55
Brisbane	10	11:05
Sydney	11	16:05
Sydney	12	16:30
Melbourne	55	19:10

Table 18: Flight Schedule for Adelaide on Sunday

Destination	Plane Code	Departure Time
Sydney	00	06:30
Brisbane	51	07:10
Darwin	01	08:45
Melbourne	76	11:10
Perth	00	12:40
Sydney	10	16:30
Melbourne	71	17:15
Sydney	76	17:20
Melbourne	51	19:10

9.2.2 Flight Schedule for Brisbane

Table 19: Flight Schedule for Brisbane on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Melbourne	13	05:05
Sydney	12	05:15
Melbourne	10	06:10
Sydney	73	07:05
Sydney	11	07:20
Adelaide	53	09:15
Melbourne	12	09:25
Perth	75	09:25
Hobart	55	09:40
Melbourne	52	10:10
Perth	57	10:15
Sydney	76	10:55
Canberra	60	12:15
Sydney	12	15:05
Sydney	73	15:05
Sydney	74	15:05
Sydney	76	15:05
Melbourne	10	15:20
Melbourne	13	15:20
Melbourne	70	16:15
Sydney	53	17:00
Adelaide	00	17:55

Table 20: Flight Schedule for Brisbane on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Darwin	13	06:00
Melbourne	12	07:00
Melbourne	11	07:20
Sydney	10	07:30
Canberra	53	08:20
Perth	56	09:00
Melbourne	76	10:05
Sydney	51	10:10
Sydney	01	10:55
Canberra	72	11:35
Melbourne	75	11:35
Adelaide	70	11:40
Sydney	60	12:15
Sydney	12	12:40
Melbourne	53	13:00
Sydney	11	13:00
Hobart	10	14:20
Perth	61	15:00
Sydney	12	16:50
Melbourne	50	18:10
Melbourne	51	18:10
Sydney	73	18:55

Table 21: Flight Schedule for Brisbane on Saturday

Destination	Plane Code	Departure Time
Melbourne	12	05:15
Sydney	10	06:35
Adelaide	11	06:50
Sydney	73	07:45
Sydney	72	08:15
Melbourne	54	08:40
Perth	55	09:00
Darwin	61	12:00
Canberra	12	12:05
Melbourne	53	12:10
Adelaide	11	13:00
Melbourne	56	13:00
Sydney	10	14:10
Perth	60	15:00
Sydney	72	15:05
Sydney	74	18:55

Table 22: Flight Schedule for Brisbane on Sunday

Destination	Plane Code	Departure Time
Melbourne	12	06:20
Melbourne	13	07:25
Sydney	11	07:30
Sydney	10	07:40
Sydney	53	08:00
Perth	72	09:25
Sydney	75	10:05
Darwin	51	10:15
Sydney	50	10:55
Darwin	11	11:40
Melbourne	10	11:50
Melbourne	12	12:00
Sydney	60	13:00
Canberra	75	14:15
Perth	61	15:00
Adelaide	01	17:40
Melbourne	53	18:10
Sydney	75	18:55

9.2.3 Flight Schedule for Canberra

Table 23: Flight Schedule for Canberra on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Sydney	57	06:40
Melbourne	60	14:35
Brisbane	12	18:40
Melbourne	56	19:20

Table 24: Flight Schedule for Canberra on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Brisbane	53	10:40
Melbourne	72	13:55
Brisbane	11	18:40
Adelaide	01	18:55
Melbourne	53	19:15
Sydney	72	19:30

Table 25: Flight Schedule for Canberra on Saturday

Destination	Plane Code	Departure Time
Sydney	70	07:15
Melbourne	53	07:40
Brisbane	12	09:45
Melbourne	50	13:00
Adelaide	12	14:25

Table 26: Flight Schedule for Canberra on Sunday

Destination	Plane Code	Departure Time
Brisbane	75	16:35
Sydney	74	18:45
Melbourne	54	18:55
Melbourne	55	19:20
Sydney	70	19:30

9.2.4 Flight Schedule for Darwin

Table 27: Flight Schedule for Darwin on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Adelaide	02	09:15
Melbourne	51	16:10

Table 28: Flight Schedule for Darwin on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Brisbane	61	10:20
Perth	13	10:40

Table 29: Flight Schedule for Darwin on Saturday

Destination	Plane Code	Departure Time
Brisbane	60	10:20
Perth	61	16:40

Table 30: Flight Schedule for Darwin on Sunday

Destination	Plane Code	Departure Time
Melbourne	55	12:50
Brisbane	01	13:00
Adelaide	51	14:55
Brisbane	11	16:20

9.2.5 Flight Schedule on Hobart

Table 31: Flight Schedule for Hobart on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Sydney	71	07:30
Melbourne	72	11:15
Brisbane	70	12:55
Melbourne	55	13:00
Sydney	55	16:30
Melbourne	50	19:15

Table 32: Flight Schedule for Hobart on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Melbourne	74	13:30
Brisbane	10	17:40
Sydney	75	18:40
Melbourne	54	19:15
Melbourne	55	19:15

Table 33: Flight Schedule for Hobart on Saturday

Destination	Plane Code	Departure Time
Sydney	50	16:25
Melbourne	53	19:15

Table 34: Flight Schedule for Hobart on Sunday

Destination	Plane Code	Departure Time
Melbourne	53	12:25
Sydney	12	16:35
Melbourne	50	16:40

9.2.6 Flight Schedule for Melbourne

Table 35: Flight Schedule for Melbourne on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Canberra	57	05:00
Perth	54	05:00
Adelaide	51	05:10
Sydney	50	05:15
Brisbane	53	06:25
Brisbane	55	06:50
Sydney	76	06:55
Brisbane	52	07:20
Sydney	70	07:20
Sydney	13	07:55
Perth	56	08:10
Adelaide	10	09:00
Sydney	61	10:05
Sydney	73	11:05
Sydney	74	11:05
Hobart	70	11:10
Darwin	51	11:20
Brisbane	12	12:15
Adelaide	01	13:00
Sydney	52	13:00
Sydney	72	13:00
Brisbane	53	14:10
Hobart	55	14:45
Sydney	02	15:20
Perth	60	16:15
Perth	61	16:15
Adelaide	52	16:50
Sydney	72	16:50
Adelaide	54	17:15
Hobart	50	17:30
Canberra	56	17:40
Brisbane	10	18:10
Brisbane	13	18:10
Sydney	70	19:05
Sydney	73	19:05
Sydney	74	19:05
Sydney	76	19:05
Adelaide	01	19:10

Table 36: Flight Schedule for Melbourne on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Sydney	52	05:00
Sydney	56	05:00
Adelaide	57	05:05
Sydney	54	05:15
Sydney	55	05:15
Brisbane	53	05:30
Perth	50	05:50
Sydney	51	06:10
Sydney	72	07:35
Sydney	70	07:40
Sydney	74	07:55
Brisbane	01	08:05
Brisbane	75	08:45
Perth	57	08:45
Brisbane	12	09:50
Brisbane	11	10:10
Perth	71	10:40
Brisbane	10	11:30
Hobart	74	11:45
Adelaide	76	12:55
Sydney	51	14:10
Sydney	75	14:25
Sydney	74	15:15
Brisbane	50	15:20
Adelaide	72	15:35
Sydney	53	15:50
Perth	60	16:15
Canberra	11	17:00
Canberra	01	17:15
Hobart	54	17:30
Hobart	55	17:30
Sydney	70	19:05
Sydney	74	19:05
Sydney	76	19:05
Adelaide	00	19:10

Table 37: Flight Schedule for Melbourne on Saturday

Destination	Plane Code	Departure Time
Sydney	55	05:00
Adelaide	51	05:05
Sydney	52	05:40
Brisbane	54	05:50
Canberra	53	06:00
Sydney	50	06:35
Canberra	12	08:05
Perth	51	08:45
Sydney	56	09:00
Brisbane	53	09:20
Sydney	52	09:30
Perth	71	10:40
Perth	54	11:30
Brisbane	72	12:15
Sydney	52	13:20
Hobart	50	14:40
Sydney	53	15:00
Sydney	56	15:50
Sydney	52	17:10
Adelaide	00	17:45
Brisbane	10	18:10
Sydney	70	19:05
Sydney	72	19:05

Table 38: Flight Schedule for Melbourne on Sunday

Destination	Plane Code	Departure Time
Perth	54	05:00
Brisbane	53	05:10
Adelaide	51	05:20
Sydney	56	05:40
Brisbane	75	07:15
Perth	52	07:40
Sydney	73	07:55
Darwin	55	08:00
Brisbane	50	08:05
Sydney	70	08:25
Sydney	71	09:05
Brisbane	12	09:10
Sydney	56	09:30
Perth	13	10:15
Adelaide	00	10:50
Brisbane	61	12:10
Sydney	70	12:15
Sydney	71	12:55
Sydney	76	13:00
Sydney	56	13:20
Sydney	53	14:10
Adelaide	10	14:40
Hobart	12	14:50
Hobart	50	14:55
Sydney	74	15:20
Sydney	70	16:05
Sydney	52	17:10
Sydney	56	17:10
Canberra	54	17:15
Canberra	55	17:40
Sydney	71	19:05

9.2.7 Flight Schedule for Perth

Table 39: Flight Schedule for Perth on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Adelaide	60	05:00
Melbourne	61	05:20
Sydney	54	09:45
Brisbane	00	11:55
Melbourne	50	12:45
Melbourne	56	12:55
Brisbane	11	15:00
Sydney	71	15:25
Sydney	75	15:25
Melbourne	57	16:15

Table 40: Flight Schedule for Perth on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Adelaide	60	05:00
Darwin	61	06:00
Melbourne	50	10:35
Melbourne	54	12:45
Melbourne	55	12:45
Brisbane	73	12:55
Sydney	52	13:30
Sydney	57	13:30
Melbourne	00	14:25
Adelaide	56	15:00
Brisbane	13	15:00
Sydney	71	15:25

Table 41: Flight Schedule for Perth on Saturday

Destination	Plane Code	Departure Time
Brisbane	61	06:00
Darwin	60	06:00
Brisbane	74	12:55
Melbourne	00	13:00
Sydney	51	13:30
Melbourne	70	14:20
Adelaide	55	15:00
Sydney	71	15:25
Sydney	73	15:25
Melbourne	54	16:15

Table 42: Flight Schedule for Perth on Sunday

Destination	Plane Code	Departure Time
Brisbane	60	07:00
Melbourne	61	07:25
Sydney	54	09:45
Melbourne	74	10:35
Melbourne	52	12:25
Brisbane	13	15:00
Sydney	72	15:25
Sydney	73	15:25
Adelaide	00	16:50

9.2.8 Flight Schedule for Sydney

Table 43: Flight Schedule for Sydney on Monday, Thursday, and Friday

Destination	Plane Code	Departure Time
Brisbane	73	05:00
Melbourne	76	05:00
Hobart	71	05:10
Melbourne	70	05:25
Perth	50	07:10
Brisbane	12	07:20
Brisbane	75	07:20
Brisbane	57	08:10
Adelaide	01	08:45
Brisbane	76	08:50
Hobart	72	08:55
Melbourne	73	09:10
Melbourne	74	09:10
Melbourne	70	09:15
Melbourne	51	09:25
Perth	11	09:25
Adelaide	13	09:50
Perth	71	09:50
Adelaide	61	12:00
Brisbane	73	13:00
Brisbane	74	13:00
Brisbane	76	13:00
Brisbane	10	13:15
Melbourne	52	14:55
Melbourne	72	14:55
Melbourne	54	15:20
Canberra	12	17:10
Melbourne	73	17:10
Melbourne	74	17:10
Melbourne	76	17:10
Adelaide	02	17:15
Melbourne	01	17:15
Melbourne	55	18:50
Melbourne	53	19:05

Table 44: Flight Schedule for Sydney on Tuesday and Wednesday

Destination	Plane Code	Departure Time
Melbourne	72	05:40
Melbourne	70	05:45
Melbourne	74	06:00
Melbourne	75	06:50
Adelaide	52	06:55
Brisbane	56	06:55
Perth	54	07:10
Perth	55	07:10
Perth	73	07:20
Adelaide	00	07:50
Brisbane	76	08:00
Brisbane	51	08:05
Melbourne	71	08:45
Brisbane	72	09:30
Brisbane	70	09:35
Melbourne	10	09:35
Melbourne	74	09:50
Melbourne	51	12:15
Adelaide	01	13:00
Melbourne	60	14:20
Brisbane	12	14:45
Melbourne	11	15:05
Brisbane	51	16:05
Hobart	75	16:20
Melbourne	70	17:10
Melbourne	74	17:10
Melbourne	76	17:10
Canberra	53	17:45
Brisbane	12	18:55
Melbourne	52	19:05
Melbourne	57	19:05

Table 45: Flight Schedule for Sydney on Saturday

Destination	Plane Code	Departure Time
Brisbane	73	05:40
Canberra	70	05:45
Brisbane	72	06:10
Brisbane	55	06:55
Perth	74	07:20
Melbourne	52	07:35
Adelaide	50	08:30
Adelaide	10	08:40
Melbourne	71	08:45
Perth	70	08:45
Perth	73	09:50
Melbourne	72	10:20
Brisbane	56	10:55
Melbourne	52	11:25
Melbourne	52	15:15
Melbourne	10	16:15
Hobart	53	16:55
Melbourne	72	17:10
Melbourne	56	17:45
Brisbane	11	18:30
Melbourne	50	18:45
Brisbane	12	18:55
Melbourne	51	19:05
Melbourne	52	19:05

Table 46: Flight Schedule for Sydney on Sunday

Destination	Plane Code	Departure Time
Perth	74	05:00
Melbourne	75	05:20
Melbourne	73	06:00
Melbourne	70	06:30
Melbourne	71	07:10
Brisbane	72	07:20
Melbourne	56	07:35
Adelaide	76	08:45
Melbourne	00	08:55
Brisbane	11	09:35
Brisbane	10	09:45
Perth	73	09:50
Hobart	53	10:05
Melbourne	70	10:20
Melbourne	71	11:00
Melbourne	56	11:25
Brisbane	75	12:10
Melbourne	50	13:00
Melbourne	70	14:10
Adelaide	71	14:50
Adelaide	76	14:55
Perth	60	15:05
Melbourne	56	15:15
Melbourne	54	15:20
Brisbane	53	16:05
Canberra	74	17:15
Canberra	70	18:00
Brisbane	10	18:55
Brisbane	12	18:55
Melbourne	52	19:05
Melbourne	56	19:05

9.2.9 Crew Scheduling with Maximum 5 Shifts

Table 47: Crew Scheduling for Adelaide (max 5 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
1	Tuesday	290	00	ADL-SYD (05:25), SYD-ADL (07:50)
1	Thursday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
1	Friday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
1	Sunday	720	01	ADL-DRW (08:45), DRW-BNE (13:00), BNE-ADL (17:40)
2	Tuesday	645	00	ADL-PER (10:15), PER-MEL (14:25), MEL-ADL (19:10)
2	Wednesday	335	01	ADL-MEL (15:25), MEL-CBR (17:15), CBR-ADL (18:55)
2	Thursday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
2	Saturday	645	00	ADL-PER (08:50), PER-MEL (13:00), MEL-ADL (17:45)
3	Monday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
3	Tuesday	550	01	ADL-MEL (06:15), MEL-BNE (08:05), BNE-SYD (10:55), SYD-ADL (13:00)
3	Wednesday	645	00	ADL-PER (10:15), PER-MEL (14:25), MEL-ADL (19:10)
3	Friday	370	01	ADL-SYD (14:50), SYD-MEL (17:15), MEL-ADL (19:10)
4	Monday	795	00	ADL-PER (07:45), PER-BNE (11:55), BNE-ADL (17:55)
4	Wednesday	290	00	ADL-SYD (05:25), SYD-ADL (07:50)
4	Thursday	370	01	ADL-SYD (14:50), SYD-MEL (17:15), MEL-ADL (19:10)
4	Friday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
4	Sunday	870	00	ADL-SYD (06:30), SYD-MEL (08:55), MEL-ADL (10:50), ADL-PER (12:40), PER-ADL (16:50)
5	Monday	370	01	ADL-SYD (14:50), SYD-MEL (17:15), MEL-ADL (19:10)
5	Tuesday	335	01	ADL-MEL (15:25), MEL-CBR (17:15), CBR-ADL (18:55)
5	Wednesday	550	01	ADL-MEL (06:15), MEL-BNE (08:05), BNE-SYD (10:55), SYD-ADL (13:00)
5	Thursday	795	00	ADL-PER (07:45), PER-BNE (11:55), BNE-ADL (17:55)
5	Friday	795	00	ADL-PER (07:45), PER-BNE (11:55), BNE-ADL (17:55)

Table 48: Crew Scheduling for Brisbane (max 5 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	340	10	BNE-MEL (15:20), MEL-BNE (18:10)
1	Tuesday	410	10	BNE-SYD (07:30), SYD-MEL (09:35), MEL-BNE (11:30)
1	Wednesday	900	13	BNE-DRW (06:00), DRW-PER (10:40), PER-BNE (15:00)
1	Thursday	550	10	BNE-MEL (06:10), MEL-ADL (09:00), ADL-SYD (10:50), SYD-BNE (13:15)
2	Monday	550	10	BNE-MEL (06:10), MEL-ADL (09:00), ADL-SYD (10:50), SYD-BNE (13:15)
2	Tuesday	900	13	BNE-DRW (06:00), DRW-PER (10:40), PER-BNE (15:00)
2	Wednesday	400	10	BNE-HBA (14:20), HBA-BNE (17:40)
2	Thursday	340	10	BNE-MEL (15:20), MEL-BNE (18:10)
2	Sunday	250	11	BNE-SYD (07:30), SYD-BNE (09:35)
3	Tuesday	340	11	BNE-MEL (07:20), MEL-BNE (10:10)
3	Wednesday	410	10	BNE-SYD (07:30), SYD-MEL (09:35), MEL-BNE (11:30)
3	Thursday	355	12	BNE-SYD (15:05), SYD-CBR (17:10), CBR-BNE (18:40)
3	Friday	550	10	BNE-MEL (06:10), MEL-ADL (09:00), ADL-SYD (10:50), SYD-BNE (13:15)
3	Saturday	825	11	BNE-ADL (06:50), ADL-BNE (09:55), BNE-ADL (13:00), ADL-SYD (16:05), SYD-BNE (18:30)
4	Monday	590	12	BNE-SYD (05:15), SYD-BNE (07:20), BNE-MEL (09:25), MEL-BNE (12:15)
4	Tuesday	250	12	BNE-SYD (16:50), SYD-BNE (18:55)
4	Friday	820	11	BNE-SYD (07:20), SYD-PER (09:25), PER-BNE (15:00)
4	Saturday	410	12	BNE-MEL (05:15), MEL-CBR (08:05), CBR-BNE (09:45)
4	Sunday	340	12	BNE-MEL (06:20), MEL-BNE (09:10)
5	Thursday	820	11	BNE-SYD (07:20), SYD-PER (09:25), PER-BNE (15:00)
5	Friday	340	13	BNE-MEL (15:20), MEL-BNE (18:10)
5	Saturday	455	10	BNE-SYD (06:35), SYD-ADL (08:40), ADL-BNE (11:05)
5	Sunday	560	11	BNE-DRW (11:40), DRW-BNE (16:20)
6	Monday	820	11	BNE-SYD (07:20), SYD-PER (09:25), PER-BNE (15:00)
6	Wednesday	480	11	BNE-SYD (13:00), SYD-MEL (15:05), MEL-CBR (17:00), CBR-BNE (18:40)
6	Thursday	340	13	BNE-MEL (15:20), MEL-BNE (18:10)

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Team	Day	Duration	Plane Code	Flight Routes
6	Sunday	550	10	BNE-MEL (11:50), MEL-ADL (14:40), ADL-SYD (16:30), SYD-BNE (18:55)
7	Tuesday	590	12	BNE-MEL (07:00), MEL-BNE (09:50), BNE-SYD (12:40), SYD-BNE (14:45)
7	Wednesday	250	12	BNE-SYD (16:50), SYD-BNE (18:55)
7	Friday	340	10	BNE-MEL (15:20), MEL-BNE (18:10)
7	Saturday	410	10	BNE-SYD (14:10), SYD-MEL (16:15), MEL-BNE (18:10)
7	Sunday	815	13	BNE-MEL (07:25), MEL-PER (10:15), PER-BNE (15:00)
8	Monday	355	12	BNE-SYD (15:05), SYD-CBR (17:10), CBR-BNE (18:40)
8	Wednesday	340	11	BNE-MEL (07:20), MEL-BNE (10:10)
8	Thursday	590	12	BNE-SYD (05:15), SYD-BNE (07:20), BNE-MEL (09:25), MEL-BNE (12:15)
8	Friday	615	13	BNE-MEL (05:05), MEL-SYD (07:55), SYD-ADL (09:50), ADL-BNE (12:15)
8	Sunday	540	12	BNE-MEL (12:00), MEL-HBA (14:50), HBA-SYD (16:35), SYD-BNE (18:55)
9	Monday	340	13	BNE-MEL (15:20), MEL-BNE (18:10)
9	Tuesday	400	10	BNE-HBA (14:20), HBA-BNE (17:40)
9	Thursday	615	13	BNE-MEL (05:05), MEL-SYD (07:55), SYD-ADL (09:50), ADL-BNE (12:15)
9	Friday	590	12	BNE-SYD (05:15), SYD-BNE (07:20), BNE-MEL (09:25), MEL-BNE (12:15)
9	Saturday	535	12	BNE-CBR (12:05), CBR-ADL (14:25), ADL-SYD (16:30), SYD-BNE (18:55)
10	Monday	615	13	BNE-MEL (05:05), MEL-SYD (07:55), SYD-ADL (09:50), ADL-BNE (12:15)
10	Tuesday	480	11	BNE-SYD (13:00), SYD-MEL (15:05), MEL-CBR (17:00), CBR-BNE (18:40)
10	Wednesday	590	12	BNE-MEL (07:00), MEL-BNE (09:50), BNE-SYD (12:40), SYD-BNE (14:45)
10	Friday	355	12	BNE-SYD (15:05), SYD-CBR (17:10), CBR-BNE (18:40)
10	Sunday	250	10	BNE-SYD (07:40), SYD-BNE (09:45)

Table 49: Crew Scheduling for Melbourne (max 5 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	220	54	MEL-ADL (17:15), ADL-MEL (19:05)
1	Thursday	220	52	MEL-ADL (16:50), ADL-MEL (18:40)
1	Friday	570	52	MEL-BNE (07:20), BNE-MEL (10:10), MEL-SYD (13:00), SYD-MEL (14:55)

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Table 49 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
1	Saturday	960	55	MEL-SYD (05:00), SYD-BNE (06:55), BNE-PER (09:00), PER-ADL (15:00), ADL-MEL (19:10)
1	Sunday	460	56	MEL-SYD (13:20), SYD-MEL (15:15), MEL-SYD (17:10), SYD-MEL (19:05)
2	Monday	570	52	MEL-BNE (07:20), BNE-MEL (10:10), MEL-SYD (13:00), SYD-MEL (14:55)
2	Tuesday	960	56	MEL-SYD (05:00), SYD-BNE (06:55), BNE-PER (09:00), PER-ADL (15:00), ADL-MEL (19:10)
2	Wednesday	340	50	MEL-BNE (15:20), BNE-MEL (18:10)
2	Thursday	200	56	MEL-CBR (17:40), CBR-MEL (19:20)
2	Friday	410	53	MEL-BNE (14:10), BNE-SYD (17:00), SYD-MEL (19:05)
3	Monday	960	57	MEL-CBR (05:00), CBR-SYD (06:40), SYD-BNE (08:10), BNE-PER (10:15), PER-MEL (16:15)
3	Wednesday	410	51	MEL-SYD (14:10), SYD-BNE (16:05), BNE-MEL (18:10)
3	Thursday	570	56	MEL-PER (08:10), PER-MEL (12:55)
3	Friday	360	55	MEL-HBA (14:45), HBA-SYD (16:30), SYD-MEL (18:50)
4	Monday	580	51	MEL-DRW (11:20), DRW-MEL (16:10)
4	Tuesday	340	50	MEL-BNE (15:20), BNE-MEL (18:10)
4	Wednesday	945	54	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45), MEL-HBA (17:30), HBA-MEL (19:15)
4	Sunday	460	56	MEL-SYD (05:40), SYD-MEL (07:35), MEL-SYD (09:30), SYD-MEL (11:25)
5	Monday	475	55	MEL-BNE (06:50), BNE-HBA (09:40), HBA-MEL (13:00)
5	Tuesday	945	54	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45), MEL-HBA (17:30), HBA-MEL (19:15)
5	Thursday	210	50	MEL-HBA (17:30), HBA-MEL (19:15)
5	Friday	220	54	MEL-ADL (17:15), ADL-MEL (19:05)
5	Sunday	570	52	MEL-PER (07:40), PER-MEL (12:25)
6	Monday	465	53	MEL-BNE (06:25), BNE-ADL (09:15), ADL-MEL (12:20)
6	Tuesday	305	53	MEL-SYD (15:50), SYD-CBR (17:45), CBR-MEL (19:15)
6	Thursday	580	51	MEL-DRW (11:20), DRW-MEL (16:10)
6	Sunday	940	51	MEL-ADL (05:20), ADL-BNE (07:10), BNE-DRW (10:15), DRW-ADL (14:55), ADL-MEL (19:10)
7	Monday	220	52	MEL-ADL (16:50), ADL-MEL (18:40)
7	Tuesday	735	57	MEL-PER (08:45), PER-SYD (13:30), SYD-MEL (19:05)
7	Wednesday	480	51	MEL-SYD (06:10), SYD-BNE (08:05), BNE-SYD (10:10), SYD-MEL (12:15)
7	Friday	220	52	MEL-ADL (16:50), ADL-MEL (18:40)
7	Sunday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)

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Team	Day	Duration	Plane Code	Flight Routes
8	Monday	570	56	MEL-PER (08:10), PER-MEL (12:55)
8	Thursday	360	55	MEL-HBA (14:45), HBA-SYD (16:30), SYD-MEL (18:50)
8	Friday	580	51	MEL-DRW (11:20), DRW-MEL (16:10)
8	Saturday	735	51	MEL-PER (08:45), PER-SYD (13:30), SYD-MEL (19:05)
8	Sunday	200	54	MEL-CBR (17:15), CBR-MEL (18:55)
9	Tuesday	570	50	MEL-PER (05:50), PER-MEL (10:35)
9	Wednesday	960	52	MEL-SYD (05:00), SYD-ADL (06:55), ADL-PER (09:20), PER-SYD (13:30), SYD-MEL (19:05)
9	Thursday	220	54	MEL-ADL (17:15), ADL-MEL (19:05)
9	Saturday	220	51	MEL-ADL (05:05), ADL-MEL (06:55)
9	Sunday	410	50	MEL-BNE (08:05), BNE-SYD (10:55), SYD-MEL (13:00)
10	Wednesday	210	55	MEL-HBA (17:30), HBA-MEL (19:15)
10	Thursday	570	52	MEL-BNE (07:20), BNE-MEL (10:10), MEL-SYD (13:00), SYD-MEL (14:55)
10	Friday	960	57	MEL-CBR (05:00), CBR-SYD (06:40), SYD-BNE (08:10), BNE-PER (10:15), PER-MEL (16:15)
10	Saturday	460	52	MEL-SYD (05:40), SYD-MEL (07:35), MEL-SYD (09:30), SYD-MEL (11:25)
10	Sunday	230	52	MEL-SYD (17:10), SYD-MEL (19:05)
11	Tuesday	620	53	MEL-BNE (05:30), BNE-CBR (08:20), CBR-BNE (10:40), BNE-MEL (13:00)
11	Thursday	735	50	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
11	Friday	370	51	MEL-ADL (05:10), ADL-SYD (07:00), SYD-MEL (09:25)
11	Saturday	200	53	MEL-CBR (06:00), CBR-MEL (07:40)
11	Sunday	540	53	MEL-BNE (05:10), BNE-SYD (08:00), SYD-HBA (10:05), HBA-MEL (12:25)
12	Monday	410	53	MEL-BNE (14:10), BNE-SYD (17:00), SYD-MEL (19:05)
12	Tuesday	480	51	MEL-SYD (06:10), SYD-BNE (08:05), BNE-SYD (10:10), SYD-MEL (12:15)
12	Wednesday	620	53	MEL-BNE (05:30), BNE-CBR (08:20), CBR-BNE (10:40), BNE-MEL (13:00)
12	Thursday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)
12	Friday	210	50	MEL-HBA (17:30), HBA-MEL (19:15)
13	Tuesday	210	55	MEL-HBA (17:30), HBA-MEL (19:15)
13	Wednesday	735	55	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
13	Thursday	370	51	MEL-ADL (05:10), ADL-SYD (07:00), SYD-MEL (09:25)
13	Friday	475	55	MEL-BNE (06:50), BNE-HBA (09:40), HBA-MEL (13:00)

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Team	Day	Duration	Plane Code	Flight Routes
13	Saturday	640	56	MEL-SYD (09:00), SYD-BNE (10:55), BNE-MEL (13:00), MEL-SYD (15:50), SYD-MEL (17:45)
14	Monday	370	51	MEL-ADL (05:10), ADL-SYD (07:00), SYD-MEL (09:25)
14	Wednesday	735	57	MEL-PER (08:45), PER-SYD (13:30), SYD-MEL (19:05)
14	Thursday	475	55	MEL-BNE (06:50), BNE-HBA (09:40), HBA-MEL (13:00)
14	Friday	200	56	MEL-CBR (17:40), CBR-MEL (19:20)
14	Saturday	700	53	MEL-BNE (09:20), BNE-MEL (12:10), MEL-SYD (15:00), SYD-HBA (16:55), HBA-MEL (19:15)
15	Monday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)
15	Tuesday	735	55	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
15	Friday	465	53	MEL-BNE (06:25), BNE-ADL (09:15), ADL-MEL (12:20)
15	Saturday	340	54	MEL-BNE (05:50), BNE-MEL (08:40)
15	Sunday	200	55	MEL-CBR (17:40), CBR-MEL (19:20)
16	Monday	735	50	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
16	Thursday	465	53	MEL-BNE (06:25), BNE-ADL (09:15), ADL-MEL (12:20)
16	Friday	735	50	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
16	Saturday	360	50	MEL-HBA (14:40), HBA-SYD (16:25), SYD-MEL (18:45)
17	Monday	210	50	MEL-HBA (17:30), HBA-MEL (19:15)
17	Tuesday	960	52	MEL-SYD (05:00), SYD-ADL (06:55), ADL-PER (09:20), PER-SYD (13:30), SYD-MEL (19:05)
17	Wednesday	305	53	MEL-SYD (15:50), SYD-CBR (17:45), CBR-MEL (19:15)
17	Friday	570	56	MEL-PER (08:10), PER-MEL (12:55)
17	Sunday	410	53	MEL-SYD (14:10), SYD-BNE (16:05), BNE-MEL (18:10)
18	Monday	360	55	MEL-HBA (14:45), HBA-SYD (16:30), SYD-MEL (18:50)
18	Wednesday	960	56	MEL-SYD (05:00), SYD-BNE (06:55), BNE-PER (09:00), PER-ADL (15:00), ADL-MEL (19:10)
18	Thursday	410	53	MEL-BNE (14:10), BNE-SYD (17:00), SYD-MEL (19:05)
18	Saturday	570	54	MEL-PER (11:30), PER-MEL (16:15)
19	Tuesday	410	51	MEL-SYD (14:10), SYD-BNE (16:05), BNE-MEL (18:10)
19	Wednesday	220	57	MEL-ADL (05:05), ADL-MEL (06:55)
19	Friday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)

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Team	Day	Duration	Plane Code	Flight Routes
19	Saturday	485	50	MEL-SYD (06:35), SYD-ADL (08:30), ADL-CBR (10:55), CBR-MEL (13:00)
19	Sunday	580	55	MEL-DRW (08:00), DRW-MEL (12:50)
20	Tuesday	220	57	MEL-ADL (05:05), ADL-MEL (06:55)
20	Wednesday	570	50	MEL-PER (05:50), PER-MEL (10:35)
20	Thursday	960	57	MEL-CBR (05:00), CBR-SYD (06:40), SYD-BNE (08:10), BNE-PER (10:15), PER-MEL (16:15)
20	Saturday	460	52	MEL-SYD (13:20), SYD-MEL (15:15), MEL-SYD (17:10), SYD-MEL (19:05)
20	Sunday	210	50	MEL-HBA (14:55), HBA-MEL (16:40)

Table 50: Crew Scheduling for Perth (max 5 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
1	Tuesday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-SYD (12:15), SYD-MEL (14:20), MEL-PER (16:15)
1	Friday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
1	Sunday	820	60	PER-BNE (07:00), BNE-SYD (13:00), SYD-PER (15:05)
2	Monday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
2	Tuesday	900	61	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
2	Wednesday	900	61	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
2	Thursday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
2	Saturday	900	60	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
3	Wednesday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-SYD (12:15), SYD-MEL (14:20), MEL-PER (16:15)
3	Thursday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
3	Friday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
3	Saturday	900	61	PER-BNE (06:00), BNE-DRW (12:00), DRW-PER (16:40)
3	Sunday	815	61	PER-MEL (07:25), MEL-BNE (12:10), BNE-PER (15:00)

Table 51: Crew Scheduling for Sydney (max 5 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	360	72	SYD-HBA (08:55), HBA-MEL (11:15), MEL-SYD (13:00)
1	Tuesday	670	74	SYD-MEL (06:00), MEL-SYD (07:55), SYD-MEL (09:50), MEL-HBA (11:45), HBA-MEL (13:30), MEL-SYD (15:15)
1	Thursday	230	74	SYD-MEL (09:10), MEL-SYD (11:05)
1	Friday	280	71	SYD-HBA (05:10), HBA-SYD (07:30)
1	Sunday	820	72	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
2	Monday	230	70	SYD-MEL (05:25), MEL-SYD (07:20)
2	Thursday	820	75	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
2	Friday	230	74	SYD-MEL (09:10), MEL-SYD (11:05)
2	Saturday	640	72	SYD-MEL (10:20), MEL-BNE (12:15), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
2	Sunday	460	71	SYD-MEL (07:10), MEL-SYD (09:05), SYD-MEL (11:00), MEL-SYD (12:55)
3	Monday	230	74	SYD-MEL (09:10), MEL-SYD (11:05)
3	Tuesday	820	73	SYD-PER (07:20), PER-BNE (12:55), BNE-SYD (18:55)
3	Wednesday	570	75	SYD-MEL (06:50), MEL-BNE (08:45), BNE-MEL (11:35), MEL-SYD (14:25)
3	Friday	480	74	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
3	Sunday	410	75	SYD-MEL (05:20), MEL-BNE (07:15), BNE-SYD (10:05)
4	Wednesday	230	76	SYD-MEL (17:10), MEL-SYD (19:05)
4	Thursday	480	76	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
4	Friday	250	73	SYD-BNE (05:00), BNE-SYD (07:05)
4	Saturday	670	73	SYD-PER (09:50), PER-SYD (15:25)
4	Sunday	735	74	SYD-PER (05:00), PER-MEL (10:35), MEL-SYD (15:20)
5	Wednesday	230	70	SYD-MEL (17:10), MEL-SYD (19:05)
5	Thursday	280	71	SYD-HBA (05:10), HBA-SYD (07:30)
5	Friday	360	72	SYD-HBA (08:55), HBA-MEL (11:15), MEL-SYD (13:00)
5	Saturday	735	70	SYD-PER (08:45), PER-MEL (14:20), MEL-SYD (19:05)
5	Sunday	670	73	SYD-PER (09:50), PER-SYD (15:25)
6	Monday	480	76	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
6	Tuesday	230	76	SYD-MEL (17:10), MEL-SYD (19:05)
6	Wednesday	670	74	SYD-MEL (06:00), MEL-SYD (07:55), SYD-MEL (09:50), MEL-HBA (11:45), HBA-MEL (13:30), MEL-SYD (15:15)

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Table 51 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
6	Thursday	250	73	SYD-BNE (05:00), BNE-SYD (07:05)
6	Saturday	735	71	SYD-MEL (08:45), MEL-PER (10:40), PER-SYD (15:25)
7	Monday	480	76	SYD-MEL (05:00), MEL-SYD (06:55), SYD-BNE (08:50), BNE-SYD (10:55)
7	Tuesday	230	70	SYD-MEL (17:10), MEL-SYD (19:05)
7	Wednesday	735	71	SYD-MEL (08:45), MEL-PER (10:40), PER-SYD (15:25)
7	Thursday	670	71	SYD-PER (09:50), PER-SYD (15:25)
7	Friday	230	70	SYD-MEL (05:25), MEL-SYD (07:20)
8	Monday	480	74	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
8	Tuesday	735	71	SYD-MEL (08:45), MEL-PER (10:40), PER-SYD (15:25)
8	Thursday	230	72	SYD-MEL (14:55), MEL-SYD (16:50)
8	Friday	670	71	SYD-PER (09:50), PER-SYD (15:25)
8	Sunday	230	73	SYD-MEL (06:00), MEL-SYD (07:55)
9	Monday	670	71	SYD-PER (09:50), PER-SYD (15:25)
9	Wednesday	230	74	SYD-MEL (17:10), MEL-SYD (19:05)
9	Friday	230	72	SYD-MEL (14:55), MEL-SYD (16:50)
9	Saturday	820	74	SYD-PER (07:20), PER-BNE (12:55), BNE-SYD (18:55)
9	Sunday	410	70	SYD-MEL (14:10), MEL-SYD (16:05), SYD-CBR (18:00), CBR-SYD (19:30)
10	Monday	230	72	SYD-MEL (14:55), MEL-SYD (16:50)
10	Tuesday	685	70	SYD-MEL (05:45), MEL-SYD (07:40), SYD-BNE (09:35), BNE-ADL (11:40), ADL-SYD (14:45)
10	Thursday	710	73	SYD-MEL (09:10), MEL-SYD (11:05), SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
10	Friday	480	76	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
10	Sunday	370	71	SYD-ADL (14:50), ADL-MEL (17:15), MEL-SYD (19:05)
11	Monday	710	73	SYD-MEL (09:10), MEL-SYD (11:05), SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
11	Tuesday	230	74	SYD-MEL (17:10), MEL-SYD (19:05)
11	Wednesday	685	70	SYD-MEL (05:45), MEL-SYD (07:40), SYD-BNE (09:35), BNE-ADL (11:40), ADL-SYD (14:45)
11	Thursday	480	74	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
11	Saturday	250	72	SYD-BNE (06:10), BNE-SYD (08:15)
12	Monday	705	70	SYD-MEL (09:15), MEL-HBA (11:10), HBA-BNE (12:55), BNE-MEL (16:15), MEL-SYD (19:05)
12	Tuesday	280	75	SYD-HBA (16:20), HBA-SYD (18:40)

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Table 51 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
12	Friday	705	70	SYD-MEL (09:15), MEL-HBA (11:10), HBA-BNE (12:55), BNE-MEL (16:15), MEL-SYD (19:05)
12	Sunday	460	70	SYD-MEL (06:30), MEL-SYD (08:25), SYD-MEL (10:20), MEL-SYD (12:15)
13	Monday	280	71	SYD-HBA (05:10), HBA-SYD (07:30)
13	Wednesday	690	72	SYD-BNE (09:30), BNE-CBR (11:35), CBR-MEL (13:55), MEL-ADL (15:35), ADL-CBR (17:25), CBR-SYD (19:30)
13	Thursday	705	70	SYD-MEL (09:15), MEL-HBA (11:10), HBA-BNE (12:55), BNE-MEL (16:15), MEL-SYD (19:05)
13	Friday	480	76	SYD-MEL (05:00), MEL-SYD (06:55), SYD-BNE (08:50), BNE-SYD (10:55)
13	Sunday	180	74	SYD-CBR (17:15), CBR-SYD (18:45)
14	Monday	820	75	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
14	Tuesday	570	75	SYD-MEL (06:50), MEL-BNE (08:45), BNE-MEL (11:35), MEL-SYD (14:25)
14	Wednesday	550	76	SYD-BNE (08:00), BNE-MEL (10:05), MEL-ADL (12:55), ADL-SYD (14:45)
14	Thursday	230	70	SYD-MEL (05:25), MEL-SYD (07:20)
15	Monday	250	73	SYD-BNE (05:00), BNE-SYD (07:05)
15	Tuesday	550	76	SYD-BNE (08:00), BNE-MEL (10:05), MEL-ADL (12:55), ADL-SYD (14:45)
15	Wednesday	820	73	SYD-PER (07:20), PER-BNE (12:55), BNE-SYD (18:55)
15	Saturday	180	70	SYD-CBR (05:45), CBR-SYD (07:15)
15	Sunday	530	75	SYD-BNE (12:10), BNE-CBR (14:15), CBR-BNE (16:35), BNE-SYD (18:55)
16	Tuesday	690	72	SYD-BNE (09:30), BNE-CBR (11:35), CBR-MEL (13:55), MEL-ADL (15:35), ADL-CBR (17:25), CBR-SYD (19:30)
16	Wednesday	230	72	SYD-MEL (05:40), MEL-SYD (07:35)
16	Thursday	480	76	SYD-MEL (05:00), MEL-SYD (06:55), SYD-BNE (08:50), BNE-SYD (10:55)
16	Friday	710	73	SYD-MEL (09:10), MEL-SYD (11:05), SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
16	Saturday	250	73	SYD-BNE (05:40), BNE-SYD (07:45)
17	Tuesday	230	72	SYD-MEL (05:40), MEL-SYD (07:35)
17	Wednesday	280	75	SYD-HBA (16:20), HBA-SYD (18:40)
17	Thursday	360	72	SYD-HBA (08:55), HBA-MEL (11:15), MEL-SYD (13:00)
17	Friday	820	75	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
17	Sunday	660	76	SYD-ADL (08:45), ADL-MEL (11:10), MEL-SYD (13:00), SYD-ADL (14:55), ADL-SYD (17:20)

9.2.10 Crew Scheduling with Maximum 4 Shifts

Table 52: Crew Scheduling for Adelaide (max 4 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Tuesday	290	00	ADL-SYD (05:25), SYD-ADL (07:50)
1	Wednesday	645	00	ADL-PER (10:15), PER-MEL (14:25), MEL-ADL (19:10)
1	Thursday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
1	Friday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
2	Monday	370	01	ADL-SYD (14:50), SYD-MEL (17:15), MEL-ADL (19:10)
2	Tuesday	645	00	ADL-PER (10:15), PER-MEL (14:25), MEL-ADL (19:10)
2	Thursday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
2	Friday	370	01	ADL-SYD (14:50), SYD-MEL (17:15), MEL-ADL (19:10)
3	Monday	880	02	ADL-DRW (05:00), DRW-ADL (09:15), ADL-MEL (13:30), MEL-SYD (15:20), SYD-ADL (17:15)
3	Tuesday	550	01	ADL-MEL (06:15), MEL-BNE (08:05), BNE-SYD (10:55), SYD-ADL (13:00)
3	Wednesday	550	01	ADL-MEL (06:15), MEL-BNE (08:05), BNE-SYD (10:55), SYD-ADL (13:00)
4	Tuesday	335	01	ADL-MEL (15:25), MEL-CBR (17:15), CBR-ADL (18:55)
4	Friday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
4	Saturday	645	00	ADL-PER (08:50), PER-MEL (13:00), MEL-ADL (17:45)
4	Sunday	870	00	ADL-SYD (06:30), SYD-MEL (08:55), MEL-ADL (10:50), ADL-PER (12:40), PER-ADL (16:50)
5	Monday	795	00	ADL-PER (07:45), PER-BNE (11:55), BNE-ADL (17:55)
5	Wednesday	335	01	ADL-MEL (15:25), MEL-CBR (17:15), CBR-ADL (18:55)
5	Thursday	370	01	ADL-SYD (14:50), SYD-MEL (17:15), MEL-ADL (19:10)
5	Friday	795	00	ADL-PER (07:45), PER-BNE (11:55), BNE-ADL (17:55)
6	Monday	510	01	ADL-SYD (06:20), SYD-ADL (08:45), ADL-MEL (11:10), MEL-ADL (13:00)
6	Wednesday	290	00	ADL-SYD (05:25), SYD-ADL (07:50)
6	Thursday	795	00	ADL-PER (07:45), PER-BNE (11:55), BNE-ADL (17:55)

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Table 52 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
6	Sunday	720	01	ADL-DRW (08:45), DRW-BNE (13:00), BNE-ADL (17:40)

Table 53: Crew Scheduling for Brisbane (max 4 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Wednesday	900	13	BNE-DRW (06:00), DRW-PER (10:40), PER-BNE (15:00)
1	Friday	340	10	BNE-MEL (15:20), MEL-BNE (18:10)
1	Saturday	535	12	BNE-CBR (12:05), CBR-ADL (14:25), ADL-SYD (16:30), SYD-BNE (18:55)
2	Tuesday	900	13	BNE-DRW (06:00), DRW-PER (10:40), PER-BNE (15:00)
2	Wednesday	400	10	BNE-HBA (14:20), HBA-BNE (17:40)
2	Saturday	455	10	BNE-SYD (06:35), SYD-ADL (08:40), ADL-BNE (11:05)
2	Sunday	250	11	BNE-SYD (07:30), SYD-BNE (09:35)
3	Monday	340	13	BNE-MEL (15:20), MEL-BNE (18:10)
3	Tuesday	400	10	BNE-HBA (14:20), HBA-BNE (17:40)
3	Wednesday	480	11	BNE-SYD (13:00), SYD-MEL (15:05), MEL-CBR (17:00), CBR-BNE (18:40)
3	Saturday	825	11	BNE-ADL (06:50), ADL-BNE (09:55), BNE-ADL (13:00), ADL-SYD (16:05), SYD-BNE (18:30)
4	Monday	355	12	BNE-SYD (15:05), SYD-CBR (17:10), CBR-BNE (18:40)
4	Thursday	550	10	BNE-MEL (06:10), MEL-ADL (09:00), ADL-SYD (10:50), SYD-BNE (13:15)
4	Friday	820	11	BNE-SYD (07:20), SYD-PER (09:25), PER-BNE (15:00)
4	Sunday	250	10	BNE-SYD (07:40), SYD-BNE (09:45)
5	Monday	550	10	BNE-MEL (06:10), MEL-ADL (09:00), ADL-SYD (10:50), SYD-BNE (13:15)
5	Tuesday	340	11	BNE-MEL (07:20), MEL-BNE (10:10)
5	Thursday	820	11	BNE-SYD (07:20), SYD-PER (09:25), PER-BNE (15:00)
5	Sunday	340	12	BNE-MEL (06:20), MEL-BNE (09:10)
6	Monday	820	11	BNE-SYD (07:20), SYD-PER (09:25), PER-BNE (15:00)
6	Wednesday	250	12	BNE-SYD (16:50), SYD-BNE (18:55)
6	Friday	355	12	BNE-SYD (15:05), SYD-CBR (17:10), CBR-BNE (18:40)
6	Sunday	540	12	BNE-MEL (12:00), MEL-HBA (14:50), HBA-SYD (16:35), SYD-BNE (18:55)
7	Tuesday	250	12	BNE-SYD (16:50), SYD-BNE (18:55)

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Table 53 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
7	Thursday	355	12	BNE-SYD (15:05), SYD-CBR (17:10), CBR-BNE (18:40)
7	Friday	550	10	BNE-MEL (06:10), MEL-ADL (09:00), ADL-SYD (10:50), SYD-BNE (13:15)
7	Sunday	815	13	BNE-MEL (07:25), MEL-PER (10:15), PER-BNE (15:00)
8	Monday	590	12	BNE-SYD (05:15), SYD-BNE (07:20), BNE-MEL (09:25), MEL-BNE (12:15)
8	Tuesday	410	10	BNE-SYD (07:30), SYD-MEL (09:35), MEL-BNE (11:30)
8	Thursday	340	13	BNE-MEL (15:20), MEL-BNE (18:10)
8	Friday	615	13	BNE-MEL (05:05), MEL-SYD (07:55), SYD-ADL (09:50), ADL-BNE (12:15)
9	Thursday	615	13	BNE-MEL (05:05), MEL-SYD (07:55), SYD-ADL (09:50), ADL-BNE (12:15)
9	Friday	340	13	BNE-MEL (15:20), MEL-BNE (18:10)
9	Saturday	410	10	BNE-SYD (14:10), SYD-MEL (16:15), MEL-BNE (18:10)
9	Sunday	560	11	BNE-DRW (11:40), DRW-BNE (16:20)
10	Monday	615	13	BNE-MEL (05:05), MEL-SYD (07:55), SYD-ADL (09:50), ADL-BNE (12:15)
10	Tuesday	480	11	BNE-SYD (13:00), SYD-MEL (15:05), MEL-CBR (17:00), CBR-BNE (18:40)
10	Wednesday	340	10	BNE-MEL (07:20), MEL-BNE (10:10)
10	Sunday	550	10	BNE-MEL (11:50), MEL-ADL (14:40), ADL-SYD (16:30), SYD-BNE (18:55)
11	Wednesday	590	12	BNE-MEL (07:00), MEL-BNE (09:50), BNE-SYD (12:40), SYD-BNE (14:45)
11	Thursday	340	10	BNE-MEL (15:20), MEL-BNE (18:10)
11	Friday	590	12	BNE-SYD (05:15), SYD-BNE (07:20), BNE-MEL (09:25), MEL-BNE (12:15)
12	Monday	340	10	BNE-MEL (15:20), MEL-BNE (18:10)
12	Tuesday	590	12	BNE-MEL (07:00), MEL-BNE (09:50), BNE-SYD (12:40), SYD-BNE (14:45)
12	Wednesday	410	10	BNE-SYD (07:30), SYD-MEL (09:35), MEL-BNE (11:30)
12	Thursday	590	12	BNE-SYD (05:15), SYD-BNE (07:20), BNE-MEL (09:25), MEL-BNE (12:15)

Table 54: Crew Scheduling for Melbourne (max 4 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	200	56	MEL-CBR (17:40), CBR-MEL (19:20)
1	Wednesday	480	51	MEL-SYD (06:10), SYD-BNE (08:05), BNE-SYD (10:10), SYD-MEL (12:15)

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Table 54 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
1	Thursday	360	55	MEL-HBA (14:45), HBA-SYD (16:30), SYD-MEL (18:50)
1	Saturday	960	55	MEL-SYD (05:00), SYD-BNE (06:55), BNE-PER (09:00), PER-ADL (15:00), ADL-MEL (19:10)
2	Monday	220	54	MEL-ADL (17:15), ADL-MEL (19:05)
2	Wednesday	410	51	MEL-SYD (14:10), SYD-BNE (16:05), BNE-MEL (18:10)
2	Friday	580	51	MEL-DRW (11:20), DRW-MEL (16:10)
2	Sunday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)
3	Tuesday	410	51	MEL-SYD (14:10), SYD-BNE (16:05), BNE-MEL (18:10)
3	Wednesday	220	57	MEL-ADL (05:05), ADL-MEL (06:55)
3	Thursday	580	51	MEL-DRW (11:20), DRW-MEL (16:10)
3	Saturday	735	51	MEL-PER (08:45), PER-SYD (13:30), SYD-MEL (19:05)
4	Wednesday	210	55	MEL-HBA (17:30), HBA-MEL (19:15)
4	Friday	735	50	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
4	Saturday	460	52	MEL-SYD (05:40), SYD-MEL (07:35), MEL-SYD (09:30), SYD-MEL (11:25)
4	Sunday	570	52	MEL-PER (07:40), PER-MEL (12:25)
5	Thursday	220	54	MEL-ADL (17:15), ADL-MEL (19:05)
5	Friday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)
5	Saturday	570	54	MEL-PER (11:30), PER-MEL (16:15)
5	Sunday	410	50	MEL-BNE (08:05), BNE-SYD (10:55), SYD-MEL (13:00)
6	Monday	210	50	MEL-HBA (17:30), HBA-MEL (19:15)
6	Thursday	735	50	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
6	Friday	570	56	MEL-PER (08:10), PER-MEL (12:55)
6	Saturday	460	52	MEL-SYD (13:20), SYD-MEL (15:15), MEL-SYD (17:10), SYD-MEL (19:05)
7	Tuesday	220	57	MEL-ADL (05:05), ADL-MEL (06:55)
7	Wednesday	570	50	MEL-PER (05:50), PER-MEL (10:35)
7	Thursday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)
7	Friday	410	53	MEL-BNE (14:10), BNE-SYD (17:00), SYD-MEL (19:05)
8	Monday	220	52	MEL-ADL (16:50), ADL-MEL (18:40)
8	Tuesday	570	50	MEL-PER (05:50), PER-MEL (10:35)
8	Wednesday	735	55	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
8	Thursday	410	53	MEL-BNE (14:10), BNE-SYD (17:00), SYD-MEL (19:05)

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Team	Day	Duration	Plane Code	Flight Routes
9	Tuesday	945	54	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45), MEL-HBA (17:30), HBA-MEL (19:15)
9	Friday	220	54	MEL-ADL (17:15), ADL-MEL (19:05)
9	Saturday	220	51	MEL-ADL (05:05), ADL-MEL (06:55)
9	Sunday	540	53	MEL-BNE (05:10), BNE-SYD (08:00), SYD-HBA (10:05), HBA-MEL (12:25)
10	Monday	960	57	MEL-CBR (05:00), CBR-SYD (06:40), SYD-BNE (08:10), BNE-PER (10:15), PER-MEL (16:15)
10	Thursday	475	55	MEL-BNE (06:50), BNE-HBA (09:40), HBA-MEL (13:00)
10	Saturday	340	54	MEL-BNE (05:50), BNE-MEL (08:40)
10	Sunday	200	54	MEL-CBR (17:15), CBR-MEL (18:55)
11	Wednesday	960	56	MEL-SYD (05:00), SYD-BNE (06:55), BNE-PER (09:00), PER-ADL (15:00), ADL-MEL (19:10)
11	Thursday	200	56	MEL-CBR (17:40), CBR-MEL (19:20)
11	Friday	465	53	MEL-BNE (06:25), BNE-ADL (09:15), ADL-MEL (12:20)
11	Saturday	360	50	MEL-HBA (14:40), HBA-SYD (16:25), SYD-MEL (18:45)
12	Monday	370	51	MEL-ADL (05:10), ADL-SYD (07:00), SYD-MEL (09:25)
12	Wednesday	960	52	MEL-SYD (05:00), SYD-ADL (06:55), ADL-PER (09:20), PER-SYD (13:30), SYD-MEL (19:05)
12	Thursday	465	53	MEL-BNE (06:25), BNE-ADL (09:15), ADL-MEL (12:20)
12	Friday	200	56	MEL-CBR (17:40), CBR-MEL (19:20)
13	Tuesday	480	51	MEL-SYD (06:10), SYD-BNE (08:05), BNE-SYD (10:10), SYD-MEL (12:15)
13	Wednesday	340	50	MEL-BNE (15:20), BNE-MEL (18:10)
13	Friday	960	57	MEL-CBR (05:00), CBR-SYD (06:40), SYD-BNE (08:10), BNE-PER (10:15), PER-MEL (16:15)
13	Sunday	200	55	MEL-CBR (17:40), CBR-MEL (19:20)
14	Monday	410	53	MEL-BNE (14:10), BNE-SYD (17:00), SYD-MEL (19:05)
14	Tuesday	620	53	MEL-BNE (05:30), BNE-CBR (08:20), CBR-BNE (10:40), BNE-MEL (13:00)
14	Friday	210	50	MEL-HBA (17:30), HBA-MEL (19:15)
14	Saturday	700	53	MEL-BNE (09:20), BNE-MEL (12:10), MEL-SYD (15:00), SYD-HBA (16:55), HBA-MEL (19:15)
15	Monday	465	53	MEL-BNE (06:25), BNE-ADL (09:15), ADL-MEL (12:20)
15	Wednesday	620	53	MEL-BNE (05:30), BNE-CBR (08:20), CBR-BNE (10:40), BNE-MEL (13:00)
15	Saturday	640	56	MEL-SYD (09:00), SYD-BNE (10:55), BNE-MEL (13:00), MEL-SYD (15:50), SYD-MEL (17:45)
15	Sunday	210	50	MEL-HBA (14:55), HBA-MEL (16:40)
16	Tuesday	210	55	MEL-HBA (17:30), HBA-MEL (19:15)

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Table 54 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
16	Wednesday	735	57	MEL-PER (08:45), PER-SYD (13:30), SYD-MEL (19:05)
16	Thursday	570	52	MEL-BNE (07:20), BNE-MEL (10:10), MEL-SYD (13:00), SYD-MEL (14:55)
16	Sunday	460	56	MEL-SYD (05:40), SYD-MEL (07:35), MEL-SYD (09:30), SYD-MEL (11:25)
17	Monday	570	52	MEL-BNE (07:20), BNE-MEL (10:10), MEL-SYD (13:00), SYD-MEL (14:55)
17	Tuesday	340	50	MEL-BNE (15:20), BNE-MEL (18:10)
17	Sunday	940	51	MEL-ADL (05:20), ADL-BNE (07:10), BNE-DRW (10:15), DRW-ADL (14:55), ADL-MEL (19:10)
18	Monday	735	50	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
18	Thursday	370	51	MEL-ADL (05:10), ADL-SYD (07:00), SYD-MEL (09:25)
18	Friday	220	52	MEL-ADL (16:50), ADL-MEL (18:40)
18	Sunday	580	55	MEL-DRW (08:00), DRW-MEL (12:50)
19	Tuesday	735	55	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45)
19	Thursday	220	52	MEL-ADL (16:50), ADL-MEL (18:40)
19	Friday	570	52	MEL-BNE (07:20), BNE-MEL (10:10), MEL-SYD (13:00), SYD-MEL (14:55)
19	Sunday	410	53	MEL-SYD (14:10), SYD-BNE (16:05), BNE-MEL (18:10)
20	Monday	570	56	MEL-PER (08:10), PER-MEL (12:55)
20	Tuesday	305	53	MEL-SYD (15:50), SYD-CBR (17:45), CBR-MEL (19:15)
20	Wednesday	945	54	MEL-SYD (05:15), SYD-PER (07:10), PER-MEL (12:45), MEL-HBA (17:30), HBA-MEL (19:15)
21	Monday	475	55	MEL-BNE (06:50), BNE-HBA (09:40), HBA-MEL (13:00)
21	Tuesday	960	56	MEL-SYD (05:00), SYD-BNE (06:55), BNE-PER (09:00), PER-ADL (15:00), ADL-MEL (19:10)
21	Friday	360	55	MEL-HBA (14:45), HBA-SYD (16:30), SYD-MEL (18:50)
22	Monday	580	51	MEL-DRW (11:20), DRW-MEL (16:10)
22	Tuesday	735	57	MEL-PER (08:45), PER-SYD (13:30), SYD-MEL (19:05)
22	Friday	370	51	MEL-ADL (05:10), ADL-SYD (07:00), SYD-MEL (09:25)
22	Sunday	230	52	MEL-SYD (17:10), SYD-MEL (19:05)
23	Tuesday	960	52	MEL-SYD (05:00), SYD-ADL (06:55), ADL-PER (09:20), PER-SYD (13:30), SYD-MEL (19:05)
23	Wednesday	305	53	MEL-SYD (15:50), SYD-CBR (17:45), CBR-MEL (19:15)
23	Thursday	210	50	MEL-HBA (17:30), HBA-MEL (19:15)

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Team	Day	Duration	Plane Code	Flight Routes
23	Saturday	485	50	MEL-SYD (06:35), SYD-ADL (08:30), ADL-CBR (10:55), CBR-MEL (13:00)
24	Monday	735	54	MEL-PER (05:00), PER-SYD (09:45), SYD-MEL (15:20)
24	Thursday	570	56	MEL-PER (08:10), PER-MEL (12:55)
24	Saturday	200	53	MEL-CBR (06:00), CBR-MEL (07:40)
24	Sunday	460	56	MEL-SYD (13:20), SYD-MEL (15:15), MEL-SYD (17:10), SYD-MEL (19:05)
25	Monday	360	55	MEL-HBA (14:45), HBA-SYD (16:30), SYD-MEL (18:50)
25	Thursday	960	57	MEL-CBR (05:00), CBR-SYD (06:40), SYD-BNE (08:10), BNE-PER (10:15), PER-MEL (16:15)
25	Friday	475	55	MEL-BNE (06:50), BNE-HBA (09:40), HBA-MEL (13:00)

Table 55: Crew Scheduling for Perth (max 4 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
1	Tuesday	900	61	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
1	Friday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
2	Thursday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
2	Friday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
2	Saturday	900	60	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
2	Sunday	820	60	PER-BNE (07:00), BNE-SYD (13:00), SYD-PER (15:05)
3	Wednesday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-SYD (12:15), SYD-MEL (14:20), MEL-PER (16:15)
3	Thursday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
3	Saturday	900	61	PER-BNE (06:00), BNE-DRW (12:00), DRW-PER (16:40)
3	Sunday	815	61	PER-MEL (07:25), MEL-BNE (12:10), BNE-PER (15:00)
4	Monday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
4	Tuesday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-SYD (12:15), SYD-MEL (14:20), MEL-PER (16:15)

Continued on the next page

Table 55 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
4	Wednesday	900	61	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)

Table 56: Crew Scheduling for Sydney (max 4 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Monday	480	76	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
1	Friday	480	74	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
1	Sunday	820	72	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
2	Tuesday	280	75	SYD-HBA (16:20), HBA-SYD (18:40)
2	Wednesday	230	74	SYD-MEL (17:10), MEL-SYD (19:05)
2	Saturday	640	72	SYD-MEL (10:20), MEL-BNE (12:15), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
2	Sunday	735	74	SYD-PER (05:00), PER-MEL (10:35), MEL-SYD (15:20)
3	Tuesday	230	70	SYD-MEL (17:10), MEL-SYD (19:05)
3	Wednesday	570	75	SYD-MEL (06:50), MEL-BNE (08:45), BNE-MEL (11:35), MEL-SYD (14:25)
3	Friday	360	72	SYD-HBA (08:55), HBA-MEL (11:15), MEL-SYD (13:00)
3	Saturday	735	70	SYD-PER (08:45), PER-MEL (14:20), MEL-SYD (19:05)
4	Tuesday	570	75	SYD-MEL (06:50), MEL-BNE (08:45), BNE-MEL (11:35), MEL-SYD (14:25)
4	Wednesday	230	76	SYD-MEL (17:10), MEL-SYD (19:05)
4	Thursday	360	72	SYD-HBA (08:55), HBA-MEL (11:15), MEL-SYD (13:00)
4	Saturday	735	71	SYD-MEL (08:45), MEL-PER (10:40), PER-SYD (15:25)
5	Monday	230	74	SYD-MEL (09:10), MEL-SYD (11:05)
5	Tuesday	550	76	SYD-BNE (08:00), BNE-MEL (10:05), MEL-ADL (12:55), ADL-SYD (14:45)
5	Wednesday	735	71	SYD-MEL (08:45), MEL-PER (10:40), PER-SYD (15:25)
5	Thursday	480	76	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
6	Monday	480	76	SYD-MEL (05:00), MEL-SYD (06:55), SYD-BNE (08:50), BNE-SYD (10:55)
6	Tuesday	735	71	SYD-MEL (08:45), MEL-PER (10:40), PER-SYD (15:25)
6	Wednesday	550	76	SYD-BNE (08:00), BNE-MEL (10:05), MEL-ADL (12:55), ADL-SYD (14:45)

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Table 56 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
6	Sunday	180	74	SYD-CBR (17:15), CBR-SYD (18:45)
7	Tuesday	670	74	SYD-MEL (06:00), MEL-SYD (07:55), SYD-MEL (09:50), MEL-HBA (11:45), HBA-MEL (13:30), MEL-SYD (15:15)
7	Wednesday	230	72	SYD-MEL (05:40), MEL-SYD (07:35)
7	Thursday	250	73	SYD-BNE (05:00), BNE-SYD (07:05)
7	Friday	710	73	SYD-MEL (09:10), MEL-SYD (11:05), SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
8	Monday	670	71	SYD-PER (09:50), PER-SYD (15:25)
8	Thursday	710	73	SYD-MEL (09:10), MEL-SYD (11:05), SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
8	Friday	230	70	SYD-MEL (05:25), MEL-SYD (07:20)
8	Sunday	230	73	SYD-MEL (06:00), MEL-SYD (07:55)
9	Tuesday	230	76	SYD-MEL (17:10), MEL-SYD (19:05)
9	Wednesday	820	73	SYD-PER (07:20), PER-BNE (12:55), BNE-SYD (18:55)
9	Thursday	480	76	SYD-MEL (05:00), MEL-SYD (06:55), SYD-BNE (08:50), BNE-SYD (10:55)
9	Sunday	410	70	SYD-MEL (14:10), MEL-SYD (16:05), SYD-CBR (18:00), CBR-SYD (19:30)
10	Monday	480	74	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
10	Tuesday	230	72	SYD-MEL (05:40), MEL-SYD (07:35)
10	Thursday	820	75	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
10	Sunday	370	71	SYD-ADL (14:50), ADL-MEL (17:15), MEL-SYD (19:05)
11	Monday	230	70	SYD-MEL (05:25), MEL-SYD (07:20)
11	Friday	480	76	SYD-MEL (05:00), MEL-SYD (06:55), SYD-BNE (08:50), BNE-SYD (10:55)
11	Saturday	820	74	SYD-PER (07:20), PER-BNE (12:55), BNE-SYD (18:55)
11	Sunday	460	70	SYD-MEL (06:30), MEL-SYD (08:25), SYD-MEL (10:20), MEL-SYD (12:15)
12	Wednesday	230	70	SYD-MEL (17:10), MEL-SYD (19:05)
12	Thursday	705	70	SYD-MEL (09:15), MEL-HBA (11:10), HBA-BNE (12:55), BNE-MEL (16:15), MEL-SYD (19:05)
12	Friday	670	71	SYD-PER (09:50), PER-SYD (15:25)
12	Saturday	250	73	SYD-BNE (05:40), BNE-SYD (07:45)
13	Monday	705	70	SYD-MEL (09:15), MEL-HBA (11:10), HBA-BNE (12:55), BNE-MEL (16:15), MEL-SYD (19:05)
13	Wednesday	670	74	SYD-MEL (06:00), MEL-SYD (07:55), SYD-MEL (09:50), MEL-HBA (11:45), HBA-MEL (13:30), MEL-SYD (15:15)
13	Thursday	230	70	SYD-MEL (05:25), MEL-SYD (07:20)

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Table 56 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
13	Friday	250	73	SYD-BNE (05:00), BNE-SYD (07:05)
14	Wednesday	690	72	SYD-BNE (09:30), BNE-CBR (11:35), CBR-MEL (13:55), MEL-ADL (15:35), ADL-CBR (17:25), CBR-SYD (19:30)
14	Thursday	280	71	SYD-HBA (05:10), HBA-SYD (07:30)
14	Friday	230	72	SYD-MEL (14:55), MEL-SYD (16:50)
14	Sunday	670	73	SYD-PER (09:50), PER-SYD (15:25)
15	Tuesday	690	72	SYD-BNE (09:30), BNE-CBR (11:35), CBR-MEL (13:55), MEL-ADL (15:35), ADL-CBR (17:25), CBR-SYD (19:30)
15	Thursday	230	72	SYD-MEL (14:55), MEL-SYD (16:50)
15	Friday	280	71	SYD-HBA (05:10), HBA-SYD (07:30)
15	Saturday	670	73	SYD-PER (09:50), PER-SYD (15:25)
16	Monday	280	71	SYD-HBA (05:10), HBA-SYD (07:30)
16	Tuesday	685	70	SYD-MEL (05:45), MEL-SYD (07:40), SYD-BNE (09:35), BNE-ADL (11:40), ADL-SYD (14:45)
16	Wednesday	685	70	SYD-MEL (05:45), MEL-SYD (07:40), SYD-BNE (09:35), BNE-ADL (11:40), ADL-SYD (14:45)
16	Thursday	230	74	SYD-MEL (09:10), MEL-SYD (11:05)
17	Monday	820	75	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
17	Tuesday	230	74	SYD-MEL (17:10), MEL-SYD (19:05)
17	Friday	480	76	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
17	Sunday	410	75	SYD-MEL (05:20), MEL-BNE (07:15), BNE-SYD (10:05)
18	Monday	710	73	SYD-MEL (09:10), MEL-SYD (11:05), SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
18	Wednesday	280	75	SYD-HBA (16:20), HBA-SYD (18:40)
18	Friday	230	74	SYD-MEL (09:10), MEL-SYD (11:05)
18	Sunday	660	76	SYD-ADL (08:45), ADL-MEL (11:10), MEL-SYD (13:00), SYD-ADL (14:55), ADL-SYD (17:20)
19	Monday	360	72	SYD-HBA (08:55), HBA-MEL (11:15), MEL-SYD (13:00)
19	Tuesday	820	73	SYD-PER (07:20), PER-BNE (12:55), BNE-SYD (18:55)
19	Saturday	180	70	SYD-CBR (05:45), CBR-SYD (07:15)
19	Sunday	530	75	SYD-BNE (12:10), BNE-CBR (14:15), CBR-BNE (16:35), BNE-SYD (18:55)
20	Monday	250	73	SYD-BNE (05:00), BNE-SYD (07:05)
20	Thursday	670	71	SYD-PER (09:50), PER-SYD (15:25)
20	Friday	705	70	SYD-MEL (09:15), MEL-HBA (11:10), HBA-BNE (12:55), BNE-MEL (16:15), MEL-SYD (19:05)
20	Saturday	250	72	SYD-BNE (06:10), BNE-SYD (08:15)
21	Monday	230	72	SYD-MEL (14:55), MEL-SYD (16:50)

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Table 56 Continued from previous page

Team	Day	Duration	Plane Code	Flight Routes
21	Thursday	480	74	SYD-BNE (13:00), BNE-SYD (15:05), SYD-MEL (17:10), MEL-SYD (19:05)
21	Friday	820	75	SYD-BNE (07:20), BNE-PER (09:25), PER-SYD (15:25)
21	Sunday	460	71	SYD-MEL (07:10), MEL-SYD (09:05), SYD-MEL (11:00), MEL-SYD (12:55)

9.2.11 Crew Scheduling with Maximum 3 Shifts

Table 57: Crew Scheduling for Perth (max 3 shifts)

Team	Day	Duration	Plane Code	Flight Routes
1	Thursday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
1	Friday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
1	Sunday	820	60	PER-BNE (07:00), BNE-SYD (13:00), SYD-PER (15:05)
2	Thursday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
2	Friday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
2	Sunday	815	61	PER-MEL (07:25), MEL-BNE (12:10), BNE-PER (15:00)
3	Monday	940	61	PER-MEL (05:20), MEL-SYD (10:05), SYD-ADL (12:00), ADL-MEL (14:25), MEL-PER (16:15)
3	Wednesday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-SYD (12:15), SYD-MEL (14:20), MEL-PER (16:15)
4	Tuesday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-SYD (12:15), SYD-MEL (14:20), MEL-PER (16:15)
4	Wednesday	900	61	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
4	Saturday	900	60	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
5	Monday	960	60	PER-ADL (05:00), ADL-BNE (09:10), BNE-CBR (12:15), CBR-MEL (14:35), MEL-PER (16:15)
5	Tuesday	900	61	PER-DRW (06:00), DRW-BNE (10:20), BNE-PER (15:00)
5	Saturday	900	61	PER-BNE (06:00), BNE-DRW (12:00), DRW-PER (16:40)

9.3 Implementation of model

Model 4.1.1

```
# Range of the maximum number of flight
F = range (12)
# Range of planes
N = range (40)
a = 0 #the day 0

m1 = gp.Model(env=env)
m1.setParam(GRB.Param.MIPGap, 0.0001)

# Decision variables
x = m1.addVars([(n,f,k,l) for n in N for f in F for k in C for l in C], vtype=GRB.BINARY, name="x")

# Objective
m1.setObjective(gp.quicksum(gp.quicksum(VC[k][l] * x[n,f,k,l] for f in F) +
    FC * x[n,0,k,l] for n in N for k in C for l in C), GRB.MINIMIZE)

# Constraints
m1.addConstrs((gp.quicksum(x[n,f,k,l] for k in C for l in C) <= 1 for f in F for n in N), name = '2')
m1.addConstrs((gp.quicksum(x[n,f,k,l] * FD[a][k][l] for f in F for k in C for l in C) <= TH for n in N), name = '3')
m1.addConstrs((gp.quicksum(x[n,f,k,l] * S for f in F for n in N) >= DM[a][k][l] for k in C for l in C), name = '4')
m1.addConstrs((gp.quicksum(x[n,f,k,l] for l in C) >= gp.quicksum(x[n,f+1,k,l]for l in C) for f in F
    if f < max(F) and f % 2 == 1 for n in N for k in C), name = '5')
m1.addConstrs((x[n,f,k,k] == 0 for n in N for f in F for k in C), name = '6')
m1.addConstrs((x[n,f,k,l] == x[n,f+1,k,l] for f in F if f < max(F) and f % 2 ==0
    for n in N for k in C for l in C), name = '7')

# Optimize
m1.optimize()

# Display optimal values of decision variables
for v in m1.getVars():
    if v.x > 1e-6:
        print(v.varName, v.x)
```

Model 4.1.2

```python
# Range of the maximum number of flight
F = range (12)
# Range of planes
N = range (30)
a = 0

#Model 2: One Plane One Home Base
m2 = gp.Model(env=env)
m2.setParam(GRB.Param.MIPGap, 0.00015)

# Decision variables
x = m2.addVars([(n,f,k,l) for n in N for f in F for k in C for l in C], vtype=GRB.BINARY, name="x")

# Objective
m2.setObjective(gp.quicksum(gp.quicksum(VC[k][l] * x[n,f,k,l] for f in F) +
    FC * x[n,0,k,l] for n in N for k in C for l in C), GRB.MINIMIZE )

# Constraints
m2.addConstrs((gp.quicksum(x[n,f,k,l] for k in C for l in C) <= 1 for f in F for n in N), name = '2')
m2.addConstrs((gp.quicksum(x[n,f,k,l] * FD[a][k][l] for f in F for k in C for l in C) <= TH for n in N), name = '3')
m2.addConstrs((gp.quicksum(x[n,f,k,l] * S for f in F if f % 2 == 0 for n in N) +
    gp.quicksum(x[n,f,l,k] * S for f in F if f % 2 == 1 for n in N) >= DM[a][k][l] for k in C for l in C), name = '8')
m2.addConstrs((gp.quicksum(x[n,f,k,l] for l in C) >=  gp.quicksum(x[n,f+1,k,l]for l in C)
    for f in F if f < max(F) and f % 2 == 1 for n in N for k in C), name = '9')
m2.addConstrs((gp.quicksum(x[n,f,k,l] for k in C) >=  gp.quicksum(x[n,f+1,k,l]for k in C)
    for f in F if f < max(F) and f % 2 == 0 for n in N for l in C), name = '10')
m2.addConstrs((x[n,f,k,k] == x[n,f+1,k,k] for n in N for f in F if f < max(F) and f % 2 == 1 for k in C), name = '11')
m2.addConstrs((x[n,0,k,k] == 0 for n in N for k in C), name = '12')
m2.addConstrs((gp.quicksum(x[n,0,k,l] for l in C) ==  gp.quicksum(x[n,5,k,l] for l in C)
    for n in N for k in C), name = '13')
m2.addConstrs((gp.quicksum(x[n,0,k,l] for l in C) ==  gp.quicksum(x[n,11,k,l] for l in C)
    for n in N for k in C), name = '14')
m2.addConstrs((gp.quicksum(x[n,0,k,l] for n in N for l in C) <= 10 for k in C), name = '15')
m2.addConstrs((gp.quicksum(x[n,0,k,l] for n in N for l in C) == 0 for k in {2,3,4}), name = '16')
m2.addConstrs((gp.quicksum(x[n,0,k,l] for n in N for l in C) >= 2 for k in set(C) - {2,3,4}), name = '17')

# Optimize
m2.optimize()

# Display optimal values of decision variables
for v in m2.getVars():
    if v.x > 1e-6:
        print(v.varName, v.x)
```

Model 4.1.3

```
# Range of the maximum number of flight
F = range (12)
# Range of planes
N = range (30)

for a in {1,5,6}:
    m2a = gp.Model(env=env)
    m2a.setParam("MIPGap", 0.01)

    # Decision variables
    x = m2a.addVars([(n,f,k,l) for n in N for f in F for k in C for l in C], vtype=GRB.BINARY, name="x")

    # Objective
    m2a.setObjective(gp.quicksum(gp.quicksum(VC[k][l] * x[n,f,k,l] for f in F) + FC * x[n,0,k,l]
        for n in N for k in C for l in C), GRB.MINIMIZE )

    # Constraints
    m2a.addConstrs((gp.quicksum(x[n,f,k,l] for k in C for l in C) <= 1 for f in F for n in N), name = '2')
    m2a.addConstrs((gp.quicksum(x[n,f,k,l] * FD[a][k][l] for f in F for k in C for l in C)
       <= TH for n in N), name = '3')
    m2a.addConstrs((gp.quicksum(x[n,f,k,l] * S for f in F if f % 2 == 0 for n in N) +
        gp.quicksum(x[n,f,l,k] * S for f in F if f % 2 == 1 for n in N) >= DM[a][k][l]
        for k in C for l in C), name = '8')
    m2a.addConstrs((gp.quicksum(x[n,f,k,l] for l in C) >= gp.quicksum(x[n,f+1,k,l]for l in C)
        for f in F if f < max(F) and f % 2 == 1 for n in N for k in C), name = '9')
    m2a.addConstrs((gp.quicksum(x[n,f,k,l] for k in C) >= gp.quicksum(x[n,f+1,k,l] for k in C)
        for f in F if f < max(F) and f % 2 == 0 for n in N for l in C), name = '10')
    m2a.addConstrs((x[n,f,k,k] == x[n,f+1,k,k] for n in N for f in F if f < max(F) and
        f % 2 == 1 for k in C), name = '11')
    m2a.addConstrs((x[n,0,k,k] == 0 for n in N for k in C), name = '12')
    m2a.addConstrs((gp.quicksum(x[n,0,k,l] for l in C) == gp.quicksum(x[n,5,k,l] for l in C)
        for n in N for k in C), name = '13')
    m2a.addConstrs((gp.quicksum(x[n,0,k,l] for l in C) == gp.quicksum(x[n,11,k,l] for l in C)
        for n in N for k in C), name = '14')
    # Adding constraint based on Model 2
    m2a.addConstrs((gp.quicksum(x[n,0,k,l] for n in N for l in C) <= CP[k] for k in C), name = '15a')

    # Optimize
    m2a.optimize()

    #Objective Value
    obj_val.append(round(float(m2a.ObjVal),0))

    #change the result from Gurobi to be list of integer
    var_int = []
    for v in m2a.getVars():
        if v.x > 0.9 and v.x < 1.1:
            var_int.append(v.varName[2:-1].split(','))
    my_var = []
    for id in var_int:
      new_id = list(np.array(id, dtype=int))
      new_id.append(FD[a][new_id[2]][new_id[3]])
      my_var.append(new_id)
    my_var = sorted(my_var, key=lambda x: x[0])

    #Determining the real flights only adding the time flights based on ET
    real_flight = realflight(homebase(routes(my_var,N)))
    time_flight[a] = updateflight(real_flight)

    #Determining the total shifts
    for key in totalshifts.keys():
        totalshifts[key] += shift_dict(time_flight[a],a)[key]
```

Model 4.2

```
def myET_1(data):

    time = [r[-1] for r in data[:-1]]
    list_ET = []

    for k in range (len(time) + 1): #Calculating the Earliness and Tardiness (ET)
        E = 0
        T = 0
        PE = 0
        PT = data[-1][-1]
        for l in range (len(time)):
            if l < k:
                E += (l + 1) * time[l]
                PE += time[l]
            if l >= k:
                T += (len(time[k:])-(l-k))*time[l]
                PT += time[l]
        if PE > 8 * 60 or PT > 8 * 60:
            ET = 10000 #Big M Value
        else:
            ET = E + T
        list_ET.append(ET)

    OT = list_ET.index(min(list_ET)) #The index of the best minimise ET
    DT = [0 for k in range (len(time)+1)]

    for k in range (len(time) + 1): #Calculating the hour of flight
        if k < OT:
            DT[k] = 780 - sum(r[-1] for r in data[k:OT])
        if k >= OT:
            DT[k] = 780 + sum(r[-1] for r in data[OT:k])

    DT_hour = ["{0:0=2d}".format(k // 60)+':'+"{0:0=2d}".format(k % 60) for k in DT] #list of departure time

    last_arrival = DT[-1] + data[-1][-1]
    FT_hour = "{0:0=2d}".format(last_arrival // 60) + ':' + "{0:0=2d}".format(last_arrival % 60) #the last arrival time

    return(DT_hour, FT_hour, min(list_ET)) #Output: departure time, last arrival time, best Earliness/Tardiness




def myET_2(data):
    ET_list1 = [] #Scheduling the plane from the first flight
    ET_list2 = [] #Scheduling the plane from the last flight

    time1 = [r[-1] for r in data]
    for k in range(len(time1)):
        value = abs(480-sum(time1[:k]))
        ET_list1.append(value)
    ET_list1

    time2 = time1[::-1]
    for k in range(len(time2)):
        value = abs(480-sum(time2[:k+1]))
        ET_list2.append(value)
    ET_list2.reverse()

    DT = [0 for k in range(len(time1))]
    if sum(ET_list1) < sum(ET_list2):
        for k in range(len(time1)):
            DT[k] = 300 + sum(time1[:k])
    else:
        for k in range(len(time2)):
            DT[k] = 1260 - sum(time2[:k+1])
        DT.reverse()

    DT_hour = ["{0:0=2d}".format(k // 60)+':'+"{0:0=2d}".format(k % 60) for k in DT] #list of departure time

    last_arrival = DT[-1] + time1[-1]
    FT_hour = "{0:0=2d}".format(last_arrival // 60) + ':' + "{0:0=2d}".format(last_arrival % 60) #the last arrival time

    return(DT_hour, FT_hour, min(sum(ET_list1),sum(ET_list2)))
```

Model 4.3

```python
def work_shift(data,ns): #ns: maximum number of shifts for each week

    #Number of team
    nt = len(data) // ns + 1

    #initial data
    days = {}
    shifts = {}
    for t in range(nt):
        days[t] = []
        shifts[t] = []

    #data sorting
    data = copy.deepcopy(data)
    sorted_data = sorted(data, key=itemgetter(2,0),reverse = True)

    myshift = [[] for t in range(nt)]
    time = [sum(k[2] for k in myshift[t] if myshift[t] != []) for t in range(nt)]
    sorted_team = list(np.argsort(time))

    for shift in sorted_data:
        for t in sorted_team:
            if shift[0] in days[t]:
                continue
            elif len(days[t]) < ns:
                days[t].append(shift[0])
                shifts[t].append(shift)
                time[t] += shift[2]
                sorted_team = list(np.argsort(time))
                break
            else:
                continue

    for shift in shifts.keys(): #sort the shifts days in the shifts data
        shifts[shift] = sorted(shifts[shift], key=itemgetter(0))

    for team in days.keys(): #sort the shifts days
        days[team] = sorted(days[team])

    new_time = {} #change time data from list to dictionary
    for day in range(len(time)):
        new_time[day] = time[day]

    return shifts, days, new_time
```