香港城市大學
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396EM Airline Operations and Scheduling/ 6075MAA Airline Scheduling and Operations

Lecture 4c
Manpower Planning

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Learning Outcome

Understand the rationale of the airline manpower planning

Formulate Mathematical Modelling by Case Study

Manpower planning

- Airline product is measured by its timeliness, accuracy, functionality, quality, and price. (Yu 1998)
- Airline employees and equipment are the factors to determine such measures.
- Manpower planning is one of the most important and challenging tasks that airlines have to face
- It covers a wide range spanning from hiring, training, to scheduling of human resources. (Yu and Thengvall 2002)
- Manpower scheduling refers to the actual work plan including working, non-working days, times, shifts, locations, and leave periods.

Airline Staff involved in the manpower planning

- Pilots
- Flight attendants
- Ground crew
- Baggage handlers
- Reservationists
- Cooks
- Janitors
- Mechanics
- Administrators

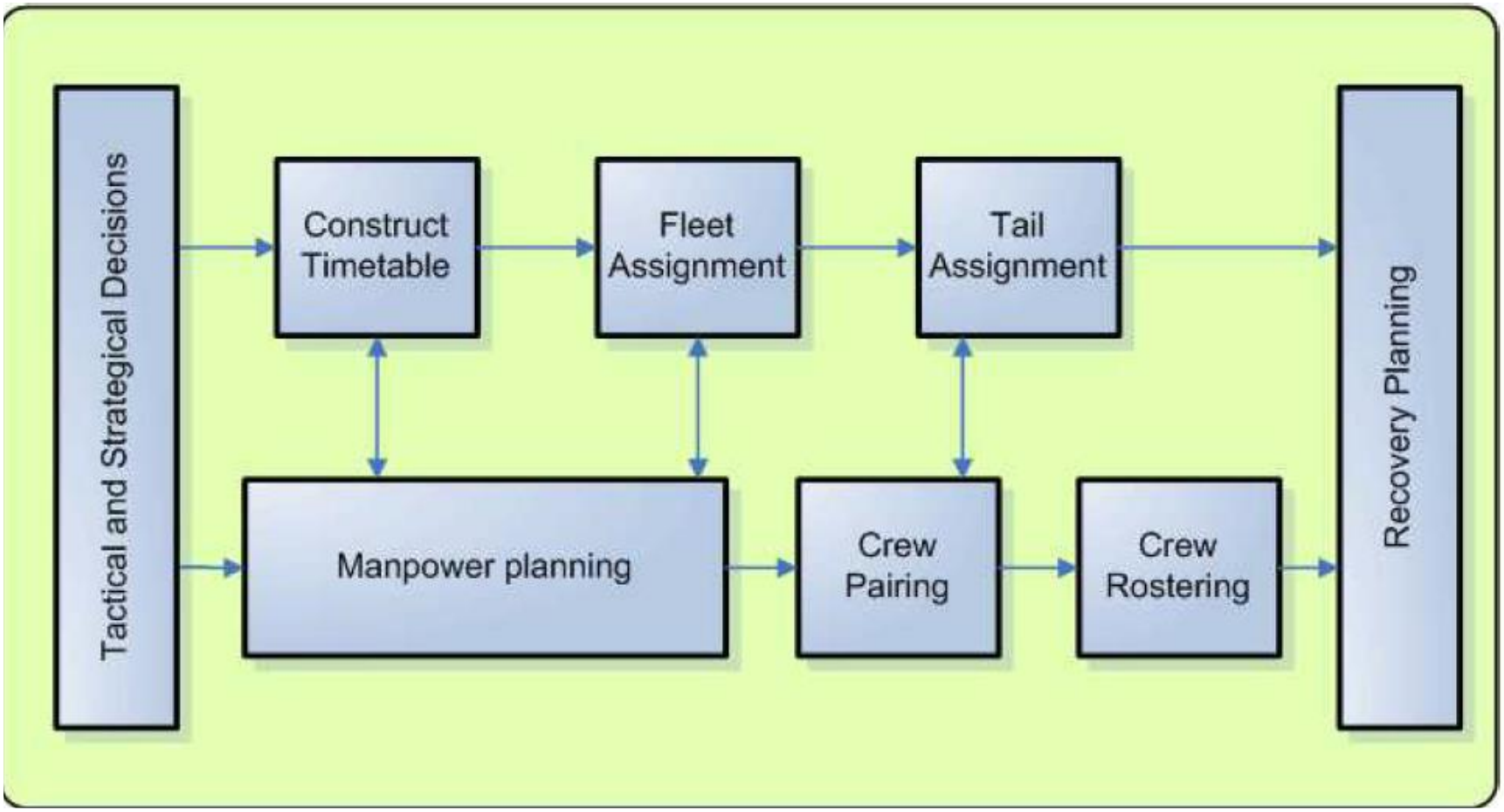
The purpose of manpower scheduling

- Derive a cyclic plan (normally weekly) for each employee in order to

  - Minimise the total manpower costs;
  - Maximise efficiency and utilisation;
  - Subject to meeting the requirements and regulations

(Brusco and Jacobs 1998)

Schematic overview of the planning process



Mathematical Modeling Case Study

- This mathematic approach is generated by Bazargan M. (2010) which is based on the Personnel Scheduling model of Brusco et al (1995) for ground operations.

- This method has been used in the development of the automated manpower planning system at United Airlines.

- A case study of Ultimate Air airline is used to illustrate this model

Case study – a weekly manpower requirements for Ground Operations (check-in counters requirement at JFK for Ultimate Air)

Shift/day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
6 a.m. – 10 a.m.	8	8	8	8	10	10	6
10 a.m. – 2 p.m.	12	10	12	10	16	16	8
2 p.m. – 6 p.m.	16	12	16	12	20	20	8
6 p.m. – 10 p.m.	9	8	9	8	12	12	4

Case study (Con't)

- The weekly manpower requirements are normally different at different times of the day, and different days of the week.
- The daily operations are separated into 4 time blocks with duration of 4 hours each.
- Each employee works for 8 hours consecutively in a day.
- There are currently 3 working shifts:
  - shift 1 (06:00 - 14:00)
  - shift 2 (10:00 - 18:00)
  - shift 3 (14:00 - 22:00)
- Each employee works for 5 days consecutively followed by 2 days off.

Case study (Con't)

- Objective: To determine the minimum size for the workforce and their working schedules and meet the above manpower requirements and regulations

- Decision Variable:
  - $X_{i,j}$ = number of employees who begin their weekly work in day i adopting shift j .
  - Index i represents the day that an employee starts his/her five-day work week
  - Index j represents the shift that the employee is assigned to

Case study (Con't)

Index for shifts (j)

8-hour shift	Index (j) for shift
6 a.m. – 2 p.m.	1
10 a.m. – 6 p.m.	2
2 p.m. – 10 p.m.	3

Index for days of the week (i)

Starting day of the working week	Index (i) for day
Mon	1
Tues	2
Wed	3
Thu	4
Fri	5
Sat	6
Sun	7

Case study (Con't)

- Objective function:

  Minimise:

  X1,1 + X1,2 + X1,3 +X2,1 + X2,2 + X2,3 + X3,1 + X3,2 + X3,3 + X4,1 + X4,2 + X4,3 + X5,1 + X5,2 + X5,3 + X6,1 + X6,2 + X6,3 + X7,1 + X7,2 + X7,3

- X1,1 – Monday 06:00 to 14:00

- X1,2 – Monday 10:00 to 18:00

- Note: the employees in decision variables are disjoin, which means no employee appears in two decision variables

Constraints – satisfy the manpower requirements for each time block of Day

- 7 days with 4-time blocks covering 3 shifts each day
- Constraints must cover the manpower requirements for every shift of every day

- Time block 06:00-10:00

  For Monday: $X_{1,1} + X_{4,1} + X_{5,1} + X_{6,1} + X_{7,1} \geq 8$

  Similarly, 6 more constraints for this time block for other days are constructed

- Time block 10:00-14:00

  For Monday: $X_{1,1} + X_{4,1} + X_{5,1} + X_{6,1} + X_{7,1} + X_{1,2} + X_{4,2} + X_{5,2} + X_{6,2} + X_{7,2} \geq 12$

  Similarly, 6 more constraints for this time block for other days are constructed

- Time block 14:00-18:00

  For Monday: $X_{1,2} + X_{4,2} + X_{5,2} + X_{6,2} + X_{7,2} + X_{1,3} + X_{4,3} + X_{5,3} + X_{6,3} + X_{7,3} \geq 16$

  Similarly, 6 more constraints for this time block for other days are constructed

- Time block 18:00-20:00

  For Monday: $X_{1,3} + X_{4,3} + X_{5,3} + X_{6,3} + X_{7,3} \geq 9$

  Similarly, 6 more constraints for this time block for other days are constructed

Solution to manpower planning

Day/shift	Shift 1 (6 a.m. – 2 p.m.)	Shift 2 (10 a.m. – 6 p.m.)	Shift 3 (2 p.m. – 10 p.m.)
Mon	2	1	3
Tue	4	0	7
Wed	0	1	0
Thu	2	4	4
Fri	2	0	0
Sat	2	2	2
Sun	0	0	0

- 21 integer decision variables and 28 constraints in this model.
- The above table shows the required number of employees who start their working week in different shifts of the day.
- A total of 36 employees are required to meet the manpower requirement for this case study

Mathematical model Summary

- This model proposed by Brusco et al. (1995) addresses both part-time and full-time employees.

- The method has been used in the development of automated manpower planning system at United Airlines called Pegasys.

Mathematical model Summary (Con't)

- Objective Function of the integer linear program: Minimize the total work force subject to availability of manpower for each time block of the day.

$$\text{Minimize} \quad \sum_{i \in D} \sum_{j \in S} x_{i,j}$$

- Constraints:

$$\sum_{i \in D} \sum_{j \in S} a_{i,j,k} \cdot x_{i,j} \geq R_k \qquad \forall\, k \in T$$

$$x_{i,j} \in Z^{+} \qquad \forall\, i \in D,\ \forall\, j \in S$$

Z^{+} represents the set of positive integer numbers

Crew Rostering Summary (Con't)

- Sets
  - D = Set of days in the weekly planning
  - S = Set of allowable shifts
  - T = Set of all time-blocks in the weekly planning

- Indices
  - i = Index for day in the weekly planning
  - j = Index for shifts
  - k = Index for time block

Crew Rostering Summary (Con't)

- Parameters

$$a_{i,j,k} = \begin{cases} 1 \text{ if time block } k \text{ is work period in shift type } j \text{ which begins in day } i \\ 0 \text{ otherwise} \end{cases}$$

R_k Number of employees required to be present in time block k

- Decision Variable
  - Xi,j = Number of employees who begin work in day i adopting shift j

Key Reference

- Bazargan, M. (2010) Airline Operations and Scheduling. 2nd edition, Ashgate
  - Chapter 7 Manpower Planning