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

Lecture 7b
Revenue and Fuel Management

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Part I : Revenue Management

Revenue (Yield Management)

- The concept is optimize it by tools and techniques rather than manage

- To determine offering the products (goods or services) or not:
  - Is it expensive or impossible to store excess inventory;
  - Certainty of future demand ;
  - Flexibility on differentiate among customer segments (i.e., customers are willing to pay different prices for the same product);
  - IF fixed cost for offering the product is high/low, while the marginal cost is low/high;
  - The capacity to offer the product is fixed or not.

Seat-Inventory Control Problem

- In airline industry, seat is the product.

- Considering that the seats offered, and their availability, are the source of revenue for the airline, the concept of revenue management thus primarily translates into a seat-inventory control problem.

- The seat-inventory control problem is to decide if a seat should be sold at a current booking request, or if it should be saved for a more profitable customer.

Nested and Non-Nested Allocations

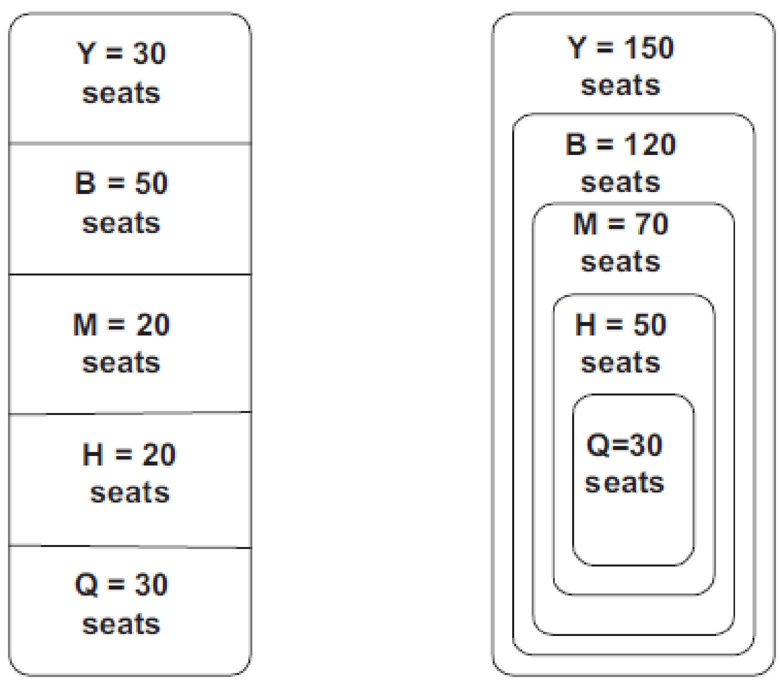
- In non-nested approaches, distinct numbers of seats called buckets are exclusively assigned to each fare class. The sum of these buckets adds up to the total aircraft seat capacity.

- In nested allocations, each fare class is assigned a booking limit, which is the total number of seats assigned to that fare class plus the sum of all seat allocations to its lower fare classes

Example of non-nested and nested airline seat allocations

Fare class	Non-nested allocation	Nested allocation
Y	30	150
B	50	120
M	20	70
H	20	50
Q	30	30

Non-Nested Nested



Expected Marginal Revenue (EMR)

- Seat inventory control system is the expected marginal revenue (EMR).
- The EMR of selling a seat potentially in a fare class is the probability of being able to fill that seat multiplied by the average fare of that class
- In order to sell S seats for fare class i, should have at least S requests for the fare class. (i.e. Si)
- ri be the random variable representing the number of requests, pi (ri) is the probability distribution for ri for fare class i .
- Assume continuous probability distribution for ri, the probability of selling Si seats in fare class:

$$P_i\left[r_i \geq S_i\right] = \int_{S_i}^{\infty} p_i\left(r_i \geq S_i\right) dr_i$$

Probability and expected marginal revenue for each seat in the fare class (Table 8.2)

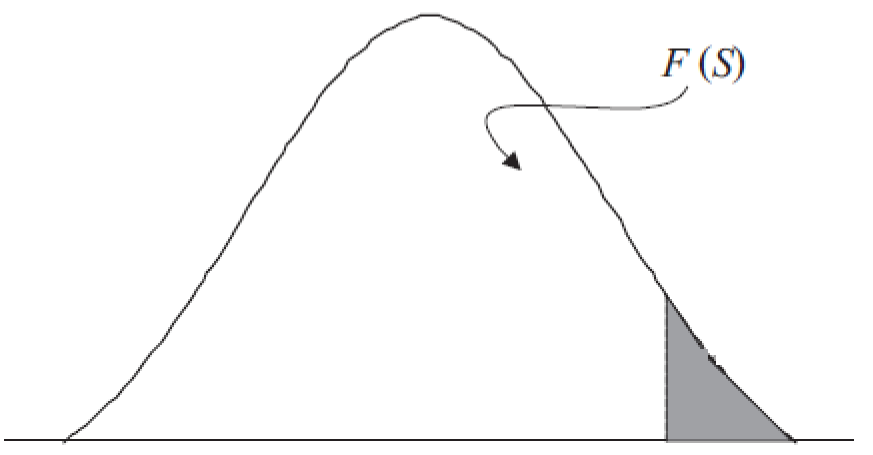
- Assume that the demand for class Y for a specific flight is normally distributed with a mean of 10 and a standard deviation of 2.
- The fare for this class is $400.

Seat (S)	$P_i(S_i)$	$EMR(S_i)$
1	1.0000	$400.00
2	1.0000	$400.00
3	0.9998	$399.91
4	0.9987	$399.46
5	0.9938	$397.52
6	0.9772	$390.90
7	0.9332	$373.28
8	0.8413	$336.54
9	0.6915	$276.58
10	0.5000	$200.00

Note: Probabilities are rounded to 4 decimal places.

Expected Marginal Revenue (EMR) (Con't)

- The previous table shows the EMR for each seat.
- The EMR of selling the first seat in this fare class is $400 because for a normal probability distribution function, with a mean of 10 and a standard deviation of 2, the probability that a first seat is sold is almost 1.
- The probability reduces to 0.8413 for the 8th seat in this class, and so on.



Shaded area representing demand exceeding a certain level.

Non-Nested Model Example

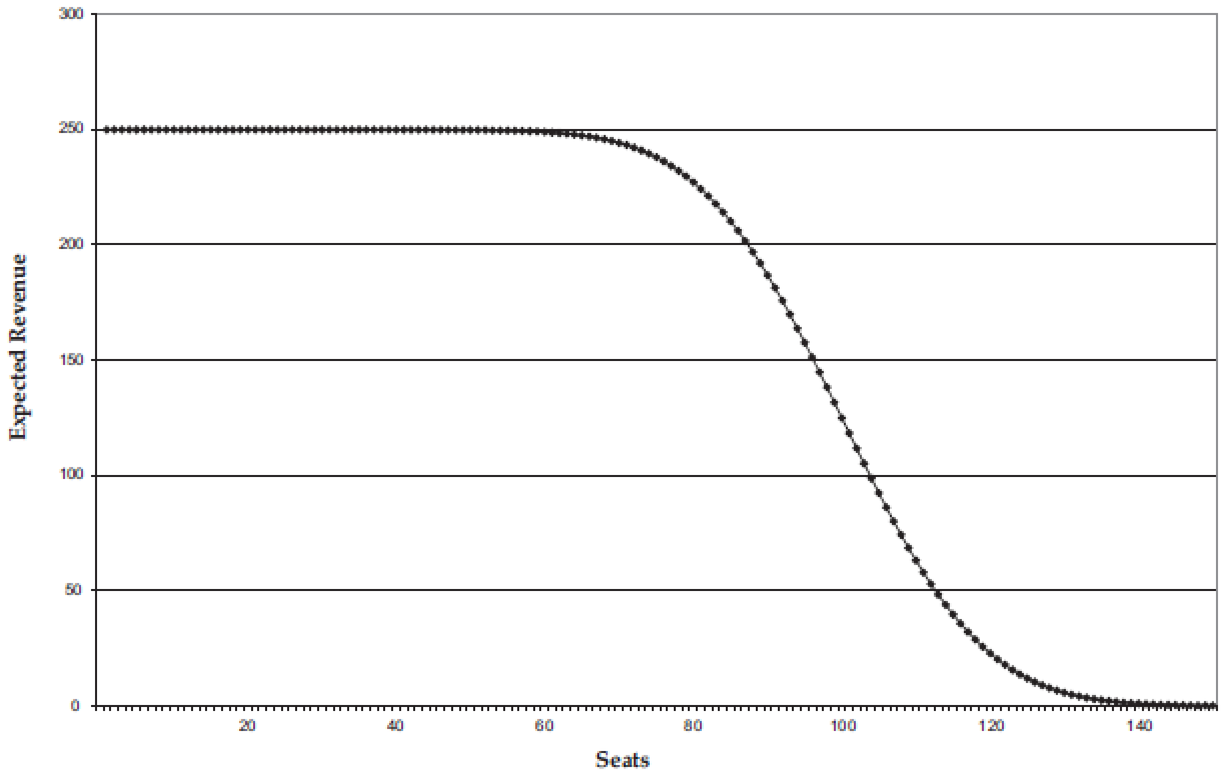
- Littlewood(1972) introduced a two-fare non-nested seat-inventory system. It proposed as long as the EMR from a seat for a higher fare Pax is larger than that of a lower fare one, the seat should not be sold at a lower fare.

- If we want to determine the number of protected seats for full fare paying passengers on an Airbus 320 with 150 seats.

- The full and discount fares on a specific flight are $250 (f1) and $100 (f2). Historical data shows that the demand for a full-fare class is normally distributed with a mean of 100 and a standard deviation of 15 passengers

Non-Nested Model Example (Con't)

- This figure shows EMR for full fare level ($250). According to this figure, the EMR starts declining from the 70th seat until it reaches around the 140th seat, which has almost zero value for EMR.



Non-Nested Model Example (Con't)

- The EMR for a full fare paying passenger for the 103rd seat is \$105.19, and for the 104th seat is \$98.72.
- Therefore the smallest value for S1 is 103.
- Thus, the airline should protect 103 seats for full fare paying passengers, and the remaining 47 (150-103) seats for the discount-fare-paying passengers.

f_1 = Full fare level
f_2 = Discount fare level
$P(r_1 \geq S_1)$ = Probability that the demand for full fare seat (r_1) is equal or exceeds S_1

$$f_2 \geq f_1 \mathrm{P}(r_1 \geq S_1)$$

Nested Model

- Belobaba (1987) extended the above two-fare-class rule to multiple nested fare classes by introducing the term expected marginal seat revenue (EMSR).

- This method generates the nested protection level for different class fares.

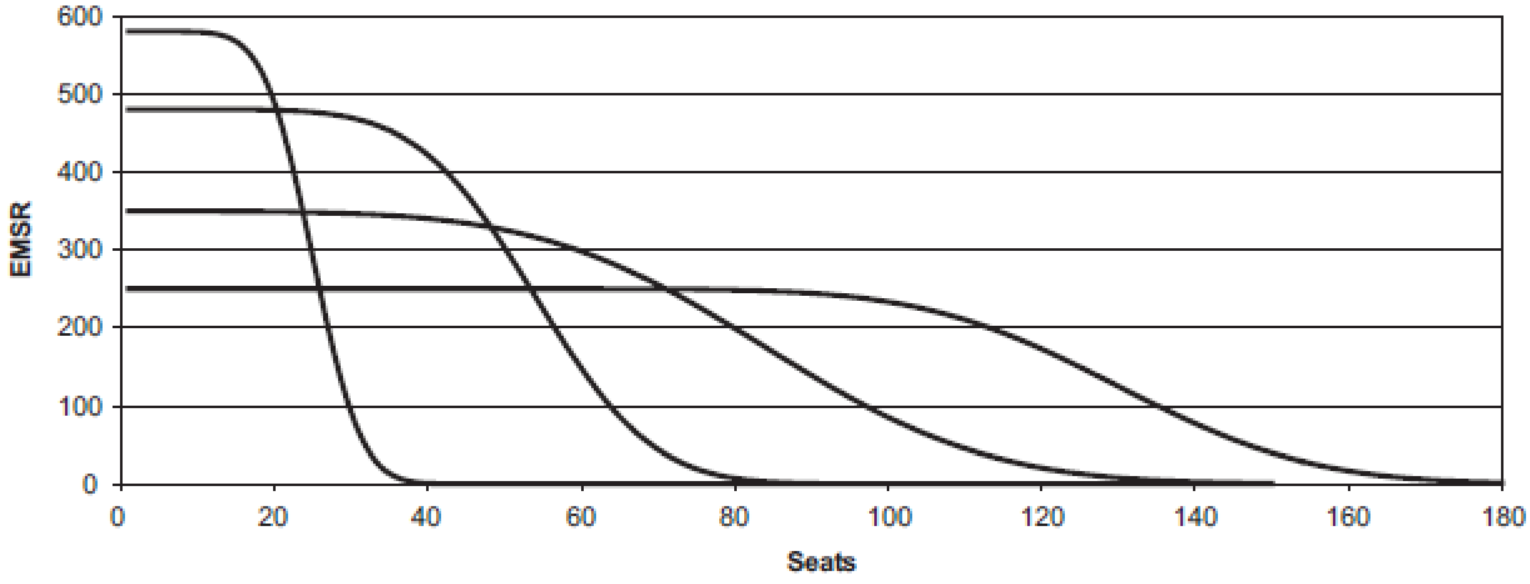
- An example is given below.

Fare classes, demand distributions and fare levels for a flight

Fare class	Demand distribution	Fare level
Y	Mean = 25 SD = 5	\$580
B	Mean = 54 SD = 12	\$480
M	Mean = 84 SD = 23	\$350
Q	Mean = 130 SD = 20	\$250

Figure 8.5 EMSR for the four-fare-class example (Figure 8.5)

- To determine the booking limits, an EXCEL spreadsheet may be useful. A table similar to Table 8.2 is constructed for every fare class. Figure 8.5 shows the EMSR for the four classes.



Protected number of seats for each fare class over lower classes

Fare class/ fare class	B (fare class 2)	M (fare class 3)	Q (fare class 4)
Y (fare class 1)	20	23	25
B (fare class 2)	-	46	53
M (fare class 3)	-	-	71

Booking limits

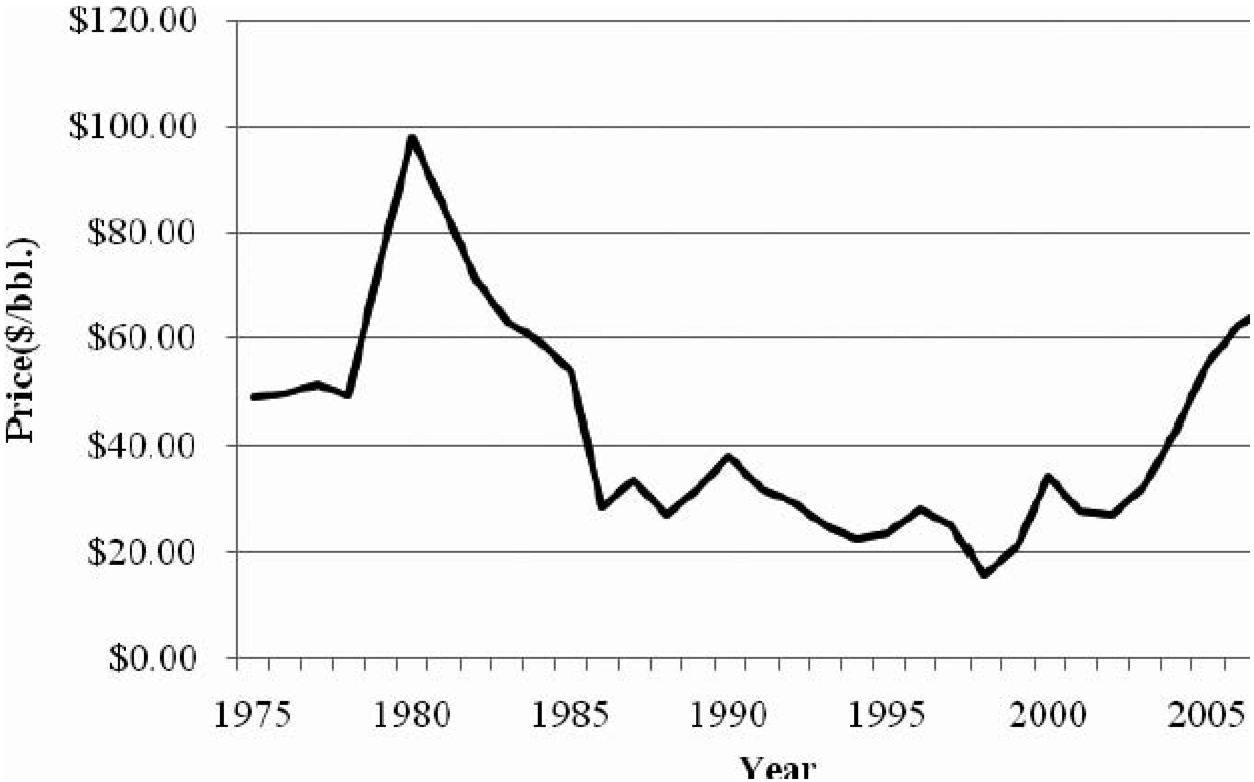
- BL1 = Total Seat Capacity (C) = 150
- BL2 = C – 20 (protected seat for Y) = 130
- BL3 = C – 69 (protected seat for Y & B) = 81
- BL4 = C – 149 (protected seat for Y, B & M) = 1
- NP1 = BL1 – BL2 = 150 – 130 = 20
- NP2 = BL2 – BL3 = 130 – 81 = 49
- NP3 = BL3 – BL4 = 81 – 1 = 80
- NP4 = C – NP1 – NP2 – NP3 = 150 – 20 – 49 – 80 = 1

- Protected for fare class Y = 20, fare class B = 49, fare Class M = 80
- Only 1 seat for fare class Q

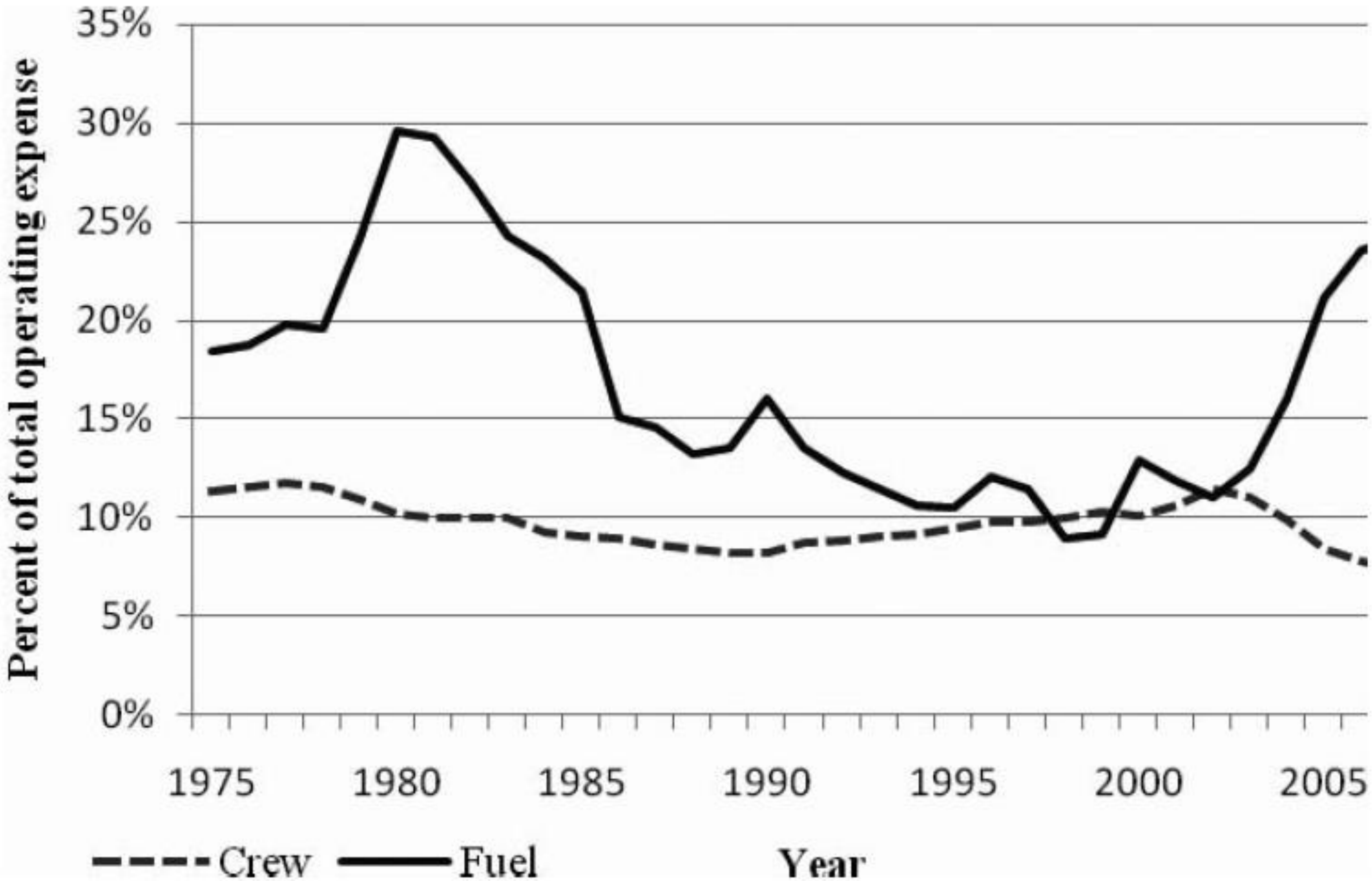
Part II : Fuel Management

Jet fuels processed from crude oil

- The prices of jet fuel and crude oil are highly correlated.
- Annual average crude oil prices



Crew and Fuel



Example

Cathay Pacific expected to post a profit rise despite hedging loss

Airline makes wrong-way bets on price of aviation fuel as cost of crude oil plunges

PUBLISHED : Sunday, 06 March, 2016, 10:01pm
UPDATED : Sunday, 06 March, 2016, 10:00pm

COMMENT: 1

Hedging

- Hedging is a strategy that typically sellers and/or buyers of commodities adopt in order to protect themselves against risk caused by fluctuations in price.
- Example, an airline wishing to purchase 1,000,000 barrels of jet fuel next month.
- Assume that the current spot price of jet fuel is $50 per barrel. The airline anticipates that the jet fuel prices are likely to increase.
- Therefore, in an effort to protect against this price hike, the airline enters into an agreement with a seller to buy each barrel of fuel at a future price of $51 delivered next month.

Lock the price

- This strategy enables the airline to lock the price of jet fuel at a fixed price in future.

- On the other hand if the prices fall to less than $51/ barrel then the airline loses money, as it could get jet fuel at a cheaper spot price but adopted the wrong strategy and locked itself to buy at $51/barrel

Hedging Strategy

- The hedging strategies adopted by airlines can be grouped into two major categories: over-the-counter and exchange-traded contracts.
- Over-the-counter agreements are contracts between an airline and another party such as an investment bank or a fuel supplier and are not regulated.
- These types of contracts are subject to risk of default on payment from either party if they go bankrupt.

Hedging Strategy (Con't)

- Exchange-traded contracts are set-up and traded through international exchanges and protect against counter-party risk.

- The main exchanges are the International Petroleum Exchange (IPE) in London and New York Mercantile Exchange (NYMEX).

Futures Contract (Example)

- A futures contract is an agreement to buy or sell a specified quantity and quality of commodity for a certain price at a designated time in the future.
- Example: An airline purchases a long position in a 3-day future contract (standard contracts are much longer).
- The contract is for 50,000 barrels of crude oil. The future price of crude oil is $45 per barrel.
- The exchange requires 20% for the initial margin and 10% for maintenance margin.
- The following table (next slide) shows the daily transaction over the three-day period.

Daily futures contract transaction over a three day period

Day	Margin	Margin	Posted to margin	Future price	Gains/loss per barrel	Total Gains/loss
0	20%	$450,000	$0	$45	0	-
1	16%	$350,000	$0	$43	($2)	($100,000)
2	8%	$150,000	$45,000	$39	($4)	($200,000)
3	13%	$270,000	$0	$41.5	$1.5	$75,000

- Day 1, the airline has to pay $2 per barrel to the seller of the contract (short position). Loses $100,000
- Day 2, the airline has to pay $4 per barrel to the seller of the contract (short position). Loses $200,000
- Day 3, the crude oil increase to $41.5, the seller of contract (short position) needs to pay $1.5 per barrel to the airline. Gain $75,000
- At the end of day 3, daily net gain/loss of airline = ($100,000) + ($200,000) + $75,000 = ($225,000)
- Total Cost of fuel = $2,075,000 ($41.5 * 50,000) +$225,000 = $2,300,000.
- Average $46 per barrel ($2,300,000/50,000)

Forward Contracts

- A forward contract is an over–the-counter agreement between two parties which involves a future transaction.

- In this type of contact, both parties agree upon a price for a commodity that will be paid on a specific future date.

- Unlike futures contracts which are settled daily, forward contracts are settled at maturity date.

Example

- An airline enters into a forward contract with its supplier for 1,000,000 gallons of jet fuel to be delivered to the airline in one month at a price of $1.40 per gallon.

- At the maturity time (one month) the airline pays the supplier $1,400,000 ($1.40 × 1,000,000).

- If at maturity the jet fuel price is more than $1.40 per gallon then the airline has made a saving through this price hedging.

- If, on the other hand, the price is lower than $1.40 in a month’s time, then the airline has lost money by engaging in this forward contact.

Options

- An option - a contract which gives the buyer (the owner or holder of the option) the right, but not the obligation, to buy or sell an underlying asset or instrument at a specified strike price on a specified date, depending on the form of the option.

- Call option – an option which gives a right to buy the underlying asset at a strike price

- Put option – an option which gives a right to sell the underlying asset at strike price.

Example

- Suppose the oil price is trading at $40.
- A call option contract with a strike price of $40 expiring in a month's time is being priced at $2.
- An airline company strongly believes that the oil will rise sharply in the coming weeks after their evaluation report.
- So the company pay certain amounts to purchase a single $40 oil call option covering some amount share.
  - Strike Price < Market Price => Exercise the call
  - Strike Price = Market Price => Be indifferent
  - Strike Price > Market Price => Do not exercise

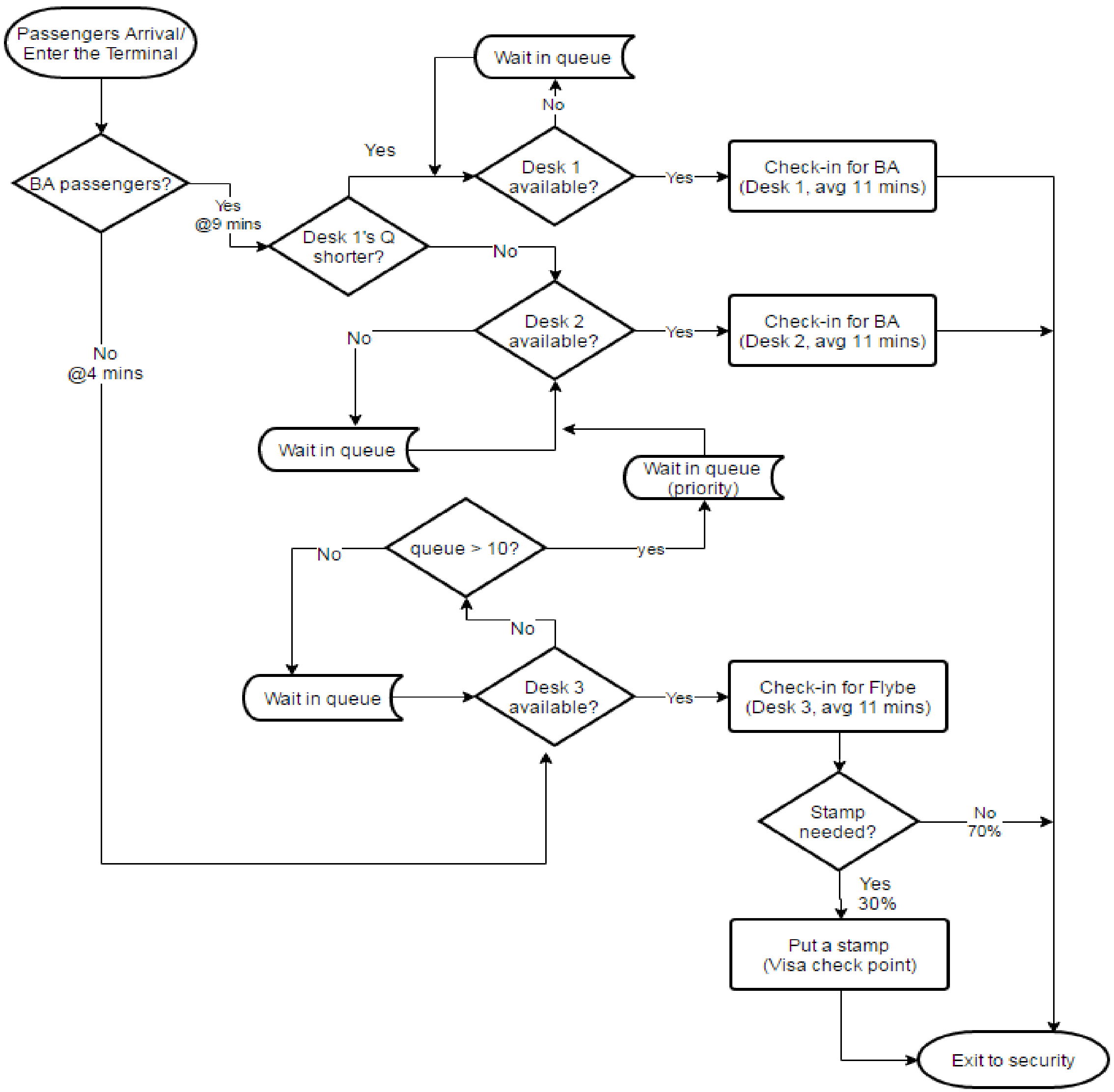
Key Reference

- Bazargan, M. (2010) Airline Operations and Scheduling. 2nd edition, Ashgate
  - Chapter 8 Revenue Management
  - Chapter 9 Fuel Management System

- Revenue Management – Finnair Career Stories
  - https://www.youtube.com/watch?v=x1LGCBPyAao

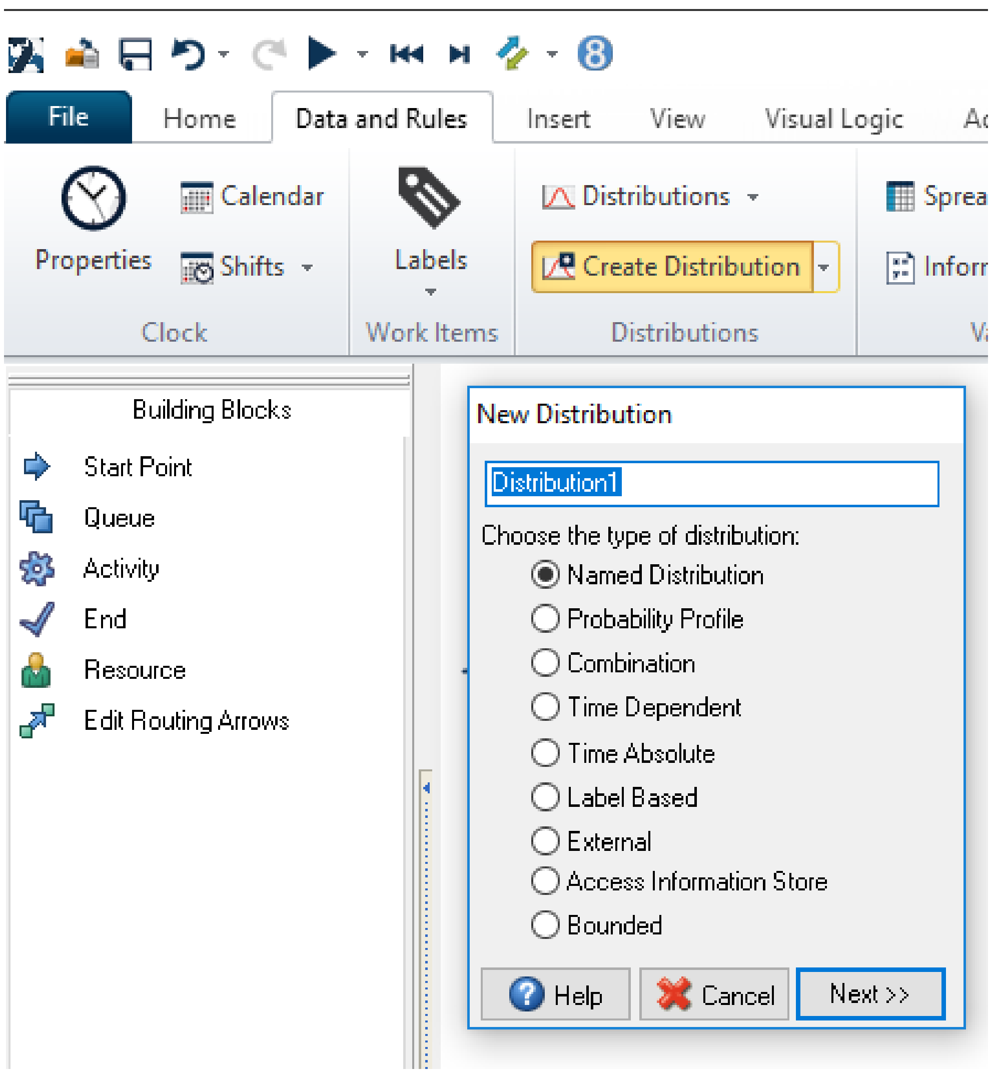
More about Flowchart

Example in Tutorial 8
Flowchart for a small airport

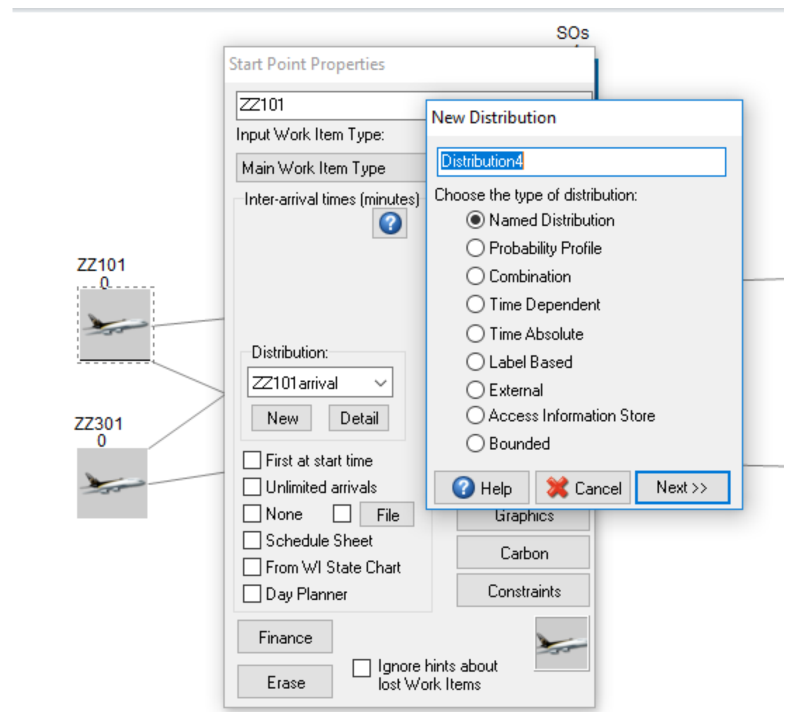


More for SIMUL8 (Demo)

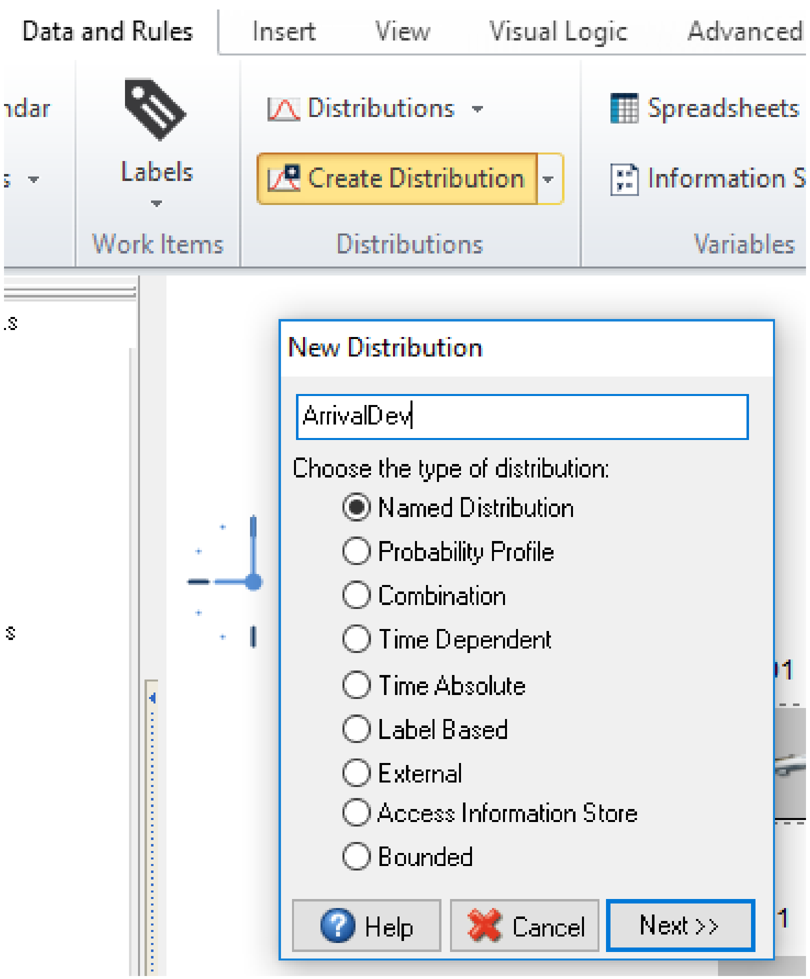
Create Distribution



- Data and Rules -> Create Distribution
- Double click “Start Point” -> Distribution click New



Named Distribution



- Data and Rules -> Create Distribution -> Type Distribution Name and click "Named Distribution"
- Click Next-> and set the corresponding time interval /distribution